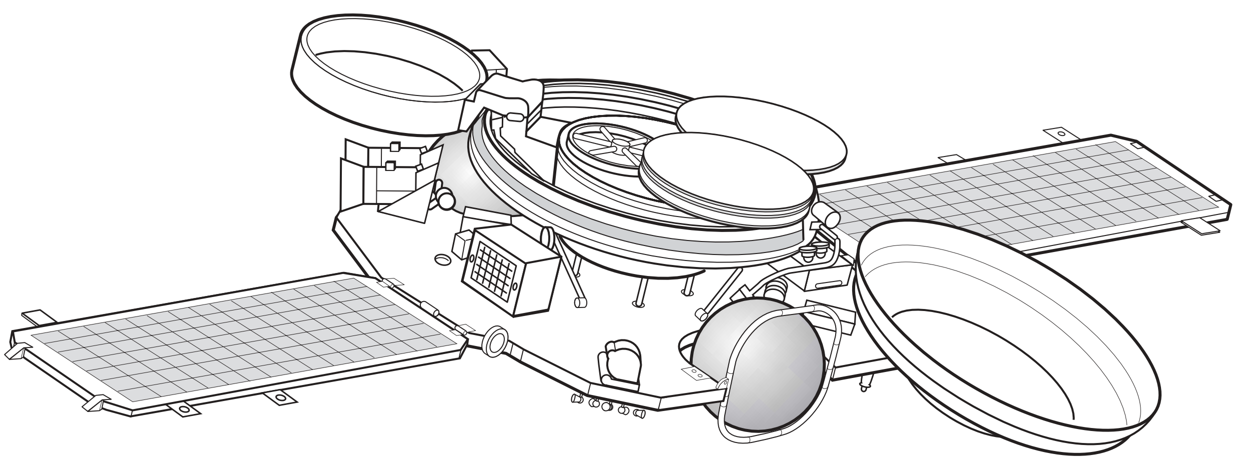
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Genesis Launch

Press Kit
July 2001



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RELEASE:

GENESIS SET TO CATCH A PIECE OF THE SUN

Genesis, a robotic NASA space mission to catch a wisp of the raw material of the Sun and return it to Earth with a spectacular mid-air helicopter capture, is set for launch on July 30, 2001, from Florida's Cape Canaveral Air Force Station.

The mission's goal is to collect and return to Earth just 10 to 20 micrograms -- or the weight of a few grains of salt -- of solar wind, invisible charged particles that flow outward from the Sun. This treasured smidgen of the Sun will be preserved in a special laboratory for study by scientists over the next century in search of answers to fundamental questions about the exact composition of our star and the birth of our solar system.

"This mission will be the Rosetta Stone of planetary science data, because it will show us the foundation by which we can judge how our solar system evolved," said Chester Sasaki, Genesis project manager at NASA's Jet Propulsion Laboratory, Pasadena, Calif. "The samples that Genesis returns will show us the composition of the original solar nebula that formed the planets, asteroids, comets and the Sun we know today."

"Genesis will return a small but precious amount of data crucial to our knowledge of the Sun and the formation of our solar system," said Dr. Donald Burnett of the California Institute of Technology, Pasadena, principal investigator and leader of the Genesis mission. "Data from Genesis will provide critical pieces for theories about the birth of the Sun and planets."

In November 2001, Genesis will arrive at a place in space well outside of Earth's atmosphere and magnetic environment that will allow it to gather pristine samples of the solar wind. The spacecraft carries four scientific instruments: bicycle-tire-sized solar wind collector arrays, made of materials such as diamond, gold, silicon and sapphire designed to entrap solar wind particles; an ion monitor, which will record the speed, density, temperature and approximate composition of the solar wind; an electron monitor, which will make similar measurements of electrons in the solar wind; and an ion concentrator, which will separate out and focus elements like oxygen and nitrogen in the solar wind into a special collector tile. Sample collection will conclude in April 2004, when the spacecraft returns to Earth. Genesis will be the first mission to return a sample of extraterrestrial material collected beyond the orbit of the Moon.

In September 2004, the samples will arrive on Earth in a dramatic helicopter capture. As the sample return capsule parachutes toward the ground at the U.S. Air Force's Utah Testing and Training Range, specially trained helicopter pilots will catch it on the fly to prevent the delicate samples from being disturbed by the impact of a parachute landing. The samples will be taken to NASA's Johnson Space Center, Houston, Texas, where the collector materials will be stored and distributed for analysis. The samples will be maintained under extremely clean conditions to preserve their purity for scientific study throughout the century.

Scientists anticipate that, in addition to today's capabilities, new analytical techniques developed in coming decades can be used to study the solar matter returned by Genesis.

Scientists say that the surface of the Sun, from which the solar wind originates, has preserved the composition of the solar nebula from which all the different planetary bodies formed. Study of Genesis' samples is expected to yield the average chemical composition of the solar system to greater accuracy. It will also provide clues to the evolutionary process that has led to the incredible diversity of environments in today's solar system.

Genesis is sponsored by NASA's Discovery Program, which competitively selects low-cost solar system exploration missions with highly focused science goals.

The Jet Propulsion Laboratory, Pasadena, Calif., manages the Genesis mission for NASA's Office of Space Science, Washington, D.C. Lockheed Martin Astronautics, Denver, Colo., designed and built the spacecraft and will operate it jointly with JPL. JPL is a division of the California Institute of Technology, the home institute of the principal investigator. Major portions of the payload design and fabrication were carried out at Los Alamos National Laboratory in New Mexico and at NASA's Johnson Space Center in Houston, Texas.

More information on the Genesis mission can be found at the mission's web site, http://genesismission.jpl.nasa.gov . Status updates and news releases on the mission will also be posted on the JPL home page at http://www.jpl.nasa.gov .

- End of General Release -

Media Services Information

NASA Television Transmission

NASA Television is broadcast on the satellite GE-2, transponder 9C, C Band, 85 degrees west longitude, frequency 3880.0 MHz, vertical polarization, audio monaural at 6.8 MHz. The schedule for television transmission of video animations, B-roll and live-interview opportunities will be available from the Jet Propulsion Laboratory, Pasadena, Calif., and NASA Headquarters, Washington, D.C.

News Releases and Status Reports

The Jet Propulsion Laboratory's Media Relations Office will issue news releases and status reports about the Genesis launch and mission. They are available online at http://www.jpl.nasa.gov .

Briefings

Briefings on the Genesis mission will be held at NASA's Kennedy Space Center, Fla., at 1 p.m. EDT Sunday, July 29, 2001, one day before launch. Additional details about the briefing will be available closer to the date from NASA Headquarters and the Jet Propulsion Laboratory.

Internet Information

Information on the Genesis mission, including an electronic copy of this press kit, press releases, fact sheets, status reports and images, is available from the Jet Propulsion Laboratory's home page at http://www.jpl.nasa.gov . Signup for email subscriptions to JPL news releases is available at the home page.

The Genesis public outreach group maintains a web page at http://www.genesismission.jpl.nasa.gov that is also mirrored at http://sun.jpl.nasa.gov .

Quick Facts

Spacecraft
Dimensions: Main structure 2.3 meters (7.5 feet) long and 2 meters (6.6 feet) wide; wingspan of solar array 6.8 meters (22 feet) tip to tip; sample return capsule 1.5 meters (4.9 feet) diameter, 1.31 meters (52 inches) tall
Weight: 636 kilograms (1,402 pounds) total, composed of 494-kilogram (1,089-pound) dry spacecraft and 142 kilograms (313 pounds) of fuel
Science instruments: Solar wind collector arrays, ion concentrator, ion and electron monitors
Power: Solar array providing up to 254 watts just after launch; storage via a nickel-hydrogen battery

Launch Vehicle
Type: Delta II 7326
Weight: 151,036 kilograms (332,878 pounds)

Mission
Launch period: July 30 to August 14, 2001
Total distance traveled relative to Earth from launch to L1 point: 1.5 million kilometers (930,000 miles)
Total distance traveled relative to Earth from launch through end of mission: 32 million kilometers (20 million miles)
Solar wind collection: October 2001 - April 2004
Arrival at L1 point: November 2001
Orbit around L1 point: November 2001 - April 2004
Number of orbits around L1 point: Five
Sample return to Earth: September 2004

Program
Cost: $164 million spacecraft development and science instruments
$45 million mission operations and science data analysis

Mysteries of the Solar Nebula

A few billion years ago, after generations of more ancient suns had been born and died, a swirling cloud of dust and gas collapsed upon itself to give birth to an infant star.

As the ball-shaped cloud fell inward it began to flatten and rotate, eventually resembling a spinning pancake. Mostly the stuff of the cloud was simple atoms of hydrogen and helium, but it was peppered here and there by more complicated elements forged in the internal furnaces and death explosions of older stars. Even as a new sun took shape at the center of the cloud, disturbances formed farther out. In a remarkably short time by astronomical standards -- "just" tens of millions of years, or less -- these whirlpools of matter condensed into planets.

Today that star system is home to an amazing diversity of environments -- from immense mountains and enormous, jagged canyons on rocky inner planets to sulfur volcanos and ice geysers on moons circling huge gas planets farther out from the star, their orbits crisscrossed by legions of comets and asteroids.

This is the story, astronomers tell us, of how the Sun, our Earth and the solar system that both of them occupy came to be. There is plenty of evidence from observations over many decades to establish the broad outlines of the story. But exactly how the placental cloud of dust and gas, called the "solar nebula," turned into the solar system that we see around us today still poses many mysteries for scientists.

One of the main ways that scientists approach the question of how the solar system formed is by comparing the elements and isotopes that made up the original cloud of dust and gas to the compositions of the planets, moons, asteroids and comets in the solar system today. (An isotope is a variation of an element that is heavier or lighter than the standard form of the element because each atom has more or fewer neutrons in its nucleus.) But what were the ingredients in the original solar nebula?

Fortunately, nature provides a fossil record of the solar nebula. Like other stars its size, the Sun has an outer atmosphere that is slowly but steadily flowing off into space. This material, consisting mostly of electrically charged atoms called ions, flows outward past the planets in a constant stream called the "solar wind." This wind is a snapshot of the materials in the surface layers of the Sun, which in turn reflects the makeup of the original solar nebula.

This is the rationale of the Genesis mission. By flying out beyond the interfering influ-

Solar Studies Past and Future

Past Missions to Collect Solar Wind

Apollo 11, 12, 14, 15 and 16 (NASA): The solar wind composition experiment on these missions that took astronauts to the Moon between 1969 and 1972 was a 1.4- by 0.3-meter (55- by 11-inch) aluminum foil sheet on a pole. This sheet was exposed to the Sun for periods ranging from 77 minutes on Apollo 11 to a period of 45 hours on Apollo 16. On Apollo 16, a platinum sheet was also used. Solar wind particles embedded themselves in the foil, which was returned to Earth for laboratory analysis. The chemical composition of the embedded solar wind included isotopes of the light noble gases: helium-3, helium-4, neon-20, neon-21, neon-22 and argon-36. Variations in the composition of the solar wind observed over the course of the Apollo missions were correlated with variations in the intensity of the solar wind established by measurements of Earth's magnetic field.

Currently Operating Space-Based Missions

Ulysses (European Space Agency and NASA): Launched October 6, 1990, Ulysses explores the Sun from a perspective above and below the ecliptic, the plane in which most of the planets orbit the Sun, to study the environment around the Sun's north and south poles. Scientists have used Ulysses data to define different types of solar wind. In addition, they have measured the strength of magnetic fields that surround the Sun and related them to the solar wind.

Solar and Heliospheric Observatory (European Space Agency and NASA): Soho orbits the same point in space targeted by Genesis -- the Lagrange 1 point, or "L1." Launched on December 2, 1995, Soho uses 12 instruments to study the physical processes in the Sun's corona, or the outermost region of the Sun's atmosphere, as well as changes in the Sun's interior by making observations in visible light as well as at ultraviolet and extreme ultraviolet wavelengths.

Advanced Composition Explorer (NASA): This spacecraft launched August 25, 1997, carries nine instruments to study the formation and evolution of the solar system and the astrophysical processes involved. It does this by sampling low-energy particles from the Sun and high-energy particles from elsewhere in the galaxy. Like Genesis, it orbits the L1 point to get a prime view of the Sun and the galactic regions beyond. The spacecraft measures particles of a wide range of energies and nuclear mass, under all solar wind flow conditions and during both large and small particle events including solar flares. It provides a one-hour warning when solar events will cause a geomagnetic storm that can interfere with the operations of satellites and telecommunications systems on Earth.

Wind (NASA): Launched November 1, 1994, the Wind spacecraft is currently in orbit around the L1 point. It is studying various facets of the interaction of Earth's magnetic environment and the solar wind.

Transition Region and Coronal Explorer (NASA): This spacecraft, called Trace, images the solar corona and the transitional region between the Sun and surrounding space. Launched April 2, 1998, Trace enables solar physicists to study the connections between the Sun's magnetic fields and associated plasma structures on the Sun. It does this by taking sequences of images of different areas -- the photosphere, or the Sun's visible surface; the corona, the outer region of the Sun's atmosphere consisting of hot ionized gases; and the transitional region between the Sun and surrounding space.

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Upcoming Solar Missions

High Energy Solar Spectroscopic Imager (NASA): This mission, known as Hessi, will explore the basic physics of how particles are accelerated and energy is released in solar flares. It will approach this task by making high-resolution images of solar flares studying the spectrums of released energy across wavelengths from X-rays to gamma rays. It is expected to observe tens of thousands of microflares, more than a thousand X-ray flares and more than a hundred gamma ray flares.

Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics mission (NASA): This mission, known by its acronym Timed, will study the influences of the Sun and humans on the least explored and understood region of Earth's atmosphere -- the mesosphere and lower thermosphere/ionosphere. This region is a gateway between Earth's environment and space, where the Sun's energy is first deposited into Earth's environment. This mission will focus on a portion of this region at an altitude of about 60 to 180 kilometers (40 to 110 miles). Scheduled to launch in September 2001, the mission will help scientists understand how conditions vary in this region, allowing predictions of effects on communications, satellite tracking, spacecraft lifetimes, degradation of spacecraft materials and on the reentry of vehicles piloted by human crews. The mission's study of space weather will help scientists gain a better understanding of the dynamics of this gateway region.

More information about Sun-exploring missions can be found at http://sec.gsfc.nasa.gov/sec_missions.htm .

ences of Earth's magnetic fields, the spacecraft can collect samples of the solar wind revealing the makeup of the cloud that formed the solar system nearly 5 billion years ago.

Astronomers have long studied the Sun's composition by breaking down the Sun's color spectrum using instruments on telescopes and satellites. But these observations are not precise enough for today's planetary science. By analyzing the solar wind in terrestrial laboratories, Genesis scientists can find precise ratios of isotopes and elements in the solar nebula. The basic data gained from the Genesis mission are needed to advance theories about the solar nebula and evolution of the planets.

Genesis' main goal is to probe the mystery of oxygen in the solar system. The amounts of oxygen isotopes vary among the solar system bodies, though the reason for the variety is totally unknown. Different parts of the solar system have distinct proportions of three isotopes of oxygen called O16, O17 and O18. O16 is the most common form of an oxygen atom, containing eight protons and eight neutrons to add up to an atomic weight of about 16. O17 has one extra neutron, whereas O18 has two extra neutrons.

Though scientists know the ratio of oxygen isotopes in bodies like asteroids, Earth, the Moon and Mars, the ratio of oxygen isotopes in the Sun is not well-understood.

Genesis will provide this last puzzle piece to determine how the solar nebula evolved into the solar system bodies.

Understanding the origins of the variations of the oxygen isotopes is a key to understanding the origin of the solar system. Does any part of today's solar system contain the same ratios of these oxygen isotopes as what Genesis finds existed in the original solar nebula? Finding out how these isotope ratio differences survived will narrow the possibilities of how the different materials or regions of the nebula mixed or didn't mix.

NASA’s Discovery Program

Genesis is the fifth mission in NASA's Discovery Program, which sponsors low-cost solar system exploration projects with highly focused science goals. Created in 1992, the Discovery Program competitively selects proposals submitted by teams led by scientists, supported by organizations that manage the project, as well as partners that build and fly the spacecraft. Discovery missions selected to date include:

❑ **Near Earth Asteroid Rendezvous** (Near) was launched February 17, 1996. It became the first spacecraft to orbit an asteroid when it reached Eros in February 2000, then carried out the first landing on an asteroid in February 2001.

❑ **Mars Pathfinder** was launched December 4, 1996 and landed on Mars on July 4, 1997, demonstrating a unique way of touching down with airbags to deliver a small robotic rover.

❑ Launched January 7, 1998, **Lunar Prospector** entered orbit around Earth's Moon five days later, circling at an altitude of about 100 kilometers (about 60 miles). The mission ended in a controlled crash on the lunar surface July 31, 1999.

❑ **Stardust** was launched February 1, 1999, and will collect comet and interstellar dust as it flies through the nucleus of Comet Wild-2 in January 2004. It will return the samples to Earth in January 2006.

❑ The **Comet Nucleus Tour** (Contour) mission, planned for launch in July 2002, will study at least two comets: Encke in 2003 and Schwassmann-Wachmann-3 in 2006. During each flyby, the spacecraft will take high-resolution pictures, analyze composition and make a precise determination of each comet's orbit.

❑ The **Mercury Surface, Space Environment, Geochemistry and Ranging** (Messenger) mission is planned for launch in March 2004. Entering orbit around the planet closest to the Sun in September 2009, the spacecraft will produce a global map and details about Mercury's surface, interior, atmosphere and magnetosphere.

❑ **Deep Impact** is slated to launch in January 2004 to travel to comet Tempel-1 and release a small impactor that will jettison material from the comet nucleus, allowing the main flyby spacecraft to identify the comet's composition.

❑ **Analyzer of Space Plasma and Energetic Atoms 3** (Aspera 3) is an instrument that will fly on Mars Express, a European Space Agency mission that will search for sub-surface water, study the planet's structure, atmosphere and geology, and drop a lander on Mars' surface. NASA is contributing hardware and software to the instrument, led by Sweden's Institute for Space Physics.

❑ **NetLander** is the first network of scientific stations ever deployed on Mars. Launching by the European Space Agency in 2007, the network will take scientific measurements on Mars' surface over one Martian year (nearly two Earth years) to measure the internal structure, magnetism and meteorology.

More information on NASA's Discovery Program is available at http://discovery.nasa.gov .

Mission Overview

Genesis' purpose is to observe the solar wind, entrap its particles and return them to Earth.

The spacecraft will travel to a point about 1.5 million kilometers (just under 1 million miles) away from Earth toward the Sun, where gravitational and centrifugal forces acting on the spacecraft are balanced: the Lagrange 1 point, or "L1." Genesis will be well outside of Earth's atmosphere and magnetic environment, allowing it to collect a pristine sample of the solar wind. Genesis' overall flight path resembles a series of loops: first curving outward from Earth to the L1 point, circling five times around it, then falling back for a brief loop around the opposite Lagrange point, called "L2," in order to position the spacecraft for return to Earth.

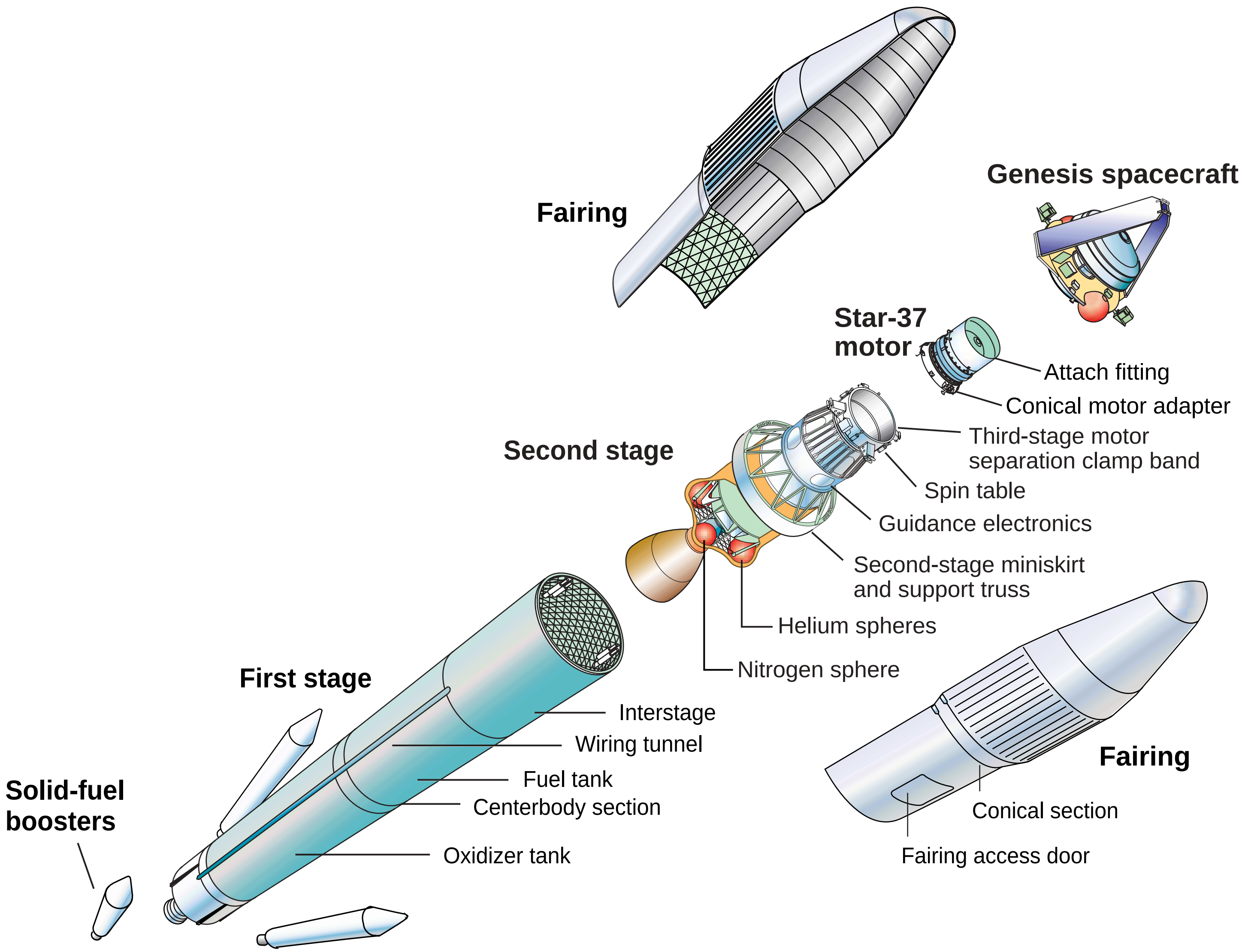
Genesis' destination, the Lagrange 1 point, is named for the Italian-French mathematician Joseph-Louis Lagrange. In 1764, he authored an essay for the Paris Academy of Sciences, defining points between bodies in space where the gravity between them balances the centrifugal force experienced at those points while orbiting with the bodies. The L1 point is a convenient place to position spacecraft designed to study the Sun. Placing a spacecraft there affords an uninterrupted view of the Sun without the need for major propulsion maneuvers to maintain the orbit. Genesis will arrive there in November 2001, about three months after launch.

Genesis will occupy what scientists call a "halo" orbit, meaning that it orbits around an empty point in space, L1, not a physical object. The spacecraft's orbit around L1 is elongated and slightly warped, as if it is tracing the outside edge of a potato chip.

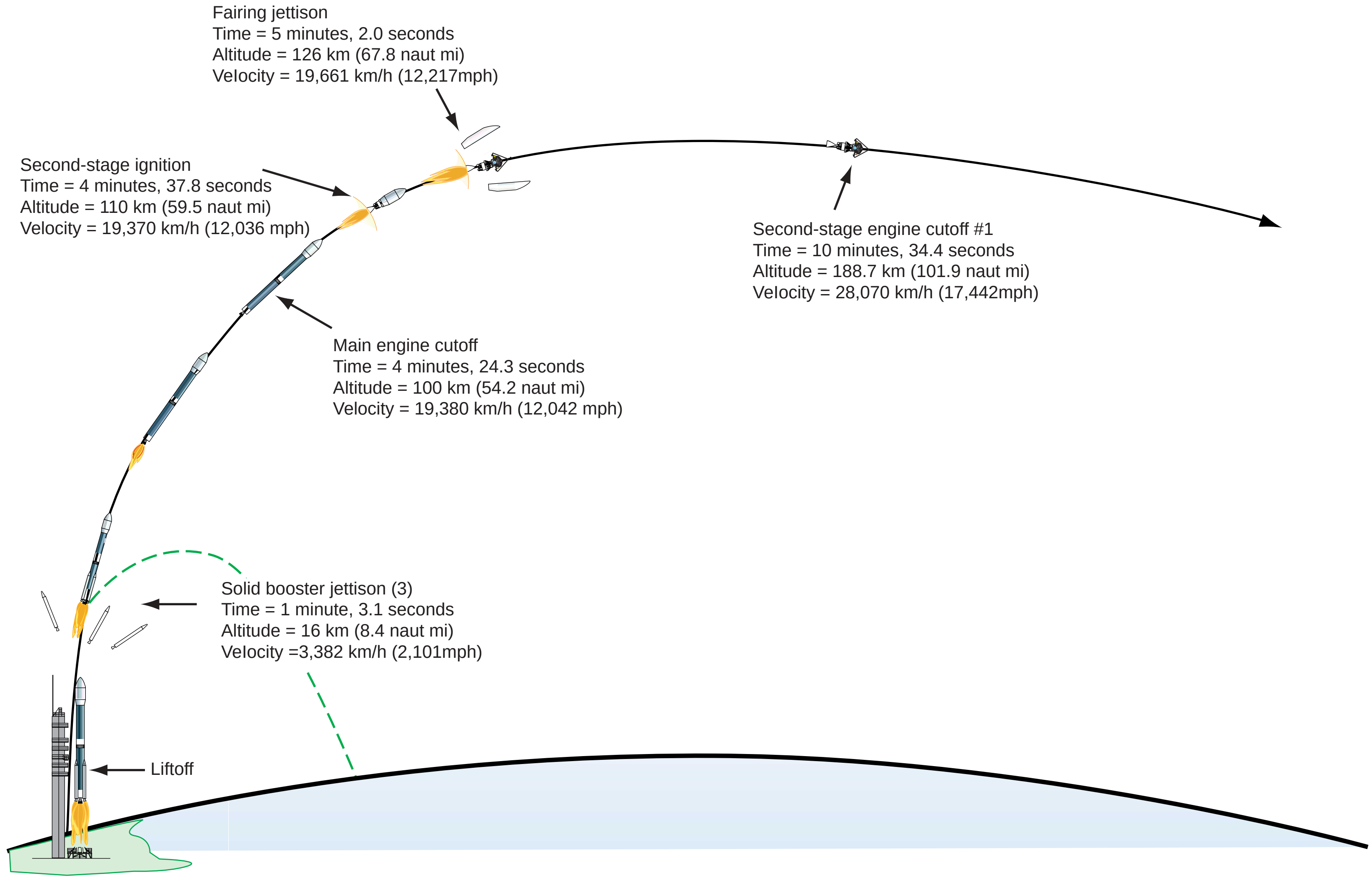
The spacecraft's science instruments will work together to categorize and sample the solar wind. The collection period will conclude in April 2004, and the spacecraft will return to Earth.

In September 2004, Genesis' samples will be returned to Earth in a dramatic helicopter capture. As the sample return capsule parachutes to the ground in the U.S. Air Force's Utah Testing and Training Range, specially trained helicopter pilots will catch it on the fly to prevent the delicate samples from being disturbed by the impact of a parachute landing. The samples will be taken to NASA's Johnson Space Center, Houston, Texas, where the collector materials will be stored and maintained under extremely clean conditions to preserve their purity for scientific study throughout the century.

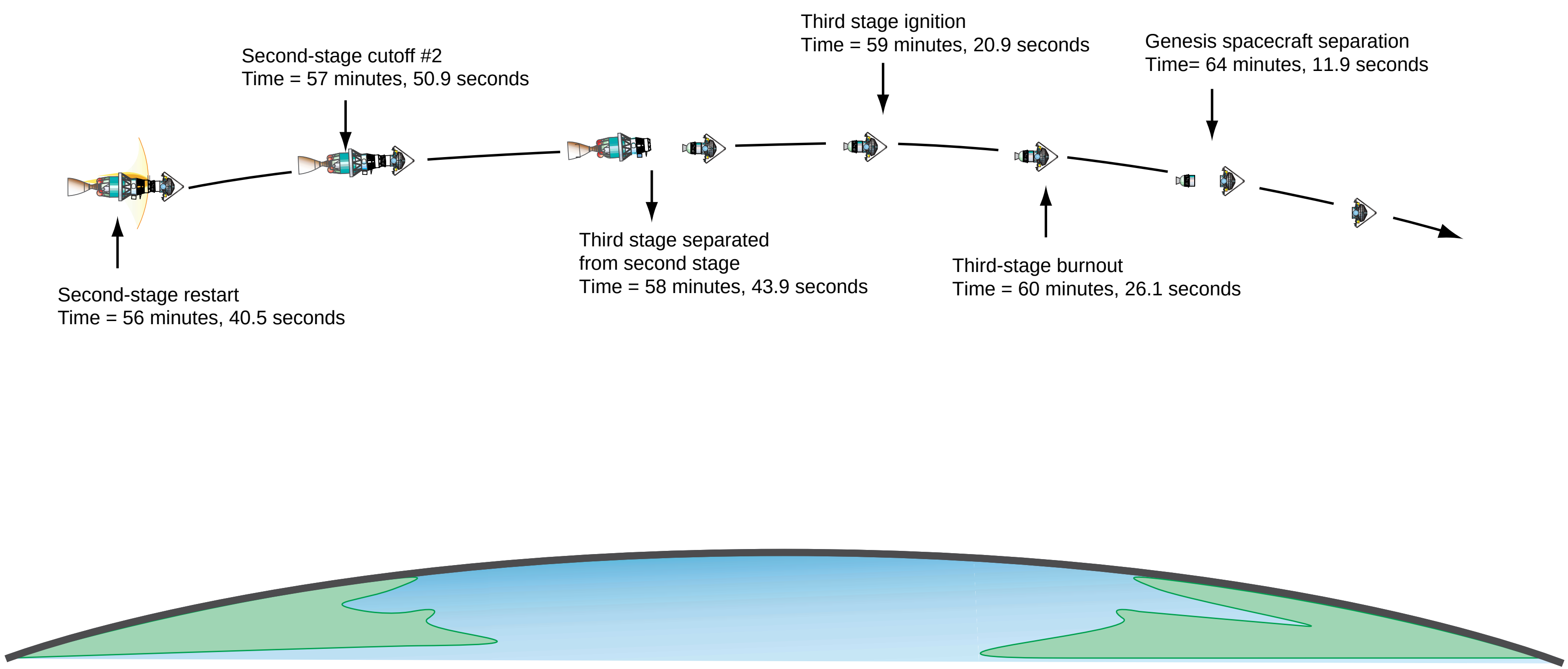
The mission is designed to fulfill the goals of NASA's Discovery program to launch many small missions with highly focused science objectives and fast turn-around times, executed as joint efforts with industry, small business and universities.



Delta II launch vehicle



Launch boost phase



Launch injection phase

Launch Vehicle

Genesis will be launched on a Delta II model 7326 rocket, similar to Deltas that have launched other recent solar system exploration missions. These rockets have differed primarily in the number of solid-fuel boosters that augment the first stage of the liquid-fuel Delta.

In the case of Genesis, three solid-fuel boosters are used. Each of these three solid rocket motors is 1 meter (3.28 feet) in diameter and 13 meters (42.6 feet) long; each contains 11,750 kilograms (25,882 pounds) of hydroxyl-terminated polybutadiene (HTPB) propellant and provides an average thrust of 485,458 newtons (109,131 pounds) at sea level. The casings on the solid rocket motors are made of lightweight graphite epoxy.

The main body of the first stage is 2.4 meters (8 feet) in diameter and 26.1 meters (85.6 feet) long. It is powered by an RS-27A engine, which uses 96,160 kilograms (212,000 pounds) of RP-1 (rocket propellant 1, a highly refined kerosene) and liquid oxygen as its fuel and oxidizer, respectively.

The second stage is 2.4 meters (8 feet) in diameter and 6 meters (19.7 feet) long, and is powered by an AJ10-118K engine. The propellant is 3,929 kilograms (8,655 pounds) of aerozine 50 (A-50), a 50/50 mixture of hydrazine and unsymmetrical dimethyl hydrazine (UDMH). The oxidizer is 2,101 kilograms (4,628 pounds) of nitrogen tetroxide. This engine is restartable and will perform two separate burns during Genesis' launch.

The third and final stage is a Thiokol Star 37FM booster, measuring 1.7 meter (5.5 feet long and 0.9 meter (3 feet) wide. Its motor carries 1,210 kilograms (2,665 pounds) of solid propellant, composed of a mixture of aluminum, ammonium perchlorate and hydroxyl-terminated polybutadiene (HTPB).

The Delta’s second stage includes a spin table supporting small rockets that are used to spin up the third stage and the attached Genesis spacecraft. A yo-yo despin system consisting of two weights on cables that unwind is used to slow down the spinning after this stage has fired.

Launch Timing

The launch period for Genesis extends from July 30 to August 14, 2001. Each day there is a two-minute window during which the spacecraft can be launched. All of the openings of the window fall shortly after noon EDT. On July 30 the window opens at 12:36:01 p.m. EDT, while on August 14 it opens at 12:14:56 p.m. EDT.

Daily Launch Opportunities

Genesis has a two-minute launch opportunity each day opening at the following times (all EDT)

Date	*Window Opens*	*Date*	*Window Opens*
7/30/01	12:36:01 p.m.	8/7/01	12:17:37
7/31/01	12:32:34	8/8/01	12:13:40
8/1/01	12:31:38	8/9/01	12:10:49
8/2/01	12:27:09	8/10/01	12:14:14
8/3/01	12:23:53	8/11/01	12:10:47
8/4/01	12:23:04	8/12/01	12:08:13
8/5/01	12:19:30	8/13/01	12:17:25
8/6/01	12:16:21	8/14/01	12:14:56

Liftoff Events

Genesis will be lofted into space from Space Launch Complex 17A at Cape Canaveral Air Force Station in Florida. Sixty-three seconds after launch, the three solid rocket boosters will be discarded. About 4 minutes, 24 seconds after liftoff, the first stage stops firing and is jettisoned, followed by ignition of the rocket's second stage. The rocket's nose cone, or "fairing," will be discarded 5 minutes, 2 seconds after launch. The first burnout of the rocket's second stage occurs at 10 minutes, 34 seconds after launch.

At this point the vehicle is in low Earth orbit at an altitude of 189 kilometers (117 miles). The vehicle will then coast for 46 minutes, assuming launch on July 30. Once it is in the correct point in its orbit, the second stage will be restarted.

Small rockets will then be fired to spin up the third stage on a turntable attached to the Delta's second stage. The third stage will separate and ignite its motor, sending the spacecraft toward the L1 point. A nutation control system -- a thruster on an arm mounted on the side of the third stage -- will be used to maintain stability during the third-stage burn. After that, the spinning of the upper stage and the attached Genesis spacecraft must be slowed so that the spacecraft can be separated and orient itself for its flight to L1. This is accomplished by a set of weights that are reeled out from the side of the spinning vehicle on flexible lines, much as spinning ice skaters slow themselves by extending their arms. Genesis will separate from the Delta third stage about 64 minutes after launch.

Immediately after Genesis separates from the Delta’s third stage, the spacecraft's solar arrays are deployed and locked in place. The spacecraft is then turned to an orientation, or "attitude," facing its solar arrays toward the Sun and enabling Genesis to communicate with Earth, and its transmitter is turned on. It is now about 1 hour, 20 minutes after launch, and the 34-meter-diameter (112-foot) antenna at the Deep Space Network complex at Goldstone, Calif., will acquire Genesis' signal.

Flight to the L1 Point

The spacecraft's flight from Earth to the Lagrange 1 point lasts about three months. The main activities during this phase include check-out and monitoring of the spacecraft and science instruments, and navigation activities necessary to determine and correct Genesis' flight path.

Science activities planned during this phase include calibration of the ion and electron monitors, beginning about a week and a half to two weeks after launch. The payload's health and status will be checked and instruments will be calibrated. The sample return capsule's lid will be opened, allowing the inside of the capsule to release, or "outgas," residual chemical compounds which could potentially contaminate the solar wind collectors.

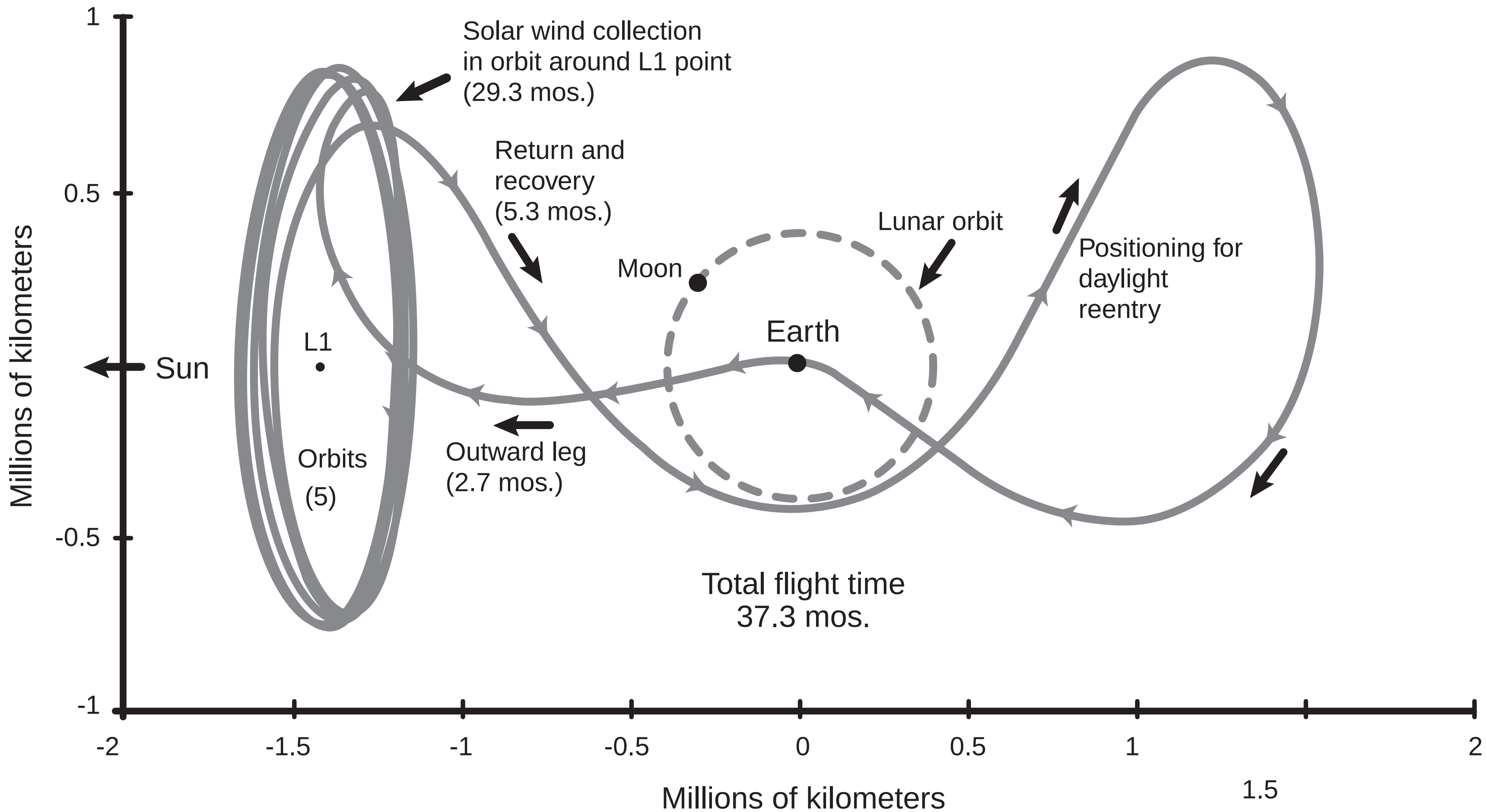
Beginning just after launch, the spacecraft's position in space will allow it to communicate with the Deep Space Network's ground stations in California, Australia or Spain. Most of the time the spacecraft will be transmitting to the stations' 34-meter-diameter (112-foot) antennas.

Genesis will transmit to Earth and receive commands using its medium-gain antenna during the early portion of its flight. Sequences of commands to control the spacecraft's onboard computer will be created and sent to Genesis about once a month during one of the regularly scheduled communications sessions with Deep Space Network ground stations.

The spacecraft will determine its orientation in space via a star tracker and Sun sensors. During most of the mission, the spacecraft will fly with its medium-gain antenna pointed toward Earth while keeping the solar panels pointed toward the Sun.

During the flight from Earth to L1, five opportunities are scheduled for the spacecraft to adjust its course, if necessary, by firing its onboard thrusters. The first of these events, called "trajectory correction maneuvers," is scheduled for two days after launch and will correct any launch injection errors and adjust the arrival spot at the L1 point. The next maneuver is optional; if the flight path needs adjustment, this thruster firing will take place seven days after launch. Collection of solar wind particles is scheduled to begin in October 2001, about a month before the spacecraft reaches the L1 point. The spacecraft will reach the L1 point in November 2001, about three months after launch.

Engineers will analyze the spacecraft's radio signal during the flight from Earth to L1 using techniques called radiometric and Doppler tracking to help pinpoint its distance from Earth as an aid to navigation. Genesis will be continuously tracked for the first 20



Mission Trajectory

days of the mission as it departs from Earth and for the last 3 to 10 days when it returns to Earth. For most of the rest of the mission, Genesis will be tracked for 12 hours per week. When trajectory correction maneuvers are being executed, the spacecraft will be tracked continuously during the maneuver.

Onboard computer commands controlling the solar wind monitoring instruments will be activated within the first two weeks after launch. Testing and calibration of the instruments will continue for three months after launch. Calibration of these instruments will focus primarily on making sure they can determine solar wind conditions accurately, and that they can autonomously control the configuration of the collection payload without intervention from ground controllers. The solar wind collection science payload will be powered on, tested and calibrated toward the end of this three-month period. Genesis is the first spacecraft to have a completely robotically controlled sample collection system in which data from science instruments is used to control sample collection.

L1 Orbit Insertion

Genesis will arrive at the L1 point in November 2001. At arrival, the spacecraft's large thrusters will fire to place Genesis into the proper halo orbit. The flight path has been designed so that eventually the spacecraft will naturally leave L1, and travel to another Sun-Earth Lagrange point called L2, and finally return to Earth. Earth lies between the Sun and the L2 point. Small thrusters will fire every eight weeks to maintain the halo orbit. Genesis will remain in this orbit for 30 months, completing five orbits. This means that 80 percent of the mission's total time will be spent in collecting particles.

Collecting Solar Wind

About 80 days after launch, Genesis will open the lid of its science canister, exposing its collector arrays, and begin to accept particles of solar wind. These collector arrays are circular plates covered on one side with palm-sized hexagonal tiles made of various high-purity materials such as silicon and sapphire, selected to capture the solar wind.

Genesis' ion and electron monitors, located on the equipment deck outside the science canister and sample return capsule, will monitor changes in the solar wind. The monitors will relay information about these changes to the main spacecraft computer, which in turn will command the collector array positions to change to expose the appropriate collector. The monitors will collect data to distinguish between three types, or “regimes,” of solar wind -- fast, slow and coronal mass ejections -- by measuring their characteristic temperature, velocity, direction and composition. There are three collector arrays that are exposed to or hidden from the solar wind, one for each of the three solar wind regimes. The appropriate array will be extended only when its designated type of solar wind passes by, as determined by onboard automated processing of monitor data.

On the inside of the science canister’s lid is one of two collectors of the bulk solar wind. The other bulk collector is the outboard array of the stack that includes the regime-specific arrays. As long as the science canister’s lid is open, these collector arrays will be exposed to the solar wind, receiving a combination of the different types of solar wind that will pass by the spacecraft.

Genesis' other dedicated science instrument, the solar wind concentrator, has been designed to concentrate the solar wind into a set of small collector tiles made of diamond and silicon carbide. The concentrator’s collector tiles will be exposed to the solar wind throughout the collection period, as long as the lid of the science canister is open and the concentrator is properly adjusted to accommodate the solar wind conditions, as determined onboard the spacecraft.

Once Genesis has completed solar wind collection, the collectors will be stowed over the concentrator and the science canister will close, sealing the solar wind samples inside the capsule. Genesis will then begin the last leg of its journey back toward its home planet. As planned, after five loops around L1 the influence of Earth, the Moon and the Sun will have altered the Genesis path from an orbit around L1 into a trajectory to L2 and finally toward Earth. Because of the position of the landing site, the U.S. Air Force's Utah Testing and Training Range, and the geometry of Genesis' flight path, it cannot approach Earth directly and make a daytime landing. Genesis must detour via L2 and loop around this point for daytime reentry and retrieval of the return capsule in Utah.

Return Phase

During the spacecraft’s return to Earth, there are six opportunities to fire its thrusters and correct the trajectory in order to achieve an accurate entry into Earth’s atmosphere. Of these six, three crucial final maneuvers using the small thrusters at 30 days, 10 days and one day before Earth entry will very accurately fine-tune the trajectory. On May 1, 2004, an Earth flyby will occur at about the distance of the Moon’s orbit, as the spacecraft heads toward L2 and lines up for the daytime landing in Utah. The final thruster firings will occur just after Genesis “rounds the bend” at L2 and heads directly for Earth.

Entry

After the final maneuver has occurred one day out, the return capsule will be aligned to its proper entry orientation about six hours before entry. At that time it will be stabilized for flight into Earth’s atmosphere by increasing its spin rate to approximately 15 rpm. The capsule will be released two hours later.

After the capsule is released, the main spacecraft will be diverted so it cannot collide with the sample return capsule. Having completed its mission of carrying the return capsule and its scientific cargo, the spacecraft will fire its large thrusters one last time, directing itself to enter the atmosphere and burn up over the Pacific Ocean, several hundred kilometers (hundreds of miles) from the United States' Northwest coast. In the event of some unexpected failure in the spacecraft or on the ground that prevents these entry events from taking place, an option exists before the release of the capsule to make a course correction that would place the entire vehicle into an elliptical or looping orbit around Earth of about 24 days' duration, followed by a second entry attempt.

The capsule slices into the atmosphere over central Oregon at a velocity of about 11 kilometers per second (24,700 miles per hour) at an angle of about 8 degrees down, its blunt nose facing in the direction of the oncoming stream of thickening air. Slowing rapidly, it heads southwest across Nevada and into Utah, finally arriving over the Utah Test and Training Range. A drogue chute and then a wing-like parachute called a parafoil will deploy, permitting the capsule to descend at a rate of about 5 meters per second (roughly 10 miles per hour) so it can be captured and retrieved by helicopter.

Sample Recovery

The landing site at the Utah Test and Training Range near Salt Lake City was chosen because the area is a vast, desolate and unoccupied salt flat controlled by the U.S. Army and Air Force. The landing footprint for the sample return capsule will be about 30 by 84 kilometers (18 by 52 miles), an ample area to allow for aerodynamic uncertainties and winds that might affect the direction the capsule travels in the atmosphere. The sample return capsule will approach the landing zone on a heading of approximately 122 degrees on a northwest to southeast trajectory. Landing is planned to take place at approximately 9 a.m. local time (Mountain time zone).

To survive entry and land within the desired footprint, the capsule's trajectory must achieve an accuracy of 0.08 degrees -- similar to the challenge of hitting a hole in one from a distance of 40 meters (about 130 feet). Navigation tracking requirements have been established to insure accurate targeting of the capsule. During the last month of Genesis' approach to Earth, ground controllers will collect tracking information that will allow them to fine-tune the spacecraft' flight path with a thruster firing 10 days before entry. The final thruster firing to target reentry will be performed 24 hours before entry.

The location of the landing footprint for the Genesis capsule will be predicted by tracking the spacecraft before the capsule's release. Since the capsule does not have a propulsion system, there is no way to abort the entry sequence following its release. Assuming the criteria for safe entry are satisfied, the capsule will be released from the spacecraft four hours before entry.

If events proceed normally, the spacecraft's main structure is expected to enter the atmosphere and burn up over the ocean off the Pacific Northwest coast. Should it be necessary to abort entry, the spacecraft, with sample return capsule still attached, will be directed into an elliptical backup orbit with a period of about 24 days, followed by another attempt to achieve reentry. In the event of a serious, mission-threatening problem, as a last resort the whole spacecraft will be diverted into the Pacific Ocean.

When it is 30 kilometers (about 20 miles) above Earth's surface, the capsule will deploy a drogue parachute to begin slowing its descent. When the capsule reaches about 6 kilometers (roughly 20,000 feet) above sea level, the wing-like parafoil will slow the capsule's descent to only about 5 meters per second (approximately 10 miles per hour). The parachute is small enough not to interfere with the process of towing the payload back to the landing pad, yet is large enough to present a good target. The parafoil's size determines its airspeed, which is chosen for best mid-air retrieval safety and reliability.

Two helicopters will alternately crisscross the falling capsule's path in up to 12 passes. The mid-air retrieval subsystem is attached to a pole fastened to the landing skid on the pilot's side of the helicopter. Held at the end of the pole is a hook attached to a cable which is used to snag the return capsule by its parachute. It is then reeled in using a winch. Tracking units on the helicopters and on the sample return capsule, along with radar tracking of the capsule, will allow the helicopters to be directed to the sample return capsule.

To ensure that the sample return capsule is found should it fall to the ground despite 12 helicopter passes, the capsule is equipped with a radio beacon. It will be turned on when the main parachute opens up and will transmit a signal as the capsule descends to Earth. The beacon is used in conjunction with locator equipment on the recovery helicopters. It is powered by redundant sets of primary cell lithium sulfur-dioxide batteries, which can operate the beacon for at least 40 hours.

The capsule will be transported to a staging area at the Utah Test and Training Range where the sample canister will be extracted. Eleven hours after Earth entry, the sample canister will be transported to its final destination, the planetary material curatorial facility at NASA's Johnson Space Center, Houston, Texas.

Telecommunications

Throughout the Genesis mission, tracking and telecommunications will be provided by NASA's Deep Space Network complexes in California, Australia and Spain. The data rate from the spacecraft will range from 7 to 41.7 kilobits per second. Most data from the spacecraft will be received by the Deep Space Network's 34-meter-diameter (112-foot) antennas, but the 26-meter (85-foot) antennas can be used as a backup.

Outreach

The Genesis project has forged partnerships with several educational enterprises to increase public awareness of the mission's goals and strategy, and to broaden the distribution of new knowledge the mission will produce. This includes courses presented as part of the Chautauqua program sponsored by the National Science Foundation and administered nationally by the University of Pittsburgh. "Genesis Grams," 100-character messages from participating members of the public, have been engraved on a microchip and placed aboard the spacecraft.

Education modules are also available on a CD-ROM titled "Genesis in Education" including two series titled "Cosmic Chemistry" and "Dynamic Design," as well as an interdisciplinary module exploring theories of the universe's origins.

Spacecraft

When Genesis' solar arrays are extended in space, the spacecraft resembles an unbuckled wristwatch. The watch's face is the science deck, and the figurative straps are the opened solar panels. The framework of the spacecraft is composed mostly of aluminum, composite materials and some titanium. The use of composites and titanium, lighter and more expensive materials, is an efficient way of conserving mass while retaining strength. Genesis' structure is similar to that used in the construction of high-performance and fighter aircraft.

The Genesis spacecraft incorporates innovative, state-of-the-art technologies pioneered by other recent missions, and uses off-the-shelf spacecraft components, designs and, in some cases, spare parts and instrumentation left over from previous missions.

There are five major science elements in the Genesis payload: the science canister, a stack of collector arrays, the ion concentrator, the electron monitor and the ion monitor. The science canister includes a bulk collector array mounted on its lid, and also houses the collector array stack and the ion concentrator.

Sample Return Capsule

The sample return capsule is the shape of two blunt-nosed cones attached at their bases, and has a diameter of 162 centimeters (64 inches). It has five major components: a heat shield, backshell, sample return or science canister, parachute system and avionics. The total mass of the capsule, including the parachute system, is 210 kilograms (460 pounds).

A hinged clamshell mechanism opens and closes the capsule. The science canister -- housing the solar wind collector arrays and ion concentrator -- fits inside, with a central rotating shaft to extend the collector arrays into the solar wind. The capsule is encased in carbon-carbon heat shielding and a silicone-based ablative material called SLA-561 to protect the samples stowed in its interior from the heat of reentry. A parachute deployed by a mortar unit is carried inside the capsule and will be used to slow its descent.

The heat shield is made of a graphite-epoxy composite covered with a thermal protection system. The thermal protection system is made of a carbon-impregnated material manufactured by Lockheed Martin Astronautics, Denver, Colo., called carbon-carbon. The capsule heat shield will remain attached to the capsule throughout descent and serve as a protective cover for the sample canister at touchdown. The aeroshell is designed to dissipate into the atmosphere more than 99 percent of the initial kinetic energy of the sample return capsule.

The backshell structure is also made of a graphite-epoxy composite covered with a thermal protection system: a silicone-based material called SLA-561V that was developed by Lockheed Martin for use on the Viking missions to Mars and that is currently used on the Space Shuttle external tank. The backshell provides the attachment points for the parachute system, and protects the capsule from the effects of recirculation flow of heat around the capsule.

The science canister is an aluminum enclosure containing the specialized and bulk collector arrays and the ion concentrator. On the inside of the lid of the science canister is a bulk solar wind collector array. The specialized collector arrays are rotated out from inside the science canister. Underneath the stowed collector arrays, the ion concentrator forms the bottom of the science canister. The canister is inside the sample return capsule, which is mounted between the backshell and heat shield on a set of support struts.

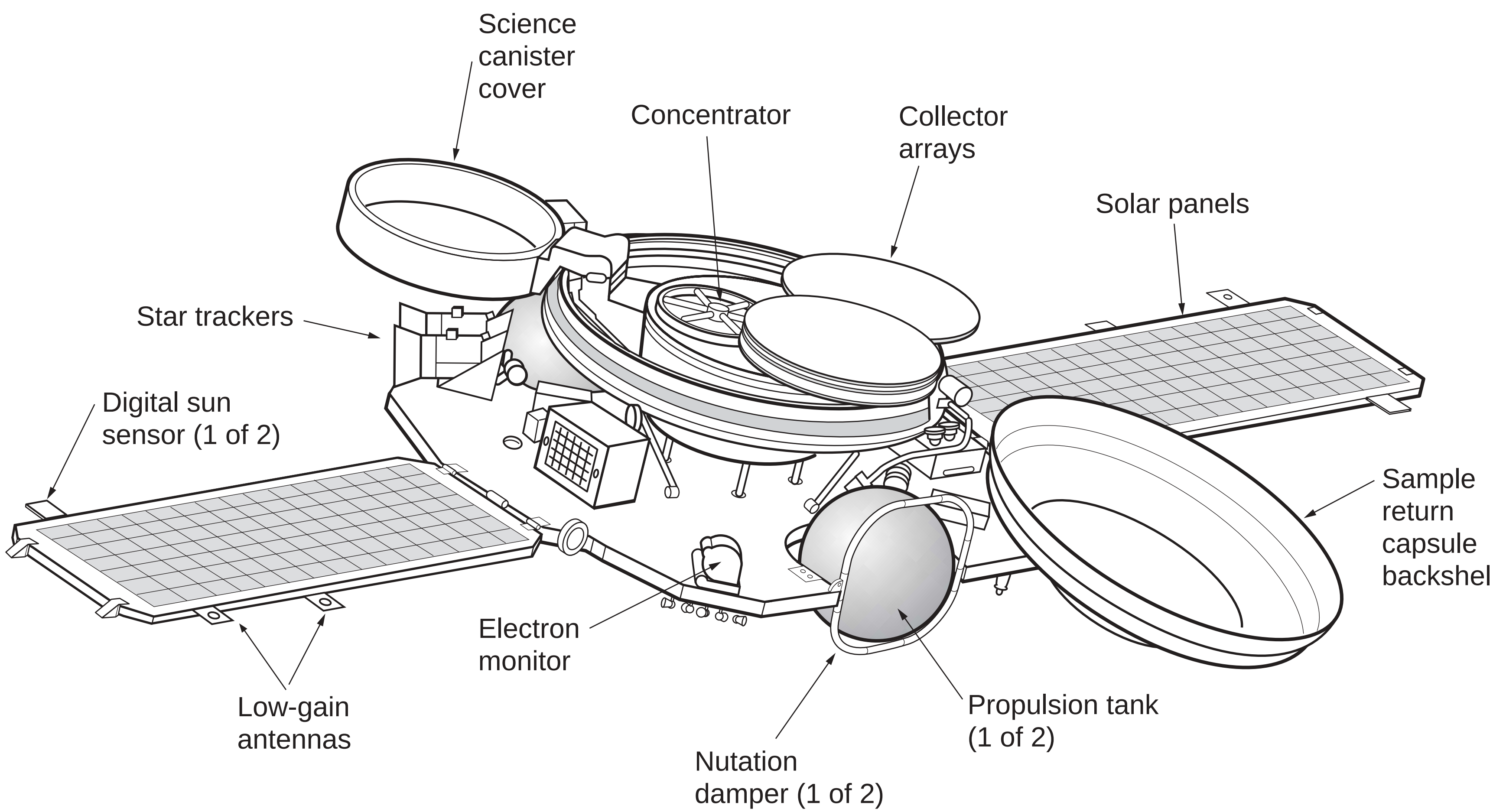
The parachute system consists of a mortar-deployed 1.6-meter (5.25-foot) drogue chute to provide stability at supersonic speeds, and a main chute 10 by 4 meters (about 33 by 13 feet) that is released at an altitude of about 6 kilometers (approximately 20,000 feet). The system incorporates the two parachutes into a single parachute canister.

Inside the parachute canister, a gas cartridge will pressurize a mortar tube and expel the drogue chute. The drogue chute will be deployed at an altitude of approximately 30 kilometers (about 20 miles) above mean sea level to provide stability to the capsule until the main chute is released. A gravity-switch sensor and timer will initiate release of the drogue chute. Based on information from timer and backup pressure transducers, a small pyrotechnic device will cut the drogue chute from the capsule at about 20 kilometers altitude (12 miles). As the drogue chute moves away, it will extract the main chute from the parachute canister. At the time of capture, the capsule will be traveling at about 5 meters per second (roughly 10 miles per hour).

Command and Data Handling

All of the spacecraft's computing functions are performed by the command and data handling subsystem. The heart of this subsystem is a RAD6000 computer, a radiation-hardened version of the PowerPC chip used in many models of Macintosh computers. With 128 megabytes of random access memory and three megabytes of non-volatile memory, which allows the system to maintain data even without power, the subsystem runs Genesis' flight software and controls the spacecraft through interface electronics.

Interface electronics make use of computer cards to communicate with external peripherals. These cards slip into slots in the computer's main board, giving the system specific functions it would not have otherwise. There are two identical strings of these computer and interface electronics, so that if one fails the spacecraft can switch to the other.



Genesis spacecraft

Communication with Genesis' sensors that measure the spacecraft's orientation in space, or "attitude," and its science instruments is done via another interface card. A master input/output card collects signals from around the spacecraft and also sends commands to the electrical power subsystem. The interface to Genesis' telecommunications subsystems is done through another card called the uplink/downlink card.

There are two other boards in the command and data handling subsystem, both internally redundant. The module interface card controls when the spacecraft switches to backup hardware and provides the spacecraft time. A converter card takes power from the electrical power subsystem and converts it into the proper voltages for the rest of the command and data handling subsystem components.

The command and data handling subsystem weighs 11.9 kilograms (26.2 pounds).

Telecommunications

Genesis' telecommunications subsystem is composed of both a radio system operating in the S-band microwave frequency range and, in the return capsule, a system that operates in the UHF range. The S-band system provides communication capability throughout all phases of the mission. It is used for communications between Earth and the spacecraft. The UHF system is used during the recovery of the capsule. It broadcasts to the ground the capsule's location during the later stages of entry based on information from a Global Positioning System receiver onboard the return capsule. The capsule also has a locator beacon.

The spacecraft's radio system communicates with Earth primarily through a medium-gain antenna. This antenna is spiral-shaped, about 10 centimeters (4 inches) in diameter, about 12 centimeters (4.87 inches) tall and weighs 105 grams (about 4 ounces). The spacecraft also uses four low-gain antennas, located on the solar arrays. These are patch antennas, which sit on a coaster-sized square (10 by 10 by 1 centimeters (4 by 4 by 0.4 inches)). These have a much wider field of view.

The low-gain antennas will be used to make initial contact with the spacecraft after it leaves the Delta rocket's third stage, and afterwards only near Earth during the return or for emergencies. The medium-gain antenna will be used for most of the spacecraft's communication with Earth.

The telecommunication subsystem weighs 10.1 kilograms (22.3 pounds).

Electrical Power

All of the spacecraft's power is generated, stored and distributed by the electrical power subsystem. The system obtains its power from an array of standard silicon solar cells arranged on two panels on either side of the equipment deck. The two solar panel wings are fixed in place after being deployed. They hold grids of silicon cells which generate a total of 254 watts at Earth's distance from the Sun. A power distribution and drive unit contains switches that send power to various loads around the spacecraft. Power is also stored in a nickel-hydrogen battery that can deliver 360 watt-hours of electrical energy.

The electrical system also contains a pyro initiator unit which fires small explosive devices that configure the spacecraft following launch, performing such tasks as unlatching Genesis' solar arrays when they are deployed and opening covers on the electron and ion monitors. The pyrotechnic system also releases the sample return capsule.

The electrical power subsystem weighs 36.5 kilograms (80.5 pounds).

Guidance, Navigation and Control

Genesis maintains its orientation in space, or "attitude," by continuously spinning in space. The spacecraft’s spin helps maintain stable pointing at the Sun. The attitude control system will keep Genesis spinning at a rate of 1.6 rpm during solar wind collection. During maneuvers, the spin rate will be increased to enhance stability. The axis of spin will point 4.5 degrees ahead of the Sun, so that collector arrays will face into the oncoming solar wind.

Genesis determines its orientation at any given time using a star tracker in combination with Sun sensors. The star tracker can track stars of third magnitude or brighter; Genesis then processes star tracker data in its main onboard computer to recognize any star patterns as they pass through the tracker’s field of view. The spacecraft uses both the directions of the Sun and of stars as measured by the Sun sensors and star tracker, respectively, to determine its orientation in space. As long as the spacecraft is spinning below about 2 rpm, it can use stars and thus determine its orientation more accurately. During maneuvers when the spacecraft is spinning faster than 2 rpm, the spacecraft will use its Sun sensors to determine a sufficiently accurate orientation. There are two star trackers on board to back each other up, and the Sun sensors also back each other up.

The guidance, navigation and control subsystem weighs 10.0 kilograms (22.0 pounds).

Propulsion

The propulsion subsystem has two sets of thrusters. The larger are used to make major trajectory correction maneuvers, and the smaller to continually maintain the spacecraft’s desired orientation and orbit.

Firing the thrusters changes the spacecraft's orientation. Two clusters of four small hydrazine thrusters each are mounted to the aft side (away from the Sun) of the spacecraft's deck, providing 0.88 newtons (0.2 pounds) of thrust each for small maneuvers to keep the spacecraft in its desired orientation and orbit, and to increase or reduce the spacecraft’s spin rate. Four more thrusters are also mounted on the spacecraft, each providing 22.2 newtons (5 pounds of thrust) for major trajectory correction maneuvers. These thrusters are only used when the sample return capsule's lid is closed, so that the exhaust does not contaminate the solar samples.

In addition to miscellaneous tubing, pyro valves and filters, the propulsion subsystem also includes two 55-centimeter-diameter (22-inch) propellant tanks, each containing hydrazine, pressurized with gaseous helium.

The propulsion subsystem weighs 36.6 kilograms (80.7 pounds).

Structures

The structure of the spacecraft is composed of an equipment deck that supports engineering components and the science instruments. The medium-gain antenna is on the underside, and the low-gain antennas are mounted on the solar wings. Except for what is inside the sample return capsule, all the equipment is mounted directly onto the equipment deck.

The structures subsystem weighs 98.6 kilograms (217.4 pounds).

Thermal Control

The thermal control subsystem is responsible for maintaining the temperatures of each component on the spacecraft within their allowable limits. It does this using a combination of active and passive control elements. The active components are the heaters. The passive components are black and white thermal paint as well as multilayer insulation blankets, some with an outer layer of carbon-impregnated black kapton, and some with an outer layer of indium-tin-oxide-coated kapton that has a gold color due to an aluminum backing that reflects light through the transparent yellow kapton.

The thermal control subsystem weighs 15.9 kilograms (35.1 pounds).

Mechanisms

The solar arrays must be stowed during launch and then released. During deployment, force from springs push the wings to rotate outward on hinges until two latches per wing engage and lock them in place.

The sample return capsule has three two-legged struts that hold it in place. The sample return capsule is mounted on its struts with its nose atop six spring-loaded cans. Following release of the struts, a ring between these cans and the nose gently shoves the capsule off its platform.

The sample return capsule's lid opens and closes on a main hinge, which is tethered to the deck. In order to keep the hinge from damaging the sample return capsule as it plunges through Earth's atmosphere, the hinge is retracted away from the capsule before reentry. Elbow joints at the top of the hinge have separation bolts and cable cutters that separate and retract the hinge assembly. The hinge carries with it the severed cables that allowed communication between the capsule and the rest of the spacecraft.

The ion and electron monitors each have a door mechanism that exposes their sensors by using pyrotechnics to expand small metallic balloons to open the doors.

Four mechanical latch/hook assemblies work to grab the lid of the sample return capsule and hold it in place throughout launch and reentry. The science canister mechanisms are: the lock ring device, canister lid mechanism and collector array deployment mechanism.

All of the mechanisms combined weigh 17.0 kilograms (37.5 pounds).

Flight Software

Genesis receives its commands and sequences from Earth and translates them into spacecraft actions. The flight software is capable of running multiple concurrent sequences, as well as executing immediate commands as they are received.

The software used during the data collection will determine solar wind conditions based on data from the ion and electron monitors. It will then command collection arrays to an appropriate configuration and adjust the ion concentrator’s voltage.

The flight software is also responsible for a number of autonomous functions, such as attitude control and fault protection, which involve frequent internal checks to determine whether a problem has occurred. If the software senses a problem, it will automatically perform a number of preset actions to resolve the problem or put the spacecraft in a safe mode until the ground can respond.

Redundancy

Most systems on the spacecraft are fully redundant. This means that, in the event of a device failure, there is a backup system or function to compensate.

A software fault protection system is used to protect the spacecraft from reasonable, credible faults but also has resiliency built into it so that many faults not anticipated can be accommodated without placing the spacecraft in a safe state.

Science Objectives

Genesis' purpose is to bring samples of solar matter to Earth. The solar wind is a convenient sample of the surface layers of the Sun, which have preserved the composition of the original solar nebula from which all planetary objects formed. Genesis will be the first mission in the present millennium to return with a package of extraterrestrial material.

Genesis will collect data on almost all of nature's elements and isotopes, and will allow scientists to determine the average composition of the solar system with high precision so that the composition of current solar system bodies can be compared.

Today's solar system holds a dazzling diversity of planets, moons, asteroids and other small bodies, which scientific theories say all formed from a homogeneous solar nebula. The chemicals and isotopes that make up the planets, moons, asteroids and comets contain a record of the processes and events in the early days of our solar system by which homogeneity was converted to diversity. The Genesis mission will provide scientists with new knowledge about the initial composition of the solar nebula, crucial data that are required for theories to explain how this conversion occurred.

Genesis will focus on determining the ratio of isotopes of different elements in solar matter. There are small but important differences in the relative abundances of isotopes of some elements, most notably oxygen and nitrogen, among the various samples of solar system materials available for study in Earth's laboratories. These differences are not explained by the standard model for the origin of the solar system.

Observations from the ground and from past spacecraft have provided a baseline set of data that Genesis' studies will greatly improve. Genesis' goal is to improve current knowledge of the Sun's composition for each element by threefold or better. Many elements are very rare, and data about the relative amounts of the different chemical elements are inaccurate or nonexistent.

Objectives

❑ Provide data on the isotopic composition of solar matter sufficiently precise for planetary science studies.

❑ Significantly improve our knowledge of the elemental composition of solar matter.

❑ Provide a reservoir of solar matter sufficient to meet the needs of 21st century planetary science.

❑ Provide independent measurements of the different kinds of solar wind.

Science Instruments

The Genesis mission's four instruments will work together to analyze, determine and sample the three types of solar wind.

Genesis' science goals will not be complete until the collector materials are analyzed. This will require developing analytical laboratory instruments on Earth with advanced capabilities beyond those presently available.

Solar Wind Collector Arrays. The solar wind collector arrays are large, meter-sized (yard-sized) panels, each containing 55 coaster-sized hexagonal tiles about 10 centimeters (4 inches) across. The tiles are made of a variety of materials including silicon, germanium, sapphire, artificially grown diamond and bulk metallic glass. These materials were selected in order to target specific elements during analysis; for example, collecting some of the solar wind material on a thin silicon layer on sapphire makes it easier to extract noble gases later in the laboratory. The tile materials must be extremely pure to guarantee that the atoms analyzed are of pristine solar origin and not due to terrestrial contamination.

There are five collector arrays mounted inside an ultra-clean canister for safe storage when not exposed to the solar wind. One array is mounted in the cover of the canister, and is exposed to the solar wind when the cover is opened. The other four arrays are mounted in a stack. The top array is exposed to the solar wind at all times. One of the

The Solar Corona and Solar Wind

The outermost layer of the Sun's atmosphere is called the solar corona. The solar wind is a continuous outflow of material from the corona -- mostly nuclei of the simple atoms of hydrogen and helium -- into interplanetary space. By the time this wind reaches Earth, its density is only about 5 to 10 particles per cubic centimeter. The Sun loses about one 100-trillionth of its mass every year from this wind.

The corona can be seen during total solar eclipses and by artificial eclipses produced by instruments called coronagraphs in solar observatories both on Earth and in space. The corona is extremely hot -- more than 1 million degrees Celsius (more than 2 million degrees Fahrenheit). The natural mechanisms within the Sun that heat the corona have not yet been completely determined and are under active investigation by space missions such as the Solar and Heliospheric Observatory (Soho) and the Transition Region and Coronal Explorer (Trace). Scientists say the mechanisms must involve the conversion of turbulent motions just below the solar surface into the twisting and occasional reconnection of magnetic fields and waves that extend into the corona.

The corona is also highly structured. These different structures give rise to three different kinds of solar wind: high-speed solar wind, low-speed solar wind and coronal mass ejections.

Images taken by telescopes with coronagraph instruments attached show some loops of glowing gas with both ends of the loops attached to the Sun, while others are open structures reaching out into space. The loops are made visible by hot, ionized gas (a material called a "plasma" made up of ionized atoms and electrons) trapped by the Sun's magnetic field.

other three is deployed depending on the type of solar wind the spacecraft is experiencing, as determined by the monitors. The canister was designed, built and tested by NASA's Jet Propulsion Laboratory, Pasadena, Calif. The canister was cleaned and the collector array materials installed in a new clean room, with only 10 particles of dust per cubic meter (or yard) (called a "class 10" clean room), at NASA's Johnson Space Center in Houston, Texas.

Solar wind ions striking the collector materials embed themselves many atom layers deep in the materials. Typical temperatures of the collector materials as they are heated by sunlight are around 200 degrees Celsius (about 400 degrees Fahrenheit). The collector materials have been selected so that diffusion is negligible after the atoms embed themselves; the collector materials can therefore serve as permanent sample containers for the returned solar matter.

Ion and Electron Monitors. Genesis' solar wind monitors will be able to measure the properties of the solar wind autonomously, allowing the spacecraft's computer to translate that knowledge into actions for the two Genesis instruments that collect solar wind. The monitors have three functions: to distinguish different types of solar wind in order to deploy the appropriate collector array, to document the properties of the solar wind, and to drive the solar wind concentrator.

Since the three kinds of solar wind can be distinguished by their speed, temperature, helium-hydrogen ratio and direction of travel of electrons, Genesis' ion and electron monitors will work together to identify the types of solar wind.

The ion monitor measures the amount of protons and alpha particles in the solar wind, as well as the energy of these particles. Alpha particles are helium atoms stripped of their electrons, leaving two protons and two neutrons together. About 96 percent of the solar wind is composed of protons, 4 percent alpha particles and less than 1 percent minor ions, of which carbon, nitrogen, oxygen, neon, magnesium, silicon and iron are the most abundant.

The ion monitor will face almost directly into the solar wind. The solar wind will enter a 1-millimeter (0.04-inch) slit in the top of the instrument and travel down between two curved, electrically charged plates. The plates' voltage pulls the ions in the direction of the curvature, allowing the ion monitor to measure the ions' energy. The amount of incoming ions is then measured over a wide range of energy.

The ion monitor is fixed on the side of Genesis that continually faces the Sun. The spacecraft spins slowly around a Sun-pointed axis. Using this spin, the instrument sweeps a narrow field of view through an approximately 50-degree-wide area centered on the average solar wind direction. The solar wind's supersonic speed can vary from 300 to 600 kilometers per second (roughly 700,000 to 1.4 million miles per hour), making its fastest Sun-Earth trip in about 45 hours.

Solar Wind Regimes

When scientists view radiation given off by the Sun in the X-ray range, some regions of the corona appear dark; these regions are called coronal holes. Instead of forming closed loops, the magnetic fields in coronal holes open out into space and the plasma is free to escape. High-speed solar wind blows out from the coronal holes like hot gas from a rocket engine. The solar wind from large coronal holes can have speeds exceeding 800 kilometers per second (500 miles per second).

Low-speed solar wind, moving at about 300 kilometers per second (about 190 miles per second), is thought to come from the boundary regions between coronal holes and certain other regions of the Sun's surface. Here the magnetic geometry keeps the solar matter from escaping easily, and the solar wind that does leave the Sun is relatively slow.

Interrupting these somewhat steady flows of solar wind are occasional events called coronal mass ejections. A coronal mass ejection occurs when a magnetic loop, or a group of magnetic loops, suddenly becomes unstable and blows out into space. The solar wind from such an ejection can be either fast or slow, depending on the energy of the explosion. These events are more frequent when the sunspot cycle is at its 11-year maximum.

Some ejections have solar flares associated with them, and some do not. A solar flare is a sudden, intense brightening emitting a burst of radiation that reaches Earth within a day or two, often interfering with satellite communications and power systems.

Material from a coronal mass ejection often includes a larger fraction of helium ions, also known as alpha particles, compared to the number of hydrogen ions, or protons. (An ion is an atom that has had one or more electrons stripped away from it, leaving it with a positive electrical charge.) Such ejections are also marked by a decrease in the temperature of ions as the material rapidly expands as it leaves the Sun. During an ejection, energetic electrons frequently stream in both directions along a magnetic loop whose ends may still be anchored in the Sun.

Genesis will provide samples of each of these three types, or “regimes,” of solar wind so that scientists can analyze them to test for differences in the proportions of elements and isotopes they are made of. (An isotope is a variation of an element that is heavier or lighter than the standard form of the element because it has more or fewer neutrons in its nucleus.)

Data from the ion and electron monitors on Genesis will be used to determine which type of solar wind is passing the spacecraft at any given time. This will allow the onboard computer to select the appropriate collector array for that type of solar wind.

The ions streaming away from the Sun contain all of the isotopes and elements found in nature, but some elements are more readily ionized and picked up by the solar wind than others. This separation, called "elemental fractionation," is somewhat different for the three types of solar wind.

Since some elements are more readily ionized and picked up by the solar wind than others, each of the five collector arrays may pick up different amounts of the elements and isotopes contained in the solar wind. Comparing the data from each collector will help assure that the composition of the solar wind that Genesis collects is the same as the composition of the Sun's surface.

In addition to the average speed, which is important for adjusting the ion concentrator and deploying two of the collector arrays, the ion monitor measures the spectrum of speeds, or energies, of the ions, which can determine their temperature. If the energy spectrum measured in the solar wind is broad, then the ions have many different energies reflecting temperatures possibly as high as 100,000 degrees Celsius (180,000 degrees Fahrenheit). If the solar wind's energy spectrum is narrow, the ions are traveling with much less commotion and are therefore relatively cool, about 10,000 degrees Celsius (18,000 degrees Fahrenheit).

The most important function of Genesis' electron monitors is to determine the direction of travel of the solar wind's electrons. This monitor also measures the energy spectrum of the electrons.

The electron monitor’s sensor head is composed of two half-spheres of charged, gold-covered metal, concentrically nested inside a drum with a slit. The solar wind electrons enter the slit and are forced between the charged plates, allowing energy analysis. The amount of incoming electrons is then measured over a wide range of energy. The instrument is located on the edge of Genesis' equipment deck so that it can look across 180 degrees -- nearly 90 degrees fore and 90 degrees aft -- and, as the spacecraft spins, measure the solar wind electrons coming in all directions.

If the electrons seem to be coming from two opposing directions simultaneously, the solar wind is likely part of a coronal mass ejection, a chunk of charged particles, or "plasma," that has lifted off the Sun's outer layer and is surrounded by magnetic fields. If the electrons are traveling only away from the Sun, the solar wind is of a different type, either "fast" or "slow" solar wind.

The shoebox-sized ion monitor weighs 3.3 kilograms (7.3 pounds) and uses 4 watts of power. It measures 29.4 centimeters (11.6 inches) long, 23.2 centimeters (9.1 inches) tall and 10.8 centimeters (4.3 inches) wide. The electron monitor is nearly the same size, and has a similar power requirement. The instruments were developed and built under the direction of Bruce Barraclough at the Los Alamos National Laboratory in New Mexico. The two monitors are nearly identical to Los Alamos instruments currently operating onboard the Advanced Composition Explorer and the Ulysses spacecraft.

Solar Wind Concentrator. Genesis' solar wind concentrator will attack the problem of collecting a high concentration of oxygen in the solar wind, filtering out the much more numerous particles of hydrogen. Oxygen is one of the most important elements in the solar wind because so much of the solar system's makeup includes oxygen, yet the differing amounts of oxygen isotopes in each type of body are puzzling.

All the oxygen that the instrument gathers will be concentrated into a collector tile made of the purest materials in order to exclude Earth oxygen. In the process, the ions are concentrated by a factor of 20 over the normal solar wind collectors.

The concentrator is installed in the sample canister, always facing the Sun. The solar wind passes through a series of charged grids into a bowl-shaped mirror, which reflects the filtered stream of oxygen and nitrogen ions upwards into the tile, poised in the center.

Several layers of grids made of wires one-quarter the diameter of a human hair manipulate the ions before concentrating them. The first grid layer is at ground potential, to keep the electric fields from the highly charged grids inside the collector from escaping and deflecting the surrounding solar wind. The next layer, called the hydrogen rejection grid, has a positive charge of up to 3,500 volts to repel the hydrogen ions that make up most of the solar wind, protecting the collecting tile. The next grid has a negative charge of minus 6,500 volts so that surviving particles are accelerated to embed them deeper in the collector tile. The acceleration also straightens stray paths of the incoming particles. The ions then pass through a bowl-shaped domed grid, which is nested above the bottom of the concentrator. The domed grid is also negatively charged to contain the electric field from the mirror just below.

The last element is the parabolic solid mirror, which has a strong positive charge. The particles passing through the domed grid are forcefully reflected toward the center of the parabola, where the collector tile waits to receive them. The mirror is a single aluminum piece with a surface consisting of steps 100 microns (.004 inch) tall, which reflect the Sun's incoming light back out of the instrument to avoid damaging the collector tile with focused sunlight.

The target tile, 26 square centimeters (4 square inches), is made of four pie wedges of ultra-pure materials: 1 diamond (carbon 13) wedge, 2 silicon carbide wedges and one wedge of silicon topped with thin diamond. The entire interior of the concentrator is coated with gold to keep all the surfaces oxygen-free.

The solar wind concentrator was developed at Los Alamos National Laboratory by Drs. Roger Wiens and Beth Nordholt. During flight, scientists at Los Alamos will monitor the health of the payload instruments and will keep a history of all solar wind conditions, and array and concentrator exposure times. These data will be made available to the scientific community at large for use in providing context for the data obtained from the returned samples.

Program/Project Management

The Genesis mission is managed by the Jet Propulsion Laboratory, Pasadena, Calif., a division of the California Institute of Technology, for NASA's Office of Space Science, Washington, D.C. At NASA Headquarters, Dr. Edward Weiler is the associate administrator for space science. Dr. Carl Pilcher is director of solar system exploration, and Dr. Jay Bergstralh is chief scientist for solar system exploration. Steven Brody is Genesis program executive, and Joseph Boyce is Genesis program scientist. David Jarrett is Discovery program manager.

At the Jet Propulsion Laboratory, Chester Sasaki is the Genesis project manager. At the California Institute of Technology, Dr. Donald Burnett is the Genesis principal investigator and leader of the mission.

Lloyd Oldham is the deputy project manager at Lockheed Martin Astronautics, Denver, Colo., where Genesis was designed, built and tested.

The spacecraft will be launched by Boeing Space Systems, Huntington Beach, Calif.

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