Juno to show Jupiter's magnetic field in high-def

Science Daily

Figuring out how this mighty engine, or dynamo, works is one goal of NASA's Juno mission, which is scheduled to begin its five-year, 400-million-mile voyage to Jupiter in August 2011. Juno will orbit the planet for about a year, investigating its origin and evolution with eight instruments to probe its internal structure and gravity field, measure water and ammonia in its atmosphere, map its powerful magnetic field and observe its intense auroras.

The magnetic field studies will be the job of Juno's twin magnetometers, designed and built at NASA's Goddard Space Flight Center in Greenbelt, Md. They will measure the field's magnitude and direction with greater accuracy than any previous instrument, revealing it for the first time in high-def.

"Valuable information about Jupiter's magnetic field was gathered by the Pioneer 10 and 11 missions in the early 1970s and Voyagers 1 and 2 in the late '70s," says NASA Goddard's Jack Connerney, Juno's deputy principal investigator and head of the magnetometer team. Connerney is collaborating with the mission's principal investigator, Scott Bolton, at the Southwest Research Institute in San Antonio, Texas. "But previous spacecraft orbited among Jupiter's moons; Juno, a polar orbiter, will be the first magnetic mapping mission to Jupiter."

"Mapping Jupiter's magnetic field is one of the very few ways available to learn about Jupiter's deep internal structure," says Juno's project scientist, Steven Levin of NASA's Jet Propulsion Laboratory in Pasadena, Calif., which manages the Juno mission. That's because Jupiter's atmosphere is compressed so much by its powerful gravity field that it becomes impenetrable to most sensing techniques.

"In addition," Levin says, "Jupiter may be the best place in the solar system to study how planetary magnetic fields are generated."

Jupiter: Just Right

Massive Jupiter has the most powerful magnetic field of any planet in the solar system. That is but one advantage. Jupiter is a gas giant that offers a clear view to its dynamo. In contrast, Earth's dynamo is partially hidden beneath a layer of magnetized crustal rock. And Earth's dynamo is buried quite deep -- about halfway to the planet's center -- whereas Jupiter's dynamo region extends much closer to the surface of that planet.

"The Juno spacecraft will pass repeatedly just above Jupiter's surface, so we will get closer to the dynamo there than we could on any other planet in the solar system," explains Connerney. "That's a very exciting prospect because it will really enhance our ability to determine what's going on." For Earth, the dynamo is generated in the liquid iron of the outer core. For Jupiter, it's generated in hydrogen, which makes up about 90 percent of the planet. Some of the hydrogen is in a special gas form -- a gas that can conduct electricity, because it's under enough pressure to squeeze the electrons off the molecules. Closer to the core, the gas gets compressed even more, turning it into a liquid called metallic hydrogen. Whether the metallic hydrogen or the electrically conducting gas is the source of Jupiter's magnetic field remains a question -- one that Juno is designed to answer.

"With Juno, we hope to see the detailed structure of Jupiter's magnetic field with a resolution far beyond that previously obtained," says Jeremy Bloxham, a Juno co-investigator at Harvard University in Cambridge, Mass. "We also hope to be able to use the structure of the field to infer the internal structure of Jupiter, in particular to determine the radius of Jupiter's inner core."

Up Close and Personal

Juno's oval-shaped, or elliptical, orbit will bring it closer to Jupiter than any other spacecraft and then take it farther than the moon Callisto and back again. Rather than flying around the equator, Juno will be the first spacecraft to orbit pole to pole, passing over the planet's north and south poles during the close-in part of its orbit. That is when Juno gets a bird's eye view of Jupiter's intense auroras, along with measurements of the charged particles and currents associated with them. The spacecraft will make about 34 of these loops, ultimately covering the entire globe during the course of roughly an earth year.

The spacecraft will come close enough to Jupiter to feel the full strength of its magnetic field -- about 10 to 12 Gauss compared to Earth's field of about half a Gauss. Yet elsewhere in the orbit, Juno will measure a field that's about 10 million times weaker.

Juno's two magnetometers are identical, and both measure fields weak and strong. The instruments sit about 6-1/2 feet apart on the magnetometer boom, a composite structure fastened to the end of one of the three solar arrays. Two magnetometers are on board in case one should fail and in case the spacecraft starts to generate its own stray magnetic field, which would need to be corrected for in the measurements. Such a field would be small, but the magnetometers can detect differences so slight that the instrument closer to the spacecraft would sense a stronger field than the one farther out on the boom.

Juno will measure the magnetic field about 60 times per second while the entire spacecraft spins twice each minute. The strength and direction of the field are measured relative to the spinning spacecraft, but scientists really want to know the field's direction relative to Jupiter and the universe. This job requires the help of the star cameras.

Each magnetometer's sensor is equipped with two star cameras to determine the sensor's exact orientation in space. The camera snaps an image of the night sky every four seconds. The star camera identifies all of the bright objects in its field of view and uses a clever algorithm to compare what it "sees" with a catalog of known stars. The sensor's orientation in space is the one that best matches the stars in the catalog.

"If we have even the tiniest little deviation when we determine the orientation, it will impact the measurement of the magnetic field," says the leader of the star-camera team, John Jorgensen of the Danish Technical University, near Copenhagen.

The exquisite accuracy of the magnetometers is due in part to this ability to pinpoint the orientation of the sensor in space, which is just as important as the design and painstaking calibration of the instruments.

"Juno's measurements may be accurate enough to detect slow time variations in Jupiter's magnetic field," Connerney says. "If Jupiter has these variations, measuring them will let us visualize for the first time how the planet's dynamo works. And that will give us a new understanding of the dynamos of other planets, both here in our solar system and beyond."

NASA's Jet Propulsion Laboratory, Pasadena, Calif., manages the Juno mission for the principal investigator, Scott Bolton, of Southwest Research Institute in San Antonio. The Juno mission is part of the New Frontiers Program managed by NASA's Marshall Space Flight Center in Huntsville, Ala. The magnetometers were designed and built at NASA's Goddard Space Flight Center in Greenbelt, Md. 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. More information is online at http://www.nasa.gov/juno [1] and http://missionjuno.swri.edu/ [2].

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