

The CBS News

Space Reporter's Handbook Mission Supplement

Shuttle Mission STS-122:
Space Station Assembly Flight 1E



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/current.html>

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12/03/07	Initial release
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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-122 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-122 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) 321-867-2692 (fax) 321-867-2525 (code-a-phone)
Johnson Space Center	281-483-5811 (voice) 281-483-2000 (fax) 281-483-8600 (code-a-phone)
Marshall Space Flight Center	256-544-0034 (voice) 256-544-5852 (fax) 256-544-6397 (code-a-phone).

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
RW	Runway
SET	Shuttle program elapsed time
SOM	Start of mission
SRB/SRM	Shuttle booster serial number
SSME	Space shuttle main engine
TD	Touchdown time
T-0	Launch time
VET	Individual vehicle elapsed time

STS-122: 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-122 NASA Press Kit	http://www.shuttlepresskit.com/
STS-122 Imagery	http://spaceflight.nasa.gov/gallery/images/shuttle/STS-122/ndxpage1.html
STS-122 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

CBS News STS-122 Mission Overview

By **WILLIAM HARWOOD**
CBS News Space Consultant

The shuttle Atlantis and its crew are set for blastoff Dec. 6 on a long-awaited flight to attach the European Space Agency's Columbus research lab to the international space station. The module represents Europe's first toehold in space and opens a new era of truly international research with Japanese research labs scheduled to follow in February and April.

"I think for Europe, it's the start of manned space flight," said Hans Schlegel, a German astronaut making his second flight aboard a space shuttle. "Because all of the sudden, we have what we are strong in - developing experiments, building experiments to be conducted in space, either in cooperation with NASA or cooperation with the Russian space agency - all of the sudden we have a module of our own which is available to us, to the scientists in Europe, 24 hours (a day), 365 days a year. This will really be the beginning."

With commander Steve Frick and pilot Alan Poindexter at the controls, Atlantis is scheduled to lift off from pad 39A at the Kennedy Space Center at 4:31:44 p.m. Thursday, roughly the moment when Earth's rotation carries the launch pad into the plane of the space station's orbit.



STS-122 crew (left to right): Leland Melvin, commander Steve Frick, Rex Walheim, Leopold Eyharts, Stan Love, pilot Alan Poindexter, Hans Schlegel

Launch will mark the eighth post-Columbia shuttle mission and the fourth flight this year, a challenging pace many believed would be impossible in the wake of a freak February hail storm that delayed the first flight of the year by three months. But the shuttle processing team overcame the setback and despite a grueling space station assembly schedule requiring 22 spacewalks so far this year, NASA is ready to launch the year's fourth flight as originally planned to attach the Columbus module.

"We have had three outstanding flights of the space shuttle so far this year and we're looking forward to a fourth," said Wayne Hale, shuttle program manager at the Johnson Space Center in Houston. "Atlantis is on the pad, ready to go, no major issues or concerns regarding that vehicle. ... The hard work of a large number of folks is really beginning to pay off."

The pace does not let up next year. NASA plans to launch two Japanese research modules in February and April, a final Hubble Space Telescope servicing mission in August, a space station resupply mission the following month and a fourth and final set of space station solar arrays next November. Counting Atlantis' flight to deliver the Columbus module, NASA plans six shuttle missions over the next 12 months.

"We've had an interesting year and the first part of the year was not very good for us," said Hale. "An act of God on Feb. 26, a major hail storm, caused us to stop and have to repair the (external fuel) tank. We learned a lot about repairing tanks again, that tank when we flew it, despite a lot of concerns, performed extraordinarily well, we had an outstanding mission. And after about a three-month stand-down we've flown three flights this year: on June the eighth, August the eighth and October 23rd and now we're set up for a launch on December sixth.

"We have been very fortunate that things have been working so very well for us and in this business, we know that it takes continuous vigilance to maintain a safe flight rate, to fly each and every flight as safely as we possibly can. The shuttle is an extraordinary vehicle with a lot of capability and a lot of flexibility, a huge payload capability, but it takes a lot of attention from a lot of people to make sure we fly safely and we have to watch every little anomaly, every little indication to make sure we continue to fly safely.

"Next year," Hale said, "it's a fairly aggressive schedule (but) we have plenty of margin in our schedule to complete the international space station, meet the president's directive to complete flying (the shuttle) by no later than Sept. 30, 2010, so that the agency can then press on and build the moon ship, the Orion and Ares rockets that will take us past low-Earth orbit and back to the moon and on, potentially, to Mars."

NASA will only have a week or so to get Atlantis off the ground before the launch window closes due to temperature constraints related to the station's orbit. If the shuttle isn't off by Dec. 13, the flight will slip to early January.

At the nearby Cape Canaveral Air Force Station, meanwhile, United Launch Alliance is preparing an unmanned Atlas 5 rocket for takeoff Dec. 10 to boost a classified National Reconnaissance Office satellite into orbit. While no final decisions have been made, that flight likely would slip a few days if Atlantis doesn't get off on time to avoid a potential conflict.

"If we get into a situation where we have to delay to January, that is not a huge impact," Hale said. "It will still allow us to complete the international space station assembly. I'm constantly amazed that the folks who put the most schedule pressure on the shuttle program, and now on the station program, are the media! We have got a job to do, it's got to be taken very seriously, it's got to be done in an orderly and careful way and the launch date is going to be what the launch date is going to be."

Frick, Poindexter, flight engineer Rex Walheim, Leland Melvin, Stan Love and European astronauts Schlegel and Leopold Eyharts, a French air force general, plan to attach the Columbus module to the newly installed Harmony module's right-side port on Dec. 9, the day after docking.

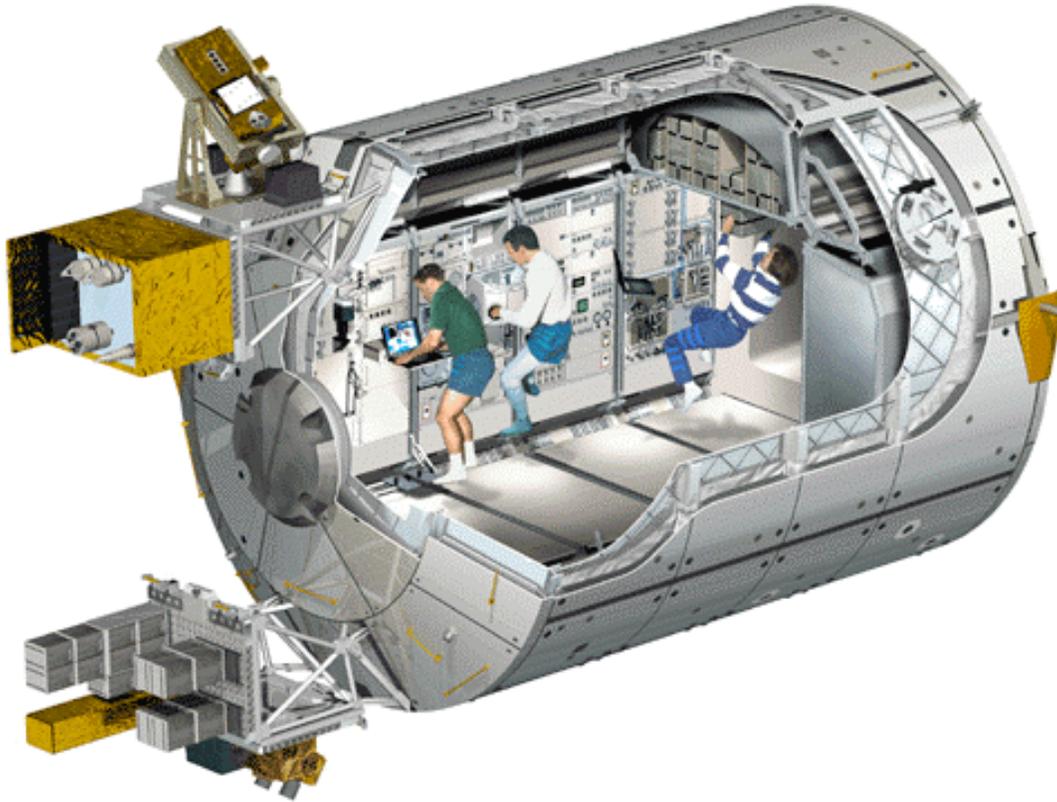
The 22.5-foot-long module weighs some 28,200 pounds and adds 2,600 cubic feet of volume to the station. Built by EADS Space Transportation, Columbus will be launched with four European science racks and one European storage rack in place. NASA later will install five racks of its own. The European Space Agency has spent about \$2 billion building Columbus, the experiments that will fly in it and the ground control infrastructure necessary to operate them.

In addition to delivering Columbus, Atlantis also will ferry Eyharts to the station. The European Space Agency astronaut, veteran of a three-week stay aboard the Russian Mir space station in 1998, will replace Expedition 16 flight engineer Dan Tani aboard the ISS. Tani, who was launched to the station Oct. 23 aboard the shuttle Discovery, will return to Earth in Eyharts' place aboard Atlantis.

Eyharts will remain aboard the lab complex with Expedition 16 commander Peggy Whitson and Russian flight engineer Yuri Malenchenko until February, when he will be replaced by NASA astronaut Garrett Reisman.

Columbus is "a tremendous contribution to the space station," Frick said in a NASA interview. "It's a very large, in our mind, orbiting laboratory that'll greatly increase the space, the facilities and the various payloads for all different types of science to do on the space station. It fills half the payload bay, and it's going to take us all of our docked time to try to get it going. And they'll be working on it after we leave, to get it completely up and running.

"The U.S. laboratory is really the heart of the space station, the U.S. segment of the space station. It's got laboratory (equipment), payloads, it's got all kinds of science resources, but it also has the heart of the U.S. segment: It has our computers, it has our power distribution, it has all the things we need to keep functioning and keep alive. The Columbus laboratory is really more of a pure laboratory - it has the resources it needs to keep its payloads going and to keep the crew members that are working inside of it healthy and able to do their job. But it relies on the other modules in the U.S. segment for resources like power and cooling and air and those kinds of things."



The European Space Agency's Columbus module

Working with Whitson and Malenchenko, Eyharts will be responsible for overseeing the activation of the Columbus module and beginning initial research operations.

"Columbus is mainly scientific module," he said in a NASA interview. "We will have four European scientific racks, which will allow Europe to perform science during, we hope, at least 10 years in the station. But there will be also American scientific racks which be installed a little bit later in the station. So with the arrival of Columbus, and later on of the Japanese module, we will start the full exploitation of the ISS as a scientific laboratory. And with the arrival of Columbus, Europe will become a co-owner of the ISS.

"Columbus is a first for Europe," he said. "This will be the first time Europe will have a permanent base in space. And of course, this is very important and this is very challenging. So in the future, of course, we hope that this first participation will help in reinforcing our technical expertise and our experience of operations to be able to go further and participate with the future of space exploration, too."<P>

Preparing the station for Columbus has been a major challenge. The station was designed for the six-port Harmony module - the eventual attachment point for Columbus and Japan's Kibo research lab - to be mounted on the front end of the station, between the U.S. Destiny lab module and the shuttle docking port, known as pressurized mating adapter No. 2.

Harmony was delivered to the station in late October aboard the shuttle Discovery and temporarily attached to the central Unity module's left side hatch. After Discovery departed, Whitson and Malchenko staged a spacewalk Nov. 9 to disconnect electrical cables from PMA-2. Then, on Nov. 12, the crew used the station's robot arm to detach PMA-2 and robotically connect it to Harmony's outboard port.

Two days later, on Nov. 14, the Harmony/PMA-2 "stack" was detached from Unity and bolted to the front end of the Destiny module. Whitson and Tani then staged spacewalks Nov. 20 and 24 to hook up power cables and connect ammonia supply and return lines between Harmony and the station's main cooling system on the lab's solar power truss. That work, along with internal outfitting, set the stage for Atlantis' launch and installation of the Columbus module.

Adding a new research lab to the space station is a major milestone in the lab's evolution. So is adding another ground control center, a state-of-the-art complex in Oberpfaffenhofen, Germany, near Munich. With the addition of Columbus, station astronauts will be in daily contact with flight controllers at the Johnson Space Center in Houston, Oberpfaffenhofen and Russian ground control in Korolev near Moscow.

"We all come into these space shuttle flights looking at the big element in the payload bay and waiting for the action when we actually install it," said station Program Manager Mike Suffredini. "This flight and the following stage and multiple stages after that will be an extra challenge for us.

"We have been working with our Russian counterparts and our Canadian counterparts for the better part of about seven years and in all that time, we evolved in our operations capability, how we work together. And now we're bringing on another partner, multiple countries, multiple control centers to operate this Columbus module.

"So the very small part you'll see during the docked operations of installing the Columbus module really will just be the tip of the iceberg as we work together in a partnership and move on into the next couple of flights," Suffredini said. "By April, we'll have the (Japanese modules) up and we'll have yet another partner in operation with us. So it's a very exciting time for us in the ISS program."

Three spacewalks are planned for the Atlantis mission, two by Walheim and Schlegel and one by Walheim and Love.

During the first excursion the day after docking, Walheim and Schlegel will attach a robot arm attachment fitting to Columbus, disconnect power cables from the new module, remove docking port covers and make preparations for a second spacewalk two days later. Melvin, meanwhile, will use the station's robot arm to move Columbus from its perch in the shuttle's cargo bay to its mounting point on the right side of Harmony. It will be locked in place by 16 motorized bolts.

If all goes well, Eyharts will float into Columbus for the first time the next day, on Dec. 10, and begin initial outfitting. The day after that, Walheim and Schlegel will venture back outside to replace a spent nitrogen tank in the main solar power truss that was used to push ammonia coolant through the supply and return lines leading to and from Harmony. The old nitrogen tank assembly will be moved to the shuttle's cargo bay for return to Earth.

A third spacewalk by Walheim and Love is planned two days later, on Dec. 13, to mount two European experiment facilities on the outboard bulkhead of the Columbus module and to move a failed control moment gyroscope from a storage platform on the station to Atlantis for return to Earth.

As it currently stands, Atlantis will land back at the Kennedy Space Center around 12:29 p.m. on Dec. 17. But depending on when Atlantis actually takes off, and how much oxygen and hydrogen are available to power the ship's electricity producing fuel cells, NASA managers may extend the mission by two days and add a fourth spacewalk.

The goal is to conduct an additional inspection of the station's right-side solar array rotary joint to help determine the source of metallic contamination in the mechanism.

The space station is equipped with two solar alpha rotary joints, or SARJs, one on each side of the lab's main power truss. The SARJ joints rotate outboard solar arrays like giant paddle wheels as the station circles the planet, keeping the blankets face-on to the sun to maximize electrical output.

Each joint features two redundant 10-foot-wide gear/race rings and two drive motors, only one of which is engaged at any given time. Twelve so-called trundle bearing assemblies are positioned around one of the two gear races and held in place with 1,000 pounds of force to allow smooth rotary operation.

The left-side SARJ is rotating normally, but earlier this fall flight controllers noticed unusual vibration and slightly higher current levels in the right-side SARJ. Tani looked inside the joint behind thermal panel No. 12 during an already planned shuttle assembly spacewalk Oct. 28.

He spotted metallic contamination and collected samples using adhesive tape. Those samples later were determined to be made up of race ring material itself. At that point, mission managers decided to lock the starboard SARJ in place to prevent additional damage.



Current configuration of the international space station

During a second inspection by Tani during a spacewalk Nov. 24, additional contamination was spotted in a different area. Engineers do not yet know what is causing the contamination, where it is originating or what might be needed to correct the problem.

In a worst-case scenario, the 12 bearing assemblies and two drive motors could be moved to the redundant gear during three to four spacewalks. But engineers do not want to consider such a drastic step until they figure out what is causing the problem with the active gear and race ring.

If a fourth spacewalk ultimately is approved for the Atlantis mission - and no such decision will be made until after launch - Love and Tani would carry out a more detailed inspection of the mechanism's drive motor, bearings and the bearing race ring now known to be damaged.

The preliminary plan calls for the spacewalkers to remove thermal covers around the SARJ to inspect the drive motors and trundle bearing assemblies and to collect samples of debris. If time is available, the astronauts will remove one of the trundle bearings - No. 5 is the initial target - and bring it back to Earth for detailed analysis.

"With some power downs, we can get a couple of extra days," said Suffredini. "So if everything goes well and we get a couple of extra days, we would attempt an EVA 4. And during an EVA 4, we would do a thorough inspection of the entire joint. We would take samples, we would remove many of the (thermal) covers. We'd like to remove them all, we're not sure we can do that in the EVA so we have a priority.

"We'll remove all the covers that will reveal all the trundle bearings, we'll remove the covers that will reveal the drive (motors), we'll inspect that, we'll take samples all the way around, we'll look with a mirror so we can see the under part of the race. And we'll take a number of photographs and then we'll retrieve one of the 12 trundle bearings. We have one selected, but if in our inspections we find one that really stands out we could choose to take that one.

"Our analysis says we can operate the joint on 11 of 12 trundle bearings and we believe that the data we could glean from one of the trundle bearings bringing it home is worth the effort. ... So that's the plan, assuming we can get the extra two days."

Suffredini said the station can safely operate with the right-side SARJ locked in place through launch of two Japanese research modules in February and April. But at some point next spring, NASA needs to get the joint rotating again, either with a repair or using different operating procedures.

Preparing for a variety of possible repair options, Atlantis' crew will carry up a new drive motor. Ten to 12 new trundle bearings will be ferried to the station aboard Endeavour in February.

"Without understanding exactly what the problem is, it's hard to drive back through the fault tree and say exactly how it is that we got there," said Kenny Todd, space station integration and operations manager at JSC. "So obviously, this will be an activity that will challenge us.

"But replacing bearings is something we know how to do. Replacing the drive lock assembly is something we know how to do. These are what we term ORUs, orbital replacement units, they exist to be able to be changed out on orbit. We're not treading new ground here when it comes to doing these tasks. They are things that we train for and we understand how to do.

"I think what's going to be important for us is to understand this particular failure enough that when we go to perform that repair we do it in a way that doesn't somehow or another exacerbate this condition on the other ring. But I think without getting a better understanding of how it was that this happened, it's going to be hard for us to say for sure here's what we'll change, here's what we'll do different."

Columbus Research Module

Source: NASA STS-122 Press Kit



The Columbus laboratory is the cornerstone of the European Space Agency's contribution to the International Space Station (ISS) and is the first European laboratory dedicated to long-term research in space. Named after the famous explorer from Genoa, the Columbus laboratory will give an enormous boost to current European experiment facilities in weightlessness and to the research capabilities of the ISS once it becomes an integral part of the space station.

During its projected lifespan of 10 years, Columbus will support sophisticated research in weightlessness, having internal and external accommodation for numerous experiments in life sciences, fluid physics and a host of other disciplines. The laboratory marks a significant enhancement in European space experimentation and hardware development when compared to the missions of the European-developed Spacelab in the 1980s and 1990s.

The 7-meter-long (23-foot-long) Columbus laboratory consists of a pressurized cylindrical hull 4.5 meters (14.7 feet) in diameter, closed with welded end cones. To reduce costs and maintain high reliability, the laboratory shares its basic structure and life-support systems with the European-built multi-purpose logistics modules (MPLMs): pressurized cargo containers, which travel in the space shuttle's cargo bay.

The primary and internal secondary structures of Columbus are constructed from aluminum alloys. These layers are covered with a multilayer insulation blanket for thermal stability and a further two tons of paneling constructed of an aluminum alloy together with a layer of Kevlar and Nextel to act as protection from space debris.

The Columbus Laboratory has a mass of 10.3 tons and an internal volume of 75 cubic meters (98 cubic yards), which can accommodate 16 racks arranged around the circumference of the cylindrical section in four sets of four racks. These racks have standard dimensions with standard interfaces, used in all non-Russian modules, and can hold for example experimental facilities or subsystems.

Ten of the 16 are International Standard Payload Racks fully outfitted with resources (such as power, cooling, video and data lines), to be able to accommodate an experiment facility with a mass of up to 700 kilograms (1,543 pounds). This extensive experiment capability of the Columbus laboratory has been achieved through a careful and strict optimization of the system configuration, making use of the end cones for housing subsystem equipment. The central area of the starboard cone carries system equipment such as video monitors and cameras, switching panels, audio terminals and fire extinguishers.

Although it is the station's smallest laboratory module, the Columbus laboratory offers the same payload volume, power, and data retrieval, for example, as the station's other laboratories. A significant benefit of this cost-saving design is that Columbus will be launched already outfitted with 2,500 kilograms (5,511 pounds) of experiment facilities and additional hardware. This includes the ESA-developed experiment facilities:

Biolab, which supports experiments on microorganisms, cell and tissue culture, and even small plants and animals;

Fluid Science Laboratory, looking into the complex behavior of fluids, which could lead to improvements in energy production, propulsion efficiency and environmental issues;

European Physiology Modules Facility, which supports human physiology experiments concerning body functions such as bone loss, circulation, respiration, organ and immune system behavior in weightlessness; and the European Drawer Rack, which provides a flexible experiment carrier for a large variety of scientific disciplines.

These multi-user facilities will have a high degree of autonomy in order to maximize the use of astronauts' time in orbit.

Outside its pressurized hull, Columbus has four mounting points for external payloads related to applications in the field of space science, Earth observation, technology and innovative sciences from space. Two external payloads will be installed after the Columbus is attached to the ISS: the European Technology Exposure Facility (EuTEF) will carry a range of experiments, which need exposure to space, and the SOLAR observatory, which will carry out a spectral study of the sun for at least 18 months.

These will be followed in the first instance by the Atomic Clock Ensemble in Space (ACES), which will test a new generation of microgravity cold-atom clock in space and the Atmosphere Space Interaction Monitor, which will study the coupling of thunderstorms processes to the upper atmosphere, ionosphere and radiation belts and energetic space particle precipitation effects in the mesosphere and thermosphere.

In addition to the accommodation for experiment facilities, three rack positions contain Columbus subsystems such as water pumps, heat exchanger and avionics, and three racks are for general storage purposes. When fully outfitted Columbus will provide a shirt sleeve environment of 25 cubic meters (33 cubic yards) in which up to three astronauts can work. The laboratory will receive a supply of up to 20 kW of electricity of which 13.5 kW can be used for experimental facilities.

For the internal environment, Columbus is ventilated by a continuous airflow from Node 2, the European-built ISS module where the Columbus Laboratory will be permanently attached. The air returns to Node 2 for refreshing and carbon dioxide removal. This air content is monitored by Columbus subsystems for contamination.

The crew can also control the temperature (16 to 30 degrees C) (61 to 86 degrees F) and humidity in Columbus. A water loop system, connected to the ISS heat removal system, serves all experimental facility and system locations for removal of heat and thus stopping equipment from overheating. In addition, there is an air/water heat exchanger to remove condensation from the cabin air. A system of electrical heaters also helps to combat the extreme cold possible at some station attitudes.

Once it is attached to the ISS, the Columbus Control Center (Col-CC) in Oberpfaffenhofen, Germany, on the premises of the DLR's German Space Operations Center will be responsible for the control and operation of the Columbus laboratory. All the European payloads on Columbus will transfer data, via the ISS data transfer system, directly to Col-CC.

Col-CC will coordinate European experiment (payload) operations. Relevant data will be distributed from Col-CC to the different User Support and Operations Centers across Europe, responsible for either complete facilities, subsystems of facilities or individual experiments.

Col-CC also will be in close contact with the Mission Control Center in Houston, which has overall responsibility for the ISS, together with the Mission Control Center in Moscow. In addition, Col-CC coordinates operations with the ISS Payload Operations and Integration Center at the Marshall Space Flight Center in Huntsville, Ala., which has overall responsibility for ISS experiment payloads.

Columbus Internal Facilities

ESA has developed a range of payload racks for the Columbus laboratory, all tailored to acquire the maximum amount of research from the minimum of space and to offer European scientists across a wide range of disciplines full access to a weightless environment that is not possible on Earth. When STS-122 is launched, Columbus will be outfitted with the five pressurized (internal) payloads: Biolab, the Fluid Science Laboratory, the European Physiology Modules facility, the European Drawer Rack, and the European Transport Carrier. The first three were developed within ESA's Microgravity Facilities for Columbus Program, while the last two fall under ESA's Utilization Program.

The above ISS experiment facilities represent a first in European research and hardware development by providing the scientific community with a European platform for running long-term experiments in weightlessness on the ISS rather than the short-term experiments typical of the earlier Spacelab missions.

The multi-user facilities are modular in design to allow for upgrading and easy refurbishment and repair because of the long-term operations foreseen in the space station era, beyond the retirement of the space shuttle in 2010. This modularity provides the opportunity and flexibility to be used over again with different experiment containers, to allow for shorter mission preparation times and contributes to a faster scientific development in the specific field.

The research facilities have been designed to be compact enough to fit into the restricted space of an International Standard Payload Rack, durable enough to withstand years of service, able to accommodate multiple users, and largely automatic and fully controllable from ground stations since the station crew has only a limited amount of time to supervise ongoing experiments.

Experiment containers to be processed in the facilities will be transported separately within the Multi-Purpose Logistics Modules (MPLMs), which are pressurized cargo transportation modules that travel inside the space shuttle cargo bay. Experiments requiring late access also can be transported within the shuttle middeck lockers. Experiment containers will also be transported using the European Automated Transfer Vehicle (ATV) or the H-II Transfer Vehicle (HTV) or the Russian

Progress vehicles. This includes certain biological and medical samples that will need to be thermally conditioned in storage in the Minus Eighty degrees Laboratory Freezer for the ISS (MELFI), which serves as the major permanent ISS refrigerator/freezer.

Internal Facilities: Biolab



Biolab is a facility designed to support biological experiments on micro-organisms, cells, tissue cultures, small plants and small invertebrates. The major objective of performing life sciences experiments in space is to identify the role that weightlessness plays at all levels of an organism, from the effects on a single cell up to a complex organism including humans.

The first experiment to take place in Biolab, when Columbus arrives at the ISS, will investigate the effect of weightlessness on the growth of seeds and will aim to better understand the cellular mechanism which impairs the immune functions and aggravates the radiation response under spaceflight conditions. This experiment is important in view of future, long-term human space missions. Further experiments will try to unravel the influence of gravity on cellular mechanisms such as signal transduction and gene

expression. These two effects are important steps in the reaction of a cell to changes in its environment, so the results are important for finding causes or treatments for diseases on Earth.

Biolab is divided physically and functionally into two sections: the automatic section in the left side of the rack, and the manual section in the right side of the rack. In the automatic section, known as the Core Unit, all activities are performed automatically by the facility, after manual sample loading by the crew. By implementing such a high level of automation, the demand on crew time is drastically reduced. The manual section, in which all activities are performed by the crew themselves, is mainly devoted to sample storage and specific crew activities of experiment handling.

The main element of the Core Unit is the large Incubator, a thermally controlled volume where the experiments take place. Inside the incubator are two centrifuges that can each hold up to six experiment containers, which contain the biological samples, and can be independently spun to generate artificial gravity in the range from 10-3 g to 2 g. This allows for the simultaneous performance of 0g experiments with 1g reference experiments in the facility.

During processing of the experiment, the facility handling mechanism will transport the samples to the facility's diagnostic instrumentation where, through teleoperations, the scientist on the ground can actively participate in the preliminary in-situ analyses of the samples. The handling mechanism also provides transport of samples into the ambient and temperature-controlled automatic stowage units for preservation or for later analysis. The typical Biolab experiment durations range from one day to three months.

Biolab's manual section carries a laptop for crew control, two temperature control units for sample storage and a BioGlovebox. The temperature control units are cooler/freezers (+10 degrees C to -20 degrees C) (50 degrees F to -4 degrees F) for storing larger items and experiment containers. The BioGlovebox is an enclosed container for handling toxic materials and delicate biological samples that must be protected against contamination by the space station environment. An ozone generator ensures sterilization of the BioGlovebox working volume.

The Biolab facility will be launched inside the European Columbus laboratory.

Internal Facilities: European Drawer Rack

There is a need in the scientific community for medium-sized, dedicated experiment equipment for space research to reduce research costs and development times. ESA's solution is the European Drawer Rack, which provides a flexible experiment carrier for a large variety of scientific disciplines. It provides the accommodation and resources to experiment modules in two types of standard ISS housings called International Subrack Interface Standard (ISIS) drawers and ISS Lockers. The facility

can accommodate up to three of these drawers, each with a payload volume of 72 liters and four lockers, each with a payload volume of 57 liters.

This approach allows a quick turn-around capability, and provides increased flight opportunities for the user community wishing to fly payloads that do not require a complete rack. The overall design of the facility is optimized for the parallel accommodation of three to four payloads, i.e., an average experiment payload accommodating two drawers/lockers, but both larger and smaller payloads may be accommodated.

The resource management covers the monitoring of resource allocations to individual payloads, but the operating concept of the European Drawer Rack assumes that payloads are largely autonomous. The facility computer distributes ISS data to payloads and routes payload data to ground and the European Drawer Rack laptop. The European Drawer Rack data management system supports all modes of payload operation, ranging from fully automatic to step-by-step control by an astronaut.

In addition to distributing Columbus resources to the experiment modules, the European Drawer Rack provides services such as an air cooling loop and conversion of the 120 volt Columbus power standard to 28 volts.

The first configuration of the European Drawer Rack will include one experiment module. This is the Protein Crystallization Diagnostics Facility and is a multi-user material science instrument, which will tackle the problems of protein crystallization in space. This facility will help to establish the conditions under which good zeolite crystals can be grown. This can only be determined in weightlessness. The results generated will hold benefits in various industrial applications.

A second module will be launched with a later flight. This is the Facility for Adsorption and Surface Tension (FASTER), which will establish a link between emulsion stability and characteristics of droplet interfaces. This research has a lot of application links in industrial domains and is linked to investigations like foam stability/ drainage/rheology.

Internal Facilities: European Physiology Modules Facility

The European Physiology Modules Facility is designed to investigate the effects of long-duration spaceflight on the human body, with typical research areas including neuroscience, cardiovascular and respiratory system, bone and muscle physiology and endocrinology and metabolism. The research into human physiology under weightless conditions also will contribute to an increased understanding of terrestrial problems such as the ageing process, osteoporosis, balance disorders, and muscle deterioration.

A selection of the first set of experiments to take place in the European Physiology Modules, when Columbus arrives at the ISS, relate to neuroscience, mechanisms of heart disease, weightless effects on human skeletal muscle function, and sodium retention in weightlessness.

The facility consists of a set of up to eight science modules mounted in a carrier infrastructure. The carrier provides these modules with data handling, thermal control and housing. It interfaces directly with Columbus and provides support for both rack-mounted and external science modules. In addition to science modules mounted in the carrier, it is possible for instruments deployed in the Columbus center aisle to interface to the carrier via a Utility Distribution Panel.

Three science modules have been selected for the first launch configuration of the European Physiology Modules Facility. These are:

Cardiolab: This is a facility for investigating the different systems that are involved in the regulation of arterial blood pressure and the heart rate. Data from Cardiolab also will be used to maintain the crew in good health during their stay on board, and to prepare the astronauts for their return to Earth. Cardiolab, developed by CNES and DLR has been added to the European Physiology Modules through cooperative agreements.

MEEMM (Multi Electrodes Encephalogram Measurement Module): MEEMM will be used to study brain activity by measuring electrical signals from electrodes mounted on the experiment subject.

PORTEEM (Portable Electroencephalogram Module): This instrument is a flexible, modular and portable digital recorder for ambulatory and sleep studies. The instrument is outfitted with a 16-channel EEG/polysomnography module for EEG sleep studies, but can be easily reconfigured for a wide variety of other applications.

ESA's European Physiology Modules Facility is closely linked to NASA's Human Research Facility racks in the U.S. Laboratory where even some of ESA's physiology science modules like the Pulmonary Function System are accommodated. The Pulmonary Function System is now in orbit and is functioning successfully.

New science modules and other necessary items will be transported to the station on the STS-122 flight and on future flights for use in conjunction with the European physiology modules. This will mainly comprise countermeasures equipment like the FlyWheel Exercise Device, a Portable Pulmonary Function System radiation monitors, etc. This European physiology modules equipment can be brought to the ISS by the European Automated Transfer Vehicle (ATV), the Russian Progress and Soyuz vehicles or the space shuttle. Samples are returned using the MPLM, the shuttle's middeck lockers and the Soyuz spacecraft.

Internal Facilities: Fluid Science Laboratory

The Fluid Science Laboratory is a multi-user facility designed to study the dynamics of fluids in the absence of gravitational forces. The major objective of performing fluid science experiments in space is to study dynamic phenomena in the absence of gravitational forces. Under weightless conditions, as on the ISS, such forces are almost entirely eliminated, resulting in significant reductions in gravitydriven convection, sedimentation, stratification and fluid static pressure. This allows the study of fluid dynamic effects normally masked by gravity.

The first experiments to take place in the Fluid Science Laboratory, when Columbus arrives at the ISS, include the heat and mass transfer from free surfaces in binary liquids, a study of emulsion stability, an investigation of geophysical flow in weightlessness, which can have importance in areas such as global-scale flow in the atmosphere and oceans, studies of electric fields on the boiling process, and a study to improve the processing of peritectic alloys.

The Fluid Science Laboratory is modular in design and based on the use of drawer elements. This facilitates the removal and transport of components, either to upgrade them or to repair defective parts. It can be operated in fully-automatic or semi-automatic mode and can be controlled on board by the ISS astronauts, or from the ground in telescience mode. The right side of the Fluid Science Laboratory contains functional subsystems for power distribution, environmental conditioning and data processing and management. The core element on the left side of the Fluid Science Laboratory consists of the Optical Diagnostics Module and Central Experiment Module, into which the experiment containers are inserted for operation.

The Optical Diagnostics Module houses the equipment for visual, velocimetric and interferometric observation, the related control electronics, and the attachment points and interfaces for special front mounted cameras.

The Central Experiment Module is divided into two parts. The first contains the suspension structure for the experiment containers, including all the functional interfaces and optical equipment. This structure is designed to be pulled out from the rack to allow insertion and removal of the standard dimension experiment containers into which the experiments are integrated. The second part contains all of the diagnostic and illumination equipment, together with the control electronics to command and monitor the electromechanical and opto-mechanical components.

Cooperative agreements have added to the facility the Microgravity Vibration Isolation System developed by the Canadian Space Agency. This system will provide good isolation for experiments from disturbances in the weightless environment from the station.

An experiment container also may be equipped with dedicated experiment diagnostics to complement the standard diagnostics provided by the Fluid Science Laboratory itself.

A facility like Fluid Science Lab, which can be used over and over again with different experiment containers, allows shorter individual mission preparation times and contributes to a faster scientific development in the specific field.

Internal Facilities: European Transport Carrier

The European Transport Carrier accommodates items for transport and stowage based on standardized cargo transfer bags that are compatible for transportation with the European-built Multi-Purpose Logistics Module (MPLM) and ATV, and for use on board ISS modules such as Columbus. The modular European Transport Carrier design, based on rigid stowage containers, offers maximum flexibility for handling different cargo transfer bag sizes. All European payload items will be transported and stored in ISS cargo transfer bags. These are Nomex® bags in four standard sizes with removable, reconfigurable dividers.

The European Transport Carrier's rigid stowage containers are optimized in size for accommodation of the different sized cargo transfer bags. There are two smaller containers for accommodating full and half-size cargo transfer bags, each one equivalent in volume to 1.5 shuttle middeck lockers. There are four containers, which offer about three times the volume of a

shuttle middeck locker. They can be filled with any combination of cargo transfer bags, up to the triple-size. All stowage containers are designed to withstand the launch and landing loads while carrying their stowage contents.

The European Transport Carrier will carry payload items that cannot be launched within the ESA facilities because of stowage or transport limitations. In orbit, it will serve as a workbench and stowage facility to support experiments with Biolab, Fluid Science Lab, European Physiology Modules and European Drawer Rack. One piece of equipment that will be brought to the ISS inside the European Transport Carrier will be the European Flywheel Exercise Device. This is a resistance exercise device that acts to countermeasure muscle atrophy, bone loss, and impairment of muscle function in astronauts. It will be transported within two of the triple-sized cargo transfer bags.

The European Transport Carrier's secondary use is within the MPLM after it is eventually replaced in Columbus by an active experiment rack. (ESA currently 'owns' five rack positions, all are active/powered positions). The European Transport Carrier may then act as a logistics carrier between Earth and the ISS for the Columbus ESA payload racks. It is designed for 15 launches, and can be reconfigured on the ground to the specific stowage needs of each flight.

In general, the European Transport Carrier will stow and transport commissioning items, complementary instruments, consumables, flight and orbital support equipment, orbital replaceable units, resupply items and science items like experiment containers and consumables.

In addition, European Transport Carrier's Zero-g Stowage Pockets (two upper, one lower) allow on-orbit use of the remaining internal volume. They can only be filled in orbit and cannot be used for launch and descent transportation.

The European Transport Carrier can carry more than 400 kilograms (882 pounds) of payload and experiment items, totaling up to about 800 liters. On-board the ISS, Zero-g Stowage Pockets extend capacity to about 1,000 liters.

Columbus External Facilities

We usually think of astronauts aboard the International Space Station performing experiments inside the pressurized laboratory modules, but external payloads offer the choice of experimentation in the open space environment with the major advantages of long duration exposure and return to Earth thereafter for examination and analysis. One noticeable example of this is the ESA Matroshka radiation dosimetry facility, which was located on the external surface of the ISS for 1.5 years following installation in March 2004.

ESA has equipped the Columbus module with the External Payload Facility, which provides four locations (platforms) to accommodate research payloads. It is a framework mounted on the module's end-cone and provides power, data and command links.

The Columbus External Payload Facility offers the opportunity for classical space science and technology experiments in a diverse array of disciplines. The External Payload Facility will enhance the station's return without significantly increasing the infrastructure cost by exploiting automated operations, with almost no crew intervention.

The External Payload program consists of two elements: early utilization (before station assembly is complete) and routine exploitation (after assembly completion). Each payload is mounted on an adaptor able to accommodate small instruments and experiments totaling up to 227 kilograms (500 pounds). Following an Announcement of Opportunity and peer review, five payloads were selected, of which four entered development. They were originally planned to use the NASA external sites but will now be located on Columbus.

Two of the payloads: The European Technology Exposure Facility (EuTEF) and SOLAR are flying on the STS-122 flight with Columbus and will be attached to the outside of Columbus during the last mission spacewalk. The Atomic Clock Ensemble in Space (ACES) and the Atmosphere Space Interaction Monitor (ASIM) will be flown to the ISS on a later flight.

This first batch of external Columbus payloads will be replaced by new payloads in the future. One such payload is ASIM, (Atmosphere/Space Interactions Monitor), payload composed of optical instruments for the observation of high altitude emission from the stratosphere and mesosphere related to thunderstorms.

In the future, the in-orbit transfer of the unpressurized payloads from the shuttle to the External Payload Facility, and vice-versa, will be performed by the Space Station Robotic Manipulator System. For SOLAR and EuTEF, however the transfer will be carried out by astronauts with robotic arm assistance, as part of EVA tasks. Future payloads like ASIM and ACES could be uploaded with the HTV; smaller/modular ones with the ATV or Progress as well.

External Facilities: European Technology Exposure Facility (EuTEF)

The European Technology Exposure Facility (EuTEF) will be mounted outside the Columbus module and carry experiments requiring exposure to the space environment. It is a programmable, fully automated, multi-user facility with modular and flexible accommodation for a variety of technology payloads. EuTEF is specifically designed to facilitate the rapid turnaround of experiments and for its first configuration on orbit will accommodate nine different instruments.

The experiments and facility infrastructure are accommodated on the Columbus External Payload Adaptor, consisting of an adapter plate, the Active Flight Releasable Attachment Mechanism and the connectors and harness. The experiments are mounted either directly on the adapter plate or a support structure that elevates them for optimum exposure to the direction of flight or pointing away from the Earth.

In total, the payload mass is under 350 kilograms (771 pounds), and requires less than 450 watts of power. The suite of experiments consists of:

MEDET, the Material Exposure and Degradation Experiment (CNES, ONERA, University of Southampton, ESA);

DOSTEL, radiation measurements (DLR Institute of Flight Medicine);

TRIBOLAB, a testbed for the tribology properties of materials in space (INTA, INASMET);

EXPOSE, photobiology and exobiology (Kayser-Threde, under ESA contract);

DEBIE-2, a micrometeoroid and orbital debris detector (Patria Finavitec, under ESA contract). Shares a standard berth with FIPEX. DEBIE-1 flew on the Proba satellite;

FIPEX, an atomic oxygen detector (University of Dresden). Shares a standard berth with DEBIE-2;

PLEGPAY, plasma electron gun payload for plasma discharge in orbit (Thales Alenia Space, under ASI contract);

EuTEMP, an experiment candidate to measure EuTEF's thermal environment during unpowered transport from the shuttle to the Columbus External Payload Facility (EFACEC, under ESA contract).

EVC: an Earth Viewing Camera, developed by ESA/Carlo Gavazzi Space for outreach activities.

External Facilities: SOLAR

Apart from contributing to solar and stellar physics, knowledge of the interaction between the solar energy flux and Earth's atmosphere is of great importance for atmospheric modeling, atmospheric chemistry and climatology. SOLAR, will study the sun with unprecedented accuracy across most of its spectral range. This is currently scheduled to last two years. It will be located on the Columbus External Payload Facility zenith position (i.e., pointing away from the Earth).

The SOLAR payload consists of three instruments complementing each other to allow measurements of the solar spectral irradiance throughout virtually the whole electromagnetic spectrum from 17 nm to 100 %m in which 99% of the solar energy is emitted. The three complementary solar science instruments are:

SOVIM (SOlar Variable & Irradiance Monitor), which covers near-UV, visible and thermal regions of the spectrum (200 nm – 100 %m) is developed by PMOD/WRC (Davos, Switzerland) with one of the instrument's radiometers provided by IRM (Brussels, Belgium).

SOLSPEC (SOlar SPECtral Irradiance measurements) covers the 180 nm 3,000 nm range. SOLSPEC is developed by CNRS (Verrières-le-Buisson, France) in partnership with IASB/BIRA (Belgium) and LSW (Germany).

SOL-ACES (SOlar Auto-Calibrating Extreme UV/UV Spectrophotometers) measures the EUV/UV spectral regime. SOL-ACES is developed by IPM (Freiburg, Germany).

SOVIM and SOLSPEC are upgraded versions of instruments that have already accomplished several space missions. SOL-ACES is a newly developed instrument.

Future External Facilities

Atomic Clock Ensemble in Space (ACES)

ACES will test a new generation of atomic clock in space. PHARAO (Projet d'Horloge Atomique par Refroidissement d'Atomes en Orbite) developed by CNES in France and the Space Hydrogen Maser developed in Switzerland will be characterized and their output signals compared with each other and with national frequency standards worldwide using a dedicated microwave link. The ultimate performance of PHARAO in microgravity will be explored and a number of fundamental physics experiments will be performed.

ACES is a complex payload involving state-of-the-art instruments and subsystems. The atomic clocks are extremely sensitive to their operating environment, so the particularly harsh environment of space provides new challenges to the clock and payload designs. Thermal and electromagnetic sensitivity places particularly severe constraints on the payload.

PHARAO uses six orthogonal laser beams to cool caesium atoms to a few μK . The combination of these slow atoms and their low acceleration in microgravity allows observation times significantly longer than on Earth, providing better stability and accuracy of the frequency.

Atmosphere Space Interactions Monitor (ASIM)

The mesosphere and lower thermosphere are the regions of the atmosphere about which the least is known. They are too low for in situ spacecraft observations, and remote sensing is hampered by low densities and a high degree of variability over a range of time and spatial scales.

ASIM (Atmosphere Space Interactions Monitor) will study the interaction of thunderstorms with the upper regions of the atmosphere, reaching into the ionosphere and magnetosphere and energetic space particle radiation effects on the mesosphere and thermosphere. The scientific objectives of this payload are complementary to the ones of the Taranis satellite mission developed by CNES.

The ASIM payload consists of two instrument units, the Miniature Multispectral Imaging Array (MMIA) and the Miniature Xand Gamma-Ray Sensor (MXGS) and subsystems.

The MMIA incorporates two CCD cameras and a photometer. Two MMIA are dedicated to limb observation with a field of view of 20 degrees. A third MMIA in conjunction with the Miniature Xand Gamma-Ray Sensor will be nadir pointing with a field of view of 80 degrees. The nadir-pointing instruments will keep track of X-ray and gamma-ray bursts.

A Critical Year for Space Station Assembly

Editor's Note:

The following discussion is intended to give readers unfamiliar with the current state of the international space station a refresher course on the status of assembly.

In March 2004, President Bush ordered NASA to complete space station assembly and retire the shuttle by the end of fiscal 2010, freeing up money to support development of a new manned spacecraft to replace the shuttle. The new Orion crew capsule, expected to debut around 2015, will ferry astronauts to and from the station and eventually back to the moon as part of a long-range push to establish a permanent lunar base in the early 2020s.

NASA now views the space station as a test bed for technology development and to collect the medical data needed for future long-duration stays on the moon or voyages to Mars. Completing the station is equally or even more important to the European and Japanese space agencies, which have spent billions developing flight hardware and facilities only to suffer through repeated delays, most recently because of the 2003 Columbia disaster.

The international space station currently consists of seven pressurized modules. At the back end of the outpost is the Russian Zvezda command module featuring two solar arrays and an aft docking port that can accommodate Progress supply ships, Soyuz crew ferry capsules and the European Space Agency's upcoming Automated Transfer Vehicle.

A combined airlock/docking module called Pirs is attached to a downward-facing port on Zvezda's front end. The module's forward port is attached to the Russian Zarya module, a supply and propulsion unit equipped with its own pair of solar arrays. Zarya's front end features a downward-facing docking port used by Progress and Soyuz spacecraft.

Zarya's front end is bolted to a pressurized mating adapter that, in turn, is attached to NASA's Unity module, a multi-hatch node with six ports. Its starboard, or right-side port, connects to the U.S. Quest airlock module while its upper zenith port accommodates the Z1 truss and the now stowed P6 solar arrays.

Unity's downward facing port has been used in the past by cargo modules brought up by the shuttle. It currently is home for another pressurized mating adapter, PMA-3. PMA-3 had been attached to Unity's left-side port but it was recently moved to the nadir port to make way for Harmony's arrival.

Harmony, a six-port connecting module similar to Unity, was delivered to the space station in October 2003 and temporarily attached to Unity's left port. After the shuttle Discovery departed, the station crew detached the station's main shuttle docking port - pressurized mating adapter No. 2 - from the front of Destiny and connected it to Harmony. The Harmony/PMA-2 "stack" then was moved to the front of Destiny and Harmony was connected to the station's power and cooling systems.

On top of the lab module is the station's main solar array truss, which is mounted at right angles to the long axis formed by the pressurized modules. Along the front side of the truss is a track used by a mobile transporter to position the station's arm at various work sites. Canadarm 2 is capable of moving, end-over-end like an inchworm, from work site to work site on the solar array truss. It also can be mounted on power and data grapple fixtures on the lab module and Harmony.

The S0 truss segment sits in the middle atop the lab, flanked by the S1 (starboard 1) and P1 (port 1) truss elements. S1, S0 and P1 house four critical electrical equipment and the station's main ammonia cooling system, including huge articulating radiator panels.

Electricity from the solar arrays, known as "primary power," is routed to components in the S0 truss called main bus switching units, or MBSUs. The four MBSUs take that 160-volt primary power and route it to transformers known as DC-to-DC Converter Units, or DDCUs, which lower the voltage to a precisely controlled 124 volts DC. This so-called "secondary power" is then directed to the station's myriad electrical systems using numerous electro-mechanical switches known as remote power controllers.

The eight solar array wings on the completed space station, four on each side, will feed power through separate lines to the MBSUs. For redundancy, power from four SAWs will flow to a pair of major circuits - 1 and 4 - while power from the other four SAWs will be directed to a second pair of circuits - 2 and 3.

The cooling system features two independent ammonia loops - loop A and B - that include large ammonia reservoirs, pumps, cold plates and the plumbing required to route the coolant through the big radiators to dissipate heat.

The loop A and B pumps were powered up during Discovery's visit last December. Expedition 14 commander Michael Lopez-Alegria and Sunita Williams completed the cooling system activation during spacewalks early this year, repositioning large fluid jumpers to route ammonia from the permanent system in loops A and B to heat exchangers in the laboratory module. The interim cooling system then was disabled. After Harmony was attached to the front end of Destiny, Expedition 16 commander Peggy Whitson and Dan Tani hooked the new module into the station's power and cooling systems.

S1 and P1 each feature three sets of ammonia radiators that extend toward the aft side of the station's power truss and rotate to maximize heat rejection.

During a shuttle flight in September 2006, the P3 truss segment and P4 solar arrays were bolted to P1 (there is no P2 or S2). Then, during a flight by Atlantis in June, the corresponding S3 and S4 truss segments were bolted onto the right side of the solar power truss. P3 and S3 both feature massive dual-motor solar alpha rotary joints, or SARJs, which are designed to rotate the outboard solar arrays like giant paddle wheels to track the sun. The S4 and P4 arrays feature solar blankets that stretch 240 feet from tip to tip when fully extended.

Last December, a short spacer truss, known as P5, was bolted to the outboard side of P4 to permit the attachment of P6 during Discovery's mission. An identical spacer segment - S5 - was bolted to S4 in August.

P6 was launched in 2001 and attached to a short truss called Z1, or zenith 1, that extends straight up from the Unity module. P6 provided the station's initial power and cooling while the main solar array truss was assembled. During shuttle flights last December and June, the P6 arrays were retracted and its cooling system disconnected. P6 then was moved to the far left end of the main truss during Discovery's October 2007 flight and re-extended.

During that process, one of the array blankets was ripped by a guidewire hangup and deployment was halted. During a subsequent spacewalk, Scott Parazynski cleared the jam and stitched the tear back together. The array then was fully extended without incident.

A final set of arrays - S6 - is scheduled for launch next year.

After Atlantis delivers the Columbus module, NASA plans just 12 more shuttle flights before the end of fiscal 2010 to carry up the Japanese modules, the final set of solar arrays, a multi-window cupola, a third and final node module, supplies and spare parts. After that, U.S. astronauts will have to hitch rides on Russian Soyuz spacecraft until the shuttle's replacement, an Apollo-like capsule known as Orion, debuts in 2015.

Here is the current space shuttle manifest (some dates TBD):

DATE	STS/ISS	ORBITER	MISSION
02/14/08	STS-123/1JA	Endeavour	Japanese experiment module; Canadian dextrous manipulator
04/24/08	STS-124/1J	Discovery	Japanese Kibo research module
08/07/08	STS-125	Atlantis	Hubble Space Telescope upgrade flight; final Atlantis mission
09/18/08	STS-126/ULF-2	Endeavour	Supplies/spares
11/06/08	STS-119/15A	Discovery	S6 solar array truss segment
03/XX/09	STS-127/2JA	Endeavour	Japanese exposed experiment facility
04/XX/09	STS-128/17A	Discovery	Crew equipment (6-person capability)
08/XX/09	STS-129/ULF-3	Endeavour	Supplies/spares
10/XX/09	STS-130/19A	Discovery	Supplies/spares
02/XX/10	STS-131/ULF-4	Endeavour	Contingency re-supply flight
04/XX/10	STS-132/20A	Discovery	Node 3, cupola; final Discovery mission
07/XX/10	STS-133/ULF-5	Endeavour	Contingency re-supply flight; final shuttle mission

By the end of assembly, the international space station will mass nearly 1 million pounds and have the pressurized volume of two 747 jumbo jets. Its finished solar array truss will stretch the length of a football field and its eight huge solar array wings will generate, on average, some 75 kilowatts of power, enough to supply 55 average homes. Crew size will be bumped up to six astronauts and cosmonauts by early 2009 with Russian Soyuz spacecraft and NASA's new Orion capsules providing crew ferry and lifeboat capability after the shuttle is retired.

STS-122: Quick-Look Mission Data

Position/Age Astronaut/Flights	Family/TIS DOB/Seat	Shuttle Hardware and Flight Data
Commander Navy Cmdr. Stephen Frick 43 STS-110 Pilot Navy Cmdr. Alan Poindexter 46 Rookie MS1 Leland Melvin 43 Rookie MS2/FE/EV1 AF Col. Rex Walheim 45 STS-110 MS3/EV2 Hans Schlegel (ESA) 56 STS-55 MS4/EV3 Stanley Love, Ph.D. 42 Rookie MS5/ISS-16 Leopold Eyharts (ESA) 46 Mir/Soyuz TM-27 ISS-16 CDR Peggy Whitson, Ph.D. 47 2: STS-111/ISS-5,ISS16 ISS-16 FE-1 Cosmonaut Yuri Malenchenko 45 4: Mir,STS-106,ISS-7,ISS16 ISS-16 FE-2 Daniel Tani (ISS-16 FE) 46 STS-108,120/ISS16	M/0 09/30/64 10.8 days Up-1/Up-1 M/2 11/05/61 0.0 Up-2/Up-2 S/0 02/15/64 0.0 Up-3/Up-3 M/2 10/10/62 10.8 Up-4/Up-4 M/7 08/03/51 10.0 Dn-5/Dn-5 M/2 06/08/65 0.0 Dn-6/Dn-6 M/1 04/28/57 21.0 Dn-7/N/A M/0 02/09/60 237.7 N/A M/1 12/22/61 375.7 N/A M/2 02/01/61 50.6 Dn-7	STS Mission STS-122 (flight 121) Orbiter Atlantis (29th flight) Payload Columbus lab module Launch 04:31:44 PM 12.06.07 Pad/MLP LC-39A/MLP-2 Prime TAL Zaragoza Landing 12:29:00 PM 12.17.07 Landing Site Kennedy Space Center Duration 10/19:58 Atlantis 245/12:45:26 STS Program 1124/13:06:55 MECO 136 X 36 sm OMS Ha/Hp 141 CX 121 sm ISS Docking 220 sm Period 91.6 minutes Inclination 51.6 Velocity 17,188 mph EOM Miles 4,505,869 EOM Orbits 171 SSMEs 2059/2052/2057 ET/SRB ET-125/Bi132-RSRM-99 Software OI-32 Left OMS LP04/29/F3 Right OMS RP01/36/F3 Forward RCS FRC4/29/F3 OBSS 2 RMS 202 Cryo/GN2 1 Spacesuits TBD Launch WGT 267,341 pounds Landing WGT 206,212 pounds
STS-122 Payload: Columbus research module		STS-122 Patch
 <p> Length: 22.5' Width: 14.6' Vol: 2,649 ^3' Mass: 28,160 lb Racks: 10 Crew: 3 Builder: EADS Port: N2 STB </p>		
Flight Plan EST	Flight Control Personnel	This will be the...
ISS Docking 12/8/07 01:18 PM EVA-1 12/9/07 11:21 AM EVA-2 12/11/07 11:21 AM EVA-3 12/13/07 10:21 AM Undocking 12/15/07 08:21 AM Landing 12/17/07 12:29 PM	Norm Knight Ascent Mike Sarafin Orbit 1 FD (lead) Tony Ceccacci Orbit 2 FD Paul Dye Planning Bryan Lunney Entry Bob Dempsey ISS Orbit 1 FD Sally Davis ISS Orbit 2 FD (lead) Ron Spencer ISS Orbit 3 FD Doug Lyons Launch director Jeff Spaulding NTD Shannon/Caine MMT George Diller Countdown PAO Rob Navias Ascent PAO	121st Shuttle mission since STS-1 8th Post-Columbia mission 96th Post-Challenger mission 29th Flight of Atlantis 92nd Day launch 68th Launch off pad 39A 52nd Day launch off pad 39A TBD 51.6-degree inclination 67th Planned KSC landing 98th Planned day landing 52nd Planned day landing at KSC 21.87 Years since STS-51L 4.85 Years since STS-107
* Ages as of launch date *Days in space as of: 12/2/07		Compiled by William Harwood

STS-122: Quick-Look Program Statistics

Orbiter	D/H:M:S	Flights	Most Recent Flight		Demographics	
Challenger*	062/07:56:22	10	STS-51L: 01/28/86		Total Fliers	467 470
Columbia*	300/17:40:22	28	STS-107: 01/16/03		Nations	35 35
Discovery	281/12:13:54	34	STS-120: 10/23/06		Male	419 422
Atlantis	245/12:45:26	28	STS-117: 06/08/07		Female	48 48
Endeavour	219/08:07:51	20	STS-118: 08/08/07		Total Tickets	1,038 1,045
Total	1124/13:06:55	120	* Vehicle lost		United States	297 300
Launches	LC-39A	LC-39B	Total		United States men	257 260
Night	16	13	29		United States Women	40 40
Daylight	51	40	91		USSR	72 72
Total	67	53	120		USSR Men	70 70
Most Recent	10/23/07	12/9/06			USSR Women	2 2
Landings	KSC	EAFB	WSSH	Total	CIS	29 29
Night	15	6	0	21	CIS Men	28 28
Daylight	51	45	1	97	CIS Women	1 1
Total	66	51	1	118	Non US/Russian	69 69
Most Recent	11/7/07	6/22/07	3/30/82		Men	64 64
STS Aborts	Date	Time	Abort	Mission	Women	5 5
Discovery	6/26/84	T-00:03	RSL5-1	STS-41D	Men with 7 flights	2 2
Challenger	7/12/85	T-00:03	RSL5-2	STS-51F	Men with 6 flights	6 6
Challenger	7/29/85	T+05:45	ATO-1	STS-51F	Women/6	0 0
Columbia	3/22/93	T-00:03	RSL5-3	STS-55	Men/5	14 14
Discovery	8/12/93	T-00:03	RSL5-4	STS-51	Women/5	6 6
Endeavour	8/18/94	T-00:02	RSL5-5	STS-68	Men/4	55 55
					Women/4	6 6
					Men/3	67 67
					Women/3	6 6
					All/2	120 124
					All/1	185 184
Increment	Launch	Land	Duration	Crew	Soyuz Aborts/Failures	
ISS-01	10/31/00	03/21/01	136/17:09	2	Soyuz 1 Entry Failure	04/24/67
ISS-02	03/08/01	08/02/01	147:16:43	3	Soyuz 11 Entry Failure	06/30/71
ISS-03	08/10/01	12/17/01	117/02:56	3	Soyuz 18A Launch Abort	04/05/75
ISS-04	12/05/01	06/19/02	181/00:44	3	Soyuz T-10A Pad Abort	09/26/83
ISS-05	06/05/02	12/07/02	171/03:33	3	Minimum Duration STS Missions	
ISS-06	11/23/02	05/03/03	161/01:17	3	1. Columbia/STS-2	Fuel cell
ISS-07	04/26/03	10/28/03	184/21:47	2	11/21/81	MET: 2/06:13
ISS-08	10/18/03	04/30/04	194/18:35	2	2. Atlantis/STS-44	IMU
ISS-09	04/19/04	10/23/04	187/21:17	2	11/19/91	MET: 6/23:52
ISS-10	10/14/04	04/24/05	192/19:02	2	3. Columbia/STS-83	Fuel cell
ISS-11	04/15/05	10/11/05	179/23:00	2	4/4/97	MET: 3/23:13
ISS-12	10/01/05	04/08/06	189/19:53	2	Compiled by William Harwood	
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	TBD	TBD	3		

STS-122 NASA Crew Thumbnails

Position/Age	Astronaut/Flights/Education	Fam/TS	DOB/Seat	Home/BKG	Hobbies/notes				
Commander Age: 43	Navy Cmdr. Stephen Frick STS-110 Master's, aeronautical engineering	M/0	09/30/64 10.8 day Up-1/Up-1	Gibsonia, PA Navy test pilot F/A-18 carrier ops	Skiing, hiking and camping; >3,200 hours flying time; >320 carrier landings				
Pilot 46	Navy Cmdr. Alan Poindexter Rookie Master's, aeronautical engineering	M/2	11/05/61 0.0 Up-2/Up-2	Rockville, MD Navy test pilot F-14 carrier ops	Motorcycles, outdoor sports; >3,500 hours flying time; >450 carrier landings				
MS1 43	Leland Melvin Rookie Master's, materials science	S/0	02/15/64 0.0 Up-3/Up-3	Lynchburg, VA NASA researcher NFL player	Photography, piano, music, cycling, tennis, snowboards; walking his dogs				
MS2/FE/EV1 45	AF Col. Rex Walheim STS-110 Master's, industrial engineering	M/2	10/10/62 10.8 Up-4/Up-4	San Carlos, CA Missile command AF test engineer	Snow skiing, hiking, softball, football				
MS3/EV2 56	Hans Schlegel (ESA) STS-55 Various; physics	M/7	08/03/51 10.0 Dn-5/Dn-5	Aachen, Germany Scientist ESA astronaut	Skiing, scuba diving, flying; seven children!				
MS4/EV3 42	Stanley Love, Ph.D. Rookie Ph.D. in astronomy	M/2	06/08/65 0.0 Dn-6/Dn-6	Eugene, OR Asteroid study JPL engineer	Flying, alpine hiking, biking, music and animation				
MS5/ISS-16 46	Leopold Eyharts (ESA) Mir/Soyuz TM-27 French air force engineer	M/1	04/28/57 21.0 Dn-7/N/A	Biarritz, France Test pilot ESA astronaut	Reading, computers and sports; general in the French air force				
ISS-16 CDR 47	Peggy Whitson, Ph.D. 2: STS-111/ISS-5,ISS16 Ph.D. in biochemistry	M/0	02/09/60 237.7 N/A	Mt. Ayr, Iowa Rice University JSC research	Weight lifting, biking, basketball and water skiing				
ISS-16 FE-1 45	Cosmonaut Yuri Malenchenko 4: Mir,STS-106,ISS-7,ISS16 Military aviation school	M/1	12/22/61 375.7 N/A	Test pilot Cosmonaut Mir/ISS/STS	Hero of the Russian Federation; no hobbies listed				
ISS-16 FE-2 46	Daniel Tani (ISS-16 FE) STS-108,120/ISS16 Master's, mechanical engineering	M/2	02/01/61 50.6 Dn-7	Lombard, Ill. Hughes engineer Orbital Sciences	Golf, flying, running, tennis, music, cooking				
Melvin	Frick	Walheim	Eyharts	Love	Poindexter	Schlegel	Tani	Whitson	Malenchenko
									
*Age, days in space as of: 12/02/07							Compiled by William Harwood		

Current Space Demographics (post STS-120)

Post STS-120		Nation	No.	Rank	Name	Days/Flts
Total Fliers	467	1	Afghanistan	1	Sergei Krikalev	803/6
Nations	35	2	Austria	2	Sergei Avdeyev	748/3
Men	419	3	Belgium	3	Valery Polyakov	679/2
Women	48	4	Brazil	4	Anatoly Solovyev	652/5
Total Tickets	1038	5	Britain			
		6	Bulgaria			
United States	297	7	Canada	8		
US Men	257	8	China	3	ISS-1	10/31/00 03/18/01 136/17:09
US Women	40	9	CIS	29	Shepherd	Gidzenko Krikalev
		10	Cuba	1	ISS-2	03/08/01 08/20/01 147/16:43
Soviet Union	72	11	Czech.	1	Usachev	Helms Voss
USSR Men	70	12	E. Germany	1	ISS-3	08/10/01 12/15/01 117/02:56
USSR Women	2	13	France	9	Culbertson	Dezhurov Tyurin
CIS	29	14	Germany	9	ISS-4	12/05/01 06/15/02 181/00:44
CIS Men	28	15	Hungary	1	Onufrienko	Bursch Walz
CIS Women	1	16	India	1	ISS-5	06/05/02 12/02/02 171/03:33
		17	Israel	1	Korzun	Whitson Treschev
Others	69	18	Italy	5	ISS-6	11/23/02 05/03/03 161/01:17
Other Men	64	19	Japan	6	Bowersox	Budarin Pettit
Other Women	5	20	Malaysia	1	ISS-7	04/25/03 10/27/03 184/21:47
		21	Mexico	1	Malenchenko	Lu N/A
Men with 7 Flights	2	22	Mongolia	1	ISS-8	10/18/03 04/29/04 194/18:35
Men with 6 flights	6	23	Netherlands	2	Foale	Kaleri N/A
Women with 6 flights	0	24	N. Vietnam	1	ISS-9	04/18/04 10/23/04 187/21:17
Men with 5 flights	14	25	Poland	1	Padalka	Fincke N/A
Women with 5 flights	6	26	Romania	1	ISS-10	10/13/04 04/24/05 192/19:02
Men with 4 flights	55	27	Saudi Arabia	1	Chiao	Sharipov N/A
Women with 4 flights	6	28	Slovakia	1	ISS-11	04/14/05 10/10/05 179/00:23
Men with 3 flights	67	29	South Africa	1	Krikalev	Phillips N/A
Women with 3 flights	6	30	Spain	1	ISS-12	10/01/05 04/08/06 189/19:53
All with 2 flights	120	31	Sweden	1	McArthur	Tokarev N/A
All with 1 flight	185	32	Switzerland	1	ISS-13	03/30/06 09/28/06 182/22:44
		33	Syria	1	Vinogradov	J Williams Reiter
TOTAL	467	34	USA	297	ISS-14	09/18/06 04/20/07 215/08:23
		35	USSR	72	Lopez-Alegria	Tyurin Various
In-flight Fatalities	18		TOTAL	467	ISS-15	04/07/07 10/21/07 196/17:5
U.S. In-Flight Fatalities	13				Yurchikhin	Kotov Various
Soviet/CIS Fatalities	4				ISS-16	10/10/07 TBD TBD
Other Nations	1				Whitson	Malenchenko Various

Projected Space Demographics (post STS-122)

Post STS-122		Nation	No.	Rank	Name	Days/Flts
Total Fliers	470	1	Afghanistan	1	Sergei Krikalev	803/6
Nations	35	2	Austria	2	Sergei Avdeyev	748/3
Men	422	3	Belgium	3	Valery Polyakov	679/2
Women	48	4	Brazil	4	Anatoly Solovyev	652/5
Total Tickets	1045	5	Britain			
		6	Bulgaria			
United States	300	7	Canada			
US Men	260	8	China	3	ISS-1	10/31/00 03/18/01 136/17:09
US Women	40	9	CIS	29	Shepherd	Gidzenko Krikalev
		10	Cuba	1	ISS-2	03/08/01 08/20/01 147/16:43
Soviet Union	72	11	Czech.	1	Usachev	Helms Voss
USSR Men	70	12	E. Germany	1	ISS-3	08/10/01 12/15/01 117/02:56
USSR Women	2	13	France	9	Culbertson	Dezhurov Tyurin
CIS	29	14	Germany	9	ISS-4	12/05/01 06/15/02 181/00:44
CIS Men	28	15	Hungary	1	Onufrienko	Bursch Walz
CIS Women	1	16	India	1	ISS-5	06/05/02 12/02/02 171/03:33
		17	Israel	1	Korzun	Whitson Treschev
Others	69	18	Italy	5	ISS-6	11/23/02 05/03/03 161/01:17
Other Men	64	19	Japan	6	Bowersox	Budarin Pettit
Other Women	5	20	Malaysia	1	ISS-7	04/25/03 10/27/03 184/21:47
		21	Mexico	1	Malenchenko	Lu N/A
Men with 7 Flights	2	22	Mongolia	1	ISS-8	10/18/03 04/29/04 194/18:35
Men with 6 flights	6	23	Netherlands	2	Foale	Kaleri N/A
Women with 6 flights	0	24	N. Vietnam	1	ISS-9	04/18/04 10/23/04 187/21:17
Men with 5 flights	14	25	Poland	1	Padalka	Fincke N/A
Women with 5 flights	6	26	Romania	1	ISS-10	10/13/04 04/24/05 192/19:02
Men with 4 flights	55	27	Saudi Arabia	1	Chiao	Sharipov N/A
Women with 4 flights	6	28	Slovakia	1	ISS-11	04/14/05 10/10/05 179/00:23
Men with 3 flights	67	29	South Africa	1	Krikalev	Phillips N/A
Women with 3 flights	6	30	Spain	1	ISS-12	10/01/05 04/08/06 189/19:53
All with 2 flights	124	31	Sweden	1	McArthur	Tokarev N/A
All with 1 flight	184	32	Switzerland	1	ISS-13	03/30/06 09/28/06 182/22:44
		33	Syria	1	Vinogradov	J Williams Reiter
TOTAL	470	34	USA	300	ISS-14	09/18/06 04/20/07 215/08:23
		35	USSR	72	Lopez-Alegria	Tyurin Various
In-flight Fatalities	18		TOTAL	470	ISS-15	04/07/07 10/21/07 196/17:5
U.S. In-Flight Fatalities	13				Yurchikhin	Kotov Various
Soviet/CIS Fatalities	4				ISS-16	10/10/07 TBD TBD
Other Nations	1				Whitson	Malenchenko 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-122 NASA Crew Biographies

1. Commander: Navy Cmdr. Stephen Frick



PERSONAL DATA: Hometown: Gibsonia, Pennsylvania. Married. He enjoys skiing, hiking, camping.

EDUCATION: Graduated from Richland High School, Gibsonia, Pennsylvania in 1982; received a bachelor of science degree in aerospace engineering from the US Naval Academy in 1986; master of science degree in aeronautical engineering from the U.S. Naval Postgraduate School in 1994.

ORGANIZATIONS: Society of Experimental Test Pilots, U.S. Naval Academy Alumni Association.

SPECIAL HONORS: Air Medal with 2 Strike-Flight awards; 3 Navy Commendation Medals, one with Combat V; Navy Unit Commendation; National Defense Service Medal; Sea Service Deployment Ribbon, 2 Southwest Asia Service Medals; and various other service awards.

EXPERIENCE: Frick was commissioned upon graduation from the U.S. Naval Academy in May 1986. After being designated as a Naval Aviator in February 1988, he reported to Strike Fighter Squadron 106 at Naval Air Station Cecil Field, Florida, for transition to the F/A-18 Hornet. Upon completion of training, he reported to Strike Fighter Squadron 83 also at Cecil Field, and deployed to

the Mediterranean Sea and Red Sea onboard the USS Saratoga (CV-60). During the 8-month deployment, he participated in Operation Desert Shield and Desert Storm, flying 26 combat missions from the Red Sea to targets in Iraq and Kuwait. He was also designated an airwing qualified landing signals officer. After leaving Strike Fighter Squadron 83 in December 1991, Frick participated in a cooperative program consisting of 15 months at the Naval Postgraduate School in Monterey, California, and 1 year with the Naval Test Pilot School at Naval Air Station Patuxent River, Maryland. Upon graduation in June 1994, he was assigned as a project officer and test pilot to the Carrier Suitability Department of the Strike Aircraft Test Squadron also located at Patuxent River. While there, he conducted shore-based and shipboard testing of the F/A-18 Hornet. Frick was assigned to Strike Fighter Squadron 125 in Lemoore, California, preparing for return to a deployed F/A-18 squadron when selected for the astronaut program in April 1996.

Frick Has logged over 3,200 flight hours in 35 different aircraft, and has over 370 carrier landings.

NASA EXPERIENCE: Selected by NASA in April 1996, Frick reported to the Johnson Space Center in August 1996. Having completed two years of training and evaluation, he is qualified for flight assignment as a pilot. Initially, Frick was assigned technical duties in the Astronaut Office Spacecraft Systems/Operations Branch. He completed his first space flight as pilot on STS-110, and has logged over 259 hours in space. Frick is assigned to command the STS-122 mission that will deliver the European Space Agency's Columbus Laboratory to the International Space Station.

SPACE FLIGHT EXPERIENCE: STS-110 Atlantis (April 8-19, 2002) was the 13th Shuttle mission to visit the International Space Station. Mission milestones included: delivery and installation of the SO (S-Zero) Truss; first maneuvering of spacewalkers using the ISS robotic arm; and the first mission on which all spacewalks were based from the station's Quest Airlock. The crew prepared the station for future spacewalks and spent a week in joint operations with the station's Expedition-4 crew. Mission duration was 10 days, 19 hours and 42 minutes.

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2. Pilot: Navy Cmdr. Alan G. Poindexter



PERSONAL DATA: Born November 5, 1961 in Pasadena, California. Considers Rockville, Maryland, to be his hometown. Married to the former Lisa A. Pfeiffer of Gulf Breeze, Florida. They have two children. Recreational interests include motorcycling, running, weight lifting, water skiing, boating, hunting, and fishing.

EDUCATION: Graduated from Coronado High School, Coronado, California in 1979. Graduated with highest honors from Georgia Institute of Technology with a bachelor of aerospace engineering degree in 1986 and a master of science in aeronautical engineering from the Naval Postgraduate School in 1995.

ORGANIZATIONS: Society of Experimental Test Pilots

AWARDS: NASA Aviation Safety Award, Navy and Marine Corps Commendation Medal with Combat V, Navy and Marine Corps Achievement Medal, various other service awards.

SPECIAL HONORS: Naval Air Warfare Center, Aircraft Division Test Pilot of the Year 1996; Top Ten Carrier Aviator, Carrier Airwing Nine.

EXPERIENCE: Poindexter was commissioned following graduation from the Georgia Institute of Technology in 1986. After a short tour of duty at the Hypervelocity Wind Tunnel Facility, Naval Surface Weapons Center, White Oak, Maryland, Poindexter reported for flight training in Pensacola, Florida. He was designated a Naval Aviator in 1988 and reported to Fighter Squadron 124, Naval Air Station Miramar, California, for transition to the F-14 Tomcat. Following his initial training, Poindexter was assigned to Fighter Squadron 211, also at Miramar, and made two deployments to the Arabian Gulf during Operations Desert Storm and Southern Watch.

During his second deployment in 1993, he was selected to attend the Naval Postgraduate School/U.S. Naval Test Pilot School Cooperative Program. Following graduation in December 1995, Poindexter was assigned as a Test Pilot and Project Officer at the Naval Strike Aircraft Test Squadron (NSATS), Naval Air Station (NAS) Patuxent River, Maryland. While at NSATS, Poindexter was assigned as the lead test pilot for the F-14 Digital Flight Control System where he logged the first carrier landing and catapult launch of an F-14 with the upgraded flight controls. He also flew numerous high angle of attack/departure tests, weapons separation tests and carrier suitability trials. Following his tour at Patuxent River, Poindexter reported to Fighter Squadron 32, NAS Oceana, Virginia, where he was serving as a department head when he was selected for Astronaut training.

Poindexter has more than 3,500 hours in over 30 aircraft types and has logged over 450 carrier landings.

NASA EXPERIENCE: Selected by NASA in June 1998, he reported for training in August 1998. Initially Poindexter served in the Astronaut Office Shuttle Operations Branch performing duties as the lead support astronaut at Kennedy Space Center. Poindexter is assigned as pilot on the STS-122 mission that will deliver the European Space Agency's Columbus Laboratory to the International Space Station.

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3. MS-1: Leland D. Melvin



PERSONAL DATA: Born February 15, 1964 in Lynchburg, Virginia. Unmarried. Recreational interests include photography, piano, reading, music, cycling, tennis, and snowboarding. Loves walking his dogs, Jake and Scout. Chosen by the Detroit Lions in the 11th round of the 1986 NFL college draft. Also participated in the Toronto Argonauts and Dallas Cowboys football training camps. His parents Deems and Grace Melvin, reside in Lynchburg, Virginia.

EDUCATION: Graduated from Heritage High School, Lynchburg, Virginia, in 1982; received a bachelor of science degree in chemistry from the University of Richmond, Richmond, Virginia in 1986; and a master of science degree in materials science engineering from the University of Virginia in 1991.

ORGANIZATIONS: National Technical Association (Hampton Roads Chapter Secretary 1993), American Chemical Society, The Society for Experimental Mechanics.

SPECIAL HONORS/AWARDS: Invention Disclosure Award for Lead Insensitive Fiber Optic Phase Locked Loop Sensor, NASA Outstanding Performance Awards (8), NASA Superior Accomplishment Award (2), Key to the City of Lynchburg, Virginia, NCAA Division I Academic All American, University of Richmond Athletic Hall of Fame Inductee.

University of Richmond Athletic Hall of Fame Inductee.

NASA EXPERIENCE: Mr. Melvin began working in the Fiber Optic Sensors group of the Nondestructive Evaluation Sciences Branch at NASA Langley Research Center in 1989 where he conducted research in the area of physical measurements for the development of advanced instrumentation for Nondestructive Evaluation (NDE). His responsibilities included using optical fiber sensors to measure strain, temperature, and chemical damage in both composite and metallic structures. Additional projects included developing optical interferometric techniques for quantitative determination of damage in aerospace structures and materials. In 1994, Mr. Melvin was selected to lead the Vehicle Health Monitoring (VHM) team for the cooperative Lockheed/NASA X-33 Reuseable Launch Vehicle (RLV) program. The team developed distributed fiber optic strain, temperature and hydrogen sensors for the reduction of vehicle operational costs and to monitor composite liquid oxygen tank and cryogenic insulation performance. In 1996, Mr. Melvin codesigned and monitored construction of an optical NDE facility capable of producing in-line fiber optic Bragg grating strain sensors at rates in excess of 1000 per hour. This facility will provide a means for performing advanced sensor and laser research for development of aerospace and civil health monitoring systems.

Selected by NASA JSC in June 1998, Mr. Melvin 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. Since then he has been assigned to the Astronaut Office Space Station Operations Branch, and the Education Department at NASA Headquarters, Washington, D.C. As co-manager of NASA's Educator Astronaut Program, Leland Melvin traveled across the country, engaging thousands of students and teachers in the excitement of space exploration, and inspiring them to pursue careers in science, technology, engineering and mathematics. He next served in the Robotics Branch of the Astronaut Office. Mr. Melvin is assigned to the STS-122 mission that will deliver the European Space Agency's Columbus Laboratory to the International Space Station.

FEBRUARY 2007

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4. MS2/FE/EV-1: Air Force Col. Rex J. Walheim



PERSONAL DATA: Born October 10, 1962, in Redwood City, California, but considers San Carlos, California his hometown. Married to the former Margie Dotson of Villa Park, California. They have two children. He enjoys snow skiing, hiking, softball and football. His father, Lawrence M. Walheim, Jr., resides in Exeter, California. His mother, Avis L. Walheim is deceased.

EDUCATION: Graduated from San Carlos High School, San Carlos, California in 1980; received a bachelor of science degree in mechanical engineering from the University of California, Berkeley, in 1984, and a master of science degree in industrial engineering from the University of Houston in 1989.

SPECIAL HONORS: Distinguished Graduate, Reserve Officers Training Corps, University of California, Berkeley. Distinguished Graduate and top flight test engineer in USAF Test Pilot School Class 92A. Meritorious Service Medal, 2 Air Force Commendation Medals, Aerial Achievement Medal, and various service awards.

EXPERIENCE: Walheim was commissioned as a second lieutenant in the Air Force in May 1984. In April of 1985 he was assigned to Cavalier Air Force Station in Cavalier, North Dakota, where he worked as a missile warning operations crew commander. In October 1986, he was reassigned to the Johnson Space Center, Houston, Texas, where he worked as a mechanical systems flight controller and was the lead operations engineer for the Space Shuttle landing gear, brakes, and emergency runway barrier. Walheim was transferred to Headquarters Air Force Space Command in Colorado Springs, Colorado, in August 1989, where he was manager of a program upgrading missile warning radars. He was selected for the flight test engineer course at USAF Test Pilot School in 1991, and attended the course at Edwards AFB California in 1992. Following his graduation, he was assigned to the F-16 Combined Test Force at Edwards where he was a project manager, and then commander of the avionics and armament flight. In January 1996, Walheim became an instructor at USAF Test Pilot School, where he served until he commenced astronaut training.

NASA EXPERIENCE: Walheim served as a flight controller and operations engineer at the Johnson Space Center from October 1986 to January 1989. He was selected by NASA in March 1996 and reported to the Johnson Space Center in August 1996. After completing two years of training and evaluation, he qualified for flight assignment as a mission specialist. Initially, Walheim was assigned technical duties in the Astronaut Office Space Station Operations Branch, where he helped develop the initial procedures and displays used on the space station, and served as a Capcom in the Mission Control Center. He served on the EVA crew of STS-110 (2002) and has logged over 259 hours in space, including over 14 EVA hours. After his first flight, he was assigned to the EVA branch, where he served as the astronaut office representative for the Extra Vehicular Mobility Unit, (the EVA spacesuit). Walheim is assigned to the STS-122 mission that will deliver the European Space Agency's Columbus Laboratory to the International Space Station.

SPACE FLIGHT EXPERIENCE: STS-110 Atlantis (April 8-19, 2002) was the 13th Shuttle mission to visit the International Space Station. Mission milestones included: the delivery and installation of the SO (S-Zero) Truss; the first time the station's robotic arm was used to maneuver spacewalkers around the station; and the first time that all of a shuttle crew's spacewalks were based from the station's Quest Airlock. Walheim performed 2 EVAs totaling 14 hours and 5 minutes. The crew mechanically attached and powered up the new truss, and spent a week in joint operations with the station's Expedition-4 crew. Mission duration was 10 days, 19 hours and 42 minutes.

JULY 2006

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5. MS3/EV2: Hans Schlegel, European Space Agency



PERSONAL DATA: Born August 3, 1951 in Überlingen, Germany, but considers Aachen to be his hometown. He has seven children. Married to Heike Schlegel-Walpot. Recreational interests include skiing, scuba diving and flying. He also enjoys reading, and being a handyman.

EDUCATION:

1957-70: Attended schools in Refrath, Bensberg and Cologne, Germany.
 1968-69: American Field Service (AFS) exchange student. Graduated from Lewis Central High School, Council Bluffs, Iowa.
 1970: Graduated from Hansa Gymnasium (secondary school emphasizing mathematics & science), Cologne, Germany.
 1972-79: Studied at the University of Aachen, Germany, graduated with a Diploma in Physics.

ORGANIZATIONS: Deutsche Physikalische Gesellschaft (German Physical Society); AFS - Interkulturelle Begegnungen (American Field Service Germany).

PUBLICATIONS: Publications and scientific reports in the field of semiconductor physics.

HONORS: Verdienstkreuz 1. Klasse des Verdienstordens der Bundesrepublik Deutschland (Federal Service Cross 1 st Class, Federal Republic of Germany). Medal of Friendship of Russia. NASA Exceptional Achievement Medal.

EXPERIENCE:

1970-72: Served as a paratrooper with the Federal Armed Forces. Left with the rank of second lieutenant.

1979-86: Member of the academic staff at Rheinisch Westfälische Technische Hochschule (RWTH) Aachen (University of Aachen) as an experimental Solid State Physicist. Research in the field of electronic transport properties and optical properties of semiconductors.

1986-88: Specialist in non-destructive testing methodology in the research and development department of the company "Institut Dr. Förster GmbH & Co. KG" in Reutlingen, Germany.

1988-90: Basic Astronaut Training at the German Aerospace Center (DLR). In addition to academic education he gained microgravity experience by conducting various experiments during approximately 1300 parabolas on the KC-135. He also became a certified research diver and holds a private pilot's licence, covering instrument rating and aerobatics.

1990: Assigned as payload specialist for the D-2 Mission (second German Spacelab mission).

1990-93: Payload Training in Cologne, Germany and at the Johnson Space Center in Houston, Texas.

1995-97: Cosmonaut Training for the German-Russian Mir-'97 Mission at Yuri A. Gagarin Training Centre (Moscow). During the mission (February 10 to March 2, 1997) served as Crew Interface Coordinator.

1997-98: Additional training and certification as 2nd board engineer for Mir at Yuri A. Gagarin Training Centre.

1998: Integrated into ESA's single European astronaut corps, which is involved in the assembly and on-board operations of the International Space Station.

1998: ESA sent him to NASA JSC in Houston for Mission Specialist Training (Astronaut Class of 1998).

1999-02: Worked in the ISS Branch on mechanisms & structures, on crew equipment and on the ISS systems.

2002-04: Worked in the Robotics Branch and as ISS CAPCOM (spacecraft communicator).

2004-05: Lead ISS CAPCOM for Increment 10.

Currently: Assigned by ESA in May 2005 as ESA Lead Astronaut at JSC. Since September 2005 has worked as Shuttle CAPCOM, as ISS Instructor CAPCOM, and in the ISS Branch as lead for systems and crew interfaces, heading up a team of 12.

Schlegel is assigned to the STS-122 mission that will deliver the European Space Agency's Columbus Laboratory to the International Space Station.

NASA SPACE FLIGHT EXPERIENCE:

04/26/93-05/06/93

Served as payload specialist on STS-55 aboard Space Shuttle Columbia. Nearly 90 experiments were conducted during the German-sponsored Spacelab D-2 mission to investigate life sciences, material sciences, physics, robotics, astronomy, and the Earth and its atmosphere.

JULY 2006

6. MS4/EV-3: Stanley G. Love, Ph.D.

PERSONAL DATA: Born June 8, 1965 in San Diego, California, but considers Eugene, Oregon to be his hometown. Married. Two children. Recreational interests include flying, alpine hiking, bicycling, music, and animation. His parents, Glen A. and Rhoda M. Love, reside in Oregon.

EDUCATION: Graduated from Winston Churchill High School, Eugene, Oregon, in 1983; received a Bachelor of Science degree in physics from Harvey Mudd College, Claremont, California, in 1987; received Master of Science and Doctor of Philosophy degrees in astronomy from the University of Washington in 1989 and 1993, respectively.

ORGANIZATIONS: American Astronomical Society; American Geophysical Union; American Institute of Aeronautics and Astronautics; Harvey Mudd College Alumni Association; Meteoritical Society.

AWARDS: NASA-JSC Performance Award (2003, 2004, 2006). NASA Space Flight Awareness Team Award (2004). NOVA Award, Jet Propulsion Laboratory (1998). O.K. Earl Prize Postdoctoral Fellowship, California Institute of Technology (1995). Dean's List Distinction, Harvey Mudd College (1985, 1986, 1987).

EXPERIENCE: Worked summers at the University of Oregon in Eugene, as a computer programming instructor (1984) and as an assistant in physics and chemistry laboratories (1985-1987). As a graduate teaching assistant at the University of Washington in Seattle beginning in 1987, he taught and led laboratory sections for undergraduate courses in general and planetary astronomy. He worked as a graduate research assistant at the University of Washington from 1989 to 1993 on a variety of projects including space propulsion and energy storage, stellar photometry and spectroscopy, analysis of space-exposed surfaces, hypervelocity impact and particle capture, atmospheric entry heating of micrometeoroids, infrared imaging of the zodiacal light, and electron microscopy of interplanetary dust particles. Moved to the University of Hawaii in Honolulu in 1994 for a postdoctoral research appointment modeling the formation of meteoritic chondrules and the collisional evolution of asteroids, and investigating the possibility of meteorites from the planet Mercury. Awarded a prize postdoctoral fellowship at the California Institute of Technology in 1995: work there included computational fluid dynamic simulations of asteroid collisions, calibration of the Cassini spacecraft dust particle impact detector, and experimental shock compression of the mineral calcite. Transferred to the Jet Propulsion Laboratory as a staff engineer in 1997 to work on computer models of spacecraft optical instrument systems and to participate in a Laboratory-wide process re-engineering effort.

NASA EXPERIENCE: Selected 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, and water and wilderness survival schools. Dr. Love served as a CAPCOM (spacecraft communicator) in Mission Control for International Space Station Expeditions 1 through 7 and for Space Shuttle missions STS-104 (ISS-7A), STS-108 (ISS-UF-1), and STS-112 (ISS-9A). He served in the Astronaut Office's Exploration Branch, helping to develop future space vehicles and missions. Dr. Love is assigned to the STS-122 mission that will deliver the European Space Agency's Columbus Laboratory to the International Space Station.

FEBRUARY 2007

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7. MS5/ISS-16 FE:French Air Force Gen. Leopold Eyharts (European Space Agency)



PERSONAL DATA: Born April 28, 1957, in Biarritz, France. He is married and has one child. His hobbies are reading, computers and sport.

EDUCATION: Graduated as an engineer from the French Air Force Academy of Salon-de-Provence in 1979.

SPECIAL HONORS: Léopold Eyharts has been decorated with the French Légion d'Honneur, the Ordre National du Mérite and Médaille d'Outre Mer, and the Russian medals of Friendship and Courage.

EXPERIENCE: He joined the French Air Force Academy of Salon-de-Provence in 1977 and was graduated as an aeronautical engineer in 1979. In 1980, he became a fighter pilot and was assigned to an operational Jaguar squadron in Istres Air Force Base (France). In 1985, he was assigned as a wing commander in Saint-Dizier Air Force base.

In 1988, he was graduated as a test pilot in the French test pilot school (EPNER) and was assigned to Bretigny flight test center near Paris. He then flew on different types of military and civilian aircraft including Mirage 2000, Alpha-jet, Mirage 3, Caravelle, C-160 mainly involved in radar and equipment testing.

He has logged 3500 flight hours as a fighter and test pilot in 40 different aircraft types, 21 parachute jumps including one ejection.

In 1990, Léopold Eyharts was selected as an astronaut by CNES (Center National d'Etudes Spatiales) and assigned to support the Hermes spaceplane program managed by the Hermes Crew office in Toulouse.

He became also one of the test pilots in charge of the CNES parabolic flights program, an experimental aircraft (Caravelle) managed by Bretigny Flight Test Center to provide a microgravity laboratory to the scientific community. In 1994, he was in charge of parabolic flight testing of the Caravelle replacement, an Airbus A300 which become operational in 1995.

In 1992, Léopold Eyharts participated in the second European Space Agency astronaut selection. At the end of the same year, he took part in an ESA evaluation of Russian "Bouran" Space Shuttle training in Moscow, where he flew in the Tupolev 154 Bouran in-flight simulator.

He also participated in two additional short-duration spaceflight training courses in Star City, Moscow—6-weeks in 1991 and 2-weeks in 1993.

Léopold Eyharts was assigned to full spaceflight training in January 1995. He trained as a back-up cosmonaut for the Cassiopeia French-Russian space mission, which took place in August 1996.

He was the prime cosmonaut for the follow-on CNES scientific space mission called "Pégase." He flew in the Mir Space Station in February 1998. During the three week Pégase mission he performed various French experiments in the area of medical research, neuroscience, biology, fluid physics and technology. In completing his first space mission, he has logged 20 days, 18 hours and 20 minutes in space.

NASA EXPERIENCE: In August 1998, Léopold Eyharts was assigned by the European Space Agency to train at NASA's Johnson Space Center in Houston, Texas. As part of the international astronauts of the 1998 class, he attended Astronaut Candidate Training which 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. Initially assigned to the Astronaut Office Space Station Operations Branch. Léopold Eyharts' assignments include serving as a flight engineer to the Expedition-12 and Expedition-13 back-up crews.

JANUARY 2007

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8. ISS-16 Commander Peggy Whitson, Ph.D.**PERSONAL DATA:**

Born Feb. 9, 1960 in Mt. Ayr, Iowa. Hometown is Beaconsfield, Iowa. Married to Clarence F. Sams, Ph.D. She enjoys weight lifting, biking, basketball, and water skiing.

EDUCATION:

Graduated from Mt. Ayr Community High School, Mt. Ayr, Iowa, in 1978; received a bachelor of science degree in biology/chemistry from Iowa Wesleyan College in 1981, and a doctorate in biochemistry from Rice University in 1985.

AWARDS/HONORS:

NASA Outstanding Leadership Medal (2006); NASA Space Flight Medal (2002). Two patents approved (1997, 1998); Group Achievement Award for Shuttle-Mir Program (1996); American Astronautical Society Randolph Lovelace II Award (1995); NASA Tech Brief Award (1995); NASA Space Act Board Award (1995, 1998); NASA Silver Snoopy Award (1995); NASA

Exceptional Service Medal (1995, 2003, 2006); NASA Space Act Award for Patent Application; NASA Certificate of Commendation (1994); Selected for Space Station Redesign Team (March-June 1993); NASA Sustained Superior Performance Award (1990); Krug International Merit Award (1989); NASA-JSC National Research Council Resident Research Associate (1986-1988); Robert A. Welch Postdoctoral Fellowship (1985-1986); Robert A. Welch Predoctoral Fellowship (1982-1985), Summa Cum Laude from Iowa Wesleyan College (1981); President's Honor Roll (1978-81); Orange van Calhoun Scholarship (1980); State of Iowa Scholar (1979); Academic Excellence Award (1978).

EXPERIENCE:

From 1981 to 1985, Whitson conducted her graduate work in biochemistry at Rice University, Houston, Texas, as a Robert A. Welch Predoctoral Fellow. Following completion of her graduate work she continued at Rice University as a Robert A. Welch Postdoctoral Fellow until Oct. 1986. Following this position, she began her studies at NASA Johnson Space Center, Houston, Texas, as a National Research Council Resident Research Associate. From April 1988 until Sept. 1989, Whitson served as the Supervisor for the Biochemistry Research Group at KRUG International, a medical sciences contractor at NASA-JSC. In 1991-1997, Whitson was also invited to be an Adjunct Assistant Professor in the Department of Internal Medicine and Department of Human Biological Chemistry and Genetics at University of Texas Medical Branch, Galveston, Texas. In 1997, Whitson began a position as Adjunct Assistant Professor at Rice University in the Maybee Laboratory for Biochemical and Genetic Engineering.

NASA EXPERIENCE:

From 1989 to 1993, Whitson worked as a Research Biochemist in the Biomedical Operations and Research Branch at NASA-JSC. From 1991-1993, she served as Technical Monitor of the Biochemistry Research Laboratories in the Biomedical Operations and Research Branch. From 1991-1992 she was the Payload Element Developer for Bone Cell Research Experiment (E10) aboard SL-J (STS-47), and was a member of the US-USSR Joint Working Group in Space Medicine and Biology. In 1992, she was named the Project Scientist of the Shuttle-Mir Program (STS-60, STS-63, STS-71, Mir 18, Mir 19) and served in this capacity until the conclusion of the Phase 1A Program in 1995. From 1993-1996 Whitson held the additional responsibilities of the Deputy Division Chief of the Medical Sciences Division at NASA-JSC. From 1995-1996 she served as Co-Chair of the U.S.-Russian Mission Science Working Group. In April 1996, she was selected as an astronaut candidate and started training, in Aug. 1996. Upon completing two years of training and evaluation, she was assigned technical duties in the Astronaut Office Operations Planning Branch and served as the lead for the Crew Test Support Team in Russia from 1998-99. From Nov. 2003 to March 2005 she served as Deputy Chief of the Astronaut Office. From Mar 2005-Nov. 2005 she served as Chief of the Station Operations Branch, Astronaut Office. Whitson trained as the backup ISS Commander for Expedition 14 from Nov. 2005-Sept. 2006

Whitson is currently serving a six month tour of duty aboard the International Space Station as the ISS Commander for Expedition 16. The crew launched on Oct. 10, 2007 aboard a Soyuz TMA-11 spacecraft, docking with the station on Oct. 12, 2007. This is Whitson's second long-duration spaceflight.

SPACE FLIGHT EXPERIENCE: The Expedition-5 crew launched on June 5, 2002 aboard STS-111 and docked with the International Space Station on June 7, 2002. During her 6-month stay aboard the Space Station, Dr. Whitson installed the Mobile Base System, the S1 truss segment, and the P1 truss segment using the space station remote manipulator system,

performed a 4 hour and 25 minute Orlan EVA to install micrometeoroid shielding on the Zvezda Service Module, and activated and checked out the Microgravity Sciences Glovebox, a facility class payload rack. She was named the first NASA Science Officer during her stay, and she conducted 21 investigations in human life sciences and microgravity sciences, as well as commercial payloads. The Expedition-5 crew (one American Astronaut and two Russian Cosmonauts) returned to Earth aboard STS-113 on Dec. 7, 2002. Completing her first flight, Dr. Whitson logged 184 days, 22 hours and 14 minutes in space.

OCTOBER 2007

9. ISS-16 FE-1 Yuri Malenchenko



PERSONAL DATA:

Born Dec. 22, 1961 in Svetlovodsk, Kirovograd Region, Ukraine.

EDUCATION:

Graduated from the Kharkov Military Aviation School in 1983, and from the Zhukovsky Air Force Engineering Academy in 1993.

HONORS:

Awarded the Hero of the Russian Federation medal, the National Hero of Kazakhstan medal, Military award of excellence, Meritorious Service medals (3), Commendation medal, Achievement medal, Medal "70 years of the Soviet Armed Forces".

EXPERIENCE:

After graduation from the Military Aviation School, he served as a pilot, senior pilot and multi-ship flight lead from 1983 till 1987 in the Odessa Region. In 1987 he was selected as a cosmonaut, and arrived at the Gagarin Cosmonaut Training Center. From Dec. 1987 to June 1989 he underwent a course of general space training. After completion of the course, Malenchenko was qualified as a test-cosmonaut. In Sept. 1989 – Dec. 1993 he was taking advanced training courses getting ready for spaceflight. In Jan.-July, 1993

Malenchenko trained as commander of the Mir-14 reserve crew. In July 1993 – Jan. 1994 he completed training as a backup commander of the Mir-15 crew. In Feb. – June 1994 he trained for the Mir-16 mission.

SPACE FLIGHT EXPERIENCE:

Malenchenko completed his first 126-day spaceflight in July 1 – Nov. 4, 1994 on the Soyuz TM-14 vehicle and the Mir station (Mir-16 mission). The mission included spaceflight of Ulf Merbold, an ESA astronaut as part of the EuroMir program.

Malenchenko completed two spacewalks that lasted 11 hours and 7 minutes total. He performed the first manual docking of the Mir station with the Progress M-24 vehicle in the teleoperator mode. Since Oct. 1998 till Sept. 2000 Malenchenko trained at NASA for a Shuttle spaceflight (2A, later 2A.2B).

Malenchenko served on the crew of STS-106 preparing the International Space Station for the arrival of the first permanent crew. The five astronauts and two cosmonauts delivered more than 6,600 pounds of supplies and installed batteries, power converters, a toilet and a treadmill on the Space Station. Yuri Malenchenko and Ed Lu performed a 6 hour and 14 minute space walk in order to connect power, data and communications cables to the newly arrived Zvezda Service Module and the Space Station.

Since Jan. 2001 he trained as a commander of the ISS 7 prime crew. Malenchenko completed his third spaceflight (with NASA astronaut Ed Lu) as an ISS 7 crew and Soyuz TMA commander. The flight lasted from April 26 till Oct. 27, 2003, with a total duration of 185 days.

Since Nov. 2003 till Sept. 2005 Malenchenko trained with a group of test-cosmonauts.

Since Oct. 2005 till Oct. 2006 he trained as a flight engineer of the ISS 14 crew and Soyuz commander.

In Oct. 2006 he started training as an ISS 16 crew flight engineer and Soyuz commander that is scheduled to launch to the ISS in Oct. 2007.

JULY 2007

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7. ISS-16 FE/MS-5 (down): Daniel Tani



PERSONAL DATA:

Born February 1, 1961 in Ridley Park, Pennsylvania, but considers Lombard, Illinois, to be his hometown. Married to the former Jane Egan from Cork, Ireland. They have two children. He enjoys golf, flying, running, tennis, music, cooking. His mother, Rose Tani, resides in Lombard, Illinois. His father, Henry N. Tani, is deceased.

EDUCATION:

Graduated from Glenbard East High School, Lombard, Illinois, in 1979; received a bachelor and a master of science degree in mechanical engineering from Massachusetts Institute of Technology (MIT) in 1984 and 1988, respectively.

AWARDS:

Honorary Doctorate of Science, Elmhurst College (IL) 2003. Recipient of the 2003 Excellence Award in Science and Technology from the U.S. Pan Asian American Chamber of Commerce. Recipient of the Japanese-American Citizen League's Nikkei of the Biennium for Science and Technology, 2002. NASA spaceflight medal, 2001. Orbital Sciences Corporation Outstanding Technical Achievement Award, 1993.

EXPERIENCE:

After Tani received his bachelor's degree from MIT, he worked at Hughes Aircraft Corporation in El Segundo, California as a design engineer in the Space and Communications group. In 1986, he returned to MIT and received his master's degree in mechanical engineering in 1988, specializing in human factors and group decision making. After graduation, Tani worked for Bolt Beranek and Newman in Cambridge, Massachusetts, in the experimental psychology department. In 1988, Tani joined Orbital Sciences Corporation (OSC) in Dulles, Virginia, initially as a senior structures engineer, and then as the mission operations manager for the Transfer Orbit Stage (TOS). In that role, he served as the TOS flight operations lead, working with NASA/JSC mission control in support of the deployment of the ACTS/ TOS payload during the STS-51 mission in September 1993. Tani then moved to the Pegasus program at OSC as the launch operations manager. In that capacity, he served as lead for the development of procedures and constraints for the launching of the air launched Pegasus unmanned rocket. Tani also was responsible for defining, training, and leading the team of engineers who worked in the launch and control room.

NASA EXPERIENCE:

Selected as an astronaut candidate by NASA in April 1996, Tani reported to the Johnson Space Center in August 1996. Having completed two years of training and evaluation, he qualified for flight assignment as a mission specialist in 1998. He held technical duties in the Astronaut Office Computer Support Branch, and EVA Branch and has served as a Crew Support Astronaut (CSA) for Expedition-4. Tani flew on STS-108 in 2001, and has logged over 11 days in space, including over 4 EVA hours in one space walk. In 2002, he was a crewmember on the Aquarius undersea research habitat for 9 days as part of the NEEMO-2 mission (NASA Extreme Environment Mission Operations). Tani then trained and qualified as the backup flight engineer for Expedition 11, which launched aboard the Soyuz TMA-6 in April 2005. He is currently assigned as a flight engineer for Expeditions 15 and 16. He will launch to the International Space Station (ISS) aboard STS-122 and will return aboard STS-122, living and working for several months on the ISS. During that time he will perform 3 spacewalks and numerous robotic operations in support of the installation and checkout of Node-2.

SPACE FLIGHT EXPERIENCE:

STS-108 Endeavour (December 5-17, 2001) was the 12th shuttle flight to visit the International Space Station. During the mission Tani served as MS-2. Endeavour's crew delivered the Expedition-4 crew and returned the Expedition-3 crew. The crew unloaded over 3 tons of supplies, logistics and science experiments from the Raffaello Multi-Purpose Logistics Module. Tani performed a space walk to wrap thermal blankets around ISS Solar Array Gimbals. STS-108 was accomplished in 185 Earth orbits, traveling 4.8 million miles in 283 hours and 36 minutes, including an EVA of 4 hours and 12 minutes.

Editor's note: Tani launched aboard shuttle Discovery on mission STS-120 on Oct. 23, 2007, replacing Expedition 15 flight engineer Clay Anderson. Tani currently is aboard the space station.

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STS-122 Crew Photographs



Commander Steve Frick



Pilot Alan Poindexter



MS-1: Leland Melvin



MS-2/EV-1 Rex Walheim



MS-3/EV-2 Hans Schlegel (ESA)



MS-4/EV-3: Stanley Love



MS-5/ISS-16 Leopold Eyharts (ESA)

ISS-16 Crew Photographs



ISS-16 CDR Peggy Whitson



ISS-16 FE Yuri Malenchenko, CSA



ISS-16 FE/MS-5: Daniel Tani

STS-122 Launch Windows

Updated: 11/30/07

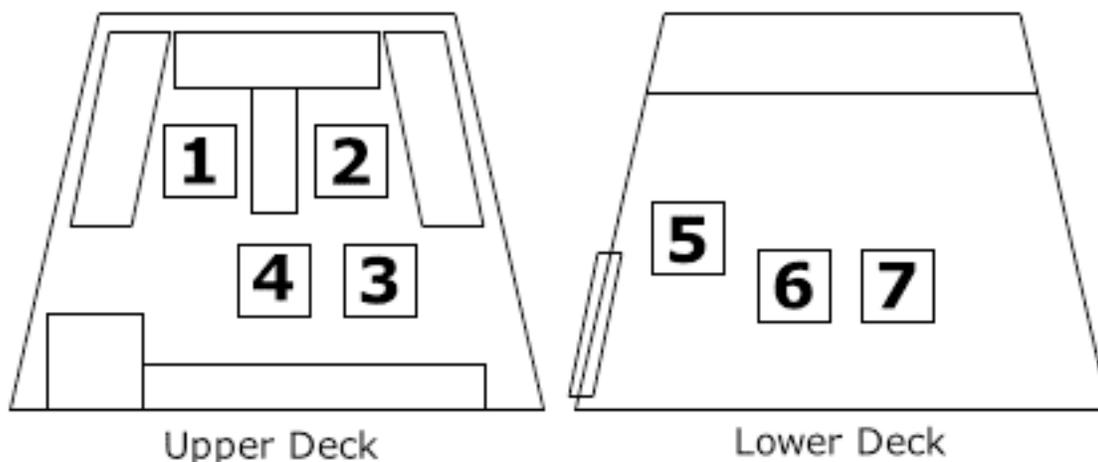
To reach the international space station, the shuttle must take off within about five minutes of the moment Earth's rotation carries the launch pad into the plane of the station's orbit. To maximize performance, NASA targets launch for right around the moment the shuttle can launch directly into that plane.. In the chart below, the target launch time is listed in the "in plane" column. All times in Eastern and subject to change.

DATE	WINDOW OPEN	IN-PLANE	WINDOW CLOSE	DOCKING	NOTES
12/06/07	04:26:44 PM	04:31:44 PM	04:36:44 PM	FD 3	
12/07/07	04:04:12 PM	04:09:12 PM	04:14:12 PM	FD 3	
12/08/07	03:38:30 PM	03:43:30 PM	03:48:30 PM	FD 3	
12/09/07	03:15:59 PM	03:20:59 PM	03:25:59 PM	FD 3	
12/10/07	02:50:17 PM	02:55:17 PM	03:00:17 PM 03:03:25 PM	FD 3 FD 4	
12/11/07	02:27:46 PM	02:32:46 PM	02:37:46 PM	FD 3	
12/12/07	02:02:03 PM	02:07:03 PM	02:12:03 PM 02:15:12 PM	FD 3 FD 4	
12/13/07	01:39:32 PM	01:44:32 PM	01:49:32 PM	FD 3	
12/14/07	01:13:49 PM	01:18:49 PM	01:23:49 PM 01:26:59 PM	FD 3 FD 4	

STS-122 Launch and Flight Control Personnel

KSC/LCC	LAUNCH	KSC PAO-Launch	KSC PAO-Fueling
Launch Director NASA Test Director OTC KSC Commentator	Doug Lyons Jeff Spaulding Gerry Goodson	George Diller	George Diller
JSC/MCC	STS FLIGHT	STS PAO	STS CAPCOM
Ascent FD Weather Orbit 1 FD (Id) Orbit 2 FD Planning FD Entry. FD Weather Team 4	Norm Knight Mike Sarafin Tony Ceccacci Paul Dye Bryan Lunney Matt Abbott	Rob Navias Nicole Lemasters Pat Ryan TBD Rob Navias	Jim Dutton Terry Virts Kevin Ford Steve Robinson Shannon Lucid Jim Dutton Terry Virts
ISS-14 MCC	ISS FLIGHT	ISS PAO	ISS CAPCOM
Orbit 1 Orbit 2 (Id) Orbit 3 ESA Interface	Bob Dempsey Sally Davis Ron Spencer Annette Hasbrook	N/A N/A N/A	Hal Getzelman Chris Cassidy Chris Zajac
Flight Support	Prime	Backup	Backup
MMT/JSC MMT/KSC MOD Rep Moscow FD LCC Westher Launch STA Entry STA Entry/EAFB STA TAL Zaragoza TAL Istres TAL Moron JSC PAO/KSC Astro Support Families	John Shannon LeRoy Cain Phil Engelauf N/A John Casper Steve Lindsey Steve Lindsey Rick Sturckow Lee Archambault/Dom Antonelli Rick Sturckow Mark Polansky Brandi Dean Butch Wilmore Lee Morin	Jose Hernandez Nicholas Patrick	Heidi Stef.Piper

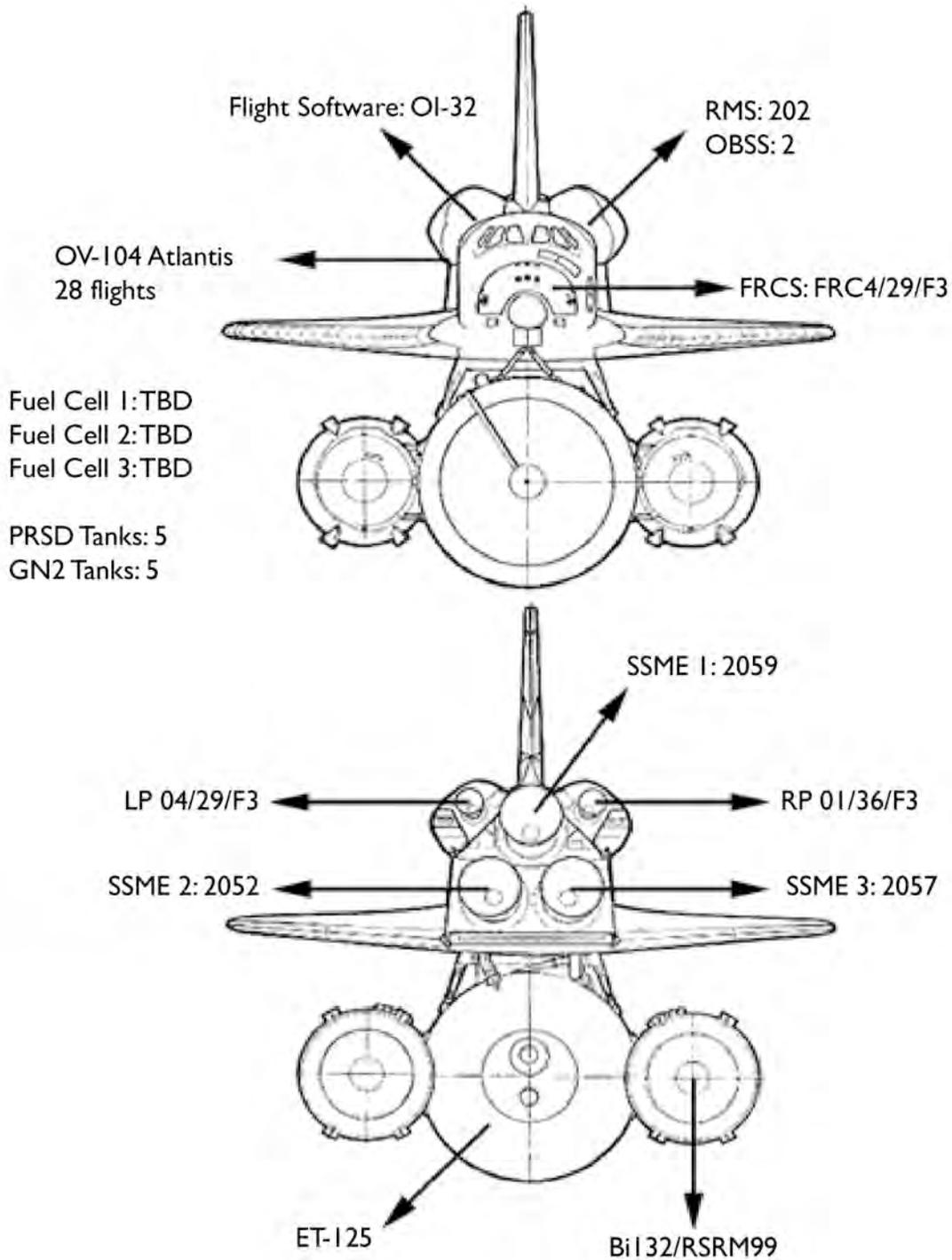
Position	Name	Launch Seating	Entry Seating
Commander	Steve Frick	1	1
Pilot	Alan Poindexter	2	2
MS1	Leland Melvin	3	3
MS2/FE/EV1	Rex Walheim	4	4
MS3/EV2	Hans Schlegel	5	5
MS4/EV3	Stan Love	6	6
MS5/ISS-16 (up)	Leopold Eyharts	7	N/A
ISS-16/MS5 (down)	Dan Tani	N/A	7



STS-122 EVA	EVAs	Suit Markings	IV
Walheim/EV-1	1,2,3	Solid red stripes	Poindexter
Schlegel/EV-2	1,2	No stripes	
Love/EV-3	3	Dashed stripes	

Task	Prime	Backup
SRMS	Checkout	Love
SRMS	TPS inspection	Love
SRMS	OBSS handoff	Melvin
SSRMS	OBSS handoff	Melvin
SSRMS	EVA-1	Melvin
SSRMS	EVA-2	Melvin
SSRMS	EVA-3	Melvin
SRMS	Late inspection	Love
Loadmaster	Melvin	Love
Columbus activation/outfitting	Eyharts	Whitson/Schlegel
Photo/TV	Poindexter	Melvin
ET photos	Schlegel	Melvin

STS-122 Flight Hardware/Software



STS-122: Atlantis Flight History

Source: NASA

Atlantis (OV-104) was delivered to Kennedy Space Center in April 1985. It lifted off on its maiden voyage on Oct. 3, 1985, on mission 51-J, the second dedicated Department of Defense flight. Later missions included the launch of the Galileo interplanetary probe to Jupiter on STS-34 in October 1989, and STS-37, with the Gamma Ray Observatory (GRO) as its primary payload, in April 1991.

Atlantis is named after a two-masted sailing ship that was operated for the Woods Hole Oceanographic Institute from 1930 to 1966..

FLT #	STS	DD	HH	MM	SS	Launch	Mission Description
N/A	51J	00	00	00	00	9/12/85	Flight readiness firing
01	21 51J	04	01	44	38	10/3/85	DOD
02	23 61B	06	21	04	49	11/26/85	3 comsats, EASE/ACCESS
03	27 27	04	09	05	37	12/2/88	DOD (Lacrosse?)
04	29 30	04	00	56	27	5/4/89	Magellan Venus probe
05	31 34	04	23	39	21	10/18/89	Galileo Jupiter probe
06	34 36	04	10	18	22	2/28/90	DOD
07	37 38	04	21	54	31	11/15/90	DOD
08	39 37	05	23	32	44	4/5/91	Gamma Ray Observatory
09	42 43	08	21	21	25	8/2/91	TDRS-5
10	44 44	06	22	50	44	11/19/91	DSP
11	46 45	08	22	09	28	3/24/92	ATLAS-1
12	49 46	07	23	15	03	7/31/92	TSS; EURECA deployment
13	66 66	10	22	34	02	11/3/94	ATLAS-3
14	69 71	09	19	22	17	6/27/95	Mir Docking No. 1
15	73 74	08	04	30	46	11/12/95	Mir Docking No. 2
16	76 76	09	05	15	53	3/22/96	Mir Docking No. 3
17	79 79	10	03	19	28	9/16/96	Mir Docking No. 4
18	81 81	10	04	55	21	1/12/97	Mir Docking No. 5
19	84 84	09	05	19	56	5/15/97	Mir Docking No. 6
20	87 86	10	19	20	50	9/25/97	Mir Docking No. 7
21	98 101	09	20	09	08	5/19/00	ISS 2A.2a (Zarya refurb)
22	99 106	11	19	11	01	9/8/00	ISS 2A.2b (outfitting)
23	102 98	12	21	20	03	2/7/01	ISS 5A (Destiny lab module)
24	105 104	12	18	34	56	7/12/01	ISS 7A (Airlock module)
25	109 110	10	19	42	38	4/8/02	ISS 8A (S0 truss)
26	111 112	10	19	57	49	10/7/02	ISS 9A (S1 truss)
27	116 115	11	19	06	35	9/9/06	ISS 12A (P3/P4 truss)
28	118 117	13	20	11	34	6/8/07	ISS-13A (S3/S4)
Vehicle Total		245	12	45	26		

STS-122 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. The final hold will be released to synch up with the planned launch five minutes later.

HH	MM	SS	EST	EVENT
Mon 12/03/07				
			12:00 PM	Crew arrives at the Kennedy Space Center
			06:30 PM	Call to stations
69	26	00	07:00 PM	Countdown begins
Tue 12/04/07				
59	26	00	05:00 AM	Fuel cell reactant load preps
53	46	00	10:40 AM	MEC/SRB power up
53	26	00	11:00 AM	Clear crew module
53	26	00	11:00 AM	Begin 4-hour built-in hold
53	26	00	11:00 AM	Clear blast danger area
52	41	00	11:45 AM	Orbiter pyro-initiator controller test
52	31	00	11:55 AM	SRB PIC test
51	31	00	12:55 PM	Master events controller pre-flight BITE test
51	26	00	01:00 PM	Mission Management Team (MMT) meets
49	26	00	03:00 PM	Resume countdown
47	56	00	04:30 PM	Fuel cell oxygen loading begins
45	26	00	07:00 PM	Fuel cell oxygen load complete
45	26	00	07:00 PM	Fuel cell hydrogen loading begins
42	56	00	09:30 PM	Fuel cell hydrogen loading complete
41	56	00	10:30 PM	Pad open; ingress white room
41	26	00	11:00 PM	Begin 4-hour built-in hold
41	26	00	11:00 PM	Crew module clean and vacuum
40	56	00	11:30 PM	OMBUU demate
Wed 12/05/07				
40	26	00	12:00 AM	APU, engine covers off; RCS paper covers
39	26	00	01:00 AM	MLP interior secured
37	26	00	03:00 AM	Countdown resumes
37	26	00	03:00 AM	Main engine preps
37	26	00	03:00 AM	MECs 1 and 2 on
35	56	00	04:30 AM	Remove OMS engine covers, throat plugs
35	26	00	05:00 AM	Deflate RSS dock seals; tile inspection
34	56	00	05:30 AM	Tile inspection
31	26	00	09:00 AM	TSM prepped for fueling
29	26	00	11:00 AM	Begin 13-hour 6-minute hold
27	56	00	12:30 PM	OIS communications check
27	06	00	01:20 PM	JSC flight control team on station
27	06	00	01:20 PM	ASP crew module cable inspection
26	56	00	01:30 PM	Crew weather briefing
25	56	00	02:30 PM	Comm activation
25	26	00	03:00 PM	Crew module voice checks
24	56	00	03:30 PM	Debris inspection
24	26	00	04:00 PM	Flight crew equipment late stow
20	26	00	08:00 PM	RSS to park position

HH	MM	SS	EST	EVENT
18	26	00	10:00 PM	Ascent switch list
19	33	00	08:53 PM	Final TPS, debris inspection
Thu 12/06/07				
16	20	00	12:06 AM	Resume countdown
16	20	00	12:06 AM	Terminate pad tours
15	00	00	01:26 AM	APU bite test
14	50	00	01:36 AM	Fuel cell activation
14	20	00	02:06 AM	Pad clear of non-essential personnel
14	20	00	02:06 AM	Booster joint heater activation
13	35	00	02:51 AM	Tanking weather update
12	50	00	03:36 AM	MEC pre-flight bite test
12	50	00	03:36 AM	Final fueling preps; launch area clear
12	20	00	04:06 AM	Red crew assembled
11	35	00	04:51 AM	Fuel cell integrity checks complete
11	20	00	05:06 AM	Begin 2-hour built-in hold (T-minus 6 hours)
11	10	00	05:16 AM	Safe-and-arm PIC test
10	26	00	06:00 AM	Crew wakeup
10	05	00	06:21 AM	Mission management team tanking meeting
09	50	00	06:36 AM	Test team ready for ET loading
09	20	00	07:06 AM	Resume countdown (T-minus 6 hours)
09	20	00	07:06 AM	LO2, LH2 transfer line chilldown
09	10	00	07:16 AM	Main propulsion system chill down
09	10	00	07:16 AM	LH2 slow fill
08	40	00	07:46 AM	LO2 slow fill
08	35	00	07:51 AM	Hydrogen ECO sensors go wet
08	30	00	07:56 AM	LO2 fast fill
08	20	00	08:06 AM	LH2 fast fill
06	25	00	10:01 AM	LH2 topping
06	20	00	10:06 AM	LH2 replenish
06	20	00	10:06 AM	LO2 replenish
06	20	00	10:06 AM	Begin 2-hour 30-minute built-in hold (T-minus 3 hours)
06	20	00	10:06 AM	Closeout crew to white room
06	20	00	10:06 AM	External tank in stable replenish mode
05	50	00	10:36 AM	Astronaut support personnel comm checks
05	15	00	11:11 AM	Pre-ingress switch reconfig
04	56	00	11:30 AM	NASA television coverage begins
04	21	00	12:05 PM	Final crew weather briefing
03	50	00	12:36 PM	Resume countdown (T-minus 3 hours)
03	41	00	12:45 PM	Crew departs O&C building
03	11	00	01:15 PM	Crew ingress
02	25	00	02:01 PM	Astronaut comm checks
02	10	00	02:16 PM	Hatch closure
01	15	00	03:11 PM	White room closeout
01	10	00	03:16 PM	Begin 10-minute built-in hold (T-minus 20m)
01	00	00	03:26 PM	NASA test director countdown briefing
01	00	00	03:26 PM	Resume countdown (T-minus 20m)
00	59	00	03:27 PM	Backup flight computer to OPS 1
00	55	00	03:31 PM	KSC area clear to launch
00	49	00	03:37 PM	Begin final built-in hold (T-minus 9m)
00	24	00	04:07 PM	NTD launch status verification
00	09	00	04:22:44 PM	Resume countdown (T-minus 9m)
00	07	30	04:24:14 PM	Orbiter access arm retraction
00	05	00	04:26:44 PM	Launch window opens
00	05	00	04:26:44 PM	Hydraulic power system (APU) start
00	04	55	04:26:49 PM	Terminate LO2 replenish

HH	MM	SS	EST	EVENT
00	04	00	04:27:44 PM	Purge sequence 4 hydraulic test
00	04	00	04:27:44 PM	IMUs to inertial
00	03	55	04:27:49 PM	Aerosurface profile
00	03	30	04:28:14 PM	Main engine steering test
00	02	55	04:28:49 PM	LO2 tank pressurization
00	02	35	04:29:09 PM	Fuel cells to internal reactants
00	02	30	04:29:14 PM	Clear caution-and-warning memory
00	02	00	04:29:44 PM	Crew closes visors
00	01	57	04:29:47 PM	LH2 tank pressurization
00	00	50	04:30:54 PM	SRB joint heater deactivation
00	00	31	04:31:13 PM	Shuttle GPCs take control of countdown
00	00	21	04:31:23 PM	SRB steering test
00	00	07	04:31:37 PM	Main engine start (T-6.6 seconds)
00	00	00	04:31:44 PM	SRB ignition (LAUNCH)

STS-122 Weather Guidelines¹

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.

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.

¹ Source: Spaceflight Meteorology Group, Johnson Space Center

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)

STS-122 Ascent Events Summary

Flight Data		EST	L-MM:SS	Terminal Countdown			
STS-122	03:37 PM	L-45:00	T-9 hold begins				
6-Dec-07	4:22:44 PM	L-09:00	Resume countdown				
04:31:44 PM	4:24:14 PM	L-07:30	Orbiter access arm retraction				
Win Close	4:26:44 PM	L-05:00	Auxilliary power unit start				
4:36:44 PM	4:26:49 PM	L-04:55	Liquid oxygen drainback begins				
-107:12:41	4:27:49 PM	L-03:55	Purge sequence 4 hydraulic test				
	4:28:49 PM	L-02:55	Oxygen tank at flight pressure				
SLF Max Wind:	4:28:49 PM	L-02:55	Gaseous oxygen vent arm retraction				
TBD	4:29:09 PM	L-02:35	Fuel cells to internal				
Wind Direction:	4:29:47 PM	L-01:57	Hydrogen tank at flight pressure				
TBD	4:30:54 PM	L-00:50	Orbiter to internal power				
SLF Crosswind:	4:31:13 PM	L-00:31	Shuttle computers control countdown				
TBD	4:31:23 PM	L-00:21	Booster steering test				
TBD	4:31:37 PM	L-00:06.6	Main engine ignition				
Abort Data		EST	L+MM:SS	Ascent Events Timeline		FPS	MPH
0:02:29 RTLS ONLY	4:31:44 PM	T+0:00	Launch	(Inertial Velocity)			
	4:31:54 PM	T+00:10	START ROLL MANEUVER	1,350	921		
	4:32:02 PM	T+00:18	END ROLL MANEUVER	1,490	1,016		
	4:32:20 PM	T+00:36	START THROTTLE DOWN (72%)	1,880	1,282		
	4:32:33 PM	T+00:49	START THROTTLE UP (104.5%)	2,130	1,452		
	4:32:44 PM	T+01:00	MAX Q (710 psf)	2,380	1,623		
	4:33:49 PM	T+02:05	SRB STAGING	5,350	3,648		
	4:33:59 PM	T+02:15	START OMS ASSIST (1:56 duration)	5,500	3,750		
0:02:25 TAL	4:34:13 PM	T+02:29	2 ENGINE TAL MORON (104.5%, 2s)	5,900	4,023		
	4:34:19 PM	T+02:35	2 ENGINE TAL ZARAGOZA (104.5%, 2s)	6,000	4,091		
	4:34:29 PM	T+02:45	2 ENGINE TAL ISTRES (104.5%, 2s)	6,200	4,228		
	4:35:35 PM	T+03:51	NEGATIVE RETURN (KSC) (104.5%, 3s)	8,100	5,523		
0:01:48 ATO	4:36:38 PM	T+04:54	PRESS TO ATO (104.5%, 2s, 160 u/s)	10,600	7,228		
	4:37:07 PM	T+05:23	DROOP ZARAGOZA (109%,0s)	12,000	8,183		
	4:37:09 PM	T+05:25	SINGLE ENGINE OPS-3 ZARAGOZA (109%,0s,2EO SIMO)	12,100	8,251		
	4:37:31 PM	T+05:47	ROLL TO HEADSUP	13,200	9,001		
	4:37:48 PM	T+06:04	1 ENGINE TAL ZARAGOZA (104.5%,2s,2EO SIMO)	14,300	9,751		
	4:37:48 PM	T+06:04	1 ENGINE TAL MORON (109%,0s,2EO SEQ,1st EO @ 5820 VI)	16,200	11,046		
	4:37:48 PM	T+06:04	1 ENGINE TAL ISTRES(109%,0s,2EO SEQ,1st EO @ 6190 VI)	16,800	11,456		
MECO HA/HP 136 X 36 sm OMS-2 HA/HP 141 X 121 sm	4:38:26 PM	T+06:42	PRESS TO MECO (104.5%, 2s, 160 u/s)	16,800	11,456		
	4:38:52 PM	T+07:08	1 ENGINE PRESS-TO-MECO (104.5%, 2s, 562 u/s)	18,900	12,888		
	4:39:05 PM	T+07:21	3G LIMITING	20,000	13,638		
	4:39:05 PM	T+07:21	NEGATIVE MORON (2@67%)	20,000	13,638		
	4:39:25 PM	T+07:41	LAST 2 ENG PRE-MECO TAL ZARAGOZA (67%)	21,800	14,865		
	4:39:25 PM	T+07:41	NEGATIVE ISTRES (2@67%)	21,800	14,865		
	4:39:32 PM	T+07:48	LAST SINGLE ENG PRE-MECO TAL ZARAGOZA (104.5%)	22,500	15,342		
	4:39:37 PM	T+07:53	23K	23,000	15,683		
	4:39:37 PM	T+07:53	LAST 3 ENG PRE-MECO TAL ZARAGOZA (67%)	23,000	15,683		
	4:40:02 PM	T+08:18	LAST TAL DIEGO GARCIA	25,300	17,252		
	4:40:07 PM	T+08:23	MECO COMMANDED	25,800	17,592		
4:40:13 PM	T+08:29	ZERO THRUST	25,819	17,605			

STS-122 Trajectory Data (predicted)

Time (EST)	T+ MM:SS	Thrust	Altitude Feet	Altitude SM	Mach	V MPH	Vi FPS	Vi MPH	Acc Gs	Range SM
04:31:44 PM	00:00	100.00	-23	0.0	0.0	0.0	1,341.0	914.4	0.3	0.0
05:31:54 PM	00:10	104.50	761	0.1	0.2	122.7	1,353.0	922.6	1.7	0.0
05:32:04 PM	00:20	104.50	3,898	0.7	0.4	302.1	1,527.0	1,041.2	1.9	0.1
05:32:14 PM	00:30	104.50	8,968	1.7	0.6	486.9	1,733.0	1,181.7	1.8	0.6
05:32:24 PM	00:40	72.00	16,821	3.2	0.9	670.3	1,960.0	1,336.5	1.7	1.4
05:32:34 PM	00:50	75.00	25,546	4.8	1.1	808.7	2,147.0	1,464.0	1.7	2.5
05:32:44 PM	01:00	104.50	35,692	6.8	1.4	981.9	2,376.0	1,620.1	2.0	3.9
05:32:54 PM	01:10	104.50	49,189	9.3	1.9	1,242.4	2,728.0	1,860.2	2.3	5.9
05:33:04 PM	01:20	104.50	63,929	12.1	2.4	1,554.7	3,184.0	2,171.1	2.5	8.3
05:33:14 PM	01:30	104.50	82,665	15.7	2.9	1,946.1	3,772.0	2,572.0	2.5	12.0
05:33:24 PM	01:40	104.50	101,596	19.2	3.4	2,321.1	4,336.0	2,956.6	2.5	16.3
05:33:34 PM	01:50	104.50	124,104	23.5	3.8	2,735.7	4,958.0	3,380.8	2.3	22.4
05:33:44 PM	02:00	104.50	145,262	27.5	3.9	2,948.4	5,286.0	3,604.4	1.0	28.9
05:33:54 PM	02:10	104.50	166,895	31.6	4.1	3,046.0	5,447.0	3,714.2	1.0	36.2
05:34:04 PM	02:20	104.50	186,062	35.2	4.3	3,159.8	5,631.0	3,839.7	1.0	43.6
05:34:14 PM	02:30	104.50	205,852	39.0	4.6	3,301.0	5,854.0	3,991.7	1.0	52.2
05:34:24 PM	02:40	104.50	222,661	42.2	5.1	3,442.1	6,073.0	4,141.1	1.1	60.6
05:34:34 PM	02:50	104.50	238,358	45.1	5.5	3,594.9	6,307.0	4,300.6	1.1	69.4
05:34:44 PM	03:00	104.50	254,358	48.2	5.9	3,776.2	6,581.0	4,487.4	1.1	79.6
05:34:54 PM	03:10	104.50	267,774	50.7	6.3	3,952.2	6,845.0	4,667.5	1.1	89.5
05:35:04 PM	03:20	104.50	281,314	53.3	6.8	4,158.1	7,151.0	4,876.1	1.2	100.9
05:35:14 PM	03:30	104.50	292,539	55.4	7.2	4,355.8	7,444.0	5,075.9	1.2	112.0
05:35:24 PM	03:40	104.50	302,756	57.3	7.4	4,563.8	7,750.0	5,284.6	1.2	123.5
05:35:34 PM	03:50	104.50	312,856	59.3	7.6	4,804.5	8,104.0	5,525.9	1.3	136.9
05:35:44 PM	04:00	104.50	321,029	60.8	7.9	5,034.3	8,440.0	5,755.1	1.3	149.7
05:35:54 PM	04:10	104.50	328,944	62.3	8.1	5,298.9	8,827.0	6,018.9	1.3	164.6
05:36:04 PM	04:20	104.50	335,184	63.5	8.3	5,547.8	9,190.0	6,266.5	1.4	178.8
05:36:14 PM	04:30	104.50	341,047	64.6	8.6	5,833.5	9,607.0	6,550.8	1.4	195.2
05:36:24 PM	04:40	104.50	345,503	65.4	8.8	6,104.2	10,001.0	6,819.5	1.5	210.8
05:36:34 PM	04:50	104.50	349,158	66.1	9.1	6,386.5	10,412.0	7,099.7	1.5	227.2
05:36:44 PM	05:00	104.50	352,296	66.7	9.5	6,710.4	10,884.0	7,421.6	1.6	246.0
05:36:54 PM	05:10	104.50	354,389	67.1	9.9	7,017.9	11,331.0	7,726.4	1.6	264.0
05:37:04 PM	05:20	104.50	355,904	67.4	10.3	7,370.4	11,844.0	8,076.2	1.7	284.8
05:37:14 PM	05:30	104.50	356,611	67.5	10.8	7,705.9	12,331.0	8,408.2	1.7	304.5
05:37:24 PM	05:40	104.50	356,726	67.6	11.3	8,055.0	12,840.0	8,755.3	1.8	325.2
05:37:34 PM	05:50	104.50	356,226	67.5	11.9	8,457.3	13,425.0	9,154.2	1.9	349.0
05:37:44 PM	06:00	104.50	355,274	67.3	12.4	8,839.2	13,981.0	9,533.4	1.9	371.7
05:37:54 PM	06:10	104.50	353,841	67.0	13.1	9,278.3	14,620.0	9,969.1	2.0	397.8
05:38:04 PM	06:20	104.50	352,316	66.7	13.7	9,697.0	15,229.0	10,384.3	2.1	422.7
05:38:14 PM	06:30	104.50	350,393	66.4	14.5	10,184.5	15,940.0	10,869.2	2.2	451.3
05:38:24 PM	06:40	104.50	348,376	66.0	15.3	10,653.0	16,622.0	11,334.2	2.3	478.6
05:38:34 PM	06:50	104.50	346,194	65.6	16.1	11,146.7	17,340.0	11,823.8	2.5	507.1
05:38:44 PM	07:00	104.50	343,733	65.1	17.1	11,720.8	18,177.0	12,394.5	2.6	540.1
05:38:54 PM	07:10	104.50	341,579	64.7	18.0	12,275.2	18,986.0	12,946.2	2.8	571.6
05:39:04 PM	07:20	104.50	339,459	64.3	19.1	12,925.0	19,933.0	13,591.9	3.0	607.8
05:39:14 PM	07:30	98.00	337,922	64.0	20.1	13,537.3	20,826.0	14,200.8	3.0	642.6

Time (EST)	T+ MM:SS	Thrust	Altitude Feet	Altitude SM	Mach	V MPH	Vi FPS	Vi MPH	Acc Gs	Range SM
05:39:24 PM	07:40	92.00	336,803	63.8	21.2	14,209.7	21,807.0	14,869.7	3.0	682.5
05:39:34 PM	07:50	87.00	336,394	63.7	22.1	14,825.4	22,705.0	15,482.1	3.0	720.6
05:39:44 PM	08:00	82.00	336,688	63.8	23.0	15,437.7	23,599.0	16,091.7	3.0	760.3
05:39:54 PM	08:10	76.00	337,983	64.0	23.9	16,112.8	24,584.0	16,763.3	3.0	805.8
05:40:04 PM	08:20	67.00	340,238	64.4	24.6	16,731.3	25,487.0	17,379.1	2.8	850.2
05:40:14 PM	08:30	67.00	343,350	65.0	24.7	16,957.0	25,817.0	17,604.1	0.0	896.0
05:40:15 PM	08:31	67.00	343,660	65.1	24.7	16,957.0	25,818.0	17,604.8	0.0	900.5
05:40:16 PM	08:32	67.00	343,970	65.1	24.7	16,957.7	25,818.0	17,604.8	0.0	904.9
05:40:17 PM	08:33	67.00	344,280	65.2	24.6	16,957.7	25,818.0	17,604.8	0.0	909.3
05:40:18 PM	08:34	67.00	344,590	65.3	24.6	16,957.0	25,818.0	17,604.8	0.0	913.8

STS-122 Flight Plan Walkthrough

Editor's Note...

Source: NASA; the reader is assumed to be familiar with NASA acronyms and procedures.

Generic Items

Flight Duration 11+1+2: At some point after launch, the extra day will most likely be added to the mission. The extra day can either accommodate a FD04 rndz, Focused Inspection beyond the 4.5 hours in the timeline, potential TPS repair prep time, or an extra docked day to work on Columbus outfitting activities.

EVAs

- All nominal EVAs are performed using the ISS airlock and the campout prebreathe protocol.
- MS2 and MS3 perform EVAs 1 & 2 while MS2 and MS4 perform EVA3. STS CDR and ISS CDR are the suit-up IVs for all three EVAs while PLT is the task IV.
- All three EVAs use METOX
- All EVA tool battery charging is performed using a Battery Stowage Assembly (BSA) charger. BSA charging for REBA, helmet light, and PGT batteries takes ~12 hours while EMU battery charging takes ~20 hours. EMU battery inits require a 4-hour cool down and thus are scheduled the day after EVAs.
- METOX regen is performed in Post EVA for all EVAs. METOX regen terms are required at least 14 hours after the inits.
- On days prior to EVAs, 2 crewmembers are required to install METOX & EMU batteries, and 3 are required for E/L Prep and EVA Tool Config.

Columbus Notes

- Columbus is ingress on FD05. For the partial ingress performed early in the day by FE-2, PPEs (mask and goggles) must be worn. The PPE requirement applies to any crewmember that enters the Columbus modules before the Cabin Fan has been activated for 40 minutes and scrubbed the cabin air of any potential debris.
- Columbus has 4 payload racks: Biolab (BLB), FSL, EDR, and EPM
- During the mission, 3 of these racks will be relocated and each rack will have an umbilical mate. There are some required powerdowns (documented in FR 1E_C9-1) for the individual umbilical mates.

EPM & FSL: only require Power Distribution Unit (PDU) powerdown

EDR: PDU + DDCU N2P2A or N2P3A

BLB: PDU + DDCU N2D1B or N2D4B

Water Flow Selection Valve (WFSV) close prior to each mate

WFSV open is part of the rack activation procedure and will not be a separate activity.

The FSL umbilical mate can be performed before working on the rear of the rack.

- Biolab - The Biolab facility, located in the Columbus lab, supports biological experiments on micro-organisms, cells, tissue cultures, small plants, and small invertebrates. There are several Biolab activities completed by MS3. At the start of the day, the Zero G Stowage Rack (ZSR) must be relocated and k-bar capture mechanisms in Bay A2 must be installed before the Biolab relocation can begin.
- European Drawer Rack (EDR) - The EDR provides room for sub-rack payloads in International drawers and lockers within International payload racks.

□ EECOM/ECLSS Items

□ A total of 13 CWC fills and 9 PWRs are filled and transferred to ISS. CWCs and PWRs cannot be filled at the same time since EECOM would not be able to tell how much water is in each bag. PWR fills cannot occur during supply nozzle dumps. A cue card listing all the water fill requirements will be uplinked on FD02.

□ Nozzle dumps are scheduled on FD03 (pre-docking), FD07 (docked), FD10 (post undock), and FD11 (EOM-1). CWCs are dumped from the waste nozzle and PWRs from the supply nozzle. Therefore, a combination of waste/CWC and supply/PWR dumps can occur simultaneously if two crewmembers are available.

□ Carbon Dioxide Monitor (CDM) ops are scheduled 4 times during the flight. A CDM activation is scheduled just prior to sleep and a CDM deactivation is scheduled immediately following wake-up. A CDM battery change-out is scheduled before the CDM is activated again.

ISS Crew Rotation: 12 hours of handover is required between FE-2(UP) and FE-2(DN). These 12 hours can be accomplished by either face-to-face handover time or functional handover, where an experienced ISS crewmember demonstrates real-time ISS ops (OJT). The current plan has 12.5 hours of handover (9 hours face-to-face and 3.5 hours functional)

□ ISS Crew Work Day Length:

□ ISS CDR & FE-1 (Peggy Whitson & Yuri Malenchenko): 6.5 hrs/day; 2.5 hrs of exercise

□ FE-2 (Dan Tani): 7 hrs/day; 2 hrs of exercise (preferably all TVIS)

□ FE-2 EXP16 (Leo Eyharts):

FD04 & 05: 6.5 hrs/day, no exercise, 2.5 hrs adaptation/day

FD06 & 07: 8 hrs/day; no exercise; 1 hr adaptation/day

FD08 to EOM: 8 hrs/day, 1hr exercise/day, no adaptation

□ Ref GR&C Pt2 3.12.3.2 crew time table

Transfer: 30 hours of transfer is required. Only Middeck transfer is required for this mission.

IMU Star of Opportunity Aligns are scheduled daily.

Docked Maneuvers: The Shuttle maneuvers the stack for post docking TEA, water dumps, reboost (if required), and undock attitude. ISS maneuvers the stack to the new TEA after Columbus install. CDR or PLT update Universal Pointing after the ISS TEA attitude changes in the event that Shuttle must take attitude control.

Attitude Control Plan: During the crew day, the Motion Control System is configured to H/O to the Shuttle for LOAC cases; during the crew night, the MCS is configured to H/O to the RS segment for LOAC cases. There are ADCO activities during pre & post sleep for these configurations.

ISS TLM Packets: ACS (ADCO Acts): ESS = all; HK1=K or L; HK2=all CBM Ops: ESS = all; HK1=all; HK2=K ROBO Ops: ESS = all; HK1=J; HK2=all Columbus Final Act: ESS = all; HK1=L; HK2=all

DAPs: The nominal undocked DAP is A1 and the nominal docked DAP is A12. DAP A14 is required for undocked OBSS operations.

APCUs: APCUs 1 & 2 each power a string of the Columbus shell heaters while berthed in the payload bay. APCU 2 powers the OBSS sensor package 2 (LCS, IDC) while the OBSS is unberthed.

Reboost: There is a reboost placeholder in the plan on FD09. STS prop margins and ISS altitude strategy will determine if the reboost is performed or not.

Docked Comm: Hardline A/G comm through DAIU is non-operable possibly due to corrosion in the ODS cable. Therefore, the SSOR RF radio is used for all docked A/G communication. Hardline ICOM through DAIU is still functional so that is used for ship-to-ship communications. SSOR is activated in the RNDZ timeline and is deactivated post undock. SSOR was not used in the past for this function because it uses more power. The use of SSOR will require the crew not turn off UHF at all while docked, including during PMCs and EVAs. The detailed pages omit steps 37 and 67 in Post EVA which turn off UHF. These steps will not be deleted generically because the procedure is used for both joint and stage EVAs. The other steps to turn off UHF in EVA Prep and Post EVA were permanently deleted from the procedures.

PMCs are scheduled in presleep and on the morning of EVAs and performed via A/G. The FD06 PMC is scheduled via OCA to verify Netmeeting operation prior to the PFCs on FD07. The crew should not turn off UHF for docked PMCs.

PAO Events:

Ku Masking: From the 118 lessons learned, the ROBO and EVA Ku box transitions will be shown on OSTP in the MCC Coord band and highlighted in magenta text. The SRMS and OBSS no longer require Ku masking.

IWIS: IWIS data takes are scheduled for docking, Columbus mating, undocking and maybe a dedicated RS thruster firing.

❑ On-orbit SBDIs, DTOs, and SDTOs

- ❑ SBDI 1634 (Sleep Short): MS1, MS2, and MS4 are scheduled to complete sleep logs at wake-up. The subjects wear Actiwatch activity monitors (watches) throughout the mission. The EV crew doff their watches prior to EVAs.
- ❑ SBDI 1490B (PMZ): MS2 and MS3 are scheduled to complete logs at wake-up. The subjects wear Actiwatch activity monitors (watches) throughout the mission. (MS2 only wears 1 watch and performs 1 sleep log per day and both 1490B and 1634 are accomplished.) In addition, if a crewmember activates the PMZ protocol (helps with motion sickness), 8 saliva samples will be required.
- ❑ SBDI 1503-S (Midodrine) is performed by MS3 and MS4 between the deorbit burn and entry.
- ❑ SBDI 1900 (Integrated Immune): MS3 and MS4 are scheduled for the saliva samples and blood draws. They provide liquid saliva samples at wake-up every other day starting FD03. Also on FDx and EOM-1, dry saliva samples are scheduled at wakeup, w/u+30 min, w/u+6hrs, w/u+10hrs, and just prior to sleep. The participants also provide a blood sample on EOM-1. ISS CDR, FE-2 (dn), and FE-2 (up) are also scheduled for a similar Integrated Immune experiment. They provide liquid saliva samples at wakeup and dry saliva samples throughout a day late in the docked timeframe. They also provide blood samples as late as possible. MS1 draws all blood samples, and all samples return on the Shuttle.
- ❑ DTO 853 Carbon Dioxide Monitor (CDM) is operated over five sleep periods during the mission to measure CO2 concentrations. The CDM is activated during sleep periods when all shuttle crew are in the middeck and not in the ISS airlock for campout. CDM is activated just prior to sleep and deactivated immediately upon wake-up so that there is minimal disturbance to the air mixing at five middeck measurement locations. After each data take, a battery changeout is performed anytime during the day and the monitoring device is relocated to a different spot in the middeck.
- ❑ MUS (MS3 and FE-2 up) and MOP (FE-2 up) are European DTO questionnaires

Robotics

Manipulator Control Interface Unit (MCIU) filter screen checks are scheduled daily, except on days when standard Filter Check is scheduled.

Flight Day 1 - Ascent

❑ Standard Activities

- ❑ After Post Insertion, FD01 standard activities are scheduled, which include: NC1 OMS burn, Aft Controller C/O, Elevon Park, RMS On Orbit Init, GIRA Install, APCU Activation, Group B Powerdown, Load DAPS, APU Reconfig, OCAC Setup, SSV Setup, and Shuttle Emergency Eyewash (SEE) Setup. Per crew agreement, RMS C/O is not scheduled until FD02.

Columbus and ICC-lite heaters are activated by activating APCUs 1 and 2 as soon as possible after PI.

PGSC Setup is performed per the nominal usage chart and a late update is performed. WLES is activated.

Ascent Imagery: ET Handheld photos and ET Umbilical well photos are downloaded twice per the procedure. ET video is downlinked over Ku.

RMS: RMS On-orbit init is performed followed by the initial MCIU filter check. RMS powerup and checkout will be performed on FD02.

P/TV01 is the general setup of camera equipment for the mission. The first few steps of the setup procedure are required prior to playing back the ET video. At least one hour of P/TV01 video setup is required prior to TPS inspection on FD02. Steps 1-9 are the minimum requirement for inspection. Additional time is scheduled on FD02.

Bleed Orifice is installed. This activity was permanently removed from the preleap procedure and should be hard scheduled on FD01.

DCS Date/Time Set activity was removed from the eZ block and hard scheduled per 118 lessons learned.

Payloads

Actiwatch: MS2-MS4 and FE-2 up all don actiwatches on this day. MS1, MS2, and MS4 don the watch in participation with the sleep short SBDI. MS2 and MS3 don the watch in participation with the PMZ SBDI.

Flight Day 2 - Inspection & RNDZ Prep

RNDZ Burns: NC2 and NC3 rendezvous burns are planned to allow adequate time for OBSS surveys. NPC burn exists in FDO's plan, but is not scheduled since it will likely be combined with another burn.

P/TV01 Setup: Time is allotted for completion of these setups if required.

TPS Surveys

All RCC is inspected during the OBSS Starboard Wing, Nose Cap, and Port Wing surveys. The two wing surveys also cover most of the areas of the crew cabin. The OMS pos is inspected using a handheld camera to take pictures from the aft flight deck windows.

The OBSS survey procedures incorporate the use of supplemental IDC images during LDRI scans, thus reducing the likelihood of needing Focused Inspection. The starboard wing survey is scheduled for 1:45, the nose cap for 1:00, and the port wing for 2:00. The OBSS unberth procedure incorporates the LDRI 3D calibration and the starboard survey the flat field calibration.

Three crewmembers are required continuously during the surveys, two for the SRMS/OBSS ops and one to operate the situational awareness cameras and sensors. Only two crewmembers are required during unberthing and berthing operations (non-laser ops).

Per CDR request, each robotics crewmember has one robotic activity OFF during the day. No crewmember should be scheduled for all robotics ops on this day.

Scans of the entire starboard wing are not easily performed, or are impossible to perform while docked, and so are scheduled first. The surveys are scheduled to continue through the night passes, but the crew may elect to pause if the night time visuals are not sufficient.

The LDRI survey attitude requires no sun within a +/-20 degree field of view (FOV) of the laser bore-sight. Additionally, no sun can be within a 10 degree half-cone directly behind the instrument; however it is highly desired to keep the sun at a 90 degree half cone behind the instrument as long as it's not directly behind.

Real-time Ku is desired (not required) during the LDRI 3D calibration in OBSS unberth. Each surface scan requires as much real-time Ku as possible to downlink DTV using TDRS E or W (not TRDS Z).

❑ Inertial attitudes are scheduled to maximize Ku and to optimize LDRI lighting. Specifically, the wing attitudes put the sun on the wing in the X-Y plane ~60 degrees from the nose, and the nose cap attitude puts the sun on the nose pitched down 30 degrees to avoid sun in the crew's eyes. All maneuvers are scheduled to occur during RMS/OBSS repositioning. If maneuvers are required during the survey, scanning will be paused. VERN/ALT attitude hold is acceptable for LDRI. DAP A14 is loaded per the unberth procedure and is used throughout the surveys. The attitude maneuvers are choreographed so to not conflict with OBSS/DAP constraints. The maneuver to nose cap is performed during a 10-minute gap between the starboard wing and nose cap surveys. This is because nose jets are inhibited and ALT/Tail-only is selected almost immediately into the nose cap survey. The maneuver to port survey is scheduled 10 minutes into the procedure. This is because free drift is selected in step 3. The maneuver to comm attitude is scheduled after OBSS berthing due to a free drift period in the berth procedure.

❑ Any video not obtained real-time is downlinked after all survey are complete. INCO provides LOS times in order to help the crew cue the tapes. Note that TDRS E or W must be used as TDRS Z does not have the capability for DTV and cannot be used to downlink critical damage video.

❑ IDC images obtained during the survey are downlinked via OCA.

❑ P/TV08 is setup for the OMS Pod Survey. The OMS pod survey requires day light, and either -ZLV (Earthshine setting) or -ZSI (Sunlit setting). Note that there is a 3 hour maximum -ZSI limit while undocked.

❑ The OBSS berth procedure leaves the SRMS in pre-cradle where it is parked overnight.

APCU 2 powers sensor package 2 and must be turned off prior to OBSS unberth and berth due to a safety inhibit. The timeline callsout for the crew to turn off APCU 2 prior to OBSS Unberth. During OBSS berth, APCU 2 is deactivated in LCH deact. The timeline calls out for APCU 2 to be reactivated during the end of the OBSS berth procedure. APCU 1 remains on throughout the day to provide power to the Columbus module shell heaters.

EVA Prep: Two EMUs are checked out and the EMUs and other EVA tools are prepared for transfer to ISS.

RNDZ Prep Activities: Centerline Camera Install and ODS Ring Extension cannot occur during OBSS surveys due to a camera view constraint and are thus scheduled after OBSS berth. Centerline Camera Install must occur before ODS Ring Extension. Rndz Tools Checkout must be decoupled with the surveys because the surveys require RSAD and DOUG on the PGSCs while the Rndz Tools Checkout requires RPOP.

Transfer: FE-2 up performs Transfer Prep.

CWC Setup: CWC fill hardware is setup for CWC fills post docking. The first CWC fill is scheduled immediately following the CWC hardware setup.

Generic Activities: Cryo O2 Snsr Check, Water Spray Boiler (WSB) controller swap, FC manual purge, FC Monitoring, Ergometer setup, and filter cleaning are performed. FCMS ops must be decoupled with SRMS ops and Rndz Tools Checkout due to PGSC limitations.

❑ Payloads

❑ Sleep Log: MS1-MS4 all perform sleep log upon wakeup. MS1, MS2, and MS4 perform the log as participation in the sleep short SBDI. MS2 and MS3 fill out the log as participation in the PMZ SBDI.

❑ MUS and MOP: At the end of the work day, FE-2 (up) completes the MOP questionnaire and MS43 and FE-2 (up) both complete the MUS questionnaire.

❑ CDM (DTO 853) is setup any time in the day, and the first activation occurs right before sleep.

Maneuvers: Prior to crew sleep, the CDR future loads the maneuver for the FD03 simo dump. The maneuver starts just before crew wakeup on FD03.

Flight Day 3 - Rendezvous

❑ Comm Items

- The Orbital Interface Unit (OIU) is activated during the RNDZ timeframe.
- DOCK AUDIO: The Docked Audio Setup is performed after docking to tie A/G1 and S/G1 together.
- The SSV outrate is changed to 3 during ISS RNDZ ops.
- The SSV outrate is changed to 2 post-docking.
- BPSMU/RWS routes the STS camera views to the RWS
- EECOM/ECLSS Items
 - A Simo Dump (Waste & Water) is scheduled to start immediately after crew wake. Prior to the dump, the orbiter maneuvers to the water dump attitude via a future loaded maneuver.
 - An N2 repress is completed during the RNDZ timeframe and is 1 hour in duration.
 - Condensate CWC setup is performed on this day.
 - During O2 RCNFG/PURGE, the O2 system will first be configured to purge the Node 2 O2 system and then reconfigured to allow the Orbiter to provide O2 for the EMU prebreathe. The duration of this activity is longer than usual in order to accommodate for Node 2 O2 purge. An O2 purge is required because particulate (contaminate) matter was discovered in the Node 2 High Pressure Oxygen Recharge Line during KSC operations, which violated cleanliness regulations. O2 Purge Prep is scheduled on the ISS prior to docking. The ISS crew will prep the Node 2 Oxygen lines for purge. A prep work activity following the O2 Reconfig/Purge activity is scheduled to allow for extra time in case the O2 Purge runs long. The Shuttle CDR is not required for all steps in O2 Purge and may move on to robotic activities as not to delay the OBSS handoff.
- EVA Items
 - Prior to docking, the EMUs are removed from the Orbiter airlock (EMU RMVL) so they are not in the way during hatch open and ingress. After docking, the EMUs will be transferred to the ISS. Additionally during MDDK PREP, EMU drink bags for EVA1 are filled.
 - EV and IV crewmembers prepare for EVA1 by transferring EVA equipment to the ISS airlock, installing and checking out the REBA, and prepping the equipment lock.
 - MS2/EV1 and MS3/EV2 perform campout procedures at the end of FD03. The EVA crewmembers will initiate repress on the morning of FD04 when 8 hours, 40 minutes at 10.2 psi has elapsed.
 - All crew members participate in an EVA1 procedure review prior to presleep.
 - CSA O2 CAL: Required prior to E-1k prep. The hardware for this calibration will be transferred in a CTB from the STS middeck after hatch opening.
- Ingress
 - After docking, leak checks are performed on the PMA and ODS. Additionally the ODS is prepared for ingress by the removal of the C/L camera. P/TV04 supports hatch opening and ingress. A safety briefing takes place after ingress.
 - The STS booster fan is activated in the ODS Prep for Ingress procedure.
- Maneuvers
 - After docking, the Shuttle maneuvers the stack to the Biased -XLV -ZVV attitude. Group B powerdown is also scheduled in this timeframe. There is no longer a requirement for us to wait for maneuver complete prior to retracting the set per the powerdown. Before opening the hatch, the Orbiter hands over attitude control to the ISS CMGs. The ISS maintains attitude control during the majority of the docked timeframe.
- Payloads

- CDM (DTO 853) is powered off immediately after wakeup.
- Sleep Log: MS1 and MS4 perform sleep log upon wakeup. This log is participation in the sleep short SBDI. MS2 and MS3 do not perform a sleep log on this day because they are at their minimum PSA requirements.
- Saliva: MS4 performs his first liquid saliva sample for the integrated immune SBDI.
- PGSC Items
 - After docking, the PGSC network is configured from a RNDZ configuration to the nominal docked ops configuration.
 - Photo TV Items
- P/TV02 DOCK S/U is setup for RNDZ and docking.
- P/TV04 SETUP is for ISS ingress.
- P/TV05 SETUP is for comm and video transfer between ISS and Shuttle. The first 20 minutes is to configure the RWS video cables and is performed prior to the safety brief on the Shuttle side. The last 20 minutes is to connect cables for BPSMU & RWS and is performed after the safety brief on the ISS. Docking video playback is scheduled after hatch open.
- PLAYBACK OPS are scheduled to downlink any docking video to the ground.
 - RNDZ Items
- The Orbiter rendezvous with the ISS. The Shuttle will perform the RBAR Pitch Maneuver (RPM) when it is 600 ft away from the ISS. At the same time, the ISS crew is taking pictures of the Orbiter belly to search for tile damage. The images are transferred via image card and downlinked via ISS OCA.
- During docking, all ISS crew members are configuring PMA2 (located on Node 2) for docking. All 3 crew members are scheduled; instead of the usual 2 since this is the first time the shuttle is docking to Node 2.
- Robotics Activities
 - Immediately after docking, the SRMS is configured to the pre-grapple (PGRPL) position for the OBSS handoff from the SSRMS (based on Node 2) to the SRMS.
 - After the safety brief, the SSRMS grapples the OBSS, the MRLs are released, and the SSRMS maneuvers to the handoff position. After MS4 sets-up the RMS workstation, CDR & MS4 grapple the OBSS with the SRMS. The SSRMS then hands-off the OBSS to the SRMS. Lastly, the CDR & MS4 maneuver the RMS to the Columbus viewing position for EVA1 activities, and FE-2(UP) & FE-2(DN) maneuver the SSRMS to the overnight park position. NOTE: the OBSS has to be taken out of the payload bay before Columbus can be unberthed.
 - There is no KU from ~01/21:30 to ~02/02:00 because of interference with the robotic arm. (Which arm?)
- Transfer
 - CTB Xfer: The CSA-O2 needs to be calibrated before E-1k prep. The Portable Gas Delivery System and the CSA Cal Adapter, required for this calibration, are launched in a CTB on the STS mddk.

ISS Ground Activities

- ACBM (Active Common Berthing Mechanism) Inspections: there is a 24 hr thermal clock between petal deploy and CBM-NOD2 COL-1ST STG (FE-2 EXP16 @ 343/2157)
- NOD2-CBM PREP-MATE: includes petal deploy [required prior to EVA2 egress since the EV crew removes launch locks and opens the CBCS flap to allow the CBCS an exterior view. (exterior Velcro flap)]. Also includes ACBM inspection

Flight Day 4 - EVA-1 and Columbus Install

Big Picture: The EV crew installs the PDGF on the Columbus module. Then SSRMS grapples and removes Columbus from the STS payload bay. The SSRMS will supply power to the Columbus shell heaters until Columbus Berthed Survival Mode Activation is complete on FD05. An overnight fine leak check of the Columbus/Node2 vestibule is started during crew Presleep.

❑ Columbus Vestibule Outfitting Prep

- ❑ INSTL PWS: (Portable Workstation (PWS) install in Node 2) The Utility Outlet Panel (UOP) is turned off for the PWS install and then turned on after it is completed. On FD06 this PWS will be deinstalled from the Node and moved into the Columbus module. The reason the PWS is installed in Node 2 is for contingency purposes. The crew can activate the Col module from the PWS if Col-CC is unable to for some reason. Also, the PWS will allow the crew to follow along in the ground activation if they desire.
- ❑ ACS-PPRV SP SEAL-R&R: (PPRV Seal R&R) The PPRV on the Node 2 Starboard Hatch has a cap on the Sample Port. We need to take the cap off and replace the hard seal with a soft seal so that the Internal Sampling Adaptor (ISA) can later be installed on the Node 2 Starboard Hatch for the leak checks. This activity must occur prior to the VAJ setup.
- ❑ PFA S/U: (Portable Fan Assembly Setup) This activity sets up the PFA in Node 2 as preparations for the FD05 vestibule and partial ingress activities. The PFA will circulate the air and help prevent CO2 pockets from forming.
- ❑ VEST OUTFIT PREP: In this activity, the crew gathers and stages tools needed for vestibule outfitting on FD05.
- ❑ Node2/Columbus pressure thermal line Quick Disconnect (QD),

❑ Columbus Install

- ❑ Centerline Berthing Camera System (CBCS) is powered on early in the crew day. This camera system aids the crew in aligning the Columbus module for installation. CBCS Removal is performed after Columbus install is complete.
- ❑ Active Common Berthing Mechanism (ACBM) verification: Prior to Columbus install the crew verifies the status of the ACBM on the ISS PCS to ensure it is ready to receive the Columbus module.
- ❑ PRLA once the SSRMS has grappled the Columbus module, the CDR releases the PRLAs to allow the SSRMS to unberth the module.
- ❑ VAJ S/U: (Vacuum Access Jumper setup) Sets up equipment for the gross and fine leak checks. There are no constraints on how early this can be scheduled.
- ❑ TCS-NODE2 QD-DISCNCT: (NODE2 QD DISCNCT) Node 2/Columbus passive thermal line QDs must be scheduled within 24 hrs of COL-ITCS JMPR-INSTL (on FD05; 1737 GMT on MS3) per Flight Rule: 1E-XXX-110. The passive line QDs inside Node 2 must be de-mated prior to installing the Columbus water loop jumpers to avoid the physical connection between the Node 2 MTL accumulator and pump and Columbus accumulator and pump while operating, which could cause undesirable transient effects on Node 2 and Columbus TCS items. Note: these QDs never need to be reconnected.
- ❑ After the Columbus module is installed a Node 2/Columbus vestibule gross leak check is performed. It is preferred to do the gross leak check prior to crew sleep to allow for any necessary troubleshooting overnight. However, if required the gross leak check can move to the morning of FD05.
- ❑ ACS-COL LK CK-INIT: (LK CK) initial vestibule pressurization; NOD2CBM BOLT-LOADING must be completed prior to ACS-COL LK CK-INIT start; wait ten minutes for thermal equalization before the next pressure reading
- ❑ ACS-COL LK CK-READ: (READ) reading after thermal equalization; Wait at least 30 min before the gross leak check
- ❑ ACS-COL LK CK-TERM: (LK CK TERM) Final gross leak check reading and complete vestibule pressurization; wait ten minutes before the fine leak check

❑ After the gross leak check is complete, a fine leak check is initiated before sleep and runs overnight. The fine leak check is not a requirement for the joint mission, but fits easily in the current timeline. If the gross leak check moves to the morning of FD05, the fine leak check will be delayed to the 1E stage.

❑ ACS-FINE LK CK-INIT: (LEAK CHECK-INIT) 5 min for Initial Pressure Reading and ISA Deactivation

❑ Crew Rotation

❑ FE-1 & FE-2(UP) will remove Tani's IELK from the Soyuz and install Eyharts' IELK in its place. Once this is complete, Tani and Eyharts home vehicles are officially swapped.

❑ Other scheduled SOKOL activities have the following constraints:

❑ SOKOL-SUIT-DRYING: (SOKL DRY) takes 2hrs to dry

❑ SOKOL-GLOVE-DRY: (GLOVE) takes 30 min to dry

❑ SOKOL-CLSOUT: (SOKOL CLS) stows the suit; schedule at least 2hrs after SOKOL-SUIT-DRYING & 30 min after SOKOL-GLOVE-DRY. There are two driers, so the SOKOL suit and gloves can dry concurrently.

❑ FE-2 (up) is scheduled for time to adapt to space and ISS.

❑ CMS OV must be completed before FE-2 (up) completes his first exercise session. This activity familiarizes the crew with the heart rate monitoring system used during exercise.

❑ Eyharts' also has RED, CEVIS, and TVIS handovers scheduled on this day. These activities count as crew handover time and are scheduled at the beginning or end of another crew member's exercise on these devices. The intent of these activities is for Leo to gain familiarity with this equipment.

❑ HMS-PMC: daily PMC for new crew; required through FDxx; can be scheduled anytime except during the EVA

❑ EECOM/ECLSS Items

❑ Two CWC fills and 1 PWR fill are scheduled for this day. Each CWC fill is 1 hour in duration, and a CWC bag transfer is scheduled after the term of each fill. The PWR fill is 30 minutes and is also followed by the bag transfer.

❑ An N2 repress is scheduled for this day and is 2 hours long.

❑ ACS-O2 LK CK-INIT: (O2 LK) A Node 2 ISS Oxygen system fine leak check initiation is a fine leak check required after the O2 purge (completed on FD03). This leak check is independent of the Columbus/Node2 leak checks. Leak check duration is at least 10 hours.

❑ EVA

❑ EVA1 Overview - At the start of the EVA, the EV crew sets-up for installing the PDGF by translating to the payload bay, disconnecting the LTA heater cables from the Columbus module (starts the thermal clock), removes the Common Berthing Mechanism (CBM) seal covers, and releasing the PDGF from the sidewall carrier. The crew then installs the PDGF on the Columbus module in preparation for the grapple by the SSRMS. Once the crew has completed the PDGF install, they translate up to P1 and begin the prep work to remove the NTA.

❑ As a result of clearance issues and successfully removing Columbus Module out of the payload bay, the KU dish is stowed prior to the start of EVA1. The KU dish is then deployed on FD05 after the SSRMS releases the Columbus Module.

❑ PLT is the IV crew member for EVA1.

❑ EVA crew members are MS2 (EV1 - free floater for this EVA) Walheim and MS3 (EV2 - on SSRMS for PDGF setup and install) Schlegel.

❑ CDR performs P/TV07 for EVA 1 viewing. CDR, ISS CDR, and FE-2 (dn) assist with Suit-up IV activities.

- ❑ Power Data Grapple Fixture (PDGF) Overview - The PDGF provides a structural fixture for the SSRMS to grapple the Columbus Module and move it from the payload bay to the installed position on the ISS Node 2. The PDGF additionally enables the Columbus Module to receive power via the SSRMS. The Columbus module has a 24 hour thermal clock which begins once the LTA heater cables are removed at the beginning of EVA1. The thermal clock is terminated once the SSRMS is providing heater power to the Columbus module. The PDGF is being installed on orbit due to clearance issues with the grapple fixture installed and the OBSS
- ❑ PDGF Setup -In this activity the EV1 translates to the payload bay. On his way to the plb from the ISS Airlock, he translates past the Node 2 stbd port. While in the area, EV1 opens the CBM flap and visually inspects the sealing surface where the Columbus module will soon be mated. Once in the payload bay, EV1 disconnects the LTA heater cable which has been providing power to the Columbus shell heaters from the STS. When the LTA cables are disconnected, the 24 hour thermal clock begins for Columbus. EV1 also uses this time to remove the upper Meteoroids & Debris Protective Shield (MDPS) to help gain access to the area that the PDGF will later be installed. While in the vicinity, EV1 also removes the CBM cover from the Columbus module and inspects the sealing surface for FOD. While EV1 is performing these activities, EV2 is setting up and ingressing an APFR and is then maneuvered down to the payload bay by the SSRMS operators. EV2 then removes the PDGF from the sidewall carrier and the SSRMS operators maneuver him over to the PDGF intall position.
- ❑ PDGF Install - EV1 and EV2 install the PDGF in its location and bolt it down. Then EV1 and EV2 to remove the lower MDPS to clear the space for the PDGF harness to be installed. Once the harness is installed, the upper and lower MDPSs are re-installed. The EV crew then cleans up the payload bay and prepares for the P1 NTA Removal Prep activity.
- ❑ P1 Nitrogen Tank Assembly (NTA) Removal Prep - During this activity the EV crew preps the NTA for removal which occurs on EVA2. The NTA's electrical lines and N2 lines are disconnected and the NTA bolts are loosened.
- ❑ P/TV-EVA IMAGE-D/L: (D/L EVA IMAGE DOWNLINK) FE-2 (dn) will put the card from the EVA camera in an ISS SSC for dowlink via ISS OCA.

❑ Maneuvers/Attitude Info

- ❑ A maneuver update is scheduled after the Columbus module is installed. This maneuver update adjusts Universal Pointing match the modified TEA.

❑ PGSC

- ❑ The STS Ku dish will be stowed prior to EVA egress. It will remain stowed for ~24 hours until the SSRMS ungrapples Columbus on FD05. Impact: the FD05 STS Execute Package (as well as any other STS message traffic during Ku stow) will be uplinked via ISS assets.
- ❑ XFER PCMCIA-SSC: Prior to Ku stow, MS4 has an activity to install a PCMCIA card into an ISS SSC. This will set up the config for the Sneakernet procedure.
- ❑ PGSC POWERDOWN: Just after Ku stow, MS4 will powerdown unnecessary PGSCs.
- ❑ LCC ACT & LCC DEACT: During EVA 1, APCU's are deactivated then later activated (during PDGF Setup). This removes critical keep-alive power to LCH (Laser Camera Head) and IDC. After LCC is activated/deactivated on FD4 evening, the LCH will be in keep-alive heater mode.

❑ Robotics Activities

- ❑ The SSRMS is used to support EV2 with PDGF Setup and Install. Prior to EVA1, the SSRMS is in the overnight park position. For the PDGF install, the SSRMS maneuvers to the Articulating Portable Foot Restraint (APFR) pre-install/ingress position. At the beginning of PDGF setup, EV2 ingresses the APFR. At the end of PDGF install, EV2 egresses the APFR. The SSRMS grapples Columbus and unberths it from the payload bay. Columbus is then maneuvered to the install position on the starboard port of Node 2. The capture phase of CBM mating is performed in 2 stages: First stage capture drives the ACBM latches across the gap between the 2 elements to "grab" the Columbus PCBM. During second stage capture, the capture latches pull Columbus allowing bolting operations to begin.
- ❑ MS1 & MS4 are the M1 and M2 SSRMS crewmembers. FE-2 down supports as M3.

- Exercise Constraint
- There is no exercise during Columbus unberth thru A-bolts.
 - Transfer
 - Transfer time is scheduled on crew members not busy with the day's EVA activities. Crewmember involved with transfer ops are scheduled for a 15 minute transfer tagup, then MS1 (loadmaster) will call MCC to perform a transfer brief with the ground.
- Payloads
 - MUS-1E-QUESTION & MOP-1E-QUESTION:(MUS and MOP)These are ESA payload questionnaires. They are low priority, and can be deleted if necessary. Scheduled on MS3 and FE-2 (up).
 - Sleep Log: MS1 and MS4 perform sleep log upon wakeup. This log is is participation in the sleep short SBDI. MS2 and MS3 do not perform a sleep log on this day because they are EVA crew members.
 - CDM: A battery changeout and device relocation occurs prior to presleep and the CDM is activated prior to sleep.
 - ISS Ground Activities
 - ETCS-LPB TRRJ-LOCK: required since the EV crew will be working close to the TRRJ
 - ETCS-NTA-VENT: (NTA Initial Venting) initial venting of the NTA. Could cause a LOAC, so ISS hands over attitude control to the Shuttle prior to the venting. Attitude control is handed back shortly after the venting is complete. Schedule PPS-BGA-FTHR 45 minutes prior to ACS-CMG/STS ATT-H/O and PPS-BGAAUTOTRACK 30 minutes after ACS-STS/CMG ATT-H/O.
 - ETCS-NTA-FINAL PREP: (NTA Final Venting) final NTA venting after the crew has disconnected the QDs and before removing the electrical connections.
 - NOD2-CBM BOLT-LOADING: (CBM Bolt Loading) ground activity; start after ACQ BOLTS completed

Flight Day 5 - Columbus Activation & Focused Inspection

Big Picture: The crew will terminate the overnight leak checks; then start the vestibule outfitting. Eyharts will partially ingress Columbus to install the IMV ducts and valves (supply side first, then return side). Columbus will be unpowered and dark at this point and is a concern for floating debris (paint chips, dust ...), so Eyharts will be wearing a mask and goggles. The first goal is to get Columbus to 'Berth Survival Mode'; basically this means the shell heaters are on and module won't die. Columbus has a 24 hour thermal clock that starts on this day once the SSRMS power latches are disconnected. This activity is performed by the ground around crew wake. After 'Berth Survival Mode'; COL-CC will start the final activation; including CFA (Common Fan Assembly) activation. FD05 also contains the place holder tasks for STS Focused Inspection. Before focused inspection can be performed the SSRMS must ungrapple the Columbus module. Once that has occurred, the STS Ku dish is scheduled to be re-deployed and activated. In addition to the focused inspection and Columbus activation activities going on this day, the crew is also preparing for EVA 2 and completes a good bit of transfer.

- Columbus Items
 - ACS-COL LKCK-TEARDWN: (LK CK T/D) Final Pressure Reading and ISA Teardown. Must be completed before CBM-DISK COVER-RMV can start. Schedule Peggy for this activity.
 - The CBM-DISK COVER-RMV (DSK CVR RMV & STRAP) must be performed before beginning the vestibule connections to Columbus. The crew can start this as soon as ACS-COL LKCK-TEARDWN is complete. It's scheduled for Peggy and Hans Schlegel (MS3) and not Peggy and Leo (Exp16 FE-2) because it would break Leo's day. The disk cover remove is scheduled as early as Shuttle rules allow. Leo is required for the afternoon activities and does not have the crew time for this activity.

- PARTL INGRS: FE-2 (up) partially ingresses the Columbus Module in order to R&R the Negative Pressure Relief Valve (NPRV) with the supply IMV as well as R&R the Negative Pressure Relief Valve (NPRV) with the Return IMV. Personal Protective Equipment (PPE) is required during the partial ingress to Columbus. This activity should be scheduled as soon as CBM Disk Cover Remove is completed.
- The crew's portion of the berth survival mode activities include: power jumper install, hardwired instrumentation jumpers install, and 1553 data jumper install. After these activities are completed, Col-CC is able perform a few activation commands and when those are complete, the Columbus Module is considered to be activated to berth survival mode. The thermal clock is stopped and the module is safe.
- Columbus Berth Survival Mode sequence:
 - SPS-NOD2 DDCU-PWDN (ground): power down for the jumper install power inhibits
 - COL-PWR JMP-INSTL (Power Jumper Install)
 - COL-HRDWRD JMPR-INSTL (Hardwire Instrumentation Jumper Install)
 - COL-1553 JMPR-INSTL (1553 Data Dumper Install)
 - SPS-NOD2 DDCU-PWRUP (ground)
 - COL-BRTH SRVIVAL-ACT: fist MCC-H portion. can start after COL1553 JMPR-INSTL is completed by the crew and after N2-DDCUPWRUP is completed by MCC-H.
 - COL-BRTH SRVIVAL-ACT: COL-CC portion
 - CPA Removal: 2 crew are required; third crew is just a helper. FWD and AFT CPAs are removed first, then the overhead and deck CPAs are removed.
 - The crew's portion of the final activation activities include: IMV supply & return duct and valve install, TCS jumper install, Condensate water jumper install, Fiber optic jumper install, and AR sample jumper install. In addition to the crew activities performed for final activation there is quite a bit of Col-CC ground commanding required. The best way to follow and understand the ground/crew interactions on this day is to review the Activation Flow Chart in the Assembly Ops book.
 - COL-NPRV SPLY-R&R: (NPRV IMV SPLY VLV) replacing a NPRV with a IVM Supply Shut-off valve (ISSOV)
 - COL-SPLY DCT-INSTL: (IMV SPLY DCT) forward CPA must be removed first; supplies air to Columbus
 - ITCS JUMPER: (Columbus Vestibule Outfitting; Step 9): (COL-ITCS JMPR-INST) Needs to be completed prior to the ground executing Steps 2&3 of COL-FINAL-ACTIVATION; cannot be started until the first set of CPAs are removed (forward and aft). (scheduled on MS3)
 - COL-CONDNST JMPR-INS: (COND JMPR) required to complete Columbus final activation. Nominally the condensate jumper is installed before starting the CFA. That way if any condensate is separated it can be sucked out to the USOS (I think the Columbus has only a very small condensate tank).
 - COL-FIBER JMPR-INSTL: (FIBER) required to complete Columbus final activation
 - COL-AR SMPL JMPR-INS (Air Sampling Jumper): (ARS) not required to complete Columbus final activation
- Columbus Ingress tied to Cabin Fan Assembly (CFA) Final Activation (completed by COL-CC). The current FR states the crew can enter Columbus safely without PPE, 40 min after CFA Final Act. This time is required for the CFA establish ventilation and cycle the air through the filters.
- Other Columbus outfitting activities scheduled on this day include: portable breathing apparatus (PBA) & portable fire extinguisher (PFE) installation, and partition posts installation.

COL-PART POSTS-INSTL: (INSTL PART POSTS) Remove the three partition posts from the launch storage location on the D2 rack floor panels, assemble and install in operative locations. Required prior to Columbus handrail install (FD06).

Crew Rotation

HMS-PMC: daily PMC for new crew; required through FDxx. Technically this can be scheduled anytime during the day; but keep it early so it won't interfere with Columbus activities.

H/O: 40 minutes of face-to-face handover is scheduled between FE-2 (dn) and FE-2 (up).

EECOM/ECLSS Items

Three CWC fills are scheduled. The fills are 1 hour in duration, and the filled CWC bags are transferred after the final fill is terminated.

Three PWR fills are scheduled. The fills are 30 minutes in duration, that includes transfer to ISS.

ACS-O2 LK CK-TERM: (O2 LK) ISS Oxygen System Fine Leak Check Term. Schedule on Tani. Leak Check duration is at least 10hrs.

EVA Items

EV crew members are scheduled to take an aspirin in the morning of FD05 to prevent an onset of the bends.

P/TV-DCS BATT-CHRG (DCS) and P/TV-EVA DCS-TURNAROUND (DCS TRN): The DCS battery is charged, and the DCS 760 camera is turned around for use during EVA2. This activity can be done any time during FD05.

METX TERM: (METOX-REGEN-TERM) The Metox init was part of the post EVA clean up on FD04 (JAL-POST EVA-H2O,MTX); schedule NET 14hrs after JALPOST EVA-H2O,MTX on FD04.

EV crew members (MS2 & MS3) prep the equipment lock and perform a tool config for EVA2.

BSA-T: (BSA-RCHRG-TERM) MS2 terminates the EMU Battery Recharge after it was initiated after EVA1. Constraint: 16 hours after BSA-RCHRG-INIT. NOTE: Nominally BSA-RCHRG-TERM & EMU-BSA RCHRG-INIT require HK1=J or K; EVA Carlos Rodriguez confirmed this requirement is relaxed for FD05.

MS2/EV1 and MS3/EV2 perform campout procedures for EVA2 at the end of FD05. The EVA crewmembers will initiate repress on the morning of FD06 when 8 hours, 40 minutes at 10.2 psi has elapsed.

All crew members participate in an EVA2 procedure review prior to presleep.

Focused Inspection

A 4.75 hour focused inspection is timelined on FD05. If a longer focused inspection is required, an extra day may be added to the mission, and focused inspection would take place on FD06.

Focused inspection may or may not be a requirement based on imagery results from FD02 inspection and RPM photos from FD03. The sensors used are based on inspection areas targeted for focused inspection and the type of images needed. LCS is considered highest priority for focused inspection. TDRS Z in not used for focused inspection.

A focused inspection DOUG review is scheduled on robotic crew members.

If focused inspection is not required, the time will most likely be filled with transfer.

KU

The KU dish is deployed and activated (after being stowed prior to EVA1 on FD04) after the SSRMS releases the Columbus Module.

MS4 is scheduled to re-power any of the PGSCs that might have been powered down while Ku was stowed.

PAO Events

P/TV05 is scheduled prior to the mission's first PAO event. Since STS KU is stowed, the PAO event will use ISS KU. P/TV05 will setup for the US PAO event.

P/TV05 is then scheduled again later in the day, prior to the second PAO event.

SSRMS Activities

COL-REL PRE-EVA MNVR: (SSRMS UNGRP COL-MNVR & SSRMS FI MNVR) MS1, MS4, and FE-2 (dn) ungrapple the Columbus Module with the SSRMS and maneuver the arm to either the focused inspection viewing position or an EVA2 position depending on the mission scenario.

Transfer

Transfer time is scheduled on available crew members periodically during the day. MS1 and FE-2 (dn) are scheduled for a 15 minute transfer tagup. Additionally, both crew members are scheduled for a transfer brief with the ground.

Double Cold Bag (DCB) unpack is scheduled no later than FD05. The DCB unpack is to transfer the WAICO samples to MELFI.

Payloads

DCB-1E-UNPACK: (DCB UNPACK) Unpacks and transfers the WAICO samples to MELFI. Schedule this NLT FD05; preferred early in FD05. The samples may thaw if not transferred by FD05. Schedule immediately after a transfer block (insures the DCB gets transferred to the station)

CDM: The CDM will be powered off immediately after wakeup, with the battery changeout and device relocation occurring later in the day.

Sleep Log: MS1, MS2 and MS4 all perform sleep log upon wakeup. MS1, MS2, and MS4 perform the log as participation in the sleep short SBDI. MS2's log also counts towards his participation in the PMZ SBDI. MS3 does not perform the sleep log on this day as he is at the min PSA requirements for EVA prep and Columbus activation activities.

Saliva: MS4 performs his first liquid saliva sample for the integrated immune SBDI.

MUS: MS4 performs the ESA payload questionnaire, MUS, prior to presleep.

ISS Ground Commanding

TLM PKT Plan: in JJK to support SSRMS ops; switch to JKK to support ADCO acts. Columbus Final activation requires HK1 to be either J or K.

SSRMS-PWR LTCH-DCNCT: releases power connection between Columbus and the SSRMS; restarts the 24 hrs Columbus thermal clock.

COL-CC-NO OP-CMD: No Op command sent by COL-CC to verify/test the command path.

COL-BERTH-SURVIVAL: can start after COL-1553 JMPR-INSTL is completed by the crew and after N2-DDCU-PWRUP is completed by MCC-H.

COL-FINAL-ACTIVATION: skips the PWS Activation step (2 PWS, 1 PCS & 1 SSC laptops are setup Columbus on FD06); starts after COL-ITCS JMPR-INSTL. The following activities are part of the final activation and are called out separately in OSTP just for team cognizance.

WPA-ACT: Columbus Water Pump Assembly activation

DMS-ACT: Data Management System (DMS) Activation

COL-IMV-ACT: Cabin Fan Assembly activation. The crew is required to have masks and goggles on until the CFA has sufficiently cycled the air within the module (across the filters). The BMEs and ECLSS have said that for this module that equates to about 40 minutes of CFA run time. So for that huge ESA PAO event, that Navias has said must be without masks and goggles if inside COLUMBUS, then the CFA must be on at least 40 minutes beforehand. Note: there is no requirement for any IMV ducting to be installed or for the NPRV valves to be replaced before CFA Act. The CFA just circulates air within the module and doesn't require IMV or even the hatch to be open.

C&T-HK2 TELEM-CNFG: CATO increases the HK2 packet throttle rate to COLCC up to 8 packets/sec; this is in support of Columbus activation. This is not a telemetry packet swap.

Flight Day 6 - EVA-2

Big Picture: Continued Columbus outfitting, EPM relocate, and EVA2. This is the first day where COL-CC and MCC-H will be working in parallel on different activities: MCC-H will be working the EVA and COL-CC will be following the station crew working in Columbus.

Columbus Items

Four laptops are set up in Columbus: one SSC, two PWS (PCS equivalent for Columbus systems) and one PCS. Prior to installing the PWS in the Columbus module, it must first be deinstalled from its location in Node 2. A second SSC will be setup during the stage.

COL-ETHRNT JMPR-INST: (ETHER) Install Ethernet Jumper; part of COLUMBUS VESTIBULE OUTFITTING; required prior to SSC Install

COL-IVA ANTENNA-INST: (ANT) Install IVA Antenna Assembly; part of COLUMBUS VESTIBULE OUTFITTING

COL-HANDRAILS-INSTL: (INSTL HNDRL) installs hand rail to aid crew mobility. Schedule as early as possible. Standard crew task; no procedure required.

COL-FOOT LOOPS-DSTW: (DSTW INSTL FOOT LPS) Destows and installs the four Portable Foot Loops (launch stowage position on COL D2 Panel). Schedule before COL-D2 FLOOR PNL-RMV since the foot loops are on the D2 panel.

COL-VBA-INSTALL: (VBA INSTL) installs the Col/Node2 vestibule barrier. This protects all the umbilicals from inadvertent kicks as the crew ingresses/egresses Columbus. OSO states this is a high priority to complete soon after COL-ETHRNT JMPR-INST & COL-IVA ANTENNA-INST.

COL-D3 FLOOR PNL-RMV & COL-D2 FLOOR PNL-RMV: (RMV D3 FLOOR PNL & RMV D2 FLOOR PNLS) hardware for Columbus outfitting is stored in these locations; exact hardware is TBD.

COL-STOW VOL-RCNFG: (RCNFG STOW VOL) retrieving Columbus hardware.

COLUMBUS PWS

Two PWS laptops will be activated in Columbus

A PWS is the Columbus equivalent of a PCS and is used to monitor/command Columbus systems

First the PWS is removed from Node 2

NODE2-UOP PWS-PREP: powers down the loads on Node 2 UOP 1. Required before powering down the UOP and unplugging the PWS.

DMS-NODE2 PWS-DEINST: (PWS DINST) physically disconnects the PWS

NODE2-UOP-POWERUP: powers up the loads on Node 2 UOP 1

- Second; both PWS laptops are physically installed DMS-PWS-INSTALL

(INSTL PWS)

Finally; both PWS laptops are activated: DMS-PWS-ACTIVATION (PWS ACT)

- COL-D3 FLOOR PNL-INS (INSTL D3 FLOOR PANEL) (on Peggy) needs to schedule simo with COL-D2 FLOOR PNL-INS (INSTL D2 FLOOR PANEL) (on Leo) since Peggy is not fully trained
- COMMS-VCA-INSTALL: (INSTL VCA2) Sets up the Columbus camera assembly. Once this is complete COL-CC has many ground activities to check out the system. After that's all done; Col-CC can receive video from Columbus (views are similar to the lab camcorder shots). My understanding is that this video does not come down via one of the 4 video channels but comes down as a data stream and is reconstructed on the ground as video.
- COL-A3F1 KBAR CM-INS: (A3 F1 KBAR INSTL) Installs the Kbar capture mechanism in the A3 and F1 rack bay locations. The Kbar must be installed in A3 before relocating EPM and installed in F1 before relocating EDR. (Note: on FD08, a Kbar will be installed in A2 before the BLB is relocated)
- PL-EPM-RLCT: (RELOCATE EPM - A3) first rack to be relocated from COL O3 to COL A3; requires 2 people. Peggy is not scheduled due to crew time constraints, but the grey space is there in case she wants to be involved. This rack is moved first to vacate COL O3 for the ZSR which will move from COL A2 to O3 on FD08.
- DMS-PCS-ACTIVATION: (PCS ACT) Installs a PCS in Columbus.
- ECS-COL FIRE IND-C/O: (Fire C/O) Verifies the functionality of Columbus Cabin Fire Indicators. Schedule after PCS INSTALL
- COL-D1 FLOOR PNL-RMV: (RMV D1 FLOOR PANEL) removing the COL D1 panel to gain access to the Water Pump Assembly (WPA) and Condensate Water Separator Assembly (CWSA)
- ITCS-WPA AVM-UNLK: (UNLK WPA AVM) Anti-vibration mechanism removal; more Columbus outfitting
- ITCS-CWSA AVM-UNLK: (UNLK CWSA AVM) Anti-vibration mechanism removal; more Columbus outfitting
- COL-D1 FLOOR PNL-INS: (INSTL D1 FLOOR PANEL) replacing the D1 panel after the AVMs are unlocked

Sleep Cycle

- The crew is going to bed 1 hour early, so the day is shortened by 1 hour. There will be a second 1 hour shift like this after EVA3. These shifts are to support Shuttle ascending landing opportunities. Note: The SCSC states the crew should sleep shift prior to critical days; that's why the sleep shifts are scheduled post EVA2 & EVA3.

Crew Rotation

- H/O: 35 minutes of face-to-face handover is scheduled between FE-2 (dn) and FE-2 (up)

EECOM/ECLSS Items

- Three CWC fills take place on this day. Each CWC fill is 1 hour in duration. The 3 filled CWC bags are transferred to ISS after the last CWC term.

EVA

- EVA2 Overview - the primary objective of EVA2 is to replace the Nitrogen Tank Assembly (NTA) located in the P1 Truss. The current NTA needs to be replaced because the N2 is running low. The new NTA is removed from the payload bay and temporarily stowed on CETA cart zenith. The old NTA is removed from P1 and is temporarily stowed on CETA cart nadir. The new NTA is then installed on P1, and the old NTA is moved from its CETA cart and stowed on ICC-L for return home. The new NTA is retrieved from the PLB and installed in the truss; the old NTA is returned to the PLB for return to Earth. There is a 50 minute SSPTS cable routing activity at the end of the EVA.

- PLT is the IV crew member for EVA2.
- EVA crew members are MS2 (EV1 - on SSRMS) Walheim and MS3 (EV2 - free floater) Schlegel.
- CDR performs P/TV07 for EVA2 viewing.
- CDR and ISS CDR assist with Suit-up IV activities.
- TRRJ Acts: the EVA crew will be working close to the Port TRRJ so the TRRJ will be parked (ETCS-LPB TRRJ-LOCK @ 1330). the NTA will be activated during the EVA (ETCS-NTA-ACT @ 2042) and the TRRJ will go back to auto track after the EVA (ETCS-LPB TRRJ-AUTO @ 2300)
- Station to Shuttle Power Transfer System (SSPTS) Cable Routing - Although Atlantis is a non-SSPTS vehicle, SSPTS cable routing is performed on PMA-2 to allow the Node 2 docking mechanism to be SSPTS capable.
- PLT is the IV crew member for EVA2 and will assist the EVA crewmembers with their activities.
- EVA crew members are MS2 (EV1) Walheim and MS3 (EV2) Schlegel.
- CDR performs P/TV07 for EVA2 viewing. CDR and ISS CDR assist with pre and post EVA activities.
- EMU-BSA RCHRG-TERM: (EMU-T) terminates the BSA battery charging started by MS1 on FD05
- BSA INIT
- P/TV-EVA IMAGE-D/L: (D/L EVA IMAGE DOWNLINK) ISS CDR will put the card from the EVA camera in an ISS SSC for dowlink via ISS OCA.
- Robotics Activities
 - The SSRMS is used to support the EVA activities. MS1 & MS4 are the SSRMS IVA support crewmembers.
 - Before the EVA begins, during the campout EVA prep timeframe, MS1 & MS4 maneuver the RMS to the EVA2 viewing position. At the end of the EVA, the RMS is maneuvered back to the Columbus viewing position.
- Transfer
 - Transfer time is scheduled on crew members not busy with the day's EVA activities. Crewmember involved with transfer ops are scheduled for a 15 minute transfer tagup, then MS1 (loadmaster) will call MCC to perform a transfer brief with the ground.
 - Payloads
- МБИ-21-FE1-EXE: PNEVMOKARD Experiment. Schedule early in the morning before exercise. Conflicts with TVIS and other МБИ-21 sessions.
- Sleep Log: MS1 and MS4 perform sleep log upon wakeup. This log is participation in the sleep short SBD1. MS2 and MS3 do not perform a sleep log on this day because they are EVA crew members.
- CDM: CDM is activated just prior to crew sleep.
- Col-CC Ground Commanding
- ECS-COL EVA MD-RECON: moding COL for EVA ops
- Commissioning activities to test file u/l & d/l functionality against file corruption:
 - File uplinks and down links after COL Final Act

- DMS-SMALL FILE-UPLK: uplinks a small file (10 Kb)
- DMS-LARGE FILE-UPLK: uplinks a large file (1 Mb)
- DMS-MMU-FILE MGMT: moves the files around
- DMS-MMU-FILE DNLK: tests the nominal S-BD dump pipe
- DMS-MMU-FILE DNLK: tests the extended S-BD dump pipe (step 4)
- DMS-MMU-FILE DNLK: tests the Ku downlink
- Columbus Video System Activation
 - COMMS-VID LIM-CNFG: sets the input current limit for the onboard VCR and Video Monitors (VMNs). Required before activating the video equipment.
 - COMMS-VDPU-ACT: Video Data Processing Unit (VDPU) activation
 - COMMS-VCA1&2-ACT: Video Camera Assembly (VCA) 1&2 Activation; video routing data in the ops note.
 - COMMS-VMN1&2-ACT: Video Monitor (VMN) 1 & 2 Activation; video routing data in the ops note.
 - COMMS-VCR1&2-ACT: VCR1&2 Activation; video routing data in the ops note.
 - Note: complete video system C/O will be on FD07 with the VCR record, VCR playbacks and crew tape exchanges.

Flight Day 7 - Columbus commissioning, off duty

Big Picture: This is primarily a shuttle crew off duty day. The second ISPR (EDR) is relocated, Columbus outfitting continues, and a large portion of handover is accomplished. In addition, the ESA VIP PAO even with the German Chancellor occurs on this day.

Columbus Items

- EPM-UMB-MATE: (EPM UMB MATE) connects the EPM to Columbus; all umbilicals located on the rack front. Note COL-CC ground activities EPS-EPM PDU OUTL-INH and TCS-EPM WFSV-CL must be completed first. Prefer to have the EPM umbilicals mated prior to EVA3 since the external payloads receive power through this rack bay. If the umbilicals are mated after the payloads are installed, additional P/L powerdowns are required while the crew mates the EPM umbilicals. PDU enable and WFSV open are included in the rack power up procedure and not called out separately (EPM power up on FD09)
- COL-BANISTERS-INSTL: (INSTL BNSTR) The Banisters are Columbus specific Crew Mobility Aids. Crew install them in crew preference locations to support mobility inside Columbus during operations. The banisters are provided with standard interfaces to seat tracks and do not require any particular training, nor procedure for their installation.
- RELOCATE EDR - F1: move the EDR Rack from its launch location, Columbus O4, to its on-orbit location, Columbus F1.
- COL-NITROGEN JMP-INS: (N2 JUMPERS & PURGE) Install the Nitrogen supply jumper between Node 2 and the Columbus module and purge the nitrogen system to remove any contamination from the lines. Verify that the connection and Columbus Nitrogen system do not increase the nominal leak rate of the integrated Nitrogen system.
- CFA-AVM-UNLK: (UNLK CFA AVM) Requires tilting of the D1 rack and ECLSS equipment to be pwr'd down. While the ECLSS equip is down, only 1 crewmember can be in Col. The 2nd crewmember is only assisting with the D1 Rack Rotate
 - Portable Fan Setup steps are included in the COL-AVM-UNLK procedure: does not require ground activities to enable or disable the fan power outlet

EECOM/ECLSS Activities

- The only mated waste dump is scheduled the morning. STS will take attitude control for the mnvrs to and from the waste dump attitude.
- 2 PWRs are scheduled to be filled. Each fill is 30 min in duration.
- Shuttle Condensate Collection Bag is scheduled for its mid-mission change out.
- Nitrogen repress is scheduled for a 2 hour duration.

 EVA Prep

- EMU RCNFG/SWAP: In this procedure MS3's suit will be swapped out of the airlock in place of MS4's suit. MS4 will perform EVA3 the following day.
- BATT/METX INSTL: the objective of this procedure is to install Metox cannisters and EMU batteries in the EMUs (MS2's and MS4's) in preparation for EVA3.
- MS2/EV1 and MS4/EV2 perform campout procedures for EVA3 at the end of FD07. The EVA crewmembers will initiate repress on the morning of FD08 when 8 hours, 40 minutes at 10.2 psi has elapsed.
- All crew members participate in an EVA3 procedure review prior to presleep.
- Prior to presleep, the CDR will put External Payload Facility (EPF) FRAM inhibits in place. This is done in preparation for the installation of the SOLAR and EuTEFF payload installations during EVA3. The inhibits remove power from the PDUs 1 and 2 and the two PPSB switches are off.

 PAO Events

- ESA PAO Event: CDR, MS3, ISS CDR, and FE-2 will participate in the first PAO event from the Columbus module. The event is with the German Chancellor and will use STS Ku. This event should remain at its scheduled time throughout the course of the mission. The timing should not be optimized for any reason other than safety of flight.
- ISS PAO Event: The ISS crew has a US PAO event prior to their mid-day meal. This event will use ISS Ku assets.

 Payloads

- CDM: The CDM will be powered off immediately after wakeup, with the battery changeout and device relocation occurring later in the day.
- MUS: MS4 performs the ESA payload questionnaire, MUS, prior to presleep.
- Saliva: MS3 performs his first liquid saliva sample for the integrated immune SBDI.
- Sleep Log: MS1-MS4 all perform sleep log upon wakeup. MS1, MS2, and MS4 perform the log as participation in the sleep short SBDI. MS2 and MS3 fill out the log as participation in the PMZ SBDI.
- MUS: MS4 performs the ESA payload questionnaire, MUS, prior to presleep.

 PGSC Operations

- All STS crewmember PFCs are scheduled on this flight day
- Prior to first PFC, the WLES file backup is disable. It is re-enabled after the last PFC is complete.

 P/TV

The crew will turn the payload bay illuminators on prior to sleep to set-up for an overnight external survey performed by the ground.

ISS GROUND COMMANDING

EPS-EPM PDU OUTL-INH: power inhibit required prior to the umbilical mate. Only Power Distribution Unit (PDU) Outlet inhibits are required for EPM and FSL. Additional DDCU inhibits are required for BLB & EDR umbilical mates

TCS-EPM WFSV-CL: Closes the Water Flow Selection Valves

Flight Day 8 - EVA-3

Big Picture: EVA3 installs the two external ESA payloads: EuTEF & SOLAR. The last ISPR, BLB, is relocated and BLB outfitting is started. Some more handover for Leo and start EDR outfitting.

Columbus Items

ETC-LAUNCH LOCK-RMV: removes launch screws to allow access to stowage compartments. Schedule before BLB relocate because there is necessary hardware for BLB activities stowed in the ETC.

BLB-RPDA PNL-INSTL: (RPDA Panel Install) checks the Remote Power Distribution Assembly (RPDA) switch configuration for the Biolab RPDA and to close the panel. Schedule prior to BLB relocate.

S&M-ZSR-RELOCATE: (ZSR Relocate) Relocates the ZSR in COL-A2 to COLO3. Must be completed before BLB Relocate.

COL-A2 KBAR CM-INSTL: (K-bar Capture Mechanism Install) required prior to relocating BLB to A2.

PL-BIOLAB-RLCT: (Relocate Biolab) moves the BLB from COL-O2 to COLA2. Before tilting the rack into its final position, install the BLB DC Converter (PLBLB DC CNVTR-INST).

PL-BLB DC CNVTR-INST: (DC Converter Install) steps 1-3 of procedure 1.701 installs the DC converter to the rear of the BLB rack. Steps 4 & 5 install video and data cables as well as installing the laptop bracket. This procedure needs to occur before Biolab is placed in its final location. It should directly follow the BLB rack relocation activity.

BLB R: Install bonding strap and remove knee brace from launch location

BLB GN2 Inspect: Check BLB life support modules gas bottles pressure and GN2 valve setting.

TCU LF RMV: (Temperature Control Unit Launch Fixation Removal) Disengage TCU 1 & 2 launch fixations.

TCU SI Instl: (Temperature Control Unit Stowage Items Installation) Install TCU door harness, TCU trays and silica gel bags for TCUs 1 & 2.

BLB INC LF RMV: (Biolab Incubator Launch Fixation Removal) Steps 1-3 of the procedure (first scheduled block) include removing screws from the door hinges and removing the door itself from the unit. Steps 4-EOP of the procedure (the second scheduled block) includes installing support jigs, removing centrifuges from the incubator, removing launch screws, replaces the centrifuges, removes the previously installed support jigs and reinstalls the incubator door.

INC CI INSTL: (Incubator Commissioning Items Installation) Install experiment containers to support incubator checkout. The procedure has the crew open the door, install the cannisters, and close the door.

EDR Rear S/U: The objective of this procedure is to install the EDR smoke detector and air duct t-junction, and to place the audible noise reduction blankets on the AAA assembly. Prior to this procedure, the EDR rack must be rotated out and once the procedure is complete, the rack can be rotated back into place.

Crew Rotation

☐ Crew Handover: 2:40 of 12:30 planned for 1E is schedule for FD08. 1:20 of the handover time on this day occurs as functional handover between FE-2 (up) and FE-2 (dn) during SSRMS operations of EVA3. The other 1:20 minutes of handover on this day is face-to-face handover between FE-2 (up) and FE-2 (dn).

☐ EECOM/ECLSS Activities

☐ 1 PWR fill and 2 CWC fills are scheduled for this day.

☐ EVA3

☐ Solar Monitoring Observatory (SOLAR) Transfer -SOLAR is one of two European Integrated Payloads. SOLAR contains three instruments for sun observation: Solar Auto-Calibrating Extreme Ultraviolet (EUV)/Ultraviolet (UV) Spectrophotometers (SOL-ACES), Solar Spectrum Measurement (SOLSPEC), and Solar Variability and Irradiance Monitor (SOVIM). During SOLAR transfer, it is released from the Integrated Cargo Carrier Lite (ICC-L) in the payload bay, maneuvered to the External Payload Facility (EPF) on the Columbus Module and fully installed. This procedure is completed with EV3 on the APFR. The EV crew then maneuvers to ESP-2 for the next portion of the EVA.

☐ Control Moment Gyroscope (CMG) Transfer - A new CMG was installed on 13A.1, and the old CMG was stowed on ESP-2. The EV crew releases the CMG from ESP-2, translates to the payload bay, and installs the CMG on ICC-L. EV3 is on the APFR for the translation of the CMG from ESP-2 to the payload bay.

☐ European Technology Exposure Facility (EuTEF) Transfer - EuTEF is the second European Integrated Payload. EuTEF houses 8 different experiments which measure orbital debris, radiation, atomic oxygen, ect. With the assistance of the APFR, EV3 releases EuTEF from the ICC-L, maneuvers to the EPF on Columbus, then installs and photographs EuTEF. EV3 egresses the APFR at the end of EVA3, before cleanup.

☐ PLT is the IV crew member for EVA3 and will assist the EVA crewmembers with their activities.

☐ EVA crew members are MS2 (EV1) Walheim and MS4 (EV3) Love.

☐ CDR performs P/TV07 for EVA3 viewing. CDR and ISS CDR perform suit-up IV responsibilities pre and post EVA.

☐ Inhibits:

☐ IV (PLT) will turn off power to the ICC-lite prior to the EV crew releasing SOLAR from the ICC.

☐ Once SOLAR is safely removed from the ICC, IV will return power to ICC-lite to keep EuTEF powered while SOLAR is installed.

☐ Once SOLAR is installed on the EPF, IV gives MCC a go for SOLAR survival heater activation.

☐ At the end of the CMG transfer procedure, IV will once again remove power from ICC-lite. This is done prior to the EV crew removing the EuTEF payload from the carrier.

☐ MCC-H will deactivate the SOLAR Survival heaters prior to the installation of the EuTEF payload on the EPF.

☐ Once EuTEF is installed on the EPF, IV gives MCC a go for SOLAR and EuTEF survival heater activation.

☐ PRLA Close: this activity should be scheduled early enough such that an EVA repair of the PRLAs is possible should it be required.

☐ EVA Images: After the post EVA activities, ISS CDR will place the images cars in an ISS SSC for downlink.

☐ Payload Activities

☐ DCB Fam: (Double Coldbag Familiarization) The objective of this activity is for FE-2 up and down to review the double coldback packing procedure in preparation for the packing of two double coldbags on FD09.

☐ CDM: a data take is started just prior to sleep with a CDM activation.

Sleep Log: MS1 and MS3 perform sleep log upon wakeup. This log is participation in the sleep short SBDI. MS2 and MS4 do not perform a sleep log on this day because they are EVA crew members.

P/TV

MS1 turns off the payload bay illuminators after post sleep. The illuminators were on to aide the ground in an external survey while the crew slept.

Robotics Activities

The SSRMS is used to support the EVA activities. MS1 & FE-2(UP) are the SSRMS IVA support crewmembers. FE-2(DN) is scheduled for SSRMS support, but is not required.

At the start of the EVA, the SSRMS maneuvers to the SOLAR retrieve position. The SOLAR is removed out of the payload bay, and the SSRMS maneuvers to the SOLAR install position on the zenith External Payload Facility (EPF) on the Columbus Module. The SSRMS then maneuvers to the CMG retrieve position on ESP-2. Then the SSRMS maneuvers to the CMG install position in the payload bay. For the EuTEF transfer activity, the SSRMS maneuvers to the EuTEF retrieve position in the payload bay. Then the SSRMS maneuvers to the EuTEF install position on the STBD EPF. At the end of the EVA, the SSRMS maneuvers to the undock position.

Sleep Shift: crew is going to bed 1 hrs early, so the day is shortened by 1 hr. The first sleep shift like this was after EVA2. These shifts are to support Shuttle landing. Note: SCSC rules state the Shuttle crew cannot sleep shift prior to critical ops; that's why the sleep shifts are scheduled post EVA2 & 3.

Flight Day 9 - Reboost, Columbus Commissioning, Hatch Closure

Big Picture: FD09 begins with a reboost. Maneuvers to and from the reboost attitude are performed by the Shuttle. The crew conference & photo, along with final transfers (including EVA hardware), and further commissioning work on the Biolab, EDR and EPM payload racks in Columbus are scheduled during this day. At the end of the afternoon, the crews close the hatches and prepare for an early undocking on FD10.

Columbus Items

BLB HM LF RMV: (Biolab Handling Mechanism Launch Fixation Removal) Open the HM door, remove launch screws, remove HM arm launch brackets and close the HM door.

HM SI INSTL: (Handling Mechanism Stowage Items Installation) The crew opens the door to the handling mechanism, installs the gripper hardware, then closes the handling mechanism door.

HM CI: (Handling Mechanism Commissioning Items Installation). The crew opens the AAS door, installs the AAS insert and then closes the door.

BLB AI CI INSTL: (Biolab Analysis Instruments Commissioning Items Installation) The HM drawer is extracted, then the Microscope (MS) access door is dismounted. A MS cassette is installed and the access door is re-installed. Then, the spectrophotometer cassette access door is opened, a cassette is installed and the door is closed. The spectrophotometer lamp assembly door is removed, the lamp assembly is installed, and the door is remounted. Once these activities are complete, the HM drawer is replaced.

ATCS SI INSTL: (Automatic Temperature Controlled Stowage, Stowage Items Installation) Installs the electronic box of ATCS 1 and 2.

ATCS CI INSTL: (Automatic Temperature Controlled Stowage Comissioning Items Installation) In this procedure, the crew installs the lower insulation and test insert of ATCS 1 and 2.

BLB UMB MATE: (Biolab Umbilical Mate) This activity mates the Biolab ISPR to the Columbus Utility Interface Panel (UIP). The UIP provides power to the payload racks once the umbilicals are mated.

INSTALL PART CVRS: (Install Partition Covers) install partition covers over the empty bays; Columbus O2, & O4. Schedule anytime after BLB is relocated.

- EDR Front Setup: (EDR Front Operations) The objectives of this procedure are to install the EDR Video Management Unit (VMU), Hard Disks (HD) 1 and 2, and install the front panel gap closing blankets in the correct positions.
- EPM-LAPTOP-INSTL: required prior to EPM-RACK-ACT (ground). Schedule no more than 10 min before EPM-RACK-ACT as the laptop is working on battery power and has uncertain battery life. The EPM Laptop is creating EPM logs for later downlink.
- Laptop C/O: (EPM Level Checkout of EPM Laptop) Verifies the EPM laptop connection at the EPM facility level.
- Self Test C/O: (EPM Self Test Report Analysis?) The crew first checks that the EPM laptop and EPM software are activated, and then analyzes the FCC, SMSC, and VU self test reports.
- UDP C/O: (EPM Checkout of Utility Distribution Panel Interfaces) In this procedure, the crew checks that the EMP laptop and software are activated, then they verify both the left utility distribution panel power outlets and the right utility distribution panel LAN connections.
- CDL S/U: (EPM Cardiolab Setup) The crew sets up the EPM Cardiolab Data Management Computer Unit (DMCU) science module.
- Crew Rotation
 - Crew Handover: 1:00 of 12:30 planned for 1E is schedule for FD09. All handover on this day is face-to-face handover between FE-2 (up) and FE-2 (dn).
- EECOM/ECLSS Activities
 - 2 PWR fills and 2 CWC fills are scheduled on this day.
 - Prior to hatch closure the ISS CDR and CDR deconfigure the O2 systems from the setup on FD03 allowing the ISS A/L to use STS O2 during EVA prep and post.
- EVA
 - EVA Tool Deconfig - in this procedure the crew deconfigures the Col WIF bag, Col HR bag and several other tools and teathers post EVA3.
 - Post EVA Reconfig and Xfer - this procedure includes steps to reconfigure EMUs for transfer, reconfig EMU systems transfer bag for transfer, prepares ISS EMUs for undock, and transfers and stows necessary EVA hardware. This procedure only requires 1:45 on two crew - this is significantly less than what the baseline flight plan has.
- Maneuvers/Attitude Control
 - ISS will handover attitude control to the Shuttle during the reboost timeframe. STS will hand attitude control back to ISS once the mnvr back to TEA is complete.
 - ISS will hand attitude control over to the Shuttle while the PMA is depressed for the hatch leak check. Once the depress is complete, STS will hand control back to ISS for the over-night period.
- Payload Activities
 - Saliva Samples: The saliva samples (liquid and dry) scattered throughout the day on MS3 and MS4 are part of SBDI 1900 integrated immune.
 - Blood Collections: Prior to hatch closure, MS1 will take blood samples from ISS CDR and FE-2 up. This sample is for the ISS Integrated Immune experiment.
 - DCB1-1E-PACK: packing 2 bags: 45 min for first crewmember then 10 min after start add the second crewmember for 25 min. Per POIC/J. Watson, there is no time constraint between packing the bags; preferred back-to-back; but just not simo.

- MUS: MS4 performs the ESA payload questionnaire, MUS, prior to presleep.
- CDM: The CDM will be powered off immediately after wakeup, with the battery changeout and device relocation occurring later in the day.
- Sleep Log: MS1-MS4 all perform sleep log upon wakeup. MS1, MS2, and MS4 perform the log as participation in the sleep short SBDI. MS2 and MS3 fill out the log as participation in the PMZ SBDI.
- PAO
 - Crew conference is scheduled prior to hatch closure. All crewmembers participate. STS Ku will be used for this event.
- PGSC Operations
 - Prior to RNDZ Tools C/O, the WLES file backup is disabled. It is re-enabled on FD10 after the final sep burn is complete.
 - An ISS PCS will be activated on the FD after hatch closure to enable the STS crew to monitor ISS C&W.
- P/TV
 - P/TV08 External Survey - IV crewmember uses the 760 camera to document STS and ISS external structures with still photos. Areas surveyed include: OMS Pod, Payload Bay, ISS Surfaces, Solar Panels, Handrails, SVS targets, Trusses, Columbus External Payloads, and ESP-2.
 - P/TV09 Structural Dynamics - scheduled during Reboost Ops
 - P/TV04 Setup for Egress
 - P/TV05 ISS Internal Ops Deact
 - P/TV03 Undock Setup

Flight Day 10 - Undock, Late Inspection

Big Picture: With hatches being closed at the end of FD09, FD10 begins with the Group B powerup and maneuver to the undock attitude. Once in the undock attitude, the Shuttle will undock and perform a 1 rev flyaround before executing the separation burns. The sep burns are followed by a simo dump and after the mid-day meal, the Shuttle crew will perform the Late Inspection surveys. At the end of the day, the OBSS is berthed and there is a period of playback scheduled for any missed LDRI data.

Columbus Items

- Comm
 - Post sep burns, SSOR is deactivated (tears down the big-loop)
 - The OIU is also deactivated
 - SSV outrate is set to 4 post sep burns.
 - After the mid-day meal, the comm string 1 checkout is scheduled. A 24 hour check of comm string 1 is scheduled. System will be reconfigured back to comm string 2 at the end of the checkout period (FD11).
- EECOM/ECLSS Items
 - After the flyaround a 1 hour simo dump is scheduled.

- Post flyaround the condensate CWC hardware is torn down and stowed for entry.

Maneuvers/Attitude Control

- Prior to maneuvering to the undock attitude, ISS will handover attitude control to the STS. The mnvr to the undock attitude will be performed using Shuttle assets.

Payload Activities

- Sleep Log: MS1-MS4 all perform sleep log upon wakeup. MS1, MS2, and MS4 perform the log as participation in the sleep short SBDI. MS2 and MS3 fill out the log as participation in the PMZ SBDI.
- CDM: a data take is started just prior to sleep with a CDM activation.
- MUS: MS4 performs the ESA payload questionnaire, MUS, prior to presleep.

PGSC Operations

- After undock/flyaround and sep activities are complete, the PGSC network is reconfigured for orbit ops.
- Post sep burn, WLES file backup is re-enabled.

Post Undock Activities

- After the final sep burn the following activities are scheduled
 - Group B powerdown
 - SSOR Deact

P/TV

- After final sep burn P/TV 03 is torn down to remove the C/L Camera
- Undock video is played back

Robotics Activities (Late Inspection)

- The RCC inspection procedures and scheduling are identical to FD02 except for the following deltas:
 - The starboard wing survey is scheduled for 1:30, the nose cap for 1:00 (same as FD02), and the port wing for 1:45.
 - The LDRI 3D calibration in unberth is not performed.
 - IDC supplemental imagery is not performed.
 - Surveys of the crew cabin areas are not performed during the wing surveys.
 - Post OBSS berth, the RMS is powered down and the MPMs are stowed.

Flight Day 11 - Landing prep activities

Nominal EOM-1 activities: FCS Checkout with WSB heater activation and filter cleaning prior; RCS Hotfire; D/O Briefing, Cabin Stow, and Ergometer Stow.

Unique EOM-1 activities:

- Launch Entry Suit Fit Check and Recumbent Seat Kit Install is performed for FE2 (dn). These activities should be performed after ergometer stow for spatial reasons.

Comm Activities

- L-1 comm checks are scheduled for a prime MLA and DFR pass.
- The MADS instrumentation is activated in prep for entry.
- Entry video is setup.
- SSV deact is performed after entry video.
- Comm string 1 checkout is complete and the system is reconfigured back to comm string 2.
- Ku stow is scheduled as late as possible.

 EECOM

- There is a dump scheduled in the afternoon to dump 2 CWC bags and 1 PWR.

Off Duty: the final hour of required off duty is scheduled for all crew members on this day.

PAO: the final PAO event is scheduled for all crew members.

 Payloads

- Saliva Samples: The saliva samples (liquid and dry) scattered throughout the day on MS3 and MS4 are part of SBDI 1900 integrated immune.
- Blood Collections: MS1 will take blood samples from MS3, MS4, and FE-2 (dn). These samples are for the Integrated Immune experiments (STS and ISS).
- CDM: The CDM will be powered off immediately after wakeup, with termination and stow scheduled later in the day.
- Sleep Log: MS1-MS4 all perform sleep log upon wakeup. MS1, MS2, and MS4 perform the log as participation in the sleep short SBDI. MS2 and MS3 fill out the log as participation in the PMZ SBDI.
- MUS: MS4 performs the ESA payload questionnaire, MUS, prior to presleep.

 PGSCs

- WLES is deactivated from the backup machine prior to PILOT ops because that machine is used for PILOT and can not have other applications running in the background. The prime WLES machine is deactivated as late as possible.
- The printer is stowed and all of the PGSC hardware is stowed late in the day.

Flight Day 12 - Deorbit and Entry

Nominal EOM activities: Group B powerup, IMU align & verification, maneuver to XSI thermal conditioning, GIRA and OCAC stow, air sample collection, final PGSC stow, and MADS enable.

 Payloads

- MUS: MS4 performs the ESA payload questionnaire, MUS, prior to presleep.
- Actiwatch: MS2-MS4 and FE-2 up all stow actiwatches on this day. MS1, MS2, and MS4 don the watch in participation with the sleep short SBDI. MS2 and MS3 don the watch in participation with the PMZ SBDI.
- Saliva kit stow: MS3 stows the integrated immune saliva kit.

- ❑ Sleep Log: MS1-MS4 all perform sleep log upon wakeup. MS1, MS2, and MS4 perform the log as participation in the sleep short SBDI. MS2 and MS3 fill out the log as participation in the PMZ SBDI.

Deorbit Prep, Entry, Landing at KSC

STS-122 Flight Plan

Editor's Note...

Current as of 10/16/07

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				
12/06/07				
Thu 04:31 PM	00	00	00	STS-122 launch
Thu 05:08 PM	00	00	37	OMS-2 rocket firing
Thu 05:21 PM	00	00	50	Post insertion timeline begins
Thu 07:01 PM	00	02	30	SRMS checkout
Thu 07:16 PM	00	02	45	Laptop computer network setup
Thu 07:30 PM	00	02	59	NC1 rendezvous rocket firing
Thu 07:41 PM	00	03	10	GIRA installation
Thu 07:46 PM	00	03	15	Group B computer powerdown
Thu 08:41 PM	00	04	10	ET handheld photography
Thu 08:56 PM	00	04	25	Umbilical well camera downlink
Thu 08:56 PM	00	04	25	ET video downlink
Thu 09:01 PM	00	04	30	TPS imagery downlink
Thu 09:21 PM	00	04	50	WLES activation
Thu 10:31 PM	00	06	00	Crew sleep begins
Flight Day 2				
12/07/07				
Fri 06:31 AM	00	14	00	Crew wakeup
Fri 08:16 AM	00	15	45	SRMS powerup
Fri 08:31 AM	00	16	00	SRMS checkout
Fri 09:09 AM	00	16	38	NC2 rendezvous rocket firing
Fri 09:56 AM	00	17	25	OBSS unberth
Fri 10:21 AM	00	17	50	Ergometer setup
Fri 10:51 AM	00	18	20	Spacesuit checkout preps
Fri 10:56 AM	00	18	25	OBSS starboard wing survey
Fri 12:51 PM	00	20	20	OBSS nose cap survey
Fri 01:51 PM	00	21	20	Crew meal
Fri 02:51 PM	00	22	20	EVA transfer preps
Fri 02:51 PM	00	22	20	OBSS port wing survey
Fri 04:51 PM	01	00	20	OBSS berthing
Fri 05:26 PM	01	00	55	Centerline camera setup
Fri 05:26 PM	01	00	55	SRMS powerdown
Fri 05:31 PM	01	01	00	OMS pod survey
Fri 05:36 PM	01	01	05	LDRI downlink
Fri 05:56 PM	01	01	25	Orbiter docking system ring extension
Fri 06:51 PM	01	02	20	Rendezvous tools checkout
Fri 07:31 PM	01	03	00	NC3 rendezvous rocket firing
Fri 10:31 PM	01	06	00	Crew sleep begins
Flight Day 3				
12/08/07				
Sat 05:46 AM	01	13	15	ISS crew wakeup

DATE/ET	DD	HH	MM	EVENT
Sat 06:31 AM	01	14	00	STS crew wakeup
Sat 07:31 AM	01	15	00	ISS daily planning conference
Sat 07:56 AM	01	15	25	Group B computer powerup
Sat 08:11 AM	01	15	40	Begin rendezvous timeline
Sat 08:59 AM	01	16	28	NC4 rendezvous rocket firing
Sat 10:16 AM	01	17	45	Middeck prepped for docking
Sat 10:30 AM	01	17	59	TI burn
Sat 10:31 AM	01	18	00	Spacesuits removed from airlock
Sat 11:51 AM	01	19	20	Approach timeline begins
Sat 01:18 PM	01	20	47	DOCKING
Sat 01:36 PM	01	21	05	Leak checks
Sat 02:01 PM	01	21	30	Group B computer powerdown
Sat 02:06 PM	01	21	35	ODS prepped for ingress
Sat 02:26 PM	01	21	55	Hatch opening
Sat 02:26 PM	01	21	55	Post-rendezvous laptop reconfig
Sat 02:51 PM	01	22	20	Welcome aboard!
Sat 02:56 PM	01	22	25	Safety briefing
Sat 03:21 PM	01	22	50	Soyuz seatliner moved to ISS
Sat 04:16 PM	01	23	45	SSRMS grapples OBSS
Sat 04:31 PM	02	00	00	EVA tools transferred to ISS
Sat 04:31 PM	02	00	00	REBA checkout
Sat 04:46 PM	02	00	15	Equipment lock prep
Sat 04:46 PM	02	00	15	SSRMS unberths OBSS
Sat 05:51 PM	02	01	20	OBSS handoff to SRMS
Sat 06:06 PM	02	01	35	SSRMS ungrapples OBSS
Sat 06:46 PM	02	02	15	EVA-1: Procedures review
Sat 08:46 PM	02	04	15	EVA-1: Mask pre-breathe for campout
Sat 09:41 PM	02	05	10	EVA-1: Campout begins (10.2 psi depress)
Sat 10:01 PM	02	05	30	ISS crew sleep begins
Sat 10:31 PM	02	06	00	STS crew sleep begin

Flight Day 4
12/09/07

Sun 06:31 AM	02	14	00	STS/ISS crew wakeup
Sun 07:06 AM	02	14	35	EVA-1: 14.7 psi repress/hygiene break
Sun 08:16 AM	02	15	45	EVA-1: Campout EVA preps
Sun 08:31 AM	02	16	00	ISS daily planning conference
Sun 08:51 AM	02	16	20	Sokol suit leak check
Sun 09:21 AM	02	16	50	Sokol suit drying
Sun 09:46 AM	02	17	15	EVA-1: Spacesuit purge
Sun 10:01 AM	02	17	30	EVA-1: Spacesuit prebreathe
Sun 10:51 AM	02	18	20	EVA-1: Crew lock depressurization
Sun 11:01 AM	02	18	30	KU-band antenna stowed for Columbus unberthing
Sun 11:21 AM	02	18	50	EVA-1: Spacesuits to battery power
Sun 11:26 AM	02	18	55	EVA-1: Airlock egress
Sun 11:41 AM	02	19	10	EVA-1: Power-Data Grapple Fixture setup
Sun 01:21 PM	02	20	50	EVA-1: PDGF installation
Sun 02:56 PM	02	22	25	SSRMS grapples Columbus
Sun 03:16 PM	02	22	45	Vestibule outfittig preps
Sun 03:16 PM	02	22	45	SSRMS unberths Columbus
Sun 03:51 PM	02	23	20	EVA-1: EV1: P1 NTA removal prep
Sun 04:01 PM	02	23	30	EVA-1: EV2: P1 NTA removal prep
Sun 04:46 PM	03	00	15	Node 2 QD disconnect
Sun 05:21 PM	03	00	50	EVA-1: Cleanup and ingress
Sun 05:31 PM	03	01	00	Columbus first stage bolting
Sun 05:51 PM	03	01	20	Columbus second stage bolting

DATE/ET	DD	HH	MM	EVENT
Sun 05:51 PM	03	01	20	EVA-1: Airlock repressurization
Sun 06:01 PM	03	01	30	Spacesuit servicing
Sun 06:06 PM	03	01	35	Bolts torqued
Sun 06:26 PM	03	01	55	Centerline berthing camera removal
Sun 10:01 PM	03	05	30	ISS crew sleep begins
Sun 10:31 PM	03	06	00	STS/ISS crew sleep begins

Flight Day 5
12/10/07

Mon 06:31 AM	03	14	00	STS/ISS crew wakeup
Mon 08:31 AM	03	16	00	ISS daily planning conference
Mon 09:31 AM	03	17	00	DSK cover removal and strap
Mon 09:36 AM	03	17	05	PAO event
Mon 09:41 AM	03	17	10	Logistics transfers
Mon 10:26 AM	03	17	55	SSRMS ungrapples Columbus module
Mon 10:36 AM	03	18	05	Power jumper
Mon 10:36 AM	03	18	05	Partial ingress
Mon 11:01 AM	03	18	30	NPRV IMV supply valve
Mon 11:26 AM	03	18	55	Forward and aft CPA removal
Mon 11:51 AM	03	19	20	Crew meals begin (staggered)
Mon 12:41 PM	03	20	10	ITCS jumper
Mon 12:41 PM	03	20	10	Overhead and deck CPA removal
Mon 12:51 PM	03	20	20	Focused inspection (if necessary)
Mon 02:41 PM	03	22	10	EVA-2: Airlock preps
Mon 03:06 PM	03	22	35	NPRV IMV return valve
Mon 03:26 PM	03	22	55	EVA-2: Tools prepped
Mon 03:51 PM	03	23	20	IMV return duct
Mon 05:06 PM	04	00	35	Columbus module ingress
Mon 05:31 PM	04	01	00	SSRMS maneuver to park
Mon 06:31 PM	04	02	00	EVA-2: Procedures review
Mon 08:16 PM	04	03	45	PAO event
Mon 08:46 PM	04	04	15	EVA-2: Mask pre-breathe for campout
Mon 09:41 PM	04	05	10	EVA-2: Campout begins (10.2 psi depress)
Mon 10:01 PM	04	05	30	ISS crew sleep begins
Mon 10:31 PM	04	06	00	STS crew sleep begins

Flight Day 6
12/11/07

Tue 06:31 AM	04	14	00	STS/ISS crew wakeup
Tue 07:06 AM	04	14	35	EVA-2: Airlock repress to 14.7 psi
Tue 08:16 AM	04	15	45	EVA-2: Campout EVA prep
Tue 08:26 AM	04	15	55	ISS daily planning conference
Tue 08:41 AM	04	16	10	Install hand rail
Tue 09:46 AM	04	17	15	EVA-2: Spacesuit purge
Tue 10:01 AM	04	17	30	EVA-2: Spacesuit pre-breathe
Tue 10:11 AM	04	17	40	Columbus SSC activation
Tue 10:51 AM	04	18	20	EVA-2: Crew lock depressurization
Tue 11:21 AM	04	18	50	EVA-2: Spacesuits to battery power
Tue 11:26 AM	04	18	55	EVA-2: Airlock egress
Tue 11:26 AM	04	18	55	SSRMS supports P1 NTA removal from payload bay
Tue 11:41 AM	04	19	10	EVA-2: P1 NTA removal from payload bay
Tue 01:16 PM	04	20	45	Crew meals begin
Tue 01:31 PM	04	21	00	EVA-2: P1 NTA installation
Tue 02:26 PM	04	21	55	Relocate EPM-A3
Tue 03:36 PM	04	23	05	EVA-2: NA stow in payload bay

DATE/ET	DD	HH	MM	EVENT
Tue 04:31 PM	05	00	00	EVA-2: Station-to-shuttle power cable routing
Tue 05:16 PM	05	00	45	EVA-2: Cleanup and airlock ingress
Tue 05:51 PM	05	01	20	EVA-2: Airlock repressurization
Tue 06:01 PM	05	01	30	Spacesuit servicing
Tue 07:21 PM	05	02	50	EVA-3: Tool prep
Tue 09:01 PM	05	04	30	ISS crew sleep begins
Tue 09:31 PM	05	05	00	STS crew sleep begins

Flight Day 7
12/12/07

Wed 05:31 AM	05	13	00	STS/ISS crew wakeup
Wed 07:31 AM	05	15	00	ISS daily planning conference
Wed 07:46 AM	05	15	15	Columbus module outfitting/activation
Wed 08:36 AM	05	16	05	Spacesuit swap
Wed 09:26 AM	05	16	55	Equipment lock preps
Wed 09:31 AM	05	17	00	Shuttle crew off duty
Wed 09:51 AM	05	17	20	ESA PAO event
Wed 10:11 AM	05	17	40	Crew off duty time begins (staggered)
Wed 11:41 AM	05	19	10	Crew meals begin
Wed 12:41 PM	05	20	10	PAO event
Wed 05:31 PM	06	01	00	EVA-3: Procedures review
Wed 07:46 PM	06	03	15	EVA-3: Mask pre-breathe for campout
Wed 08:41 PM	06	04	10	EVA-3: Campout begins (10.2 psi depress)
Wed 09:01 PM	06	04	30	ISS crew sleep begins
Wed 09:31 PM	06	05	00	STS crew sleep begins

Flight Day 8
12/13/07

Thu 05:31 AM	06	13	00	STS/ISS crew wakeup
Thu 06:06 AM	06	13	35	EVA-3: Airlock repress to 14.7 psi
Thu 07:16 AM	06	14	45	EVA-3; Campout EVA prep
Thu 07:31 AM	06	15	00	ISS daily planning conference
Thu 07:46 AM	06	15	15	Columbus module setup
Thu 08:46 AM	06	16	15	Biolab relocation
Thu 08:46 AM	06	16	15	EVA-3: Spacesuit purge
Thu 09:01 AM	06	16	30	EVA-3: Spacesuit pre-breathe
Thu 09:51 AM	06	17	20	EVA-3: Airlock depressurization
Thu 10:21 AM	06	17	50	EVA-3: Spacesuits to battery power
Thu 10:26 AM	06	17	55	EVA-3: Airlock egress
Thu 10:41 AM	06	18	10	EVA-3: SOLAR transfer from shuttle to Columbus
Thu 12:56 PM	06	20	25	Crew meals begin
Thu 01:21 PM	06	20	50	EVA-3: CMG transfer from ESP-2 to shuttle
Thu 02:36 PM	06	22	05	EVA-3: EUTEF transfer from shuttle to Columbus
Thu 04:11 PM	06	23	40	EVA-3: Cleanup and ingress
Thu 04:51 PM	07	00	20	EVA-3: Airlock repressurization
Thu 05:01 PM	07	00	30	Spacesuit servicing
Thu 08:01 PM	07	03	30	ISS crew sleep begins
Thu 08:31 PM	07	04	00	STS crew sleep begins

Flight Day 9
12/14/07

Fri 04:31 AM	07	12	00	STS/ISS crew wakeup
Fri 06:31 AM	07	14	00	ISS daily planning conference
Fri 06:46 AM	07	14	15	Columbus module setup

DATE/ET	DD	HH	MM	EVENT
Fri 07:36 AM	07	15	05	EVA tools deconfigured
Fri 07:41 AM	07	15	10	Logistics transfers
Fri 08:11 AM	07	15	40	Reboost operations (placeholder)
Fri 11:31 AM	07	19	00	Joint crew news conference
Fri 12:11 PM	07	19	40	Joint crew photo
Fri 12:31 PM	07	20	00	Joint crew meal
Fri 01:31 PM	07	21	00	Rendezvous tools checkout
Fri 04:01 PM	07	23	30	Farewell ceremony
Fri 04:16 PM	07	23	45	Hatches closed
Fri 04:31 PM	08	00	00	Centerline camera setup
Fri 04:46 PM	08	00	15	Leak checks
Fri 08:01 PM	08	03	30	ISS crew sleep begins
Fri 08:31 PM	08	04	00	STS crew sleep begins

Flight Day 10
12/15/07

Sat 04:31 AM	08	12	00	STS/ISS crew wakeup
Sat 06:01 AM	08	13	30	ISS daily planning conference
Sat 06:36 AM	08	14	05	Group B computer power up
Sat 07:31 AM	08	15	00	Undocking operations begin
Sat 08:01 AM	08	15	30	PMA-2 prepped for undocking
Sat 08:21 AM	08	15	50	UNDOCKING
Sat 08:46 AM	08	16	15	PMA-2 depressurization
Sat 08:46 AM	08	16	15	Flyaround
Sat 09:36 AM	08	17	05	Separation burn No. 1
Sat 10:04 AM	08	17	33	Separation burn No. 2
Sat 10:11 AM	08	17	40	Group B computer power down
Sat 10:11 AM	08	17	40	Post undocking network reconfiguration
Sat 10:41 AM	08	18	10	Crew meal
Sat 11:41 AM	08	19	10	Spacesuit installation
Sat 12:01 PM	08	19	30	OBSS unberth
Sat 12:11 PM	08	19	40	Starboard wing survey
Sat 12:11 PM	08	19	40	EVA unpack and stow
Sat 12:41 PM	08	20	10	Post-ISS EVA entry preps
Sat 01:51 PM	08	21	20	Nose cap survey
Sat 02:51 PM	08	22	20	Port wing survey
Sat 04:36 PM	09	00	05	OBSS berthing
Sat 05:11 PM	09	00	40	SRMS powerdown
Sat 05:41 PM	09	01	10	Laser scanner downlink
Sat 06:01 PM	09	01	30	NC-5 rocket firing
Sat 07:01 PM	09	02	30	ISS crew sleep begins
Sat 08:01 PM	09	03	30	STS crew sleep begins

Flight Day 11
12/16/07

Sun 04:01 AM	09	11	30	Crew wakeup
Sun 06:36 AM	09	14	05	Cabin stow
Sun 08:01 AM	09	15	30	FCS checkout
Sun 09:11 AM	09	16	40	RCS hotfire
Sun 09:26 AM	09	16	55	PILOT landing practice
Sun 10:36 AM	09	18	05	PAO event
Sun 10:56 AM	09	18	25	Deorbit review
Sun 11:26 AM	09	18	55	Crew meal
Sun 02:31 PM	09	22	00	Launch/entry suit checkout
Sun 02:51 PM	09	22	20	Ergometer stow

DATE/ET	DD	HH	MM	EVENT
Sun 03:21 PM	09	22	50	Wing leading edge sensors deactivated
Sun 03:31 PM	09	23	00	Recumbent seat setup
Sun 03:41 PM	09	23	10	Laptop network teardown
Sun 03:48 PM	09	23	17	Orbit adjustment rocket firing (placeholder)
Sun 03:51 PM	09	23	20	KU-band antenna stow
Sun 04:01 PM	09	23	30	Crew off duty
Sun 08:01 PM	10	03	30	Crew sleep begins

Flight Day 12
12/17/07

Mon 04:01 AM	10	11	30	Crew wakeup
Mon 06:16 AM	10	13	45	Group B computer powerup
Mon 06:31 AM	10	14	00	IMU alignment
Mon 07:06 AM	10	14	35	GIRA stow; OCAC stow
Mon 07:26 AM	10	14	55	Deorbit timeline begins
Mon 11:28 AM	10	18	57	Deorbit ignition (rev. TBD)
Mon 12:29 PM	10	19	58	Landing

STS-122 Television Schedule (initial release)

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	EST	GMT
MONDAY, DECEMBER 3			
....COUNTDOWN STATUS BRIEFING.....		10:00 AM	15:00
....ISS EXPEDITION 16 COMMENTARY.....		11:00 AM	16:00
....STS-122 CREW ARRIVAL.....		12:30 PM	17:30
....VIDEO FILE.....		1:00 PM	18:00
TUESDAY, DECEMBER 4			
....COUNTDOWN STATUS BRIEFING.....		10:00 AM	15:00
....ISS EXPEDITION 16 COMMENTARY.....		11:00 AM	16:00
....VIDEO FILE.....		12:00 PM	17:00
....LAUNCH READINESS NEWS CONFERENCE.....		4:00 PM	21:00
WEDNESDAY, DECEMBER 5			
....COUNTDOWN STATUS BRIEFING.....		10:00 AM	15:00
....ISS EXPEDITION 16 COMMENTARY.....		11:00 AM	16:00
....VIDEO FILE.....		12:00 PM	17:00
....ESA COLUMBUS/ATV BRIEFING.....		1:00 PM	18:00
THURSDAY, DECEMBER 6 - Flight Day 1			
....ATLANTIS LAUNCH COVERAGE BEGINS.....		11:30 AM	16:30
....LAUNCH.....	00/00:00	04:31 PM	21:31
....MECO.....	00/00:08	04:39 PM	21:39
1...LAUNCH REPLAYS.....	00/00:13	04:44 PM	21:44
1...ADDITIONAL LAUNCH REPLAYS FROM KSC.....	00/00:45	05:16 PM	22:16
1...POST LAUNCH NEWS CONFERENCE.....	00/00:59	05:30 PM	22:30
2...PAYLOAD BAY DOOR OPENING.....	00/01:25	05:56 PM	22:56
3...ASCENT FLIGHT TEAM VIDEO REPLAY.....	00/03:59	08:30 PM	01:30
5...LAUNCH ENGINEERING REPLAYS FROM KSC.....	00/04:59	09:30 PM	02:30
5...ATLANTIS CREW SLEEP BEGINS.....	00/06:00	10:31 PM	03:31
6...FLIGHT DAY 1 HIGHLIGHTS.....	00/06:29	11:00 PM	04:00
FRIDAY, DECEMBER 7 - Flight Day 2			
10...ATLANTIS CREW WAKE UP (FD 2).....	00/14:00	06:31 AM	11:31
12...RMS CHECKOUT.....	00/16:00	08:31 AM	13:31
12...RMS GRAPPLE & UNBERTH OF OBSS.....	00/17:25	09:56 AM	14:56

ORBIT EVENT	MET	EST	GMT
13...RMS/OBSS TPS SURVEY BEGINS.....	00/18:25	10:56 AM	15:56
13...EMU CHECKOUT.....	00/18:50	11:21 AM	16:21
16...MISSION STATUS BRIEFING.....	00/23:59	04:30 PM	21:30
17...OBSS BERTH.....	01/00:20	04:51 PM	21:51
17...CENTERLINE CAMERA INSTALLATION.....	01/00:55	05:26 PM	22:26
17...RMS OMS POD SURVEY.....	01/01:00	05:31 PM	22:31
18...ODS RING EXTENSION.....	01/01:25	05:56 PM	22:56
18...POST-MMT BRIEFING.....	01/01:29	06:00 PM	23:00
18...RENDEZVOUS TOOL CHECKOUT.....	01/02:20	06:51 PM	23:51
19...VIDEO FILE.....	01/03:29	08:00 PM	01:00
21...ATLANTIS CREW SLEEP BEGINS.....	01/06:00	10:31 PM	03:31
21...FLIGHT DAY 2 HIGHLIGHTS.....	01/06:29	11:00 PM	04:00
SATURDAY, DECEMBER 8 - Flight Day 3			
25...ATLANTIS CREW WAKE UP (FD 3).....	01/14:00	06:31 AM	11:31
27...RENDEZVOUS OPERATIONS BEGIN.....	01/15:40	08:11 AM	13:11
29...TI BURN.....	01/17:59	10:30 AM	15:30
30...ATLANTIS RPM DOCUMENTATION BEGINS....	01/19:46	12:17 PM	17:17
31...ATLANTIS/ISS DOCKING.....	01/20:46	01:17 PM	18:17
31...ATLANTIS/ISS CREW HATCH OPENING.....	01/21:55	02:26 PM	19:26
32...SSRMS GRAPPLE OF OBSS.....	01/23:45	04:16 PM	21:16
32...TANI/EYHARTS SOYUZ SEATLINER SWAP....	01/23:50	04:21 PM	21:21
....(EYHARTS JOINTS ISS CREW)			
32...MISSION STATUS/POST- MMT BRIEFING....	01/23:59	04:30 PM	21:30
32...OBSS UNBERTH.....	02/00:15	04:46 PM	21:46
32...SSRMS HANDOFF OF OBSS TO RMS.....	02/01:20	05:51 PM	22:51
33...VTR PLAYBACK OF DOCKING.....	02/01:35	06:06 PM	23:06
33... EVA 1 PROCEDURE REVIEW.....	02/02:15	06:46 PM	23:46
34...WALHEIM AND SCHLEGEL CAMPOUT BEGINS..	02/04:15	08:46 PM	01:46
36...ISS CREW SLEEP BEGINS.....	02/05:30	10:01 PM	03:01
36...ATLANTIS CREW SLEEP BEGINS.....	02/06:00	10:31 PM	03:31
37...FLIGHT DAY 3 HIGHLIGHTS.....	02/06:29	11:00 PM	04:00
SUNDAY, DECEMBER 9 - Flight Day 4			
42...ATLANTIS/ISS CREW WAKE UP (FD 4).....	02/14:00	06:31 AM	11:31
42...EVA #1 PREPARATIONS RESUME.....	02/14:35	07:06 AM	12:06
43...ISS FLIGHT DIRECTOR UPDATE.....	02/15:29	08:00 AM	13:00
43...ISS FLIGHT DIRECTOR UPDATE REPLAY....	02/16:29	09:00 AM	14:00
45...SHUTTLE KU-BAND ANTENNA STOW.....	02/18:30	11:01 AM	16:01
45...EVA #1 BEGINS FROM ISS QUEST AIRLOCK.	02/18:50	11:21 AM	16:21
45...PDGF INSTALLATION.....	02/20:50	01:21 PM	18:21
45...SSRMS GRAPPLE OF COLUMBUS MODULE....	02/22:25	02:56 PM	19:56
45...SSRMS UNBERTH OF COLUMBUS MODULE....	02/22:45	03:16 PM	20:16
47...P1 NTA REMOVAL PREPARATIONS.....	02/23:20	03:51 PM	20:51
48...COLUMBUS INSTALL/EVA #1 ENDS.....	03/01:20	05:51 PM	22:51
50...MISSION STATUS BRIEFING.....	03/03:29	08:00 PM	01:00
52...ISS CREW SLEEP BEGINS.....	03/05:30	10:01 PM	03:01
52...ATLANTIS CREW SLEEP BEGINS.....	03/06:00	10:31 PM	03:31
52...FLIGHT DAY 4 HIGHLIGHTS.....	03/06:29	11:00 PM	04:00
MONDAY, DECEMBER 10 - Flight Day 5			
57...ATLANTIS/ISS CREW WAKE UP (FD 5).....	03/14:00	06:31 AM	11:31

ORBIT EVENT	MET	EST	GMT
56...ISS FLIGHT DIRECTOR UPDATE.....	03/15:29	08:00 AM	13:00
57...ISS FLIGHT DIRECTOR UPDATE REPLAY....	03/16:29	09:00 AM	14:00
60...COLUMBUS MODULE OUTFITTING BEGINS....	03/17:00	09:31 AM	14:31
60...U.S. PAO EVENT.....	03/17:05	09:36 AM	14:36
61...SSRMS UNGRAPPLES COLUMBUS MODULE.....	03/17:55	10:26 AM	15:26
61...COLUMBUS MODULE PARTIAL INGRESS.....	03/18:05	10:36 AM	15:36
61...SHUTTLE KU-BAND ANTENNA REDEPLOYMENT..	03/19:00	11:31 AM	16:31
62...SSRMS/OBSS FOCUSED INSPECTION.....	03/20:20	12:51 PM	17:51
....(if necessary)			
62...COLUMBUS MODULE INGRESS.....	04/00:35	05:06 PM	22:06
64...MISSION BRIEFING/POST-MMT BRIEFING...	04/00:59	05:30 PM	22:30
65...U.S. PAO EVENT.....	04/03:45	08:16 PM	01:16
66...VIDEO FILE.....	04/03:59	08:30 PM	01:30
66...WALHEIM AND SCHLEGEL CAMPOUT BEGINS..	04/04:15	08:46 PM	01:46
67...ISS CREW SLEEP BEGINS.....	04/05:30	10:01 PM	03:01
67...ATLANTIS CREW SLEEP BEGINS.....	04/06:00	10:31 PM	03:31
68...FLIGHT DAY 5 HIGHLIGHTS.....	04/06:29	11:00 PM	04:00
TUESDAY, DECEMBER 11 - Flight Day 6			
73...ATLANTIS/ISS CREW WAKE UP (FD 6).....	04/14:00	06:31 AM	11:31
73...EVA #2 PREPARATIONS RESUME.....	04/14:35	07:06 AM	12:06
73...ISS FLIGHT DIRECTOR UPDATE.....	04/15:29	08:00 AM	13:00
74...COLUMBUS MODULE OUTFITTING CONTINUES..	04/16:10	08:41 AM	13:41
74...ISS FLIGHT DIRECTOR UPDATE REPLAY....	04/16:29	09:00 AM	14:00
77...EVA #2 BEGINS.....	04/18:50	11:21 AM	16:21
77...SSRMS REMOVAL OF P1 NTA.....	04/19:10	11:41 AM	16:41
78...P1 NTA REMOVAL AND REPLACEMENT.....	04/21:00	01:31 PM	18:31
79...OLD P1 NTA STOWED IN PAYLOAD BAY.....	04/23:05	03:36 PM	20:36
80...EVA #2 ENDS.....	05/01:20	05:51 PM	22:51
82...MISSION STATUS BRIEFING.....	05/03:29	08:00 PM	01:00
83...ISS CREW SLEEP BEGINS.....	05/04:30	09:01 PM	02:01
82...VIDEO FILE.....	05/04:59	09:30 PM	02:30
83...ATLANTIS CREW SLEEP BEGINS.....	05/05:00	09:31 PM	02:31
83...FLIGHT DAY 6 HIGHLIGHTS.....	05/05:29	10:00 PM	03:00
WEDNESDAY, DECEMBER 12 - Flight Day 7			
89...ATLANTIS/ ISS CREW WAKE UP (FD 7)....	05/13:00	05:31 AM	10:31
89...ISS FLIGHT DIRECTOR UPDATE.....	05/14:29	07:00 AM	12:00
90...COLUMBUS MODULE OUTFITTING CONTINUES..	05/15:00	07:31 AM	12:31
90...ISS FLIGHT DIRECTOR UPDATE REPLAY....	05/15:29	08:00 AM	13:00
92...ESA PAO EVENT.....	05/17:20	09:51 AM	14:51
93...ATLANTIS CREW OFF DUTY PERIODS BEGIN..	05/17:40	10:11 AM	15:11
93...INTERPRETED REPLAY OF ESA PAO EVENT..	05/18:29	11:00 AM	16:00
94...U.S. PAO EVENT.....	05/19:40	12:11 PM	17:11
94...VIDEO FILE.....	06/21:29	02:00 PM	19:00
95...MISSION STATUS BRIEFING.....	05/23:29	04:00 PM	21:00
96...EVA 3 PROCEDURE REVIEW.....	06/01:00	05:31 PM	22:31
98...WALHEIM AND LOVE CAMPOUT BEGINS.....	06/03:15	07:46 PM	00:46
98...ISS CREW SLEEP BEGINS.....	06/04:30	09:01 PM	02:01
99...ATLANTIS CREW SLEEP BEGINS.....	06/05:00	09:31 PM	02:31
99...FLIGHT DAY 7 HIGHLIGHTS.....	06/05:29	10:00 PM	03:00

ORBIT EVENT	MET	EST	GMT
THURSDAY, DECEMBER 13 - Flight Day 8			
104...ATLANTIS/ISS CREW WAKE UP (FD 8)....	06/13:00	05:31 AM	10:31
104...EVA #3 PREPARATIONS RESUME.....	06/13:35	06:06 AM	11:06
104...ISS FLIGHT DIRECTOR UPDATE.....	06/14:29	07:00 AM	12:00
104...COLUMBUS MODULE OUTFITTING.....	06/15:15	07:46 AM	12:46
105...ISS FLIGHT DIRECTOR UPDATE REPLAY...	06/15:29	08:00 AM	13:00
107...EVA #3 BEGINS.....	06/17:50	10:21 AM	15:21
.....SOLAR TRANSFER TO COLUMBUS			
109...FAILED CMG-3 TRANSFER TO SHUTTLE....	06/20:50	01:21 PM	18:21
110...EUTEF TRANSFER TO COLUMBUS MODULE...	06/22:05	02:36 PM	19:36
112...EVA #3 ENDS.....	07/00:20	04:51 PM	21:51
113...MISSION STATUS BRIEFING.....	07/02:29	07:00 PM	00:00
114...ISS CREW SLEEP BEGINS.....	07/03:30	08:01 PM	01:01
115...VIDEO FILE.....	07/03:59	08:30 PM	01:30
115...ATLANTIS CREW SLEEP BEGINS.....	07/04:00	08:31 PM	01:31
115...FLIGHT DAY 8 HIGHLIGHTS.....	07/04:29	09:00 PM	02:00
FRIDAY, DECEMBER 14 - Flight Day 9			
120...ATLANTIS/ISS CREW WAKE UP (FD 9)...	07/12:00	04:31 AM	09:31
120...COLUMBUS OUTFITTING CONTINUES.....	07/14:15	06:46 AM	11:46
120...ISS FLIGHT DIRECTOR UPDATE.....	07/14:29	07:00 AM	12:00
122...ISS FLIGHT DIRECTOR UPDATE REPLAY...	07/15:29	08:00 AM	13:00
122...ISS REBOOST (if required).....	07/15:40	08:11 AM	13:11
125...JOINT CREW NEWS CONFERENCE.....	07/19:00	11:31 AM	16:31
125...JOINT CREW NEWS CONFERENCE REPLAY...	07/20:29	01:00 PM	18:00
126...RENDEZVOUS TOOL CHECKOUT.....	07/21:00	01:31 PM	18:31
127...FAREWELL AND HATCH CLOSURE.....	07/23:30	04:01 PM	21:01
128...MISSION STATUS BRIEFING.....	08/23:59	04:30 PM	21:30
128...CENTERLINE CAMERA INSTALLATION.....	08/00:00	04:31 PM	21:31
128...VIDEO FILE.....	08/01:29	06:00 PM	23:00
129...ISS CREW SLEEP BEGINS.....	08/03:30	08:01 PM	01:01
130...ATLANTIS CREW SLEEP BEGINS.....	08/04:00	08:31 PM	01:31
130...FLIGHT DAY 9 HIGHLIGHTS.....	08/04:29	09:00 PM	02:00
SATURDAY, DECEMBER 15 - Flight Day 10			
135...ATLANTIS/ISS CREW WAKE UP (FD 10)...	08/12:00	04:31 AM	09:31
133...ISS FLIGHT DIRECTOR UPDATE.....	08/13:29	06:00 AM	11:00
135...ISS FLIGHT DIRECTOR UPDATE REPLAY...	08/14:29	07:00 AM	12:00
138...ATLANTIS UNDOCKS FROM ISS.....	08/15:50	08:21 AM	13:21
138...ATLANTIS FLYAROUND BEGINS.....	08/16:15	08:46 AM	13:46
139...FINAL SEPARATION FROM ISS.....	08/17:33	10:04 AM	15:04
139...VTR PLAYBACK OF UNDOCKING.....	08/17:45	10:16 AM	15:16
141...RMS/OBSS LATE INSPECTION.....	08/19:40	12:11 PM	17:11
143...MISSION STATUS BRIEFING.....	08/21:59	02:30 PM	19:30
144...OBSS BERTH.....	09/00:05	04:36 PM	21:36
145...ATLANTIS CREW SLEEP BEGINS.....	09/03:30	08:01 PM	01:01
146...FLIGHT DAY 10 HIGHLIGHTS.....	09/04:29	09:00 PM	02:00
SUNDAY, DECEMBER 16 - Flight Day 11			
151...ATLANTIS CREW WAKE UP (FD 11).....	09/11:30	04:01 AM	09:01
152...CABIN STOWAGE BEGINS.....	09/14:05	06:36 AM	11:36
153...FCS CHECKOUT.....	09/15:30	08:01 AM	13:01

ORBIT EVENT	MET	EST	GMT
154...RCS HOT-FIRE TEST.....	09/16:40	09:11 AM	14:11
155...U.S. PAO EVENT.....	09/18:05	10:36 AM	15:36
156...CREW DEORBIT PREPARATION BRIEFING...	09/18:25	10:56 AM	15:56
158...MISSION STATUS BRIEFING.....	09/21:59	02:30 PM	19:30
158...RECUMBENT SEAT SETUP.....	09/23:05	03:36 PM	20:36
159...KU-BAND ANTENNA STOWAGE.....	09/23:20	03:51 PM	20:51
159...POST MMT BRIEFING.....	09/23:29	04:00 PM	21:00
159...CREW OFF DUTY PERIOD BEGINS.....	09/23:30	04:01 PM	21:01
161...ATLANTIS CREW SLEEP BEGINS.....	10/03:30	08:01 PM	01:01
161...FLIGHT DAY 11 HIGHLIGHTS.....	10/04:29	09:00 PM	02:00

MONDAY, DECEMBER 17 - Flight Day 12

167...ATLANTIS CREW WAKEUP (FD 12).....	10/11:30	04:01 AM	09:01
168...DEORBIT PREPARATIONS BEGIN.....	10/14:55	07:26 AM	12:26
168...PAYLOAD BAY DOOR CLOSING.....	10/16:17	08:48 AM	13:48
171...DEORBIT BURN.....	10/18:57	11:28 AM	16:28
171...MILA C-BAND RADAR ACQUISITION.....	10/19:45	12:16 PM	17:16
172...KSC LANDING.....	10/19:58	12:29 PM	17:29

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Appendix 1: Space Shuttle Flight and Abort Scenarios

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

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

Based on the type of main engines aboard Discovery, 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 RLS 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 RLS abort occurred in August 1994).

An RLS 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 Details²

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.

² The remainder of this appendix, with clearly noted exceptions, is taken directly from shuttle-builder Rockwell International's Shuttle Reference book.

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.

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.

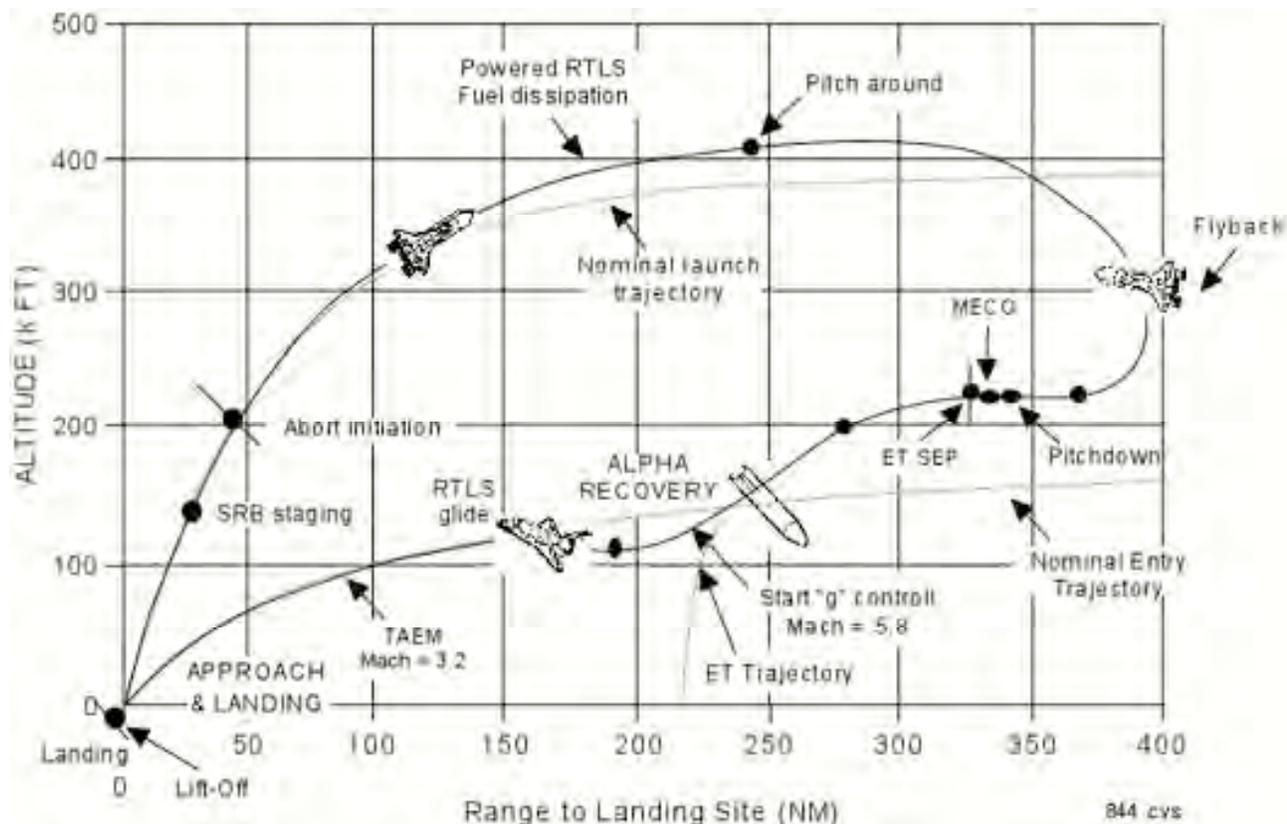
The flight crew selects the abort mode by positioning an abort mode switch and depressing an abort push button.

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)³ 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.

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)⁴ Abort

³ ECALs were not included in the original Rockwell Shuttle Reference. This information is provided by the author.

⁴ 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.

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.

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.

Appendix 2: STS-51L and STS-107 Remembering Challenger and Columbia⁵



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

STS-51L: Challenger's Final Flight

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

NASA says astronauts apparently dead

By WILLIAM HARWOOD

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

⁵ 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 when 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 held 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



A rupture in Challenger's right-side booster is evident in this photo from a long-range tracking camera.

committing 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 than 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, Discovery 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 Langley 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 it 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 manager 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.



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.



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

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

The Fate of Challenger's Crew

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

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

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

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

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

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

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

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

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

- | | |
|-----------|---|
| Mid-March | Four astronaut "personal egress air packs," called PEAPs, are recovered along with other cabin wreckage. |
| April 18 | NASA announced the crew cabin recovery operation was complete and that identifiable remains of all seven astronauts were on shore undergoing analysis. |
| April 25 | The Armed Forces Institute of Pathology notified NASA it had been unable to determine a cause of death from analysis of remains. Joseph Kerwin, director of life sciences at the Johnson Space Center, began an in-depth analysis of the wreckage in a search for the answer. |
| May 20 | Johnson Space Center crew systems personnel began analysis of the four PEAPs, emergency air packs designed for use if a shuttle crew must attempt an emergency exit on the ground when dangerous vapors might be in the area. |
| May 21 | Investigators found evidence some of the PEAPs had been activated. |

June 4	Investigators determined PEAP activation was not caused by crew cabin impact in the ocean.
June 9	Smith's PEAP was identified by serial number.
June 25	The PEAPs were sent to the 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."

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.



Challenger's crew departs the Kennedy Space Center

STS-107: Columbia's Final Voyage

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

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 Columbia astronauts, led by commander Rick Husband (front right) leave crew quarters at the Kennedy Space Center and head for the launch pad.

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.



Columbia takes off on mission STS-107

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 endeavour, 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.

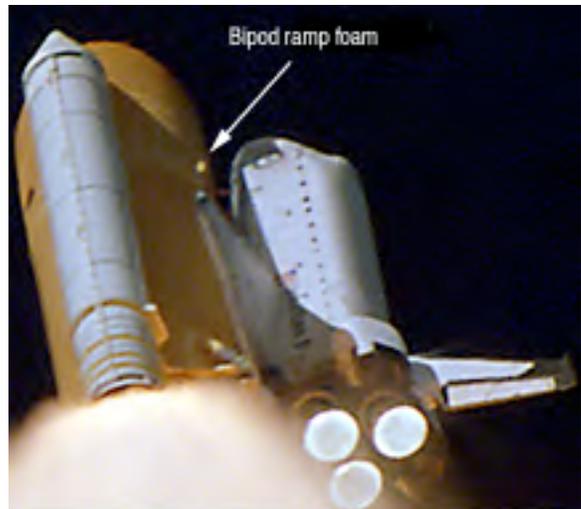
More than 80 experiments were on board, most of them in a Spacehab research module in Columbia's cargo bay. To collect as much data as possible, the astronauts worked around the clock in two 12-hour shifts. By all accounts, the crew accomplished all of their major objectives.

At an afternoon news conference, shuttle program Ronald Dittmore 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.

"We're devastated because of the events that unfolded this morning," Dittmore 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."

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.



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."



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.



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.

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.

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.

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."



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.

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."

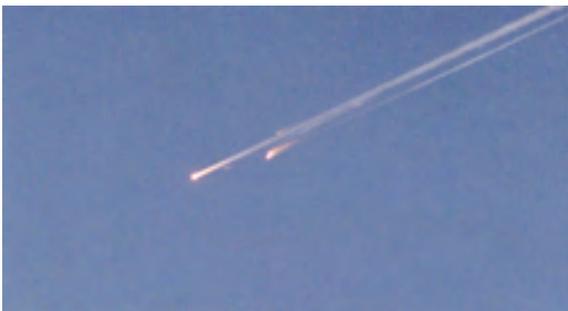
The 13-member Columbia Accident Investigation Board spent seven months investigating the Feb. 1 Columbia disaster, reviewing more than 30,000 documents, conducting more than 200 formal interviews and collecting testimony from expert

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.



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.

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.



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

"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.

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



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

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, Dittmore or other members of the mission management team.

Ham and Dittmore 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.

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.

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 Dittmore 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

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."

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."



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

"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

demanding 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 difference 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 fully 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 Reinforced 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-Carbon panel assemblies and associated support components to ensure that decisions on Reinforced 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 alternate 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 program to upgrade the Shuttle engineering drawing system including:
- Reviewing drawings for accuracy
 - Converting all drawings to a computer-aided drafting system
 - Incorporating engineering changes

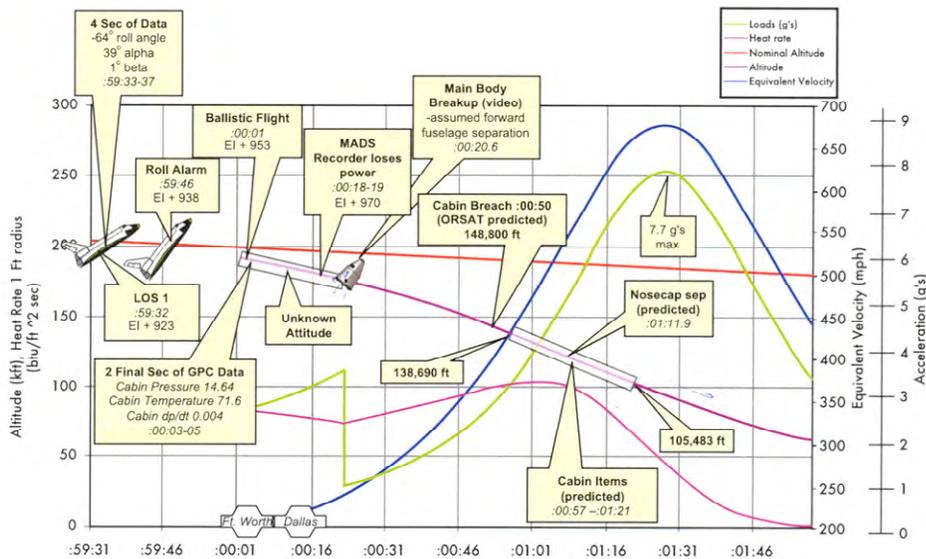


The Fate of Columbia's Crew

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 X0576 and X0582 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