Payloads

Mission to America's Remarkable Schools

Payload Bay

270 lb lbs.

Prime:
Backup:

Principal Investigator: Dennis Chamberland, KSC

Overview

This life sciences payload, sponsored by the NASA's Kennedy Space Center (KSC), contains 20 experiments from schools across the United States. The projects include seeds of various types reflown from SEEDS I and II as well as regionally important seed varieties such as lettuce and spinach. In addition, some schools submitted cellular specimens like chlorella and e.Coli (from commercial high school scientific supply houses).

Each experiment is placed in a 2-inch-diameter PVC tube inside a Complex Autonomous Payload (CAP)/Getaway Special (GAS) canister. The CAP/GAS is positioned in space shuttle cargo bay 13, port side, forward position.

MARS is a passive payload that does not require any power or crew interaction. Experiments are self-contained, back-filled with dry nitrogen at one atmosphere before launch, and sealed throughout the mission.

History/Background

The Complex Autonomous Payload project grew out of the Getaway Special program as a means to fly designated canisters as shuttle secondary payloads sponsored by NASA. These CAP experiments offer an inexpensive means for educational institutions to experiment in space. The GAS program also provides inexpensive access to space for non-NASA experiments. The GAS program allows educational institutions to develop a payload that fits in the NASA standard 5-cubic-foot GAS canister. The payload control weight is 270 pounds--100 pounds for the experiment and 170 pounds for the carrier. The Goddard Space Flight Center Wallops Island facility manages the GAS program.

The primary program objective is outreach to schools with an emphasis on NASA space life sciences, encouraging direct student participation in the space shuttle program. The program is managed by KSC and the NASA Space Life Sciences Outreach Program Intercenter Working Group.

Further information on the Getaway Special program, as well as other shuttle carrier programs managed by Goddard Space Flight Center, can be found at http://sspp.gsfc.nasa.gov.

Benefits

Encourages student participation and experimentation in space life sciences.

Updated: 03/27/2000

Payloads

Space Experiment Module 6

Payload Bay

Prime:

Backup:

Overview

Ten passive experiments will fly on STS-101 as part of NASA's Space Experiment Module program, which is managed by the Goddard Space Flight Center's Wallops Flight Facility in Wallops Island, Va. The SEM program is an educational initiative to increase access to space for students in kindergarten through the university level. Since its first flight in 1995, SEM has allowed tens of thousands of students in the United States and other countries to fly their experiments in space. SEM-06 is a mixture of experiments from the United States and Argentina.

Idaho Tubers in Space: Shoshone-Bannock High School, Fort Hall, Idaho
Students will study the effect of space on Idaho tubers. The "Spuds in Space" experiment was developed by students from the Fort Hall Indian Reservation.

Seeds/CREPLD II: Purdue University, West Lafayette, Indiana
This experiment will study the effects of the space environment on seeds and on programmable logic devices.

Effects of Microgravity on Samples/GADGET: Glenbrook High School, Northbrook, Illinois
Students will determine the effects of the space environment on different types and colors of paint. Secondary experiment samples from other Illinois schools consist of dried shrimp, sand, hair, and feathers.

Yeast in Space: Brock Bridge Elementary, Laurel, Maryland
Students will study the effects of microgravity and temperature on yeast.

Effects of Cosmic Radiation: Benfield Elementary, Severna Park, Maryland
Students will study the effects of the space environment (cosmic radiation and microgravity) on various items, such as film, seeds, bulbs, yeast, beans, and popcorn.

Effects of Space on Fluids and Seeds: Technical School No. 469, Rosario, Argentina
Students will investigate the effects of the space environment on seeds and liquids such as colored fluids, oil, and water.

GERMINAR-2: National University of Patagonia, Argentina
This experiment will study the effects of the space environment on bee glue and various seeds.

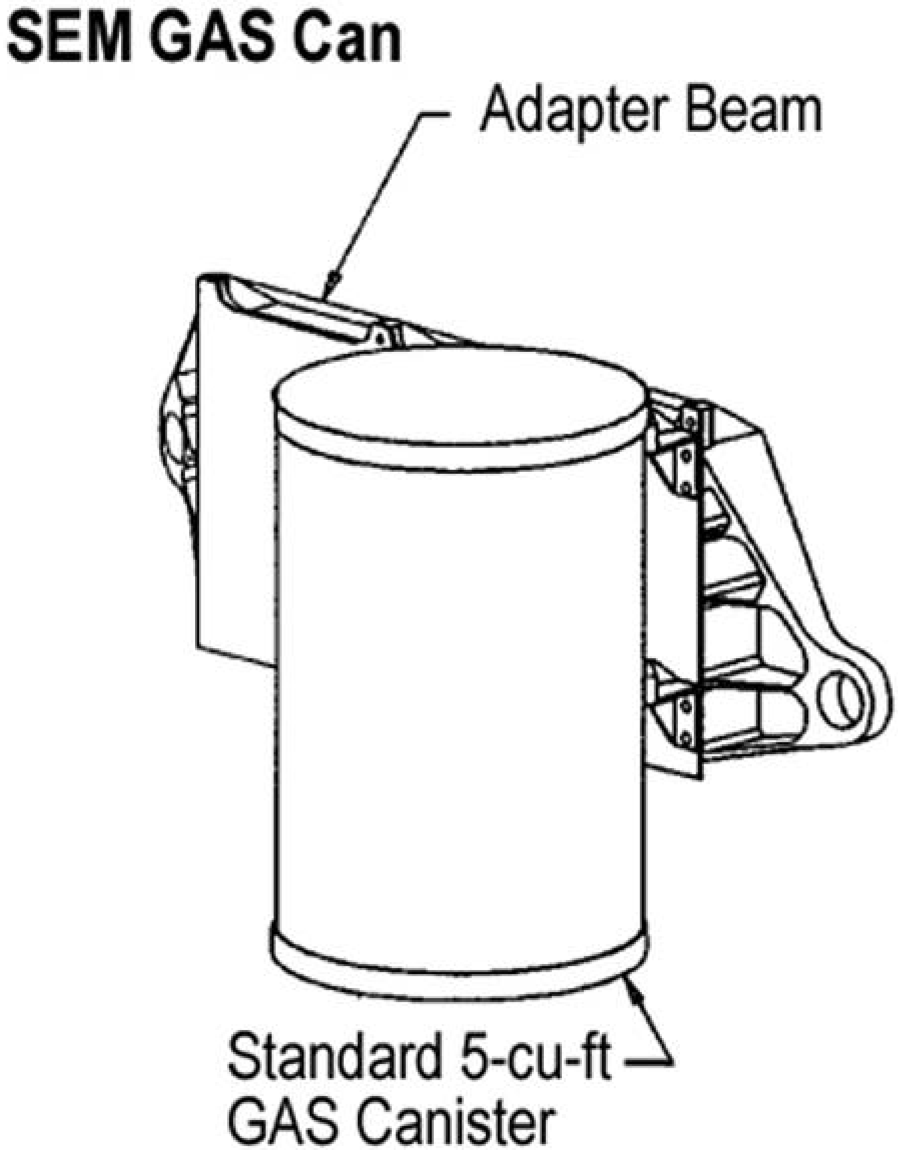
Seeds and Sea Monkeys in Space: Rosario National University, Argentina
This experiment will study the effects of the space environment on Patagonic seeds (trees), humus, and Artemias Salina (sea monkeys).

Electronics and Magnetic Recording Devices: Rosario National University/St. Hilda's School, Argentina
Students will study the effects of the space environment on electronics and magnetic chips such as those used in diskettes, CD ROMs, PC boards, and phone cards.

Cosmic Ray Detectors: Buenos Aires National School/Rosario National University, Argentina
This experiment will use thermoluminiscent detectors to study the effect of cosmic rays.

History/Background

SEM-06 uses a standard 5-cubic-foot Getaway Special (GAS) canister, mounted on an SSP/JSC-provided adapter beam in bay 13, port side, forward position in the orbiter payload bay. SEM-06 is passive: no batteries or power utilities are supplied by the orbiter.



NASA began the Space Experiment Module (SEM) program in 1995 as an offshoot of the Getaway Special program, managed by the Shuttle Small Payloads Project at Goddard Space Flight Center in Greenbelt, Md., and the Wallops Flight Facility, Wallops Island, Va. Since 1982, GAS canisters have flown on the shuttle, offering economic access to space to a broader array of experimenters, particularly students. But participation was still somewhat limited by the high-level engineering skills required to design GAS experiments.

In 1995, the program directors started SEM to relieve students of the engineering burden and let them concentrate on creating their experiments. Since the module is equipped with electrical power, there is no need to engineer and build battery boxes, etc. Students of all ages can create, design, and build experiments with a little help from teachers or mentors. The experiments--which can be simple or complicated, active or passive--are placed in half-moon-shaped SEMs, ten of which are then stacked in a GAS canister.

This is the fourth flight of SEM.

More information about the Space Experiment Module program can be found at http://www.wff.nasa.gov/~sspp/sem.html.

Benefits

Economical and simplified access for space experimenters, especially students.

Interests young students in science and math.

Updated: 03/27/2000

Payloads

SPACEHAB

Payload Bay

Prime:

Backup:

Overview

U.S. and Russian hardware for the International Space Station will be carried in the SPACEHAB logistics double module, a pressurized laboratory in the shuttle's cargo bay that is connected to the middeck area of the orbiter. The seven-member crew will transfer more than 2,700 pounds of U.S. supplies and more than 2,200 pounds of Russian supplies from the module to the Unity and Zarya modules of the ISS.

The logistics include clothing and personal hygiene articles, health care supplies, exercise equipment, food, TV and movie equipment, a fire detection and suppression system, computers, and sensors. The hardware is stowed in SPACEHAB's numerous lockers and Soft Stowage bags and is mounted to the fronts of stowage racks and the module floor.

In addition to the logistics and maintenance cargo, SPACEHAB is carrying a commercial payload, the Self-Standing Drawer--Morphological Transition and Model Substances.

Designed to augment the shuttle orbiter's middeck, the SPACEHAB double module has a total cargo capacity of up to 10,000 pounds and contains systems necessary to support astronauts, such as ventilation, lighting, and limited power. Crew access to SPACEHAB is through a tunnel system located between the orbiter middeck and the SPACEHAB module.

Generally, two crew members are required for SPACEHAB operations. The SPACEHAB environmental control system is designed to nominally accommodate two crew members on a continuous basis. Additional crew members can be accommodated for brief periods at the expense of reduced cabin air heat rejection capability.

Microgravity Research Program

Working in partnership with the scientific community and commercial industry, NASA's Microgravity Research Program strives to increase understanding of the effects of gravity on biological, chemical, and physical systems.

Using both space flight- and ground-based experiments, researchers throughout the nation, as well as international partners, are working together to benefit economic, social, and industrial aspects of life for the United States and the entire Earth. U.S. universities, designated by NASA as commercial space centers, share these space advancements with U.S. industry to create new commercial products, applications, and processes.

Under the NASA Headquarters' Office of Life and Microgravity Sciences and Application, the Microgravity Research Program supports NASA's strategic plan in the Human Exploration and Development of Space Enterprise.

Microgravity research has been performed by NASA for more than 25 years. The term *microgravity* means a state of very little gravity. The prefix micro comes from the Greek word *mikros* ("small"). In metric terms, the prefix means one part in a million (0.000001).

Gravity dominates everything on Earth, from the way life has developed to the way materials interact. But aboard a spacecraft orbiting the Earth, the effects of gravity are barely felt. In this microgravity environment, scientists can conduct experiments that are all but impossible to perform on Earth. In this virtual absence of gravity as we know it, space flight gives scientists a unique opportunity to study the states of matter (solids, liquids, and gases) and the forces and processes that affect them.

Marshall Space Flight Center in Huntsville, Ala., is the lead center for NASA's Microgravity Research Program. The program manages Microgravity Science and Applications Project Offices at the Lewis Research Center in Cleveland, Ohio, and the Jet Propulsion Laboratory in Pasadena, Calif., and project offices at Marshall.

Under the project offices, the Microgravity Research Program is divided into nine major areas: five science disciplines, three research infrastructure programs, and the Space Products Development Office.

The science disciplines include biotechnology, fluid physics, materials science, combustion science and fundamental physics. The infrastructure activities include acceleration measurement, advanced technology, and the Glovebox Flight Program.

Marshall manages the Biotechnology Program and Material Science Program as well as the Glovebox Flight Program and the Space Products Development Office. Lewis Research Center manages the Fluid Physics, Combustion Science and Acceleration Measurement programs, while the Jet Propulsion Laboratory manages the Fundamental Physics and the Advanced Technology Development Program. As an element of the Biotechnology Program, Johnson Space Center manages bioreactor research in cell tissue growth.

In addition to the U.S. and Russian hardware for the International Space Station carried within the SPACEHAB module, additional unpressurized equipment for transfer to the space station will be carried on the new SPACEHAB integrated cargo carrier. The ICC, a cross-bay carrier that can accommodate 6,000 pounds of cargo, will be carrying parts of the Russian cargo crane known as Strela, the SPACEHAB Oceaneering Space System box, and DTO 700-21.

History/Background

Early in the shuttle program, it became evident that the orbiter middeck is the best place to conduct crew-tended experiments in space. Each shuttle orbiter has 42 middeck lockers, but most are used to stow crew gear for a typical seven-day mission, leaving only seven or eight for scientific studies. But SPACEHAB, the first crew-tended commercial payload carrier, has initiated a new era of space experimentation.

The basic SPACEHAB module, which takes up a quarter of the orbiter's payload bay, is like a second middeck. The 10-foot-long pressurized module adds 1,100 cubic feet of pressurized work space that can hold 61 lockers or experiment racks or a combination of the two. The lockers are sized and equipped like those in the shuttle middeck so that experiments can be moved from one location to the other. The lockers accommodate up to 60 pounds of experiment hardware in about 2 cubic feet. A rack, which can be single or double, takes the space of ten lockers. Double racks are similar in size and design to those planned for the space station so that they can serve as test beds for future projects. A single rack can carry 655 pounds of hardware in 22.5 cubic feet.

A new double module, developed specifically for shuttle missions to Mir, will be used on STS-96. The double module, which can accommodate nearly 10,000 pounds of cargo, was created by joining two single modules.

The astronauts enter the module through a modified Spacelab tunnel adapter. SPACEHAB can accommodate two crew members on a continuous basis, but additional crew members can work in the module for brief periods. Power, command and data services, cooling, vacuum, and other utilities are supplied by orbiter crew cabin and payload bay resources.

SPACEHAB was privately developed and is privately operated by SPACEHAB, Inc., of Arlington, Va. STS-101 is the 14th flight of SPACEHAB.

Benefits

Using both space- and ground-based experiments, researchers throughout the nation, as well as international partners, are working together to develop economic, social, and industrial benefits for the United States and the entire Earth. U.S. universities, designated by NASA as commercial space centers, share these space advancements with U.S. industry to create new commercial products, applications, and processes.

Updated: 04/06/2000

Experiments

Biotechnology Ambient Generic (PCG-BAG)

Prime:	**Principal Investigator:**	Dr. Daniel Carter of New Century Pharmaceuticals Inc., Huntsville, Ala.
Backup:	**Project Scientist:**	Todd Holloway of NASA's Marshall Space Flight Center in Huntsville, Ala.

Overview

Objective:

The Protein Crystal Growth Biotechnology Ambient Generic payloads are designed to provide opportunities to grow high-quality protein crystals in microgravity.

Researchers use these crystals to understand the molecular structure of the proteins. This information can be used to develop drugs that someday may battle the effects of aging, and treat cancer, rheumatoid arthritis, periodontal disease, influenza, septic shock, emphysema and AIDS.

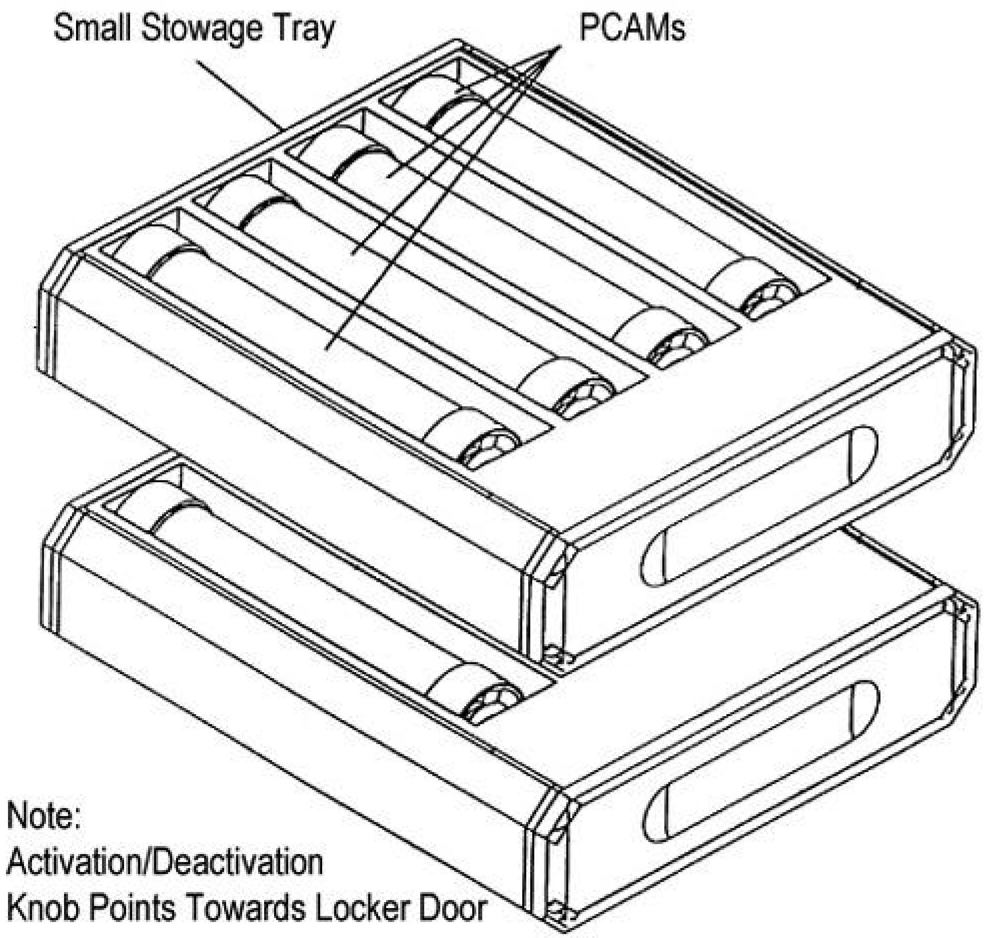
History/Background

While many protein crystal growth microgravity experiments are conducted with stringent temperature controls and extensive participation by shuttle crew members, the Biotechnology Ambient Generic experiments require minimal crew support.

The payloads are flown as stowage items in Atlantis's middeck, where they are subject to normal temperature conditions aboard the shuttle.

Shortly after lift-off, 504 individual experiments, stored in eight cylindrical containers, will be activated. Each experiment consists of two reservoirs separated by a flexible seal. When the seal is opened, the fluid in the protein drop will evaporate, starting the crystallization process. During the mission, this evaporation process will result in the growth of crystals that investigators can later study to determine the molecular structure of protein compounds.

Block I PCAM Single-Locker Configuration



Updated: 04/06/2000

Experiments

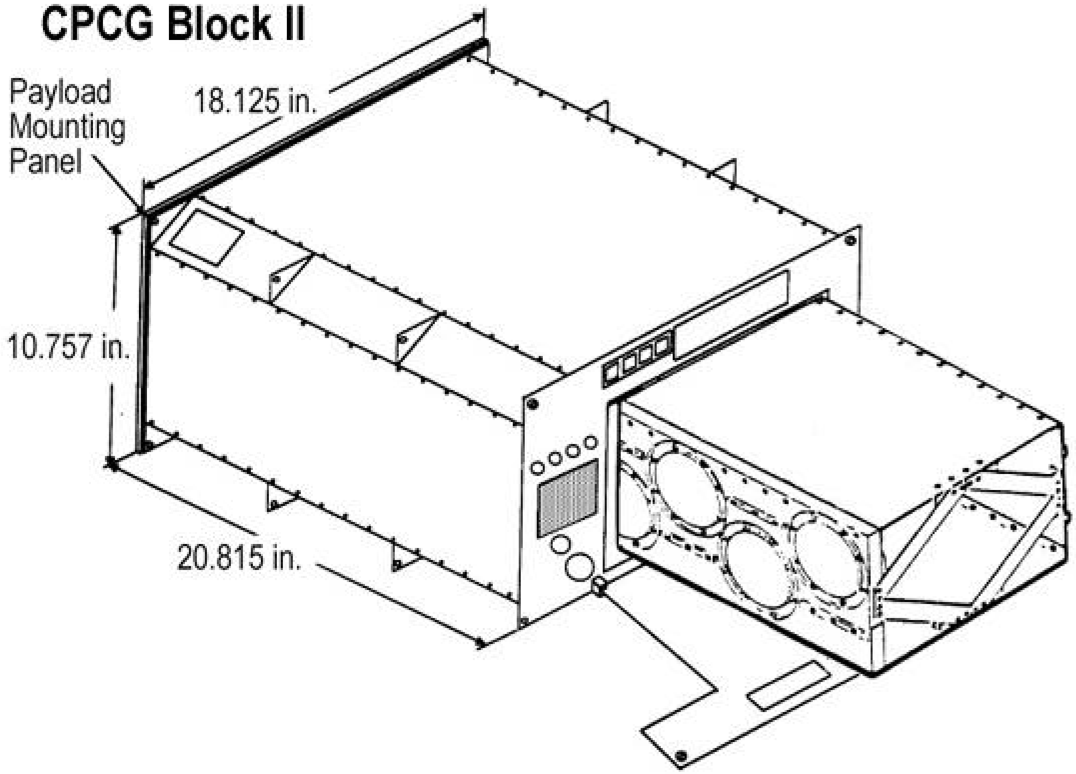
Commercial Protein Crystal Growth

Prime:	**Principal Investigator:**	Dr. Larry DeLucas, director of the Center for Biophysical Science and Engineering at the University of Alabama at Birmingham.
Backup:	**Project Scientist:**	Steve Lide of the Space Product Development Office at the Marshall Space Flight Center in Huntsville, Ala.

Overview

Through protein crystallography, protein crystals are grown in the laboratory and examined to determine their three-dimensional structure. That information is used to develop new drugs targeting the protein's structure. But crystals grown in Earth's gravity frequently have defects that make such analysis difficult or impossible. Space-grown crystals often have fewer defects and are larger than their Earth-grown counterparts, making them easier to examine.

The objective of the STS-101 protein crystal growth experiments is to grow crystals of human alpha interferon 2b--a protein pharmaceutical used against several afflictions, including human viral hepatitis B and C, melanoma, hairy cell leukemia, multiple myeloma and AIDS-related Kaposi's sarcoma. These alpha interferon samples will be crystallized under a range of conditions in sufficient size and quantity to assess the concentration and distribution of impurities. The protein is supplied by the Schering Plough Research Institute of Kenilworth, N.J. The experiments will be performed in the protein crystallization facility that stimulates crystal growth through changes in temperature.



This Commercial Protein Crystal Growth experiment aboard STS-101 is sponsored by the Center for Biophysical Science and Engineering at the University of Alabama at Birmingham. The center is part of NASA's Commercial Space Center Program, which forms a bridge between NASA and private industry to develop methods for crystallizing large molecules in microgravity.

By fostering such commercial projects aboard the space shuttle, NASA contributes to research that may lead to a new generation of drugs for treating diseases such as cancer, rheumatoid arthritis, periodontal disease, influenza, septic shock, emphysema and AIDS.

Updated: 04/06/2000

Experiments

Gene Transfer Experiment using ASTROCULTURETM Glove Box (ASC-GB)

Prime:	**Principal Investigator:**	Dr. Bratislav Stankovic,Wisconsin Center for Space Automation and Robotics, University of Wisconsin, Madison, Wis
Backup:	**Project Scientist:**	Dr. Weijia Zhou, Wisconsin Center for Space Automation and Robotics, University of Wisconsin, Madison, Wis.

Overview

Objectives: The objective of the experiment is to evaluate a novel method for production of commercially important transgenic plant materials in microgravity using Agrobacterium tumefaciens. This transformation method, developed by the Wisconsin Center for Space Automation and Robotics and its industrial partner, was first tested during the STS-95 mission in October 1998. That testing found increased transformation efficiency in comparison to the identical ground experiments.

The gene transfer experiment to be conducted on the STS-101 mission is a cooperative venture between Producers' Natural Processing Corporation (PNP) and the Wisconsin Center for Space Automation and Robotics. PNP is a for-profit, privately owned company which: takes advantage of proprietary patented technologies in genetic transformation that will allow in planta production of proteins, enzymes, antibodies and vaccines; utilizes its relationship with prominent life science companies to deliver specific, identity-preserved crop attributes to the end user; and utilizes its new product development division and partners for the production of nutraceuticals, industrial enzymes, plant-based edible vaccines, and pharmaceutical intermediates.

Description: Crop production and utilization are undergoing significant modifications and improvements that emanate from adaptation of recently developed plant biotechnologies. One of these is the transfer of desirable genes from organisms to economically important crop species in a way that cannot be accomplished with traditional plant breeding techniques. These new technologies offer opportunities to improve crop species in various characteristics, as well as to use source materials for specific industrial applications, and hence, to convert plant materials that originally have no commercial values to plant materials that represent commercially important crop varieties.

For the STS-101 mission, a sample size of 1,000 soybean seeds will be co-incubated on orbit, with Agrobacterium tumefaciens containing the proprietary commercial gene and rs-GFP reporter gene that will be used for in vivo detection of transformation events that had occurred during the time the seeds were in microgravity. The results will be analyzed to determine the percentage of transient and stable transformation events, which will be compared with the results obtained during the STS-95 mission. During the STS-101 mission, the transformation procedures will be performed by the crew.

The ASTROCULTURETM flight experiment series is sponsored by the Space Product Development Program managed at the Marshall Space Flight Center in Huntsville, Ala.

Updated: 04/06/2000

DTO/DSO/RMEs

Monitoring Latent Virus Reactivation and Shedding in Astronauts
DSO 493

Prime: **Principal Investigator:** Duane L. Pierson
Backup:

Overview

The premise of this DSO is that the incidence and duration of latent virus reactivation in saliva and urine will increase during space flight. The objective is to determine the frequency of induced reactivation of latent viruses, latent virus shedding, and clinical disease after exposure to the physical, physiological, and psychological stressors associated with space flight.

Space-flight-induced alterations in the immune response become increasingly important on long missions, particularly the potential for reactivation and dissemination (shedding) of latent viruses. An example of a latent virus is Herpes Simplex Type 1 (HSV-1), which infects 70 to 80% of all adults. Its classic manifestations are cold sores, pharyngitis, and tonsillitis, and it usually is acquired through contact with the saliva, skin, or mucous membranes of an infected individual. However, many recurrences are asymptomatic, resulting in shedding of the virus. Twenty subjects have been studied for Epstein-Barr virus. Three additional viruses will be examined in an expanded subject group.

Updated: 03/27/2000

DTO/DSO/RMEs

Space Flight and Immune Function
DSO 498

Prime:
Backup:

Principal Investigator: Duane L. Pierson

Overview

The objective of this DSO is to characterize the effects of space flight on neutrophils, monocytes, and cytotoxic cells, which play an important role in maintaining an effective defense against infectious agents. The premise of this study is that the space environment alters the essential functions of these elements of human immune response.

Researchers will conduct a funtional analysis of neutrophils and monocytes from blood samples taken from astronauts before and after the flight. They will also assess the subjects' pre- and postflight production of cytotoxic cells and cytokine.

This study will complement previous and continuing immunology studies of astronauts' adaptation to space.

History/Background

Astronauts face an increasing risk of contracting infectious diseases as they work and live for longer periods in the crowded conditions and closed environmnets of spacecraft such as the Russian Mir space station and the International Space Station. The effects of space flight on the human immune system, which plays a pivotal role in warding off infections, is not fully understood. Understanding the changes in immune function caused by exposure to microgravity will allow researchers to develop countermeasures to minimize the risk of infection.

Updated: 03/27/2000

DTO/DSO/RMEs

Cabin Air Monitoring
DTO 623

Prime:
Backup:

Overview

A solid sorbent sampler will continuously sample the orbiter's atmosphere throughout the flight for possible impurities due to outgassing and particulate matter. This is the 25th flight for this DTO.

Updated: 03/27/2000

DTO/DSO/RMEs

Crosswind Landing Performance
DTO 805

Prime:
Backup:

Overview

This DTO will continue to gather data to demonstrate the capability to perform a manually controlled landing with a 90-degree, 10- to 15-knot steady-state crosswind. This DTO can be performed regardless of landing site or vehicle mass properties. During a crosswind landing, the drag chute will be deployed after nose gear touchdown when the vehicle is stable and tracking the runway centerline. This DTO has been manifested on 58 previous flights.

Updated: 03/27/2000

DTO/DSO/RMEs

SIGI Orbital Attitude Readiness
DTO 700-21

Prime:
Backup:

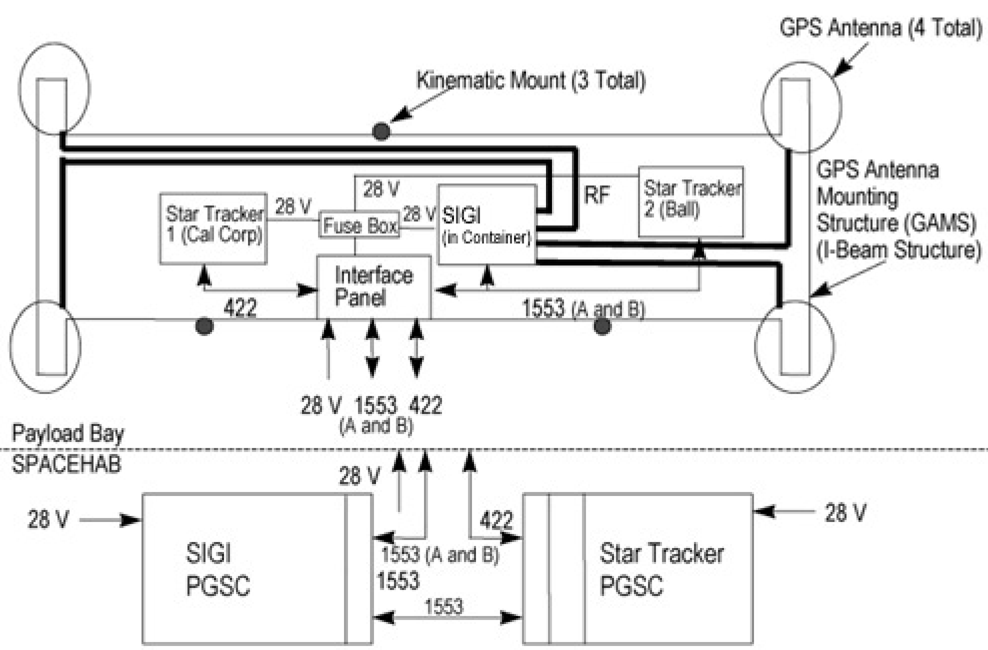
Overview

The objective of DTO 700-21 is to demonstrate the operation of the space integrated Global Positioning System/inertial navigation system (SIGI) on orbit. The SIGI is intended to be the primary GPS source for the International Space Station (ISS) and the primary navigation source for the crew return vehicle (CRV). The ability of the SIGI to perform GPS attitude determination in space has not been demonstrated. Data from this DTO will be used to evaluate the SIGI design before it is used on the ISS or CRV.

The payload consists of the SIGI in a pressurized container on a GPS antenna mounting structure (GAMS). The SIGI has RF connections to four antenna assemblies, which are mounted on the corners of the GAMS. A payload and general support computer (PGSC) located in SPACEHAB is used for commanding and data storage. Data from two star trackers mounted on the GAMS will be collected by a separate PGSC inside SPACEHAB.

This is the first flight of DTO 700-21.

SIGI Orbital Attitude Readiness Configuration



DTO/DSO/RMEs

Single-String Global Positioning System
DTO 700-14

Prime:
Backup:

Overview

The purpose of this DTO is to evaluate the performance and operation of the Global Positioning System as a shuttle navigation aid during the ascent, on-orbit, entry and landing phases of the mission. A modified military GPS receiver processor and the orbiter's existing GPS antenna will be used for this evaluation.

This is the ninth flight for DTO 700-14. It was last flown on STS-96.

Updated: 03/27/2000

DTO/DSO/RMEs

Solid-State Star Tracker Size Limitations
DTO 847

Prime:
Backup:

Overview

The objective of this DTO is to characterize the performance of the orbiter's solid-state star tracker with a large, bright target-the International Space Station. Laboratory tests show that the SSST can track significantly larger and brighter objects that the orbiter's other star tracker-the image-dissecting tracker. It may be necessary to use the SSST to track the station during orbiter passes because the ISS will reach a size that could prohibit the use of the image-dissecting tracker under certain conditions very early in the assembly sequence.

At a minimum, the SSST should be verified to track the ISS accurately up to 22.6 arcminutes, which is the largest size tested in the lab and the number that was used in analyzing potential problems that might be caused by the size of the ISS. If possible, the absolute upper limit to the size of an object that the SSST can track will be determined.

This DTO will be performed when the orbiter separates from the ISS but only if specific lighting conditions exist.

This is the second of three planned flights for this DTO.

Updated: 03/27/2000

Shuttle Reference and Data

Shuttle Abort Modes

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 also 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.

INTACT ABORTS

There are four types of intact aborts: abort to orbit (ATO), abort once around (AOA), transoceanic abort landing (TAL) and return to launch site (RTLS).

ABORT TO ORBIT (ATO)

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.

ABORT ONCE AROUND (AOA)

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.

TRANSOCEANIC ABORT LANDING (TAL)

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.

RETURN TO LAUNCH SITE (RTLS)

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.

ABORT DECISIONS

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.

RETURN TO LAUNCH SITE OVERVIEW

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.

TRANSATLANTIC LANDING ABORT OVERVIEW

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.

ABORT TO ORBIT OVERVIEW

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.

ABORT ONCE AROUND OVERVIEW

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.

CONTINGENCY ABORT OVERVIEW

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.

Updated: 03/27/2000

Shuttle Reference and Data

Space Shuttle External Tank

The external tank contains the liquid hydrogen fuel and liquid oxygen oxidizer and supplies them under pressure to the three space shuttle main engines in the orbiter during lift-off and ascent. When the SSMEs are shut down, the ET is jettisoned, enters the Earth's atmosphere, breaks up, and impacts in a remote ocean area. It is not recovered.

The largest and heaviest (when loaded) element of the space shuttle, the ET has three major components: the forward liquid oxygen tank, an unpressurized intertank that contains most of the electrical components, and the aft liquid hydrogen tank. The ET is 153.8 feet long and has a diameter of 27.6 feet.

The ET is attached to the orbiter at one forward attachment point and two aft points. In the aft attachment area, there are also umbilicals that carry fluids, gases, electrical signals and electrical power between the tank and the orbiter. Electrical signals and controls between the orbiter and the two solid rocket boosters also are routed through those umbilicals.

Liquid Oxygen Tank

The liquid oxygen tank is an aluminum monocoque structure composed of a fusion-welded assembly of preformed, chem-milled gores, panels, machined fittings and ring chords. It operates in a pressure range of 20 to 22 psig. The tank contains anti-slosh and anti-vortex provisions to minimize liquid residuals and damp fluid motion. The tank feeds into a 17-inch-diameter feed line that conveys the liquid oxygen through the intertank, then outside the ET to the aft right-hand ET/orbiter disconnect umbilical. The 17-inch-diameter feed line permits liquid oxygen to flow at approximately 2,787 pounds per second with the SSMEs operating at 104 percent or permits a maximum flow of 17,592 gallons per minute. The liquid oxygen tank's double-wedge nose cone reduces drag and heating, contains the vehicle's ascent air data system (for nine tanks only) and serves as a lightning rod. The liquid oxygen tank's volume is 19,563 cubic feet. It is 331 inches in diameter, 592 inches long and weighs 12,000 pounds empty.

Intertank

The intertank is a steel/aluminum semimonocoque cylindrical structure with flanges on each end for joining the liquid oxygen and liquid hydrogen tanks. The intertank houses ET instrumentation components and provides an umbilical plate that interfaces with the ground facility arm for purge gas supply, hazardous gas detection and hydrogen gas boiloff during ground operations. It consists of mechanically joined skin, stringers and machined panels of aluminum alloy. The intertank is vented during flight. The intertank contains the forward SRB/ET attach thrust beam and fittings that distribute the SRB loads to the liquid oxygen and liquid hydrogen tanks. The intertank is 270 inches long, 331 inches in diameter and weighs 12,100 pounds.

Liquid Hydrogen Tank

The liquid hydrogen tank is an aluminum semimonocoque structure of fusion-welded barrel sections, five major ring frames, and forward and aft ellipsoidal domes. Its operating pressure range is 32 to 34 psia. The tank contains an anti-vortex baffle and siphon outlet to transmit the liquid hydrogen from the tank through a 17-inch line to the left aft umbilical. The liquid hydrogen feed line flow rate is 465 pounds per second with the SSMEs at 104 percent or a maximum flow of 47,365 gallons per minute. At the forward end of the liquid hydrogen tank is the ET/orbiter forward attachment pod strut, and at its aft end are the two ET/orbiter aft attachment ball fittings as well as the aft SRB/ET stabilizing strut attachments. The liquid hydrogen tank is 331 inches in diameter, 1,160 inches long, and has a volume of 53,518 cubic feet and a dry weight of 29,000 pounds.

ET Thermal Protection System

The ET thermal protection system consists of sprayed-on foam insulation and premolded ablator materials. The system also includes the use of phenolic thermal insulators to preclude air liquefaction. Thermal isolators are required for liquid hydrogen tank attachments to preclude the liquefaction of air-exposed metallic attachments and to reduce heat flow into the liquid hydrogen.

ET Hardware

Each propellant tank has a vent and relief valve at its forward end. This dual-function valve can be opened by ground support equipment for the vent function during prelaunch and can open during flight when the ullage (empty space) pressure of the liquid hydrogen tank reaches 38 psig or the ullage pressure of the liquid oxygen tank reaches 25 psig.

The liquid oxygen tank contains a separate, pyrotechnically operated, propulsive tumble vent valve at its forward end. At separation, the liquid oxygen tumble vent valve is opened, providing impulse to assist in the separation maneuver and more positive control of the entry aerodynamics of the ET.

There are eight propellant-depletion sensors, four each for fuel and oxidizer. The fuel-depletion sensors are located in the bottom of the fuel tank. The oxidizer sensors are mounted in the orbiter liquid oxygen feed line manifold downstream of the feed line disconnect. During SSME thrusting, the orbiter general-purpose computers constantly compute the instantaneous mass of the vehicle due to the usage of the propellants. Normally, main engine cutoff is based on a predetermined velocity; however, if any two of the fuel or oxidizer sensors sense a dry condition, the engines will be shut down.

The locations of the liquid oxygen sensors allow the maximum amount of oxidizer to be consumed in the engines, while allowing sufficient time to shut down the engines before the oxidizer pumps cavitate (run dry). In addition, 1,100 pounds of liquid hydrogen are loaded over and above that required by the 6:1 oxidizer/fuel engine mixture ratio. This assures that MECO from the depletion sensors is fuel-rich; oxidizer-rich engine shutdowns can cause burning and severe erosion of engine components.

Four pressure transducers located at the top of the liquid oxygen and liquid hydrogen tanks monitor the ullage pressures.

Each of the two aft external tank umbilical plates mate with a corresponding plate on the orbiter. The plates help maintain alignment among the umbilicals. Physical strength at the umbilical plates is provided by bolting corresponding umbilical plates together. When the orbiter GPCs command external tank separation, the bolts are severed by pyrotechnic devices.

The ET has five propellant umbilical valves that interface with orbiter umbilicals: two for the liquid oxygen tank and three for the liquid hydrogen tank. One of the liquid oxygen tank umbilical valves is for liquid oxygen, the other for gaseous oxygen. The liquid hydrogen tank umbilical has two valves for liquid and one for gas. The intermediate-diameter liquid hydrogen umbilical is a recirculation umbilical used only during the liquid hydrogen chill-down sequence during prelaunch.

The ET also has two electrical umbilicals that carry electrical power from the orbiter to the tank and the two SRBs and provide information from the SRBs and ET to the orbiter.

A swing-arm-mounted cap to the fixed service structure covers the oxygen tank vent on top of the ET during the countdown and is retracted about two minutes before lift-off. The cap siphons off oxygen vapor that threatens to form large ice on the ET, thus protecting the orbiter's thermal protection system during launch.

ET Range Safety System

A range safety system provides for dispersing tank propellants if necessary. It includes a battery power source, a receiver/decoder, antennas and ordnance.

Various parameters are monitored and displayed on the flight deck display and control panel and are transmitted to the ground.

The contractor for the external tank is Martin Marietta Aero space, New Orleans, La. The tank is manufactured at Michoud, La. Motorola, Inc., Scottsdale, Ariz., is the contractor for range safety receivers.

Shuttle Reference and Data

Space Shuttle Rendezvous Maneuvers

COMMON SHUTTLE RENDEZVOUS MANEUVERS

OMS-1 (Orbit insertion): Rarely used ascent abort burn

OMS-2 (Orbit insertion): Typically used to circularize the initial orbit following ascent, completing orbital insertion. For ground-up rendezvous flights, also considered a rendezvous phasing burn

NC (Rendezvous phasing): Performed to hit a range relative to the target at a future time

NH (Rendezvous height adjust): Performed to hit a delta-height relative to the target at a future time

NPC (Rendezvous plane change): Performed to remove planar errors relative to the target at a future time

NCC (Rendezvous corrective combination): First on-board targeted burn in the rendezvous sequence. Using star tracker data, it is performed to remove phasing and height errors relative to the target at Ti

Ti (Rendezvous terminal intercept): Second on-board targeted burn in the rendezvous sequence. Using primarily rendezvous radar data, it places the orbiter on a trajectory to intercept the target in one orbit

MC-1, MC-2, MC-3, MC-4 (Rendezvous midcourse burns): These on-board targeted burns use star tracker and rendezvous radar data to correct the post-Ti trajectory in preparation for the final, manual proximity operations phase

Updated: 03/29/2000

Shuttle Reference and Data

Space Shuttle Solid Rocket Boosters

The two SRBs provide the main thrust to lift the space shuttle off the pad and up to an altitude of about 150,000 feet, or 24 nautical miles (28 statute miles). In addition, the two SRBs carry the entire weight of the external tank and orbiter and transmit the weight load through their structure to the mobile launcher platform.

Each booster has a thrust (sea level) of approximately 3,300,000 pounds at launch. They are ignited after the three space shuttle main engines' thrust level is verified. The two SRBs provide 71.4 percent of the thrust at lift-off and during first-stage ascent. Seventy-five seconds after SRB separation, SRB apogee occurs at an altitude of approximately 220,000 feet, or 35 nautical miles (41 statute miles). SRB impact occurs in the ocean approximately 122 nautical miles (141 statute miles) downrange.

The SRBs are the largest solid-propellant motors ever flown and the first designed for reuse. Each is 149.16 feet long and 12.17 feet in diameter.

Each SRB weighs approximately 1,300,000 pounds at launch. The propellant for each solid rocket motor weighs approximately 1,100,000 pounds. The inert weight of each SRB is approximately 192,000 pounds.

Primary elements of each booster are the motor (including case, propellant, igniter and nozzle), structure, separation systems, operational flight instrumentation, recovery avionics, pyrotechnics, deceleration system, thrust vector control system and range safety destruct system.

Each booster is attached to the external tank at the SRB's aft frame by two lateral sway braces and a diagonal attachment. The forward end of each SRB is attached to the external tank at the forward end of the SRB's forward skirt. On the launch pad, each booster also is attached to the mobile launcher platform at the aft skirt by four bolts and nuts that are severed by small explosives at lift-off.

During the downtime following the Challenger accident, detailed structural analyses were performed on critical structural elements of the SRB. Analyses were primarily focused in areas where anomalies had been noted during postflight inspection of recovered hardware.

One of the areas was the attach ring where the SRBs are connected to the external tank. Areas of distress were noted in some of the fasteners where the ring attaches to the SRB motor case. This situation was attributed to the high loads encountered during water impact. To correct the situation and ensure higher strength margins during ascent, the attach ring was redesigned to encircle the motor case completely (360 degrees). Previously, the attach ring formed a C and encircled the motor case 270 degrees.

Additionally, special structural tests were performed on the aft skirt. During this test program, an anomaly occurred in a critical weld between the hold-down post and skin of the skirt. A redesign was implemented to add reinforcement brackets and fittings in the aft ring of the skirt.

These two modifications added approximately 450 pounds to the weight of each SRB.

The propellant mixture in each SRB motor consists of an ammonium perchlorate (oxidizer, 69.6 percent by weight), aluminum (fuel, 16 percent), iron oxide (a catalyst, 0.4 percent), a polymer (a binder that holds the mixture together, 12.04 percent), and an epoxy curing agent (1.96 percent). The propellant is an 11-point star-shaped perforation in the forward motor segment and a double-truncated-cone perforation in each of the aft segments and aft closure. This configuration provides high thrust at ignition and then reduces the thrust by approximately a third 50 seconds after lift-off to prevent overstressing the vehicle during maximum dynamic pressure.

The SRBs are used as matched pairs and each is made up of four solid rocket motor segments. The pairs are matched by loading each of the four motor segments in pairs from the same batches of propellant ingredients to minimize any thrust imbalance. The segmented-casing design assures maximum flexibility in fabrication and ease of transportation and handling. Each segment is shipped to the launch site on a heavy-duty rail car with a specially built cover.

The nozzle expansion ratio of each booster beginning with the STS-8 mission is 7 to 79. The nozzle is gimbaled for thrust vector (direction) control. Each SRB has its own redundant auxiliary power units and hydraulic pumps. The all-axis gimbaling capability is 8 degrees. Each nozzle has a carbon cloth liner that erodes and chars during firing. The nozzle is a convergent-divergent, movable design in which an aft pivot-point flexible bearing is the gimbal mechanism.

The cone-shaped aft skirt reacts the aft loads between the SRB and the mobile launcher platform. The four aft separation motors are mounted on the skirt. The aft section contains avionics, a thrust vector control system that consists of two auxiliary power units and hydraulic pumps, hydraulic systems and a nozzle extension jettison system.

The forward section of each booster contains avionics, a sequencer, forward separation motors, a nose cone separation system, drogue and main parachutes, a recovery beacon, a recovery light, a parachute camera on selected flights and a range safety system.

Each SRB has two integrated electronic assemblies, one forward and one aft. After burnout, the forward assembly initiates the release of the nose cap and frustum and turns on the recovery aids. The aft assembly, mounted in the external tank/SRB attach ring, connects with the forward assembly and the orbiter avionics systems for SRB ignition commands and nozzle thrust vector control. Each integrated electronic assembly has a multiplexer/demultiplexer, which sends or receives more than one message, signal or unit of information on a single communication channel.

Eight booster separation motors (four in the nose frustum and four in the aft skirt) of each SRB thrust for 1.02 seconds at SRB separation from the external tank. Each solid rocket separation motor is 31.1 inches long and 12.8 inches in diameter.

Location aids are provided for each SRB, frustum/drogue chutes and main parachutes. These include a transmitter, antenna, strobe/converter, battery and salt water switch electronics. The location aids are designed for a minimum operating life of 72 hours and when refurbished are considered usable up to 20 times. The flashing light is an exception. It has an operating life of 280 hours. The battery is used only once.

The SRB nose caps and nozzle extensions are not recovered.

The recovery crew retrieves the SRBs, frustum/drogue chutes, and main parachutes. The nozzles are plugged, the solid rocket motors are dewatered, and the SRBs are towed back to the launch site. Each booster is removed from the water, and its components are disassembled and washed with fresh and deionized water to limit salt water corrosion. The motor segments, igniter and nozzle are shipped back to Thiokol for refurbishment.

Each SRB incorporates a range safety system that includes a battery power source, receiver/decoder, antennas and ordnance.

HOLD-DOWN POSTS

Each solid rocket booster has four hold-down posts that fit into corresponding support posts on the mobile launcher platform. Hold-down bolts hold the SRB and launcher platform posts together. Each bolt has a nut at each end, but only the top nut is frangible. The top nut contains two NASA standard detonators, which are ignited at solid rocket motor ignition commands.

When the two NSDs are ignited at each hold-down, the hold-down bolt travels downward because of the release of tension in the bolt (pretensioned before launch), NSD gas pressure and gravity. The bolt is stopped by the stud deceleration stand, which contains sand. The SRB bolt is 28 inches long and is 3.5 inches in diameter. The frangible nut is captured in a blast container.

The solid rocket motor ignition commands are issued by the orbiter's computers through the master events controllers to the hold-down pyrotechnic initiator controllers on the mobile launcher platform. They provide the ignition to the hold-down NSDs. The launch processing system monitors the SRB hold-down PICs for low voltage during the last 16 seconds before launch. PIC low voltage will initiate a launch hold.

SRB IGNITION

SRB ignition can occur only when a manual lock pin from each SRB safe and arm device has been removed. The ground crew removes the pin during prelaunch activities. At T minus five minutes, the SRB safe and arm device is rotated to the arm position. The solid rocket motor ignition commands are issued when the three SSMEs are at or above 90-percent rated thrust, no SSME fail and/or SRB ignition PIC low voltage is indicated and there are no holds from the LPS.

The solid rocket motor ignition commands are sent by the orbiter computers through the MECs to the safe and arm device NSDs in each SRB. A PIC single-channel capacitor discharge device controls the firing of each pyrotechnic device. Three signals must be present simultaneously for the PIC to generate the pyro firing output. These signals--arm, fire 1 and fire 2--originate in the orbiter general-purpose computers and are transmitted to the MECs. The MECs reformat them to 28-volt dc signals for the PICs. The arm signal charges the PIC capacitor to 40 volts dc (minimum of 20 volts dc).

The fire 2 commands cause the redundant NSDs to fire through a thin barrier seal down a flame tunnel. This ignites a pyro booster charge, which is retained in the safe and arm device behind a perforated plate. The booster charge ignites the propellant in the igniter initiator; and combustion products of this propellant ignite the solid rocket motor initiator, which fires down the length of the solid rocket motor igniting the solid rocket motor propellant.

The GPC launch sequence also controls certain critical main propulsion system valves and monitors the engine-ready indications from the SSMEs. The MPS start commands are issued by the onboard computers at T minus 6.6 seconds (staggered start--engine three, engine two, engine one--all approximately within 0.25 of a second), and the sequence monitors the thrust buildup of each engine. All three SSMEs must reach the required 90-percent thrust within three seconds; otherwise, an orderly shutdown is commanded and safing functions are initiated.

Normal thrust buildup to the required 90-percent thrust level will result in the SSMEs being commanded to the lift-off position at T minus three seconds as well as the fire 1 command being issued to arm the SRBs. At T minus three seconds, the vehicle base bending load modes are allowed to initialize (movement of approximately 25.5 inches measured at the tip of the external tank, with movement towards the external tank).

At T minus zero, the two SRBs are ignited, under command of the four onboard computers; separation of the four explosive bolts on each SRB is initiated (each bolt is 28 inches long and 3.5 inches in diameter); the two T-0 umbilicals (one on each side of the spacecraft) are retracted; the onboard master timing unit, event timer and mission event timers are started; the three SSMEs are at 100 percent; and the ground launch sequence is terminated.

The solid rocket motor thrust profile is tailored to reduce thrust during the maximum dynamic pressure region.

ELECTRICAL POWER DISTRIBUTION

Electrical power distribution in each SRB consists of orbiter-supplied main dc bus power to each SRB via SRB buses A, B and C. Orbiter main dc buses A, B and C supply main dc bus power to corresponding SRB buses A, B and C. In addition, orbiter main dc bus C supplies backup power to SRB buses A and B, and orbiter bus B supplies backup power to SRB bus C. This electrical power distribution arrangement allows all SRB buses to remain powered in the event one orbiter main bus fails.

The nominal dc voltage is 28 volts dc, with an upper limit of 32 volts dc and a lower limit of 24 volts dc.

HYDRAULIC POWER UNITS

There are two self-contained, independent HPUs on each SRB. Each HPU consists of an auxiliary power unit, fuel supply module, hydraulic pump, hydraulic reservoir and hydraulic fluid manifold assembly. The APUs are fueled by hydrazine and generate mechanical shaft power to a hydraulic pump that produces hydraulic pressure for the SRB hydraulic system. The two separate HPUs and two hydraulic systems are located on the aft end of each SRB between the SRB nozzle and aft skirt. The HPU components are mounted on the aft skirt between the rock and tilt actuators. The two systems operate from T minus 28 seconds until SRB separation from the orbiter and external tank. The two independent hydraulic systems are connected to the rock and tilt servoactuators.

The APU controller electronics are located in the SRB aft integrated electronic assemblies on the aft external tank attach rings.

The APUs and their fuel systems are isolated from each other. Each fuel supply module (tank) contains 22 pounds of hydrazine. The fuel tank is pressurized with gaseous nitrogen at 400 psi, which provides the force to expel (positive expulsion) the fuel from the tank to the fuel distribution line, maintaining a positive fuel supply to the APU throughout its operation.

The fuel isolation valve is opened at APU startup to allow fuel to flow to the APU fuel pump and control valves and then to the gas generator. The gas generator's catalytic action decomposes the fuel and creates a hot gas. It feeds the hot gas exhaust product to the APU two-stage gas turbine. Fuel flows primarily through the startup bypass line until the APU speed is such that the fuel pump outlet pressure is greater than the bypass line's. Then all the fuel is supplied to the fuel pump.

The APU turbine assembly provides mechanical power to the APU gearbox. The gearbox drives the APU fuel pump, hydraulic pump and lube oil pump. The APU lube oil pump lubricates the gearbox. The turbine exhaust of each APU flows over the exterior of the gas generator, cooling it, and is then directed overboard through an exhaust duct.

When the APU speed reaches 100 percent, the APU primary control valve closes, and the APU speed is controlled by the APU controller electronics. If the primary control valve logic fails to the open state, the secondary control valve assumes control of the APU at 112-percent speed.

Each HPU on an SRB is connected to both servoactuators on that SRB. One HPU serves as the primary hydraulic source for the servoactuator, and the other HPU serves as the secondary hydraulics for the servoactuator. Each sevoactuator has a switching valve that allows the secondary hydraulics to power the actuator if the primary hydraulic pressure drops below 2,050 psi. A switch contact on the switching valve will close when the valve is in the secondary position. When the valve is closed, a signal is sent to the APU controller that inhibits the 100-percent APU speed control logic and enables the 112-percent APU speed control logic. The 100-percent APU speed enables one APU/HPU to supply sufficient operating hydraulic pressure to both servoactuators of that SRB.

The APU 100-percent speed corresponds to 72,000 rpm, 110-percent to 79,200 rpm, and 112-percent to 80,640 rpm.

The hydraulic pump speed is 3,600 rpm and supplies hydraulic pressure of 3,050, plus or minus 50, psi. A high-pressure relief valve provides overpressure protection to the hydraulic system and relieves at 3,750 psi.

The APUs/HPUs and hydraulic systems are reusable for 20 missions.

THRUST VECTOR CONTROL

Each SRB has two hydraulic gimbal servoactuators: one for rock and one for tilt. The servoactuators provide the force and control to gimbal the nozzle for thrust vector control.

The space shuttle ascent thrust vector control portion of the flight control system directs the thrust of the three shuttle main engines and the two SRB nozzles to control shuttle attitude and trajectory during lift-off and ascent. Commands from the guidance system are transmitted to the ATVC drivers, which transmit signals proportional to the commands to each servoactuator of the main engines and SRBs. Four independent flight control system channels and four ATVC channels control six main engine and four SRB ATVC drivers, with each driver controlling one hydraulic port on each main and SRB servoactuator.

Each SRB servoactuator consists of four independent, two-stage servovalves that receive signals from the drivers. Each servovalve controls one power spool in each actuator, which positions an actuator ram and the nozzle to control the direction of thrust.

The four servovalves in each actuator provide a force-summed majority voting arrangement to position the power spool. With four identical commands to the four servovalves, the actuator force-sum action prevents a single erroneous command from affecting power ram motion. If the erroneous command persists for more than a predetermined time, differential pressure sensing activates a selector valve to isolate and remove the defective servovalve hydraulic pressure, permitting the remaining channels and servovalves to control the actuator ram spool.

Failure monitors are provided for each channel to indicate which channel has been bypassed. An isolation valve on each channel provides the capability of resetting a failed or bypassed channel.

Each actuator ram is equipped with transducers for position feedback to the thrust vector control system. Within each servoactuator ram is a splashdown load relief assembly to cushion the nozzle at water splashdown and prevent damage to the nozzle flexible bearing.

SRB RATE GYRO ASSEMBLIES

Each SRB contains two RGAs, with each RGA containing one pitch and one yaw gyro. These provide an output proportional to angular rates about the pitch and yaw axes to the orbiter computers and guidance, navigation and control system during first-stage ascent flight in conjunction with the orbiter roll rate gyros until SRB separation. At SRB separation, a switchover is made from the SRB RGAs to the orbiter RGAs.

The SRB RGA rates pass through the orbiter flight aft multiplexers/demultiplexers to the orbiter GPCs. The RGA rates are then mid-value-selected in redundancy management to provide SRB pitch and yaw rates to the user software. The RGAs are designed for 20 missions.

SRB SEPARATION

SRB separation is initiated when the three solid rocket motor chamber pressure transducers are processed in the redundancy management middle value select and the head-end chamber pressure of both SRBs is less than or equal to 50 psi. A backup cue is the time elapsed from booster ignition.

The separation sequence is initiated, commanding the thrust vector control actuators to the null position and putting the main propulsion system into a second-stage configuration (0.8 second from sequence initialization), which ensures the thrust of each SRB is less than 100,000 pounds. Orbiter yaw attitude is held for four seconds, and SRB thrust drops to less than 60,000 pounds.

The SRBs separate from the external tank within 30 milliseconds of the ordnance firing command.

The forward attachment point consists of a ball (SRB) and socket (ET) held together by one bolt. The bolt contains one NSD pressure cartridge at each end. The forward attachment point also carries the range safety system cross-strap wiring connecting each SRB RSS and the ET RSS with each other.

The aft attachment points consist of three separate struts: upper, diagonal and lower. Each strut contains one bolt with an NSD pressure cartridge at each end. The upper strut also carries the umbilical interface between its SRB and the external tank and on to the orbiter.

There are four booster separation motors on each end of each SRB. The BSMs separate the SRBs from the external tank. The solid rocket motors in each cluster of four are ignited by firing redundant NSD pressure cartridges into redundant confined detonating fuse manifolds.

The separation commands issued from the orbiter by the SRB separation sequence initiate the redundant NSD pressure cartridge in each bolt and ignite the BSMs to effect a clean separation.

Updated: 03/29/2000

Shuttle Reference and Data

Space Shuttle Super-Lightweight Tank (SLWT)

The super-lightweight external tank (SLWT)made its first shuttle flight June 2, on mission STS-91. The SLWT is 7,500 pounds lighter than the standard external tank. The lighter weight tank will allow the shuttle to deliver International Space Station elements (such as the service module) into the proper orbit.

The SLWT is the same size as the previous design. But the liquid hydrogen tank and the liquid oxygen tank are made of aluminum lithium, a lighter, stronger material than the metal alloy used for the shuttle's current tank. The tank's structural design has also been improved, making it 30 percent stronger and 5 percent less dense.

The SLWT, like the standard tank, is manufactured at Michoud Assembly, near New Orleans, Louisiana, by Lockheed Martin.

The 154-foot-long external tank is the largest single component of the space shuttle. It stands taller than a 15-story building and has a diameter of about 27 feet. The external tank holds over 530,000 gallons of liquid hydrogen and liquid oxygen in two separate tanks. The hydrogen (fuel) and liquid oxygen (oxidizer) are used as propellants for the shuttle's three main engines.

Updated: 03/29/2000

Media Assistance

NASA Television Transmission

NASA Television is available through the GE2 satellite system which is located on Transponder 9C, at 85 degrees west longitude, frequency 3880.0 MHz, audio 6.8 MHz.

The schedule for television transmissions from the orbiter and for mission briefings will be available during the mission at Kennedy Space Center, FL; Marshall Space Flight Center, Huntsville, AL; Dryden Flight Research Center, Edwards, CA; Johnson Space Center, Houston, TX; and NASA Headquarters, Washington, DC. The television schedule will be updated to reflect changes dictated by mission operations.

Status Reports

Status reports on countdown and mission progress, on-orbit activities and landing operations will be produced by the appropriate NASA newscenter

Briefings

A mission press briefing schedule will be issued before launch. During the mission, status briefings by a flight director or mission operations representative and when appropriate, representatives from the payload team, will occur at least once each day. The updated NASA television schedule will indicate when mission briefings are planned.

Internet Information

Information is available through several sources on the Internet. The primary source for mission information is the NASA Shuttle Web, part of the World Wide Web. This site contains information on the crew and its mission and will be updated regularly with status reports, photos and video clips throughout the flight. The NASA Shuttle Web's address is:

http://shuttle.nasa.gov

If that address is busy or unavailable, Shuttle Information is available through the Office of Space Flight Home Page:

http://www.hq.nasa.gov/osf/

General information on NASA and its programs is available through the NASA Home Page and the NASA Public Affairs Home Page:

http://www.nasa.gov

or

http://www.nasa.gov/newsinfo/index.html

Information on other current NASA activities is available through the Today@NASA page:

http://www.nasa.gov/today.html

The NASA TV schedule is available from the NTV Home Page:

http://www.nasa.gov/ntv

Status reports, TV schedules and other information also are available from the NASA headquarters FTP (File Transfer Protocol) server, ftp.hq.nasa.gov. Log in as anonymous and go to the directory /pub/pao. Users should log on with the user name "anonymous" (no quotes), then enter their E-mail address as the password. Within the /pub/pao directory there will be a "readme.txt" file explaining the directory structure:

* Pre-launch status reports (KSC): **ftp.hq.nasa.gov/pub/pao/statrpt/ksc**
* Mission status reports (KSC): **ftp.hq.nasa.gov/pub/pao/statrpt/jsc**
* Daily TV Schedules: **ftp.hq.nasa.gov/pub/pao/statrpt/jsc/tvsked.**

NASA Spacelink, a resource for educators, also provides mission information via the Internet. Spacelink may be accessed at the following address:

http://spacelink.nasa.gov

Access by Compuserve

Users with Compuserve accounts can access NASA press releases by typing "GO NASA" (no quotes) and making a selection from the categories offered.

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