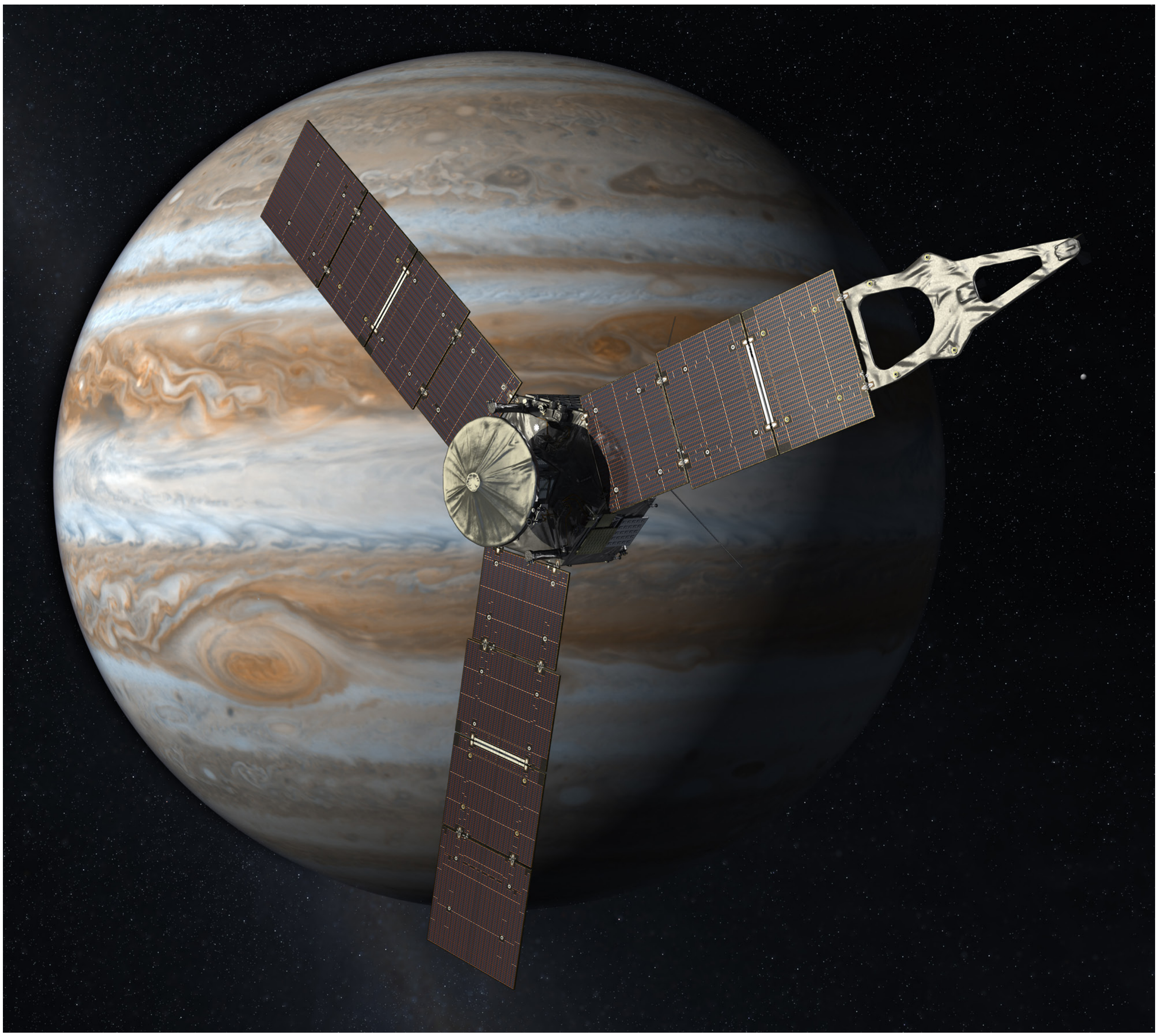
National Aeronautics and Space Administration

PRESS KIT/AUGUST 2011

Juno Launch



www.nasa.gov

Media Contacts

Dwayne Brown NASA Headquarters Washington	Policy/Program Management	202-358-1726 dwayne.c.brown@nasa.gov
DC Agle Jet Propulsion Laboratory Pasadena, Calif.	Juno Mission	818-393-9011 agle@jpl.nasa.gov
Maria Martinez Southwest Research Institute San Antonio	Science Investigation	210-522-3305 maria.martinez@swri.org
Gary Napier Lockheed Martin Space Systems Denver	Spacecraft	303-971-4012 gary.p.napier@lmco.com

Contents

Media Services Information

NASA Television Transmission

The NASA TV Media Channel is available on an MPEG-2 digital C-band signal accessed via satellite AMC-6, at 72 degrees west longitude, transponder 17C, 4040 MHz, vertical polarization. In Alaska and Hawaii, it's available on AMC-7 at 137 degrees west longitude, transponder 18C, at 4060 MHz, horizontal polarization. A Digital Video Broadcast compliant Integrated Receiver Decoder is required for reception. For digital downlink information for NASA TV's Media Channel, access to NASA TV's Public Channel on the Web and a schedule of programming for Juno activities, visit http://www.nasa.gov/ntv .

Media Credentialing

News media representatives who wish to cover the Juno launch must contact NASA Kennedy Space Center Public Affairs in advance at: 321-867-2468.

Briefings

A pre-launch news conference will be held at the Kennedy Space Center Press Site at 1 p.m. EDT on Aug. 3, 2011. The news conference will be televised on NASA TV.

Launch Status

Recorded status reports will be available beginning two days before launch at 321-867-2525 and 301-286-NEWS.

Internet Information

More information on the Juno mission, including an electronic copy of this press kit, news releases, status reports and images, can be found at http://missionjuno.swri.edu/ and http://www.nasa.gov/juno/ .

Quick Facts

Mission Name

The Juno spacecraft will, for the first time, see below Jupiter's dense cover of clouds. This is why the mission was named after the Roman goddess, who was Jupiter's wife, and who could also see through clouds.

Spacecraft

Dimensions: 11.5 feet (3.5 meters) high, 11.5 feet (3.5 meters) in diameter.

Solar Arrays: length of each solar array 29.5 feet (9 meters) by 8.7 feet (2.65 meters). Total surface area of solar arrays: more than 650-feet (60-meters) squared. Total number of individual solar cells: 18,698. Total power output (Earth distance from sun): approximately 14 kilowatts; (Jupiter distance from sun): approximately 400 watts.

Weight: 7,992 pounds (3,625 kilograms) total at launch, consisting of 3,513 pounds (1,593 kilograms) of spacecraft, 2,821 pounds (1,280 kilograms) of fuel and 1,658 pounds (752 kilograms) of oxidizer.

Launch Vehicle

Type: Atlas V551 (Atlas first stage with five solid rocket boosters, Centaur upper stage)

Height with payload: 197 feet (60 meters)

Mass fully fueled: 1,265,255 pounds (574,072 kilograms)

Juno Mission Milestones and Distances Traveled

Launch period: Aug. 5–26, 2011 (22 days)

Launch location: Pad SLC-41, Cape Canaveral Air Force Station, Fla.

Earth–Jupiter distance at time of launch: 445 million miles (716 million kilometers)

Time it takes light to travel from Earth to Jupiter on Aug. 5, 2011: 39 minutes, 50 seconds

Earth gravity assist flyby: October 9, 2013

Distance Juno travels launch to Earth gravity assist: 994 million miles (1,600 million kilometers)

Juno's altitude over Earth's surface at closest point during gravity assist: 311 miles (500 kilometers)

Jupiter arrival: July 4, 2016, 7:29 p.m. (PDT)

Distance of Jupiter to Earth at time of Jupiter orbit insertion: 540 million miles (869 million kilometers)

One-way speed-of-light time from Jupiter to Earth in July 2016: 48 minutes, 19 seconds

Total distance traveled, launch to Jupiter orbit insertion: 1,740 million miles (2,800 million kilometers)

End of mission (deorbit): October 16, 2017

Distance traveled in orbit around Jupiter: 348 million miles (560 million kilometers)

Total distance, launch through Jupiter impact: 2,106 million miles (3,390 million kilometers)

Program

The Juno mission investment is approximately $1.1 billion in total. This cost includes spacecraft development, science instruments, launch services, mission operations, science processing and relay support for 74 months.

Jupiter at a Glance

If you take everything else in the solar system (not including the sun), it would all fit inside Jupiter…

The largest and most massive of the planets was named after the king of the gods, called Zeus by the Greeks and Jupiter by the Romans; he was the most important deity in both pantheons.

As the most massive inhabitant of our solar system, and with four large moons of its own and many smaller moons, Jupiter forms its own kind of miniature solar system. In fact, Jupiter resembles a star in composition, and if it had been about 80 times more massive, it would have become a star rather than a planet.

Jupiter's appearance is a tapestry of beautiful colors and atmospheric features. Most visible clouds are composed of ammonia. Water clouds exist deep below and can sometimes be seen through clear spots in the clouds. The planet's "stripes" are created by strong east-west winds in Jupiter's upper atmosphere. Within these belts and zones are storm systems that can rage for years. The Great Red Spot, a giant spinning storm, has been observed for more than 300 years. In recent years, three storms merged to form the Little Red Spot, about half the size of the Great Red Spot.

The composition of Jupiter is similar to that of the sun — mostly hydrogen and helium. Deep in the atmosphere, the pressure and temperature increase, compressing the hydrogen gas into a liquid. At depths of about a third of the way down, the hydrogen becomes a liquid that conducts electricity like a metal. It is in this metallic layer that scientists think Jupiter's powerful magnetic field is generated by electrical currents driven by Jupiter's fast rotation. At the center, the immense pressure may support a core of heavy elements much larger than Earth.

Jupiter's enormous magnetic field is nearly 20,000 times as powerful as Earth's. Trapped within Jupiter's magnetosphere (the vast area of space that the planet's magnetic field dominates) are swarms of charged particles. The magnetic field traps some of these electrons and ions in an intense radiation belt that bathes Jupiter's rings and moons. The Jovian magnetosphere, comprising these particles and fields, balloons 600,000 to 2 million miles (1 to 3 million kilometers) toward the sun and tapers into a windsock-shaped tail extending more than 600 million miles (1 billion kilometers) behind Jupiter, as far as Saturn's orbit.

On Jan. 7, 1610, using his primitive telescope, astronomer Galileo Galilei saw four small "stars" near Jupiter. He had discovered Jupiter's four largest moons, now called Io, Europa, Ganymede and Callisto. These four moons are known today as the Galilean satellites. Not including the "temporary" moons, Jupiter has 64 confirmed moons. (Temporary moons are comets that have been temporarily captured by Jupiter's massive gravity field. These temporary satellites may circle Jupiter for years before continuing on their way through the solar system or burn up as they enter its atmosphere.) Jupiter has three thin rings around its equator, which are much fainter than the rings of Saturn. Jupiter's rings appear to consist mostly of fine dust particles and may be formed by dust kicked up as interplanetary meteoroids smash into the giant planet's four small inner moons. They were discovered in 1979 by NASA's Voyager 1 spacecraft.

Significant Dates in Jovian History

- 1610: Galileo Galilei makes the first detailed observations of Jupiter.
- 1973: NASA's Pioneer 10 becomes the first spacecraft to cross the asteroid belt and fly past Jupiter.
- 1979: NASA's Voyager 1 and 2 discover Jupiter's faint rings, several new moons and volcanic activity on Io's surface.
- 1994: Astronomers and NASA's Galileo spacecraft observe as pieces of comet Shoemaker-Levy 9 collide with Jupiter's southern hemisphere.
- 1995: The Galileo spacecraft and probe arrive at Jupiter to explore Jupiter's atmosphere directly for the first time and to conduct an extended study of the giant planet system.

Why Juno?

Jupiter is by far the largest planet in the solar system. Humans have been studying it for hundreds of years, yet still many basic questions about the gas world remain. In 1995, NASA's Galileo mission made the voyage to Jupiter. One of its jobs was to drop a probe into Jupiter's atmosphere. The data returned from that probe showed us that Jupiter's composition was different than scientists thought, indicating that our theories of planetary formation were wrong. Today, there remain major unanswered questions about this giant planet and the origins of our solar system hidden beneath the clouds and massive storms of Jupiter's upper atmosphere.

- How did Jupiter form?
- How much water or oxygen is in Jupiter?
- What is the structure inside Jupiter?
- Does Jupiter rotate as a solid body, or is the rotating interior made up of concentric cylinders?
- Is there a solid core, and if so, how large is it?
- How is its vast magnetic field generated?
- How are atmospheric features related to the movement of the deep interior?
- What are the physical processes that power the auroras?
- What do the poles look like?

Juno's primary goal is to reveal the story of the formation and evolution of the planet Jupiter. Using long-proven technologies on a spinning spacecraft placed in an elliptical polar orbit, Juno will observe Jupiter's gravity and magnetic fields, atmospheric dynamics and composition, and the coupling between the interior, atmosphere and magnetosphere that determines the planet's properties and drives its evolution. An understanding of the origin and evolution of Jupiter, as the archetype of giant planets, can provide the knowledge needed to help us understand the origin of our solar system and planetary systems around other stars.

Mission Overview

The Juno spacecraft is scheduled to launch aboard an Atlas V551 rocket from Cape Canaveral, Fla., in Aug. 2011, reaching Jupiter in July 2016.

Following launch from Cape Canaveral Air Force Station, Fla., the Juno spacecraft is scheduled to use its main rocket motor twice (for an Aug. 5 launch, it would be used on Aug. 30, and Sept. 3, 2012) to modify its trajectory towards Jupiter. During cruise, there are also 13 planned trajectory correction maneuvers to refine its orbital path. An Earth flyby 26 months after launch will provide a boost of spacecraft velocity, placing it on a trajectory for Jupiter. The transit time to Jupiter following the Earth flyby is about three years, including the period of the initial capture orbit. The 30-minute orbit insertion burn will place Juno in orbit around Jupiter in early July 2016.

To accomplish its science objectives, Juno orbits over Jupiter's poles and passes very close to the planet. Juno needs to get extremely close to Jupiter to make the very precise measurements the mission is after. This orbital path carries the spacecraft repeatedly through hazardous radiation belts — but avoids the most powerful radiation belts. Jupiter's radiation belts are analogous to Earth's Van Allen belts — but far more deadly.

The spacecraft will orbit Jupiter 33 times, skimming to within 3,100 miles (5,000 kilometers) above the planet's cloud tops every 11 days, for approximately one year.

Mission Phases

Phase	Begin	Duration (days)
Pre-Launch	L-3d 08/02/11	3
Launch	L-0.75h 08/05/11	2.3
Inner Cruise 1	L+2.3d 08/08/11	61
Inner Cruise 2	L+63d 10/08/11	598
Inner Cruise 3	L+661d 05/28/13	161
Quiet Cruise	L+822d 11/05/13	791
Jupiter Approach	JOI-182d 01/05/16	178
JOI	JOI-4d 07/01/16	4
Capture Orbit	JOI+1h 07/05/16	106
PRM	PRM-18h 10/19/16	1
Orbit 1-2	PRM+11h 10/20/16	20
Science Orbits	PJ3-1d 11/09/16	336
Deorbit	AJ33-1h 10/11/17	5.5

Thirteen mission phases have been defined to describe the different periods of activity during Juno's travels. These phases are: Pre-Launch, Launch, Inner Cruise 1, Inner Cruise 2, Inner Cruise 3, Quiet Cruise, Jupiter Approach, Jupiter Orbit Insertion, Capture Orbit, Period Reduction Maneuver, Orbit 1-2, Science Orbits and Deorbit.

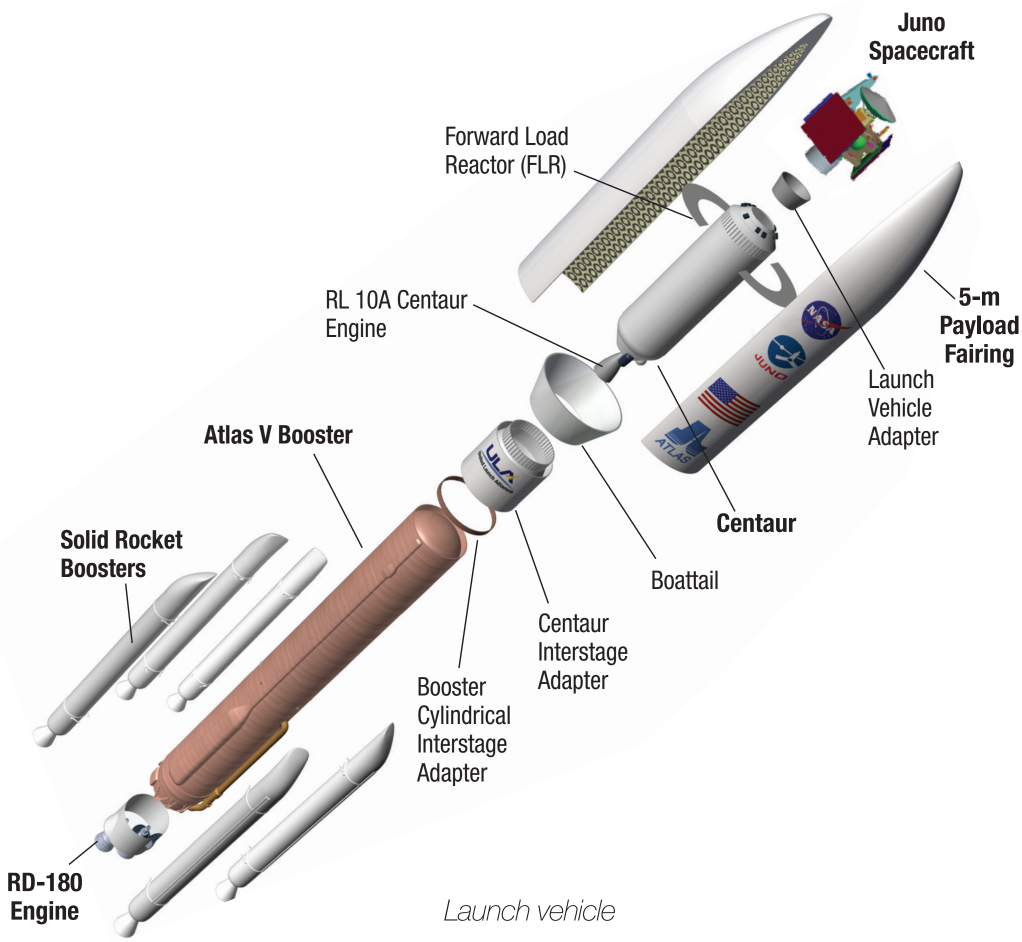
Pre-Launch Phase

The Flight System is mated to the launch vehicle at L-10 days. Juno uses Space Launch Complex 41 (SLC-41) at Cape Canaveral Air Force Station, the same launch pad used by NASA's New Horizons mission and other Atlas V launch vehicles.

The Pre-Launch mission phase lasts from spacecraft power-up at L-3 days to final spacecraft configuration at L-45 minutes. Juno's launch period lasts 22 days (Aug. 5–26, 2011) with a launch window at least 60 minutes in duration every day of the launch period. The launch period has been optimized to maximize injected mass into Jupiter science orbits.

Launch Vehicle

The Atlas V551 is a two-stage launch vehicle that uses a standard Atlas booster with five solid rocket boosters in the first stage and a Centaur upper stage for the second. The Centaur upper stage has a restartable engine and is three-axis stabilized. Guidance and navigation are provided by the Centaur following launch. The Juno spacecraft is enclosed for the flight through Earth's atmosphere in the Atlas's 16.4-foot (5-meter) diameter, 68-foot (20.7-meter) long payload fairing.



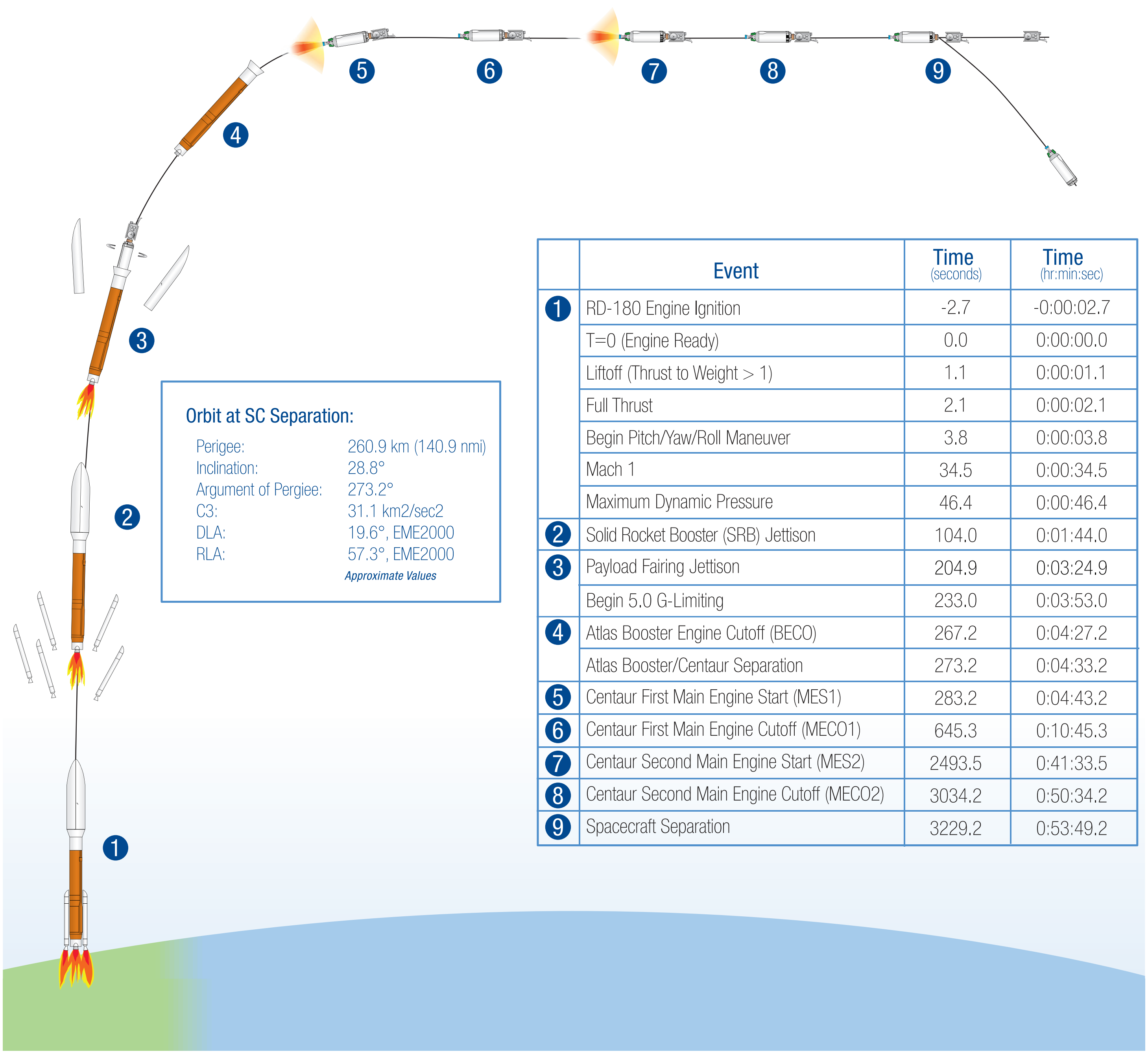
Launch vehicle

Boost Profile and Injection

The boost phase begins with the ignition of the booster engine system. Liftoff occurs when the Atlas's five solid rocket boosters are ignited.

Upon burnout of the solid rocket boosters (at approximately 104 seconds after launch) they are stagger jettisoned: first solids 1 and 2, then 1.5 seconds later, solids 3, 4 and 5.

The launch vehicle is throttled to maintain 2.5 g's for Payload Fairing Jettison, which occurs a little under three-and-a-half minutes after launch. Following jettison of the payload fairing, acceleration is maintained at 5.0 g's until booster engine cutoff. The Atlas/Centaur separation occurs approximately six seconds after booster engine cutoff. The first burn of the second stage of the Centaur rocket begins 10 seconds after the separation. The first Centaur burn lasts about six minutes and completes when the vehicle has achieved its target parking orbit.



Orbit at SC Separation:

Perigee:	260.9 km (140.9 nmi)
Inclination:	28.8°
Argument of Pergiee:	273.2°
C3:	31.1 km2/sec2
DLA:	19.6°, EME2000
RLA:	57.3°, EME2000

Approximate Values

	Event	Time (seconds)	Time (hr:min:sec)
1	RD-180 Engine Ignition	-2.7	-0:00:02.7
	T=0 (Engine Ready)	0.0	0:00:00.0
	Liftoff (Thrust to Weight > 1)	1.1	0:00:01.1
	Full Thrust	2.1	0:00:02.1
	Begin Pitch/Yaw/Roll Maneuver	3.8	0:00:03.8
	Mach 1	34.5	0:00:34.5
	Maximum Dynamic Pressure	46.4	0:00:46.4
2	Solid Rocket Booster (SRB) Jettison	104.0	0:01:44.0
3	Payload Fairing Jettison	204.9	0:03:24.9
	Begin 5.0 G-Limiting	233.0	0:03:53.0
4	Atlas Booster Engine Cutoff (BECO)	267.2	0:04:27.2
	Atlas Booster/Centaur Separation	273.2	0:04:33.2
5	Centaur First Main Engine Start (MES1)	283.2	0:04:43.2
6	Centaur First Main Engine Cutoff (MECO1)	645.3	0:10:45.3
7	Centaur Second Main Engine Start (MES2)	2493.5	0:41:33.5
8	Centaur Second Main Engine Cutoff (MECO2)	3034.2	0:50:34.2
9	Spacecraft Separation	3229.2	0:53:49.2

Launch profile

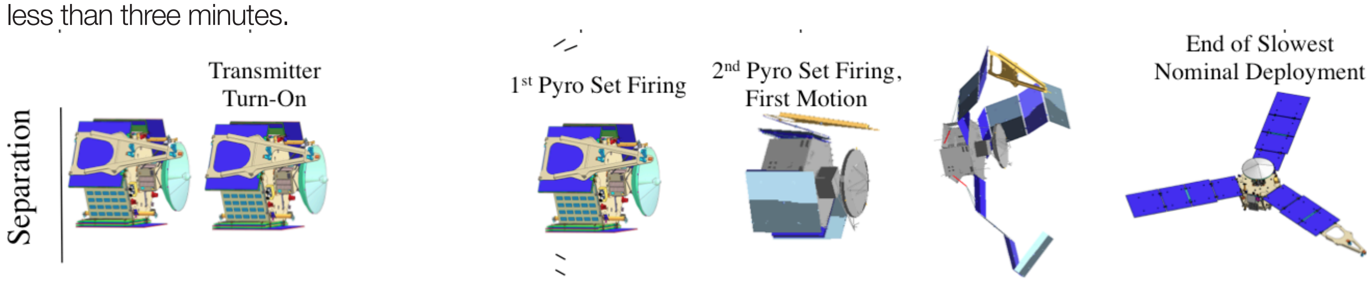
During the parking orbit coast period (approximately 30 minutes in length), the Centaur turns itself and the spacecraft to the required attitude for the start of its second burn. The Centaur's second burn (approximately nine minutes in length) places Juno on the desired departure trajectory.

Following the completion of its second burn, the Centaur turns to a pre-planned separation attitude and initiates a 1.4 revolutions per minute roll rate. The Juno spacecraft is scheduled to separate from its Centaur booster about three-and-a-half minutes after the Centaur completes its burn. At the time of separation, a clampband releases and push-off springs push the Juno spacecraft from the Centaur.

Solar Array Deployment

Juno's massive solar arrays are scheduled to begin deployment about five minutes following separation. The length of time it takes for deployment is expected to be less than three minutes.

Transition to the Cruise mission phase is expected to occur three days after launch.



Solar array deployment sequence

Cruise Phases

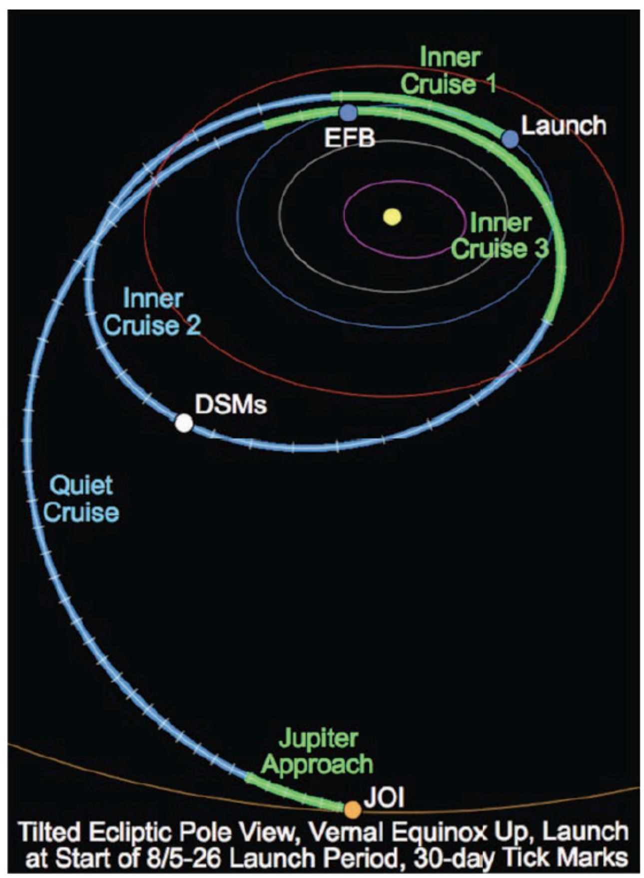
Juno's trajectory to Jupiter consists of five phases over five years and one-and-a-half loops of the sun.

There are four cruise phases: Inner Cruise 1 (61 days), Inner Cruise 2 (598 days), Inner Cruise 3 (161 days), and Quiet Cruise (791 days).

During cruise, the spacecraft is usually oriented so that its high-gain antenna is Earth-pointed. However, close to the sun there are times where thermal and power requirements do not allow for Earth-pointing of the antenna. At these times the spacecraft is pointed off-sun in such a way that thermal requirements can be met.

Inner Cruise Phase 1

The Inner Cruise 1 phase spans the interval from L+3 to L+63 days. It is characterized by initial spacecraft and instrument checkouts, deployment of the Waves instrument antenna, Juno's first trajectory correction maneuver, and the location of the spacecraft far enough from the sun to allow Earth-pointing instead of sun-pointing.



Earth–Jupiter trajectory

Inner Cruise Phase 2

The Inner Cruise 2 phase spans the period from L+63 days until L+661 days (1.6 years in length). The mission's two deep space maneuvers occur during this phase, prior to the spacecraft's one Earth flyby. Other spacecraft activities during the Inner Cruise 2 phase include calibrations and alignments associated with using the high-gain antenna for the first time. The spacecraft's science instruments are also checked out again.

Inner Cruise Phase 3

The Inner Cruise 3 phase spans the interval from L+661 days to L+822 days. During this time, the Juno flight team is focused on performing the required maneuvers, as well as an integrated operations exercise around Earth flyby.

The Earth flyby occurs as the spacecraft is completing one elliptical orbit around the sun. It will boost Juno's velocity by 16,330 miles per hour (about 7.3 kilometers per second), placing the spacecraft on its final trajectory for Jupiter. Closest approach to Earth occurs on Oct. 9, 2013, at an altitude of 310 miles (500 kilometers). The exact time of closest approach will vary by about eight hours on this date, depending on launch date.

During the flyby, Juno will pass behind Earth as seen from the sun, causing an interval when Earth blocks the sun's rays from reaching the spacecraft's solar panels, The time in eclipse is about 20 minutes, and represents the only time after Launch Phase when Juno will not receive direct sunlight.

Three trajectory correction maneuvers are planned before and one after Earth flyby to refine Juno's trajectory.

Quiet Cruise Phase

The Quiet Cruise phase lasts from L+822 days until the start of Jupiter Approach at L+1,613 days. During the tail end of the Quiet Cruise phase, which lasts for 26 months, the Juno project team will be staffed up to levels anticipated as needed for upcoming operations around Jupiter.

Jupiter Approach Phase

The Jupiter Approach phase lasts the final six months of cruise (178 days) before Jupiter Orbit Insertion. The phase ends at Jupiter Orbit Insertion minus four days, which is the start of the critical sequence that will result in the spacecraft orbiting Jupiter.

This phase is characterized by instrument checkouts as well as initial science observations of Jupiter. Calibrations and science observations performed during this phase go a long way toward validating instrument performance in the Jupiter environment, testing the data processing pipeline, and preparing the team for successfully returning baseline Jupiter science data starting in Orbit 3.

Jupiter Orbit Insertion Phase

The Jupiter Orbit Insertion phase begins four days before the start of the orbit insertion maneuver and ends one hour after the start of the insertion maneuver. Jupiter Orbit Insertion occurs at closest approach to Jupiter, and slows the spacecraft enough to let it be captured by Jupiter into a 107-day-long orbit. The insertion maneuver also sets up the orbital geometry for future 11-day science orbits.

The Jupiter Orbit Insertion burn is performed on the main engine (the third large main engine burn of the mission). The burn will last 30 minutes and is designed to be performed in view of Earth. After the burn, the spacecraft is in a polar orbit around Jupiter.

Capture Orbit Phase

The Capture Orbit phase starts at Jupiter Orbit Insertion plus one hour and ends 18 hours before the Period Reduction Maneuver 106 days later. The 107-day Capture Orbit provides substantial propellant savings with respect to a direct Jupiter Orbit Insertion entry into an 11-day orbit.

A cleanup maneuver 7.6 days after the beginning of this phase is performed to ensure the timing of the large burn in the upcoming phase. Instruments are on for most of the Capture Orbit, and there are routine checkouts and science observations.

The Capture Orbit is an opportunity to gain valuable early orbital operations experience with the spacecraft as well as the instruments. The team plans to have all the instruments on and taking data beginning 50 hours after Jupiter Orbit Insertion.

As with Jupiter Approach observations, calibrations and science observations performed during the Capture Orbit go a long way toward validating instrument performance in the Jupiter Environment.

Period Reduction Maneuver Phase

During the Period Reduction Maneuver phase, Juno transitions from an orbit that takes 107 days to circumnavigate Jupiter to one that takes only 11 days. The phase starts 18 hours before the maneuver and concludes 11 hours after the maneuver is complete. The rocket firing that takes place during this maneuver is a larger burn in duration (37 minutes) than the Jupiter Orbit Insertion burn. The Period Reduction Maneuver burn is performed on the main engine (the fourth and last large main engine burn of the mission). No science observations are planned during this phase.

Orbits 1–2 Phase

The Orbits 1–2 phase starts 11 hours after the Period Reduction Maneuver burn — near the beginning of the first 11-day orbit. This phase ends 20 days later with the commencement of the mission's first science orbit.

Orbit 2 and Planned Science

In addition to calibrations and other instrument preparations for the science orbits, preliminary Orbit 2 science plans include: remote sensing movies and atmospheric dynamics measurements, water abundance observations and fields and particles observations like those planned for the science orbits.

Science Orbits Phase

The Science Orbits phase includes Orbit 3 through Orbit 33 and lasts 336 days. Small orbital trim maneuvers are planned about four hours after each set of perijove (closest approach to Jupiter) science observations. These maneuvers target the longitude required for science observations in the next orbit.

Juno's Highly Elliptical Polar Orbits

Orbiting Jupiter around the poles carries Juno repeatedly over every latitude. As the planet rotates beneath the spacecraft, the entire surface can be covered by Juno's suite of instruments.

For many of the instruments to do their job, the spacecraft has to get closer to Jupiter than any previous mission. To avoid the highest levels of radiation in the belts surrounding Jupiter, mission navigators have designed a highly elongated orbit that approaches the gas giant from the north. Flying south, the spacecraft's point of closest approach will be about 3,100 miles (5,000 kilometers) above the cloud tops. As Juno exits over the south pole, its orbit carries it far beyond even the Jovian moon Callisto's orbit.

Juno's elliptical orbit around Jupiter has another benefit. It allows the spacecraft's three massive solar panels to be constantly bathed in sunlight. This is important because the amount of sunlight that reaches Jupiter is only 1/25th that which reaches Earth. To keep the spacecraft's instruments and operating systems powered requires the solar panels to have an almost constant exposure to the available sunlight.

Deorbit Phase

The Deorbit phase occurs during the final orbit of the mission. The 5.5-day phase starts several days after the Orbit 33 science pass and ends with impact into Jupiter during the following orbit.

The deorbit maneuver was designed to satisfy NASA's planetary protection requirements and ensure that Juno does not impact Europa (as well as Ganymede and Callisto).

By orbit 34, a deorbit burn will be executed, placing the spacecraft on a trajectory that will reset its point of closest approach to the planet to an altitude that is below the cloud tops at 34 degrees North Jupiter latitude on Oct. 16, 2017. Juno is not designed to operate inside an atmosphere and will burn up.

Spacecraft

Juno uses a spinning, solar-powered spacecraft in a highly elliptical polar orbit that avoids most of Jupiter's high-radiation regions. The designs of the individual instruments are straightforward and the mission did not require the development of any new technologies.

Why A Rotating Spacecraft?

For Juno, like NASA's earlier Pioneer spacecraft, spinning makes the spacecraft's pointing extremely stable and easy to control. Just after launch, and before its solar arrays are deployed, Juno will be spun-up by rocket motors on its still-attached second-stage rocket booster. Juno's planned spin rate varies during the mission: 1 RPM for cruise, 2 RPM for science operations and 5 RPM for main engine maneuvers.

To simplify and decrease weight, all instruments are fixed. While in orbit at Jupiter, the spinning spacecraft will sweep the fields of view of its instruments through space once for each rotation. At two rotations per minute, the instruments' fields of view sweep across Jupiter about 400 times in the two hours it takes Juno to fly from pole to pole.

Structure

The spacecraft's main body measures 11.5 feet (3.5 meters) tall and 11.5 feet (3.5 meters) in diameter. The spacecraft's hexagonal two-deck structure uses composite panel and clip construction for decks, central cylinder and gusset panels. Polar mounted off-center spherical tanks provide spinning spacecraft designs with high stability.

Propulsion System

For weight savings and redundancy, Juno uses a dual-mode propulsion subsystem, with a bi-propellant main engine and mono-propellant reaction control system thrusters.

The Leros-1b main engine is a 645-Newton bi-propellant thruster using hydrazine–nitrogen tetroxide. Its engine bell is enclosed in a micrometeoroid shield that opens for engine burns. The engine is fixed to the spacecraft body firing aft and is used for major maneuvers and flushing burns.

The 12 reaction control system thrusters are mounted on four rocket engine modules. They allow translation and rotation about three axes. They are also used for most trajectory correction maneuvers.

Command and Data Handling

Command and data handling includes a RAD750 flight processor with 256 megabytes of flash memory and 128 megabytes of DRAM local memory. It provides 100 Mbps total instrument throughput, more than enough for payload requirements.

Electronics Vault

To protect sensitive spacecraft electronics, Juno will carry the first-of-its-kind radiation shielded electronics vault, a critical feature for enabling sustained exploration in such a heavy radiation environment. Each of the titanium cube's eight sides measures nearly a square meter (nearly 9 square feet) in area, about a third of an inch (1 centimeter) in thickness, and 4 pounds (18 kilograms) in mass. This titanium box — about the size of an SUV's trunk — encloses Juno's command and data handling box (the spacecraft's brain), power and data distribution unit (its heart) and about 20 other electronic assemblies. The whole vault weighs about 500 pounds (200 kilograms).

Power

Juno's Electrical Power Subsystem manages the spacecraft power bus and distribution of power to payloads, propulsion, heaters and avionics. The power distribution and drive unit monitors and manages the spacecraft power bus, manages the available solar array power to meet the spacecraft load and battery state of charge, and provides controlled power distribution.

Power generation is provided by three solar arrays consisting of 11 solar panels and one MAG boom. Two 55 amp-hour lithium-ion batteries provide power when Juno is off-sun or in eclipse, and are tolerant of the Jupiter radiation environment. The power modes during science orbits are sized for either data collection during an orbit emphasizing microwave radiometry or gravity science.

Solar Power

Jupiter's orbit is five times farther from the sun than Earth's, so the giant planet receives 25 times less sunlight than Earth. Juno will be the first solar-powered spacecraft designed to operate at such a great distance from the sun, thus the surface area of solar panels required to generate adequate power is quite large.

Juno benefits from advances in solar cell design with modern cells that are 50 percent more efficient and radiation-tolerant than silicon cells available for space missions 20 years ago. The mission's power needs are modest. Juno has energy-efficient science instruments. Solar power is possible on Juno due to the energy-efficient instruments and spacecraft, a mission design that can avoid Jupiter's shadow and a polar orbit that minimizes the total radiation.

The spacecraft's three solar panels extend outward from Juno's hexagonal body, giving the overall spacecraft a span of more than 66 feet (20 meters). The solar panels will remain in sunlight continuously from launch through end of mission, except for a few minutes during the Earth flyby. Before deployment in space, the solar panels are folded into four-hinged segments so the spacecraft can fit into the launch vehicle's payload fairing.

Thermal Control

Juno's thermal control subsystem uses a passive design with heaters and louvers. The main component of the thermal control subsystem consists of an insulated, louvered electronics vault atop an insulated, heated propulsion module. This design accommodates all mission thermal environments from Earth orbit to Jupiter orbital operations. During cruise, while the spacecraft is close to the sun, the high-gain antenna is used as a heat shield to protect the vault avionics.

Most instrument electronics are contained within the radiation vault and are thermally managed as part of the vault thermal control system. Science sensors are externally mounted to the deck and are individually blanketed and heated to maintain individual temperature limits.

Telecommunications

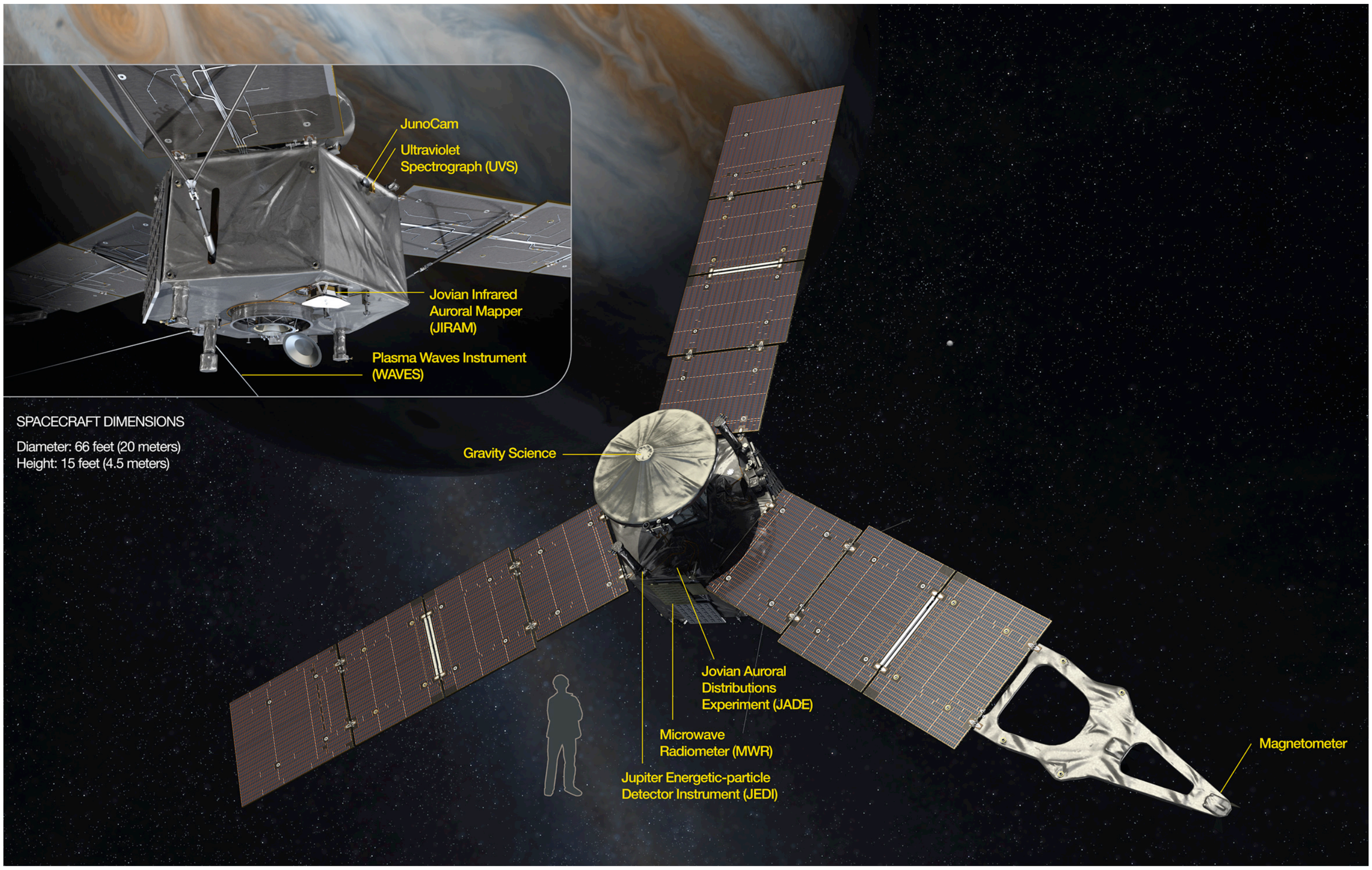
The gravity science and telecom subsystem provides X-band command uplink and engineering telemetry and science data downlink for the entire post-launch, cruise and Jupiter orbital operations. The subsystem also provides for dual-band (X- and Ka-band) Doppler tracking for gravity science at Jupiter.

Science Instruments

The Juno spacecraft carries a payload of 29 sensors, which feed data to nine onboard instruments. Eight of these instruments (MAG, MWR, Gravity Science, Waves, JEDI, JADE, UVS, JIRAM) are considered the science payload. One instrument, JunoCam, is aboard to generate images for education and public outreach.

Primary science observations are obtained within three hours of closest approach to Jupiter, although calibrations, occasional remote sensing and magnetospheric science observations are planned throughout the science orbits around Jupiter.

Juno is spin-stabilized. Because of the spacecraft mission design and the fact that its science instruments were all developed together, and there is no need for a scan platform to point instruments in different directions. Gravity science and microwave sounding of the atmosphere observations are obtained through orientation of the spacecraft's spin plane. All other experiments utilize ride-along pointing and work in either one or both orientations. This design allows for very simple operations.



Juno spacecraft

Gravity Science

The Gravity Science experiment will enable Juno to measure Jupiter's gravitational field and reveal the planet's internal structure.

Two transponders operating on different frequencies (Ka- and X-band) will detect signals sent from NASA's Deep Space Network on Earth and immediately send signals in return. Small changes in the signal's frequencies (as they are received on Earth) provide data on how much Juno's velocity has been modified due to local variations in Jupiter's gravity. These subtle shifts in Juno's velocity reveal the gas giant's gravity (and how the planet is arranged on the inside), and provide insight into the gas giant's internal structure.

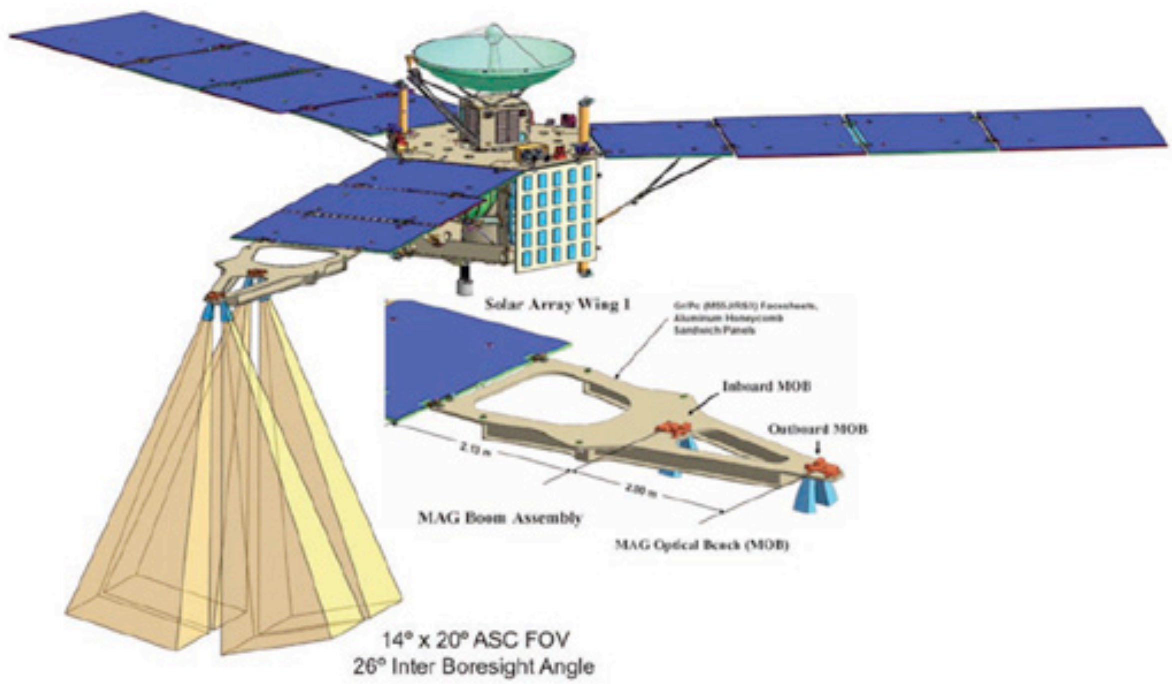
Agenzia Spaziale Italiana in Rome, Italy contributed the Ka-band translator system.

Magnetometer (MAG)

Juno's Magnetometer creates a detailed three-dimensional map of Jupiter's magnetic field.

Juno's Magnetometer instrument is a flux gate type magnetometer, which measures the strength and direction of Jupiter's magnetic field lines. An Advanced Stellar Compass images stars to provide information on the exact orientation of the magnetometer sensors. This enables Juno's very precise magnetic field measurement. Magnetometer sensors are mounted on the magnetometer boom at the end of one of Juno's three solar arrays — as far away from the spacecraft body as possible. This was done to avoid the instruments from confusing the spacecraft magnetic field with Jupiter's. The boom is designed to mimic the outermost solar array panel (of the remaining two solar array structures) in mass and mechanical deployment.

The spacecraft magnetic field is further separated from Jupiter's field by the use of two magnetometer sensors — one 33 feet (10 meters) from the center of the spacecraft and one 39 feet (12 meters) from the center. By comparing measurements from both sensors, scientists can isolate the magnetic field of Juno from Jupiter. The Flux Gate Magnetometer was designed and built by NASA's Goddard Space Flight Center Greenbelt, Md., and the Advanced Stellar Compass was designed and built by the Danish Technical University in Lyngby, Denmark.



Magnetometer

Microwave Radiometer (MWR)

Juno's Microwave Radiometer instrument will probe beneath Jupiter's cloud tops to provide data on the structure, movement and chemical composition to a depth as great as 1,000 atmospheres — about 342 miles (550 kilometers) below the visible cloud tops.

The Microwave Radiometer consists of six radiometers designed to measure the microwaves coming from six cloud levels. Each of the six radiometers has an antenna extending from Juno's hexagonal body. Each antenna is connected by a cable to a receiver, which sits in the instrument vault on top of the spacecraft. NASA's Jet Propulsion Laboratory in Pasadena, Calif. provided the Microwave Radiometer subsystem components, including the antennas and receivers.

Jupiter Energetic Particle Detector Instrument (JEDI)

The Jupiter Energetic Particle Detector Instrument will measure the energetic particles that stream through space and study how they interact with Jupiter's magnetic field.

JEDI comprises three identical sensor units each with 6 ion and 6 electron views. The instrument works in coordination with the JADE and Waves instruments to investigate Jupiter's polar space environment, with a particular focus on the physics of Jupiter's intense and impressive northern and southern auroral lights.

The instrument was designed and built by the Johns Hopkins University's Applied Physics Laboratory, Laurel, Md.

Jovian Auroral Distributions Experiment (JADE)

The Jovian Auroral Distributions Experiment will work with some of Juno's other instruments to identify the particles and processes that produce Jupiter's stunning auroras.

The Jovian Auroral Distributions Experiment consists of an electronics box shared by four sensors: three will detect the electrons that surround the spacecraft ,and the fourth will identify positively charged hydrogen, helium, oxygen and sulfur ions. When Juno flies directly over auroras, the instrument will be able to characterize the particles that are coming down Jupiter's magnetic field lines and crashing into Jupiter's atmosphere.

The Jovian Auroral Distributions Experiment was designed and built by the Southwest Research Institute in San Antonio.

Waves

The Waves instrument will measure radio and plasma waves in Jupiter's magnetosphere, helping us understand the interactions between the magnetic field, the atmosphere and the magnetosphere.

The Waves instrument consists of a V-shaped antenna that is about 13 feet (four meters) from tip to tip, similar to the rabbit-ear antennas that were once common on TVs. One of the ears of the Waves instrument detects the electric component of radio and plasma waves, while the other is sensitive to the magnetic component. The magnetic antenna — called a magnetic search coil — consists of a coil of fine wire wrapped 10,000 times around a 5.9-inch (15-centimeter) long core. The search coil measures magnetic fluctuations in the audio frequency range.

The Waves instrument was designed and built by the University of Iowa in Iowa City.

Ultraviolet Imaging Spectrograph (UVS)

The Ultraviolet Imaging Spectrograph will take pictures of Jupiter's auroras in ultraviolet light. Working with Juno's JADE and JEDI instruments, which measure the particles that create the auroras, UVS will help us understand the relationship between the auroras, the streaming particles that create them and the magnetosphere as a whole.

The Ultraviolet Imaging Spectrograph instrument consists of two separate sections: a dedicated telescope/spectrograph assembly and a vault electronics box. The telescope/spectrograph assembly contains a telescope which focuses collected light into a spectrograph. The instrument's electronics box is located in Juno's radiation-shielded spacecraft vault.

The Ultraviolet Imaging Spectrograph instrument was designed and built by Southwest Research Institute in San Antonio.

Jovian Infrared Auroral Mapper (JIRAM)

The Jovian Infrared Auroral Mapper will study Jupiter's atmosphere in and around the auroras, helping us learn more about the interactions between the auroras, the magnetic field and the magnetosphere. JIRAM will be able to probe the atmosphere down to 30 to 45 miles (50 to 70 kilometers) below the cloud tops, where the pressure is five to seven times greater than on Earth at sea level.

The Jovian Infrared Auroral Mapper instrument consists of a camera and a spectrometer, which splits light into its component wavelengths, like a prism. The camera will take pictures in infrared light, which is heat radiation, with wavelengths of two to five microns (millionths of a meter) — three to seven times longer than visible wavelengths.

The Jovian Infrared Auroral Mapper instrument was designed and built by the Italian National Institute for Astrophysics, Milano, Italy, and funded by the Agenzia Spaziale Italiana in Rome.

JunoCam

JunoCam will capture color pictures of Jupiter's cloud tops in visible light.

JunoCam will provide a wide-angle view of Jupiter's atmosphere and poles. JunoCam is designed as an outreach full-color camera to engage the public. The public will be involved in developing the images from raw data and even helping to design which areas of Jupiter should be imaged.

The JunoCam camera head has a lens with a 58-degree cross-scan field of view. It acquires images by sweeping out that field while the spacecraft spins to cover an along-scan field of view of 360 degrees. Lines containing dark sky are subsequently compressed to an insignificant data volume. It takes images mainly when Juno is very close to Jupiter, with a maximum resolution of up to 1 to 2 miles (2 to 3 kilometers) per pixel. The wide-angle camera will provide new views of Jupiter's atmosphere.

JunoCam's hardware is based on a descent camera that was developed for NASA's Mars Science Laboratory rover. Some of its software was originally developed for NASA's Mars Odyssey and Mars Reconnaissance Orbiter spacecraft. JunoCam is provided by Malin Space Science Systems, San Diego. Calif.

Science Overview

The Giant Planet Story is the Story of the Solar System

The principal goal of NASA's Juno mission is to understand the origin and evolution of Jupiter. Underneath its dense cloud cover, Jupiter safeguards secrets to the fundamental processes and conditions that governed our solar system during its formation. As our primary example of a giant planet, Jupiter can also provide critical knowledge for understanding the planetary systems being discovered around other stars.

With its suite of science instruments, Juno will investigate the existence of a possible solid planetary core, map Jupiter's intense magnetic field, measure the amount of water and ammonia in the deep atmosphere, and observe the planet's auroras.

Juno will let us take a giant step forward in our understanding of how giant planets form and the role these titans played in putting together the rest of the solar system.

Jupiter's Origins and Interior

Theories about solar system formation all begin with the collapse of a giant cloud of gas and dust, or nebula, most of which formed the infant sun, our star. Like the sun, Jupiter is mostly hydrogen and helium, so it must have formed early, capturing most of the material left after our star came to be. How this happened, however, is unclear. Did a massive planetary core form first and capture all that gas gravitationally, or did an unstable region collapse inside the nebula, triggering the planet's formation? Differences between these scenarios are profound.

Even more importantly, the composition and role of icy planetesimals, or small protoplanets, in planetary formation hangs in the balance — and with them, the origin of Earth and other terrestrial planets. Icy planetesimals likely were the carriers of materials like water and carbon compounds that are the fundamental building blocks of life.

Unlike Earth, Jupiter's giant mass allowed it to hold onto its original composition, providing us with a way of tracing our solar system's history. Juno will measure the amount of water and ammonia in Jupiter's atmosphere and help determine if the planet has a core of heavy elements, constraining models on the origin of this giant planet and thereby the solar system. By mapping Jupiter's gravitational and magnetic fields, Juno will reveal the planet's interior structure and measure the mass of the core.

Atmosphere

How deep Jupiter's colorful zones, belts and other features penetrate is one of the most outstanding fundamental questions about the giant planet. Juno will determine the global structure and motions of the planet's atmosphere below the cloud tops for the first time, mapping variations in the atmosphere's composition, temperature, clouds and patterns of movement down to unprecedented depths.

Magnetosphere

Deep in Jupiter's atmosphere, under great pressure, hydrogen gas is squeezed into a fluid known as metallic hydrogen. At these enormous pressures, the hydrogen acts like an electrically conducting metal, which is believed to be the source of the planet's intense magnetic field. This powerful magnetic environment creates the brightest auroras in our solar system, as charged particles precipitate down into the planet's atmosphere. Juno will directly sample the charged particles and magnetic fields near Jupiter's poles for the first time, while simultaneously observing the auroras in ultraviolet light produced by the extraordinary amounts of energy crashing into the polar regions. These investigations will greatly improve our understanding of this remarkable phenomenon, and also of similar magnetic objects, like young stars with their own planetary systems.

Juno Science Objectives

The primary science objectives of the mission are as follows:

Origin
Determine the abundance of water and place an upper limit on the mass of Jupiter's possible solid core to decide which theory of the planet's origin is correct

Interior
Understand Jupiter's interior structure and how material moves deep within the planet by mapping its gravitational and magnetic fields

Atmosphere
Map variations in atmospheric composition, temperature, cloud opacity and dynamics to depths greater than 100 bars at all latitudes.

Magnetosphere
Characterize and explore the three-dimensional structure of Jupiter's polar magnetosphere and auroras
The overall goal of the Juno mission is to improve our understanding of the solar system by understanding the origin and evolution of Jupiter. It addresses science objectives central to three NASA Science divisions: Solar System (Planetary), Earth–Sun System (Heliophysics), and Universe (Astrophysics).

Juno's primary science goal of understanding the formation, evolution, and structure of Jupiter is directly related to the conditions in the early solar system, which led to the formation of our planetary system. The mass of Jupiter's possible solid core and the abundance of heavy elements in the atmosphere discriminate among models for giant planet formation. Juno constrains the core mass by mapping the gravitational field, and measures through microwave sounding the global abundances of oxygen (water) and nitrogen (ammonia).

Juno reveals the history of Jupiter by mapping the gravitational and magnetic fields with sufficient resolution to constrain Jupiter's interior structure, the source region of the magnetic field, and the nature of deep convection. By sounding deep into Jupiter's atmosphere, Juno determines to what depth the belts and zones penetrate. Juno provides the first survey and exploration of the three-dimensional structure of Jupiter's polar magnetosphere.

Missions to Jupiter

Since 1972, Jupiter has been a port-of-call or final destination for eight NASA missions.

Pioneer 10
Launch: March 2, 1972
Jupiter flyby: December 3, 1973

NASA's Pioneer 10 was the first spacecraft to pass through the Asteroid Belt and explore Jupiter. It flew within 124,000 miles (200,000 kilometers) of the Jovian cloud tops. Scientists were surprised at the tremendous radiation levels experienced by the spacecraft as it passed the gas giant planet.

Pioneer 11
Launch: April 5, 1973
Jupiter flyby: December 2, 1974

Pioneer 11 flew within 21,100 miles (34,000 kilometers) of the Jovian cloud tops. The spacecraft studied the planet's magnetic field and atmosphere and took pictures of the planet and some of its moons.

Voyager 1
Launch: September 5, 1977
Jupiter encounter: January 4 to April 13, 1979

Launched 16 days after Voyager 2, Voyager 1 was on the fast track to Jupiter and actually arrived four months ahead of the other spacecraft. Voyager 1 flew by Jupiter on March 5, 1979, taking more than 18,000 images of planet and its moons.

Voyager 2
Launch: August 20, 1977
Jupiter encounter: April 25 to August 5, 1979

Voyager 2 flew by Jupiter on July 9, 1979, and took approximately 18,000 images of Jupiter and its moons.

Galileo
Launch: October 18, 1989
Jupiter probe descent: December 7, 1995
Jupiter orbit insertion: December 8, 1995
Plunge into Jupiter: September 22, 2003

Galileo was the first spacecraft to dwell in a giant planet's magnetosphere long enough to identify its global structure and investigate the dynamics of Jupiter's magnetic field. It revealed that Jupiter had a ring system. Galileo was the first spacecraft to deploy a probe into an outer planet's atmosphere. The spacecraft's mission was extended three times in order to study the Galilean satellites Io, Europa, Ganymede and Callisto.

To avoid any possibility of the spacecraft contaminating any of Jupiter's moons, upon completion of its third mission extension, Galileo was deliberately sent into the planet's atmosphere, where it burned up.

Ulysses
Launch: October 6, 1990
Jupiter flyby: February 8, 1992

Ulysses' mission was to study the north and south pole of the sun. To get into an orbit that would take it over the sun's poles, Ulysses used the strong Jovian gravity to bend its trajectory. As Ulysses flew by the planet, instruments onboard the spacecraft studied Jupiter's strong magnetic field and radiation levels.

Cassini–Huygens
Launch: October 15, 1997
Jupiter flyby: December 30, 2000

Cassini–Huygens' orbital path to Saturn required flybys of Venus, Earth and Jupiter. The Cassini mission team used its encounter with Jupiter to test the spacecraft's instruments and operations.

New Horizons
Launch: January 19, 2006
Jupiter flyby: January–May, 2007

New Horizons used Jupiter's massive gravity to place it on a trajectory for Pluto. Beginning in early 2007, the spacecraft observed Jupiter over five months. Date of its closest approach with Jupiter was on February 28, 2007.

Program/Project Management

Juno's principal investigator is Scott Bolton of Southwest Research Institute in San Antonio. Steve Levin of NASA's Jet Propulsion Laboratory, Pasadena, Calif., is project scientist.

NASA's Jet Propulsion Laboratory, Pasadena, Calif., manages the Juno mission for the principal investigator. The Juno mission is part of the New Frontiers Program managed at NASA's Marshall Space Flight Center in Huntsville, Ala. Lockheed Martin Space Systems, Denver, built the spacecraft. Launch management for the mission is the responsibility of NASA's Launch Services Program at the Kennedy Space Center in Florida. JPL is a division of the California Institute of Technology in Pasadena. At NASA Headquarters, Ed Weiler is associate administrator for the Science Mission Directorate. Jim Green is director of the Planetary Science Division. Dennon Clardy is the manager of the Discovery/New Frontiers Program office, Adrianna O'Campo is Juno program executive, and Mary Mellot is Juno program scientist.

At JPL, Jan Chodas is project manager. Rick Nybakken is deputy project manager.

Lockheed Martin Space Systems in Denver designed and built Juno and will handle its day-to-day operations. Tim Gasparrini is the company's Juno program manager and leads the Juno flight team. The United Launch Alliance is responsible for the Atlas V rocket that will carry Juno into space.

More information about Juno is online at http://www.nasa.gov/juno and http://missionjuno.swri.edu .

NASA's New Frontiers Program

The Juno mission is the second spacecraft designed under NASA's New Frontiers Program. The first was the Pluto New Horizons mission, launched in January 2006 and scheduled to reach Pluto's moon Charon in 2015. The third mission will be the Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer, or OSIRIS-Rex — the first U.S. mission to carry materials from an asteroid back to Earth. The program provides opportunities to carry out medium-class missions identified as top priority objectives in the Decadal Solar System Exploration Survey, conducted by the Space Studies Board of the National Research Council in Washington.

More information is online at http://newfrontiers.nasa.gov/program_plan.html .

Juno Science Team

Scott Bolton, principal investigator,
Southwest Research Institute, San Antonio

John Connerney, deputy principal investigator,
Goddard Space Flight Center, Greenbelt, Md.

Steve Levin, project scientist,
NASA's Jet Propulsion Laboratory, Pasadena, Calif.

Instrument Leads

Michael Janssen — MWR Instrument Lead,
Jet Propulsion Laboratory

John Connerney — MAG Instrument Lead,
Goddard Space Flight Center

David McComas — JADE Instrument Lead,
Southwest Research Institute

William Folkner — Gravity Science Investigation Lead,
Jet Propulsion Laboratory

Barry Mauk — JEDI Instrument Lead,
Johns Hopkins University/Applied Physics Laboratory

William Kurth — Waves Instrument Lead, Univ. of Iowa

Randy Gladstone — UVS Instrument Lead,
Southwest Research Institute

Michael Ravine — JunoCam Instrument Lead,
Malin Space Science Systems

Angioletta Coradini — JIRAM Instrument Lead,
Italian Space Agency

Co-Investigators

Michael Allison	Goddard Space Flight Center
John Anderson	Jet Propulsion Laboratory
Sushil Atreya	University of Michigan
Fran Bagenal	University of Colorado
Michel Blanc	L'Observatoire Midi Pyrénées
Jeremy Bloxham	Harvard University
Stanley Cowley	University of Leicester
Eric DeJong	Jet Propulsion Laboratory
Daniel Gautier	LESIA Observatoire de Paris
Tristan Guillot	Observatoire de la Cote d'Azur
Samuel Gulkis	Jet Propulsion Laboratory
Candice Hansen	Planetary Science Institute
William Hubbard	University of Arizona
Andrew Ingersoll	California Institute of Technology
Jonathan Lunine	University of Arizona
Toby Owen	University of Hawaii
Ed Smith	Jet Propulsion Laboratory
Paul Steffes	Georgia Tech
David Stevenson	California Institute ofTechnology
Ed Stone	California Institute ofTechnology
Richard Thorne	University of California Los Angeles