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Microwave Anisotropy Probe (MAP) Mission

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**NASA TO "MAP" BIG BANG REMNANT
TO SOLVE UNIVERSAL MYSTERIES**

The Microwave Anisotropy Probe (MAP), scheduled for launch June 30, will journey into deep space on a voyage to explore some of the deepest mysteries of the cosmos.

Scientists hope to determine the content, shape, history, and the ultimate fate of the universe, by constructing a full-sky picture of the oldest light. MAP is designed to capture the afterglow of the Big Bang, which comes to us from a time well before there were any stars, galaxies or quasars. Patterns imprinted within this afterglow carry with them the answers to mysteries such as: What happened during the first instant after the Big Bang? How did the Universe evolve into the complex patterns of galaxies that we see today? Will the Universe expand forever or will it collapse?

To answer these questions, MAP's measured pattern of the Big Bang's afterglow, like a fingerprint, will be compared against the unique fingerprint pattern predicted by each cosmic scenario to find the right match. "We are tremendously excited about this mission because it will help answer basic questions that people have been asking for ages," said Dr. Charles L. Bennett, Principal Investigator for the MAP mission at NASA's Goddard Space Flight Center, Greenbelt, MD. "MAP's unprecedented accuracy and precision will allow us to determine the nature and destiny of the universe."

According to the Big Bang theory, the universe began about 14 billion years ago as an unimaginably hot and dense fog of light and exotic particles. The Universe has since continuously expanded and cooled. The whole Universe is bathed in the afterglow light from the Big Bang. The light that is now reaching us has been traveling for about 14 billion years, thus allowing us a look back through time to see the early Universe.

"The cosmic microwave light is a fossil," says Professor David T. Wilkinson, Princeton University, Princeton, NJ. "Just as we can study dinosaur bones and reconstruct their lives of millions of years ago, we can probe this ancient light and reconstruct the Universe as it was about 14 billion years ago."

MAP views the infant universe by measuring the tiny temperature differences within the extraordinarily evenly dispersed microwave light, which now averages a frigid 2.73 degrees above absolute zero temperature. MAP will resolve the slight temperature fluctuations, which vary by only millionths of a degree. These temperature differences point back to density differences in the young Universe, where denser regions gave way to the vast web-like structure of galaxies that we see today.

A great deal of effort over the past 35 years has gone into measurements of the afterglow light from the Big Bang. In 1992, NASA's Cosmic Background Explorer satellite discovered tiny patterns, or "anisotropy," in its full-sky picture of the light. Balloon-borne and ground-based experiments have further advanced our knowledge. The upcoming MAP full-sky picture, to be made with unprecedented accuracy and precision, will dramatically revolutionize our view of the Universe.

MAP required an extraordinary design to achieve its accurate and precise measurement capability. "Nothing has ever been built like it before," said Dr. Edward Wollack, a science team member at Goddard. "To measure the cosmic glow reliably to a part in a million, to millionths of a degree has been the grand challenge. That's like measuring the weight of a cup of sand down to the resolution of a single grain."

About a month after its launch on a Delta II rocket from Cape Canaveral, FL, MAP will swing past the Moon, boosting its orbit to the second Lagrange Point, or L2. This is the first time a spacecraft will be in orbit around the L2 point. The Italian-French mathematician Josef Lagrange discovered five special points in the vicinity of two orbiting masses where a third, smaller mass can orbit at a fixed distance from the larger masses. L2 is four times further than the Moon in the direction away from the Sun and requires very little fuel to maintain orbit.

After a three month journey, MAP will begin to chart the faint microwave glow from the Big Bang. It will take about 18 months to build up a full-sky picture and perform the analysis. The MAP hardware and software were produced by Goddard and Princeton. Science team members are also located at the University of Chicago, IL; the University of California, Los Angeles; Brown University, Providence, RI; and the University of British Columbia, Vancouver. MAP, an Explorer mission, cost about $145 million. More information is available on the Internet at:

http://www.gsfc.nasa.gov/gsfc/spacesci/map/map.htm
http://map.gsfc.nasa.gov

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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. On launch day, television coverage will begin at (TBD) EDT and continue through spacecraft separation. The schedule for television transmissions for MAP will be available on the NASA Television homepage at http://www.nasa.gov/ntv/

Audio

Audio only will be available on the V circuits that may be reached by dialing 321/867-1220, 1240, 1260, 7135, 4003, 4920.

Briefings

The L-1 pre-launch press briefing at NASA Kennedy Space Center (KSC) is scheduled for June 29 at 1:00 p.m. EDT to discuss launch, spacecraft readiness and weather. A science briefing will immediately follow the L-1 pre-launch briefing. Both briefings will be carried live on NASA Television and the V circuits.

News Center/Status Reports

The MAP News Center at KSC will open June 28 (L-2) and may be reached at (321) 867-2468. Recorded status reports will be available beginning L-2 at (321) 867-2525 and (301) 286-NEWS.

Launch Media Credentials

Media desiring launch accreditation information should contact the KSC Newsroom by close of business on June 28 at:

George Diller, Office of Public Affairs
MAP Launch Accreditation
NASA XA-E1
NASA Kennedy Space Center
Kennedy Space Center, Fla. 32899
Fax: 321-867-2692
Telephone: 321-267-2468

***Requests must be on the letterhead of the news organization and must specify the editor making the assignment to cover the launch.

Internet Information

More information on the MAP mission, including an electronic copy of this press kit, press releases, fact sheets, status reports and images, can be found at: http://www.gsfc.nasa.gov/gsfc/spacesci/map/map.htm

MAP project information can be found at:

http://map.gsfc.nasa.gov

MAP Quick Facts

Spacecraft Dimensions**:** 150 inches (3.8 meters) high by 198inches (5 meters) wide

Weight: 1,850 pounds (840 kilograms)

Science Instrument: Passively cooled differential microwave radiometers with dual Gregorian 4.6 x 5.3 feet (1.4 x 1.6) meter primary reflectors

Power: 419 Watts

Mission Lifetime: 27 months (3 months transit to L-2, 24 months observing at L2)

Trajectory: Earth-Moon phasing loops with lunar assist to L2

Orbit**:** Lissajous orbit about L2 Sun-Earth Lagrange point, 1 million miles (1.5 million kilometers) from Earth. Lissajous orbits are named after Jules Antoine Lissajous (1822-1880), a French physicist. Lissajous orbits continuously go about a point, but do not come back to the same place or path after a revolution.

Expendable Launch Vehicle: Med-Lite Delta II 7425-10

Launch Site: Cape Canaveral, Fla.

Launch Date and Time: June 30, 2001 at 3:46 p.m. EDT

First Acquisition of Signal: Approximately one hour and 15 minutes after launch

Spacecraft Separation: Approximately one hour and 25 minutes after launch

In-Orbit Check-out: Begins approximately 3 hours after launch

Cost: The total mission cost for MAP is approximately $145 million

Launch Vehicle Provider: The Boeing Company, Huntington Beach. Calif.

Launch Vehicle/Operations: Kennedy Space Center, Fla.

Mission Management: Goddard Space Flight Center, Greenbelt, Md.

MAP Science Mission

The Microwave Anisotropy Probe (MAP) will determine conditions in the early universe by making a full sky map of the cosmic microwave background temperature. The MAP mission is set to make major advances in cosmology, the science that attempts to answer fundamental questions such as: "What is the origin and structure of the universe? How did it evolve? What is its fate?"

In 1992, NASA's Cosmic Background Explorer (COBE) satellite detected tiny fluctuations, or "anisotropy," in the cosmic microwave background. It found, for example, one part of the sky has a temperature of 2.7251 kelvins, while another part of the sky has a temperature of 2.7250 kelvins. (kelvin, is a unit of temperature: 0 kelvin is the complete absence of heat, called "absolute zero," and 273 kelvins is the same as 0 degrees Celsius). These fluctuations are related to fluctuations in the density of matter in the early Universe and thus carry information about the initial conditions for the formation of cosmic structures such as galaxies, clusters, and voids.

If viewed from afar, we would see the Earth as a uniform sphere. When viewed with improved resolution, we would see blurry images of the continents and oceans. With yet better resolution, the rich features of the Earth --deserts, mountains and forests -- would become visible. The first observations of the microwave background revealed only a uniform sky. The smallest features that COBE could distinguish were about 7 degrees wide on the sky, so COBE made the equivalent of the first detection of continents and oceans. Over the past few years, balloon-borne and ground-based experiments have made high-resolution images of small portions of the sky. MAP will make a high-resolution image of the whole sky. Analysis of the new information revealed by the MAP observations will help cosmologists to answer several key questions, such as: What is the density of atoms in the Universe? What is the density of exotic dark matter in the Universe? How old is the Universe? How did structures such as galaxies and clusters of galaxies form in the Universe? When did the first such structures form?

The only widely accepted scientific theory for the origin of our Universe is the Big Bang theory. According to the theory, the Universe began about 14 billion years ago as an unimaginably hot and dense soup of exotic particles, and has since continuously expanded and cooled. (It is the space itself that expanded, and is still expanding today. The Universe did not expand into something else.)

For the first 400,000 years or so after the Big Bang, the Universe was a seething cauldron of matter (electrons, protons, neutrons, and a small percentage of heavier atomic nuclei), and light (photons). Since photons scatter or bounce off electrons, the universe was opaque. As space expanded, the Universe cooled and the electrons combined with the protons (and other atomic nuclei) to create the first atoms, primarily hydrogen. The first light of creation could finally be freed from its pinball-like interactions with the electrons at which point the Universe became transparent.

Since this time, this light has effectively moved through the cosmos unimpeded and brings to us an image of the infant Universe. It is the oldest light that can be detected. Cosmologists studying the first light from the Big Bang, called the "cosmic microwave background" (CMB) radiation, look back through time and space to about 400,000 years after the Big Bang, when the Universe was opaque.

One of the most fascinating things about the Universe is its mystery. It seems that every question that is answered with some certainty gives rise to ten more. The data collected from MAP should help to answer some of the most fundamental questions before astronomers today.

MAP Spacecraft

The composite/aluminum spacecraft dimensions are 150 inches (3.8 meters) high by 198 inches (5 meters) wide. MAP weighs 1,850 pounds (840 kilograms) and is supplied with 419 watts of power. The MAP mission lifetime is 27 months, three months of transit to L2 and 24 months of observing time. The MAP spacecraft is comprised of:

• **Solar panels** - 6 GaAs/Ge panels supply 419 Watts.

• **Battery** - 23 Amp-hour nickel hydrogen pressure vessel stores energy.

• **Power supply electronics** - regulates the use of the battery and solar panels to supply power the all of the spacecraft system.

• **Sun shield** - protects the instrument from microwave radiation from the Sun, Earth, and Moon.

• **Transponders** - Prime and redundant transponders send and receive telemetry at data rates ranging from 2 to 666 kilobits per second.

• **Two omni antennas** - transmit and receive telemetry to and from Earth.

• **Two medium gain antennas** - transmit data to Earth during normal operations at L2 at a rate of 666 kilobits per second.

• **Three reaction wheels** - used to maneuver the spacecraft and control MAP's nominal operation spin (0.464 rpm) and precession (1 revolution per hour).

• **Two star trackers** - determine the direction of instrument observation.

• **Gyros** - determine the spacecraft's rate of angular motion.

- **Thrusters** - eight one pound (4.45 Newton) thrusters are used to place and maintain the spacecraft in its final orbit.

- **Coarse Sun sensors** - six sensors are used to determine the spacecraft attitude.

- **Digital Sun sensors** - two sensors are used to determine the spacecraft attitude.

- **Attitude control electronics**- control and read information from the attitude components. Helps maintain the spacecraft in the right orientation.

- **Propellant** - hydrazine fuel.

- **Propulsion tank** - holds 72 kg of propellant.

- **Command and data handling system** - the flight computer controls the hardware and packages the data for transmission to the ground.

MAP Instrument

The MAP instrument consists of a set of passively cooled microwave radiometers with 4.6 x 5.3 feet (1.4 x 1.6) meter diameter primary reflectors to provide the desired angular resolution. Measuring the temperature of the microwave sky to an accuracy of one millionth of a degree requires careful attention to possible sources of systematic errors.

- The instrument has five frequency bands from 22 to 90 GHz to facilitate separation of galactic foreground signals from the cosmic background radiation.

- MAP is a differential experiment. MAP measures the temperature difference between two points in the sky rather than measuring absolute temperatures.

- An orbit about the Sun-Earth L2 libration point provides for a very stable thermal environment and near 100 percent observing efficiency since the Sun, Earth, and Moon are always behind the instruments field of view.

- MAP uses a scan strategy that rapidly covers the sky and allows for a comparison of many sky pixels on many time scales.

Instrument Components

- **Two primary reflectors** - 4.6 x 5.3 feet (1.4 x 1.6) meter - radiation hits here first and is reflected toward the secondary reflectors.

• **Two secondary reflectors** - reflect radiation toward receivers.

• **Differential microwave receivers** - receives radiation simultaneously from the dual Gregorian set of optics at five different frequencies. The receivers retain polarization information.

• **Diffraction shielding** - shields receiver from stray microwave emission.

• **Thermally isolating cylinder** - gamma alumina composite material thermally isolates the warm spacecraft from the cold instrument.

• **Passive radiators** - passively cools the instrument to 95 Kelvin.

• **Instrument electronics** - controls and provides regulated power to the instrument and reports the science information.

L2 Orbit and How MAP Gets There

While two other spacecraft, Geotail and ISEE-3 have flown through the vicinity of L2, MAP is the first spacecraft to use an orbit around the L2 point as its observing station. MAP's own propulsion system, and a lunar gravity-assist, will carry the spacecraft to its final destination in orbit around the second Lagrange (L2) point of the Sun-Earth system. L2 is four times farther from the Earth than the Moon in the direction opposite the Sun, or about one million miles (1.5 million kilometers) from Earth. An orbit about the Sun-Earth L2 point provides for a very stable thermal environment and near 100 percent observing efficiency since the Sun, Earth, and Moon are always behind the instruments field of view. MAP will perform a series of "phasing loops" in the Earth-Moon system to place it in the proper position for the lunar flyby, which will occur approximately a month after launch. MAP will reach L2 approximately 3 months after launch. This trajectory is designed to minimize the use of fuel. From L2, MAP will have an unobstructed view of the sky, and will be free from near-Earth disturbances such as magnetic fields and microwave emission.

Science Observations and Data Collection

MAP does not measure the absolute sky temperature, but rather the difference in temperature between two points in the sky approximately 140 degrees apart. MAP spins every two minutes and its spin axis maintains a fixed angle of 22.5 degrees to the Sun-Earth line. The spin axis moves around the Sun-Earth line, allowing the instrument to view 30 percent of the sky every hour. In addition, MAP rotates annually with the Earth around the Sun so MAP can see all points in the sky from many different viewpoints. It will take six months at L2 for MAP to see the entire sky. To determine the validity of the signals received, MAP will cover the sky multiple times and at multiple frequencies. Five frequency bands from 22 GHz to 90 GHz will allow emission from our Galaxy and environmental disturbances to be modeled and removed based on their frequency dependence.

During the phasing loops and until MAP is past the Moon, MAP communicates with Earth with the use of its transponders and two omni antennas located at the top and bottom of the spacecraft. On the way to L2, MAP will switch to use of the Medium Gain Antennas located at the bottom of the spacecraft. Data is transmitted to Earth once per day from L2. On orbit operations are conducted at NASA's Goddard Space Flight Center.

Control of Scientific Measurement Errors

To realize the full value of the MAP measurements, sources of error must be controlled to an extraordinary level. This was the most important factor driving the MAP design, and led to the following design choices:

- **Differential:** MAP measures temperature differences on the sky using symmetric microwave receivers coupled to back-to-back telescopes. By measuring temperature differences, rather than absolute temperatures, most spurious signals will cancel. This is analogous to measuring the relative height of bumps on a high plateau rather than each bump's elevation above sea level.

- **Sky scan pattern:** MAP spins like a top. This observing pattern covers a large fraction of the sky (approximately 30 percent) during each one hour precession.

- **Multifrequency:** Five frequency bands from 22 GHz to 90 GHz will allow emission from the Galaxy and environmental disturbances to be modeled and removed based on their frequency dependence.

- **Stability:** The L2 Lagrange point offers an exceptionally stable environment and an unobstructed view of deep space, with the Sun, Earth, and Moon always behind MAP's protective shield. MAP's large distance from Earth protects it from near-Earth emission and other disturbances. At L2, MAP maintains a fixed orientation with respect to the Sun for thermal and power stability.

New Technology Associated with MAP

At the core of the MAP instrument is a complex set of state-of-the-art microwave receivers that turn the very faint microwaves from the early Universe into signals that common electronic equipment can process. The MAP microwave receivers carefully measure the difference in temperature between two directions of the sky. This is done with very low noise and with minimal additional receiver artifacts.

The MAP receivers split the incoming microwaves into separate paths, each with their own independent amplification. Any differences in these signals are due to instrumental changes, while common signals are from the sky. This automatically neutralizes the adverse affects that would otherwise occur due to naturally occurring changes of receiver gain.

This MAP receiver approach was enabled by the creation of amplifiers (which are only a little bigger than a box of matches) that were custom designed by Marian Pospieszalski and built for MAP by the National Radio Astronomy Observatory in Charlottesville, Virginia. The MAP receivers contain 80 of these amplifiers.

The microwaves are directly amplified, even at MAP's highest frequency (about 100 GHz) with high sensitivity over a 20 percent wide range of frequencies. In the past, it would have been necessary to convert the microwave signals to lower frequencies in a process that resulted in a considerable loss of sensitivity and which often introduced other problems. The MAP receivers also preserve the polarization information of the original signal, which provides additional constraints on cosmology.

A Medium-class Explorers Mission

The purpose of the Explorers Program is to allow for frequent, high quality space science investigations. MAP is the second satellite in the series of Medium Class Explorer (MIDEX) missions, IMAGE was the first. NASA attempts to launch approximately one MIDEX each year. The MIDEX Program is managed by the Goddard Space Flight Center in Greenbelt, Md.

Partners/Science Team

Goddard; Princeton University, New Jersey; University of California at Los Angeles (UCLA); and the University of Chicago; Brown University, Providence RI; and University of British of Columbia (UBC), Vancouver, Canada are where the MAP Science Team are located. Goddard and Princeton University worked as closely cooperating partners on the procurement and/or fabrication of all flight hardware and software. UCLA, Chicago, Brown and UBC provide additional scientific guidance, expertise, and oversight of the scientific conduct of the mission. All institutions contribute to the development of the data analysis software.

For more Science Team information visit:
http://map.gsfc.nasa.gov/html/institutions.html

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