Probing the Sun

NASA has decided to go to the Sun. "We are going to visit a living, breathing star for the first time," says program scientist Lika Guhathakurta of NASA Headquarters. "This is an unexplored region of the solar system, and the possibilities for discovery are off the charts."

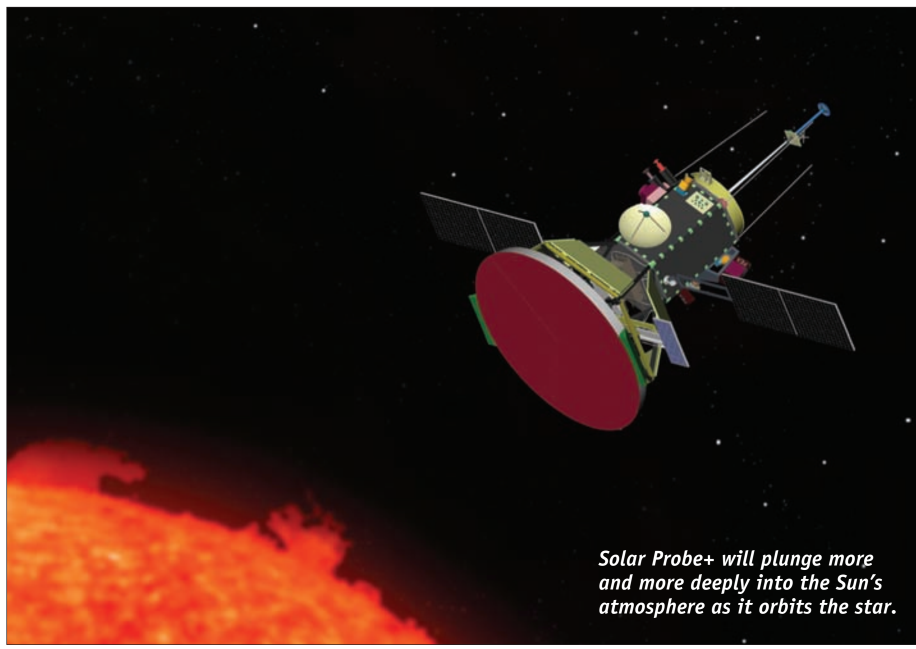
The name of the mission is Solar Probe+. The probe is a heat-resistant spacecraft designed to plunge deep into the Sun's atmosphere, where it can sample solar wind and magnetism firsthand. Launch could happen as early as 2015. By the time the mission ends seven years later, planners believe Solar Probe+ will have solved two great mysteries of astrophysics and have made many new discoveries along the way.

The probe is still in its early design phase, called "pre-phase A" at Headquarters, says Guhathakurta. "We have a lot of work to do, but it is very exciting."

Scientists at Johns Hopkins' Applied Physics Lab will design and build the spacecraft for NASA. APL already has had experience sending probes toward the Sun. The lab's Messenger spacecraft completed its first flyby of Mercury in January 2008, and many of the same heat-resistant technologies employed on Messenger will be used to fortify Solar Probe+.

At its closest approach, Solar Probe+ will be 7 million km or 9 solar radii from the Sun. There, the spacecraft's carbon-composite heat shield must withstand temperatures greater than 1,400 C and survive exposure to levels of radiation not experienced by any previous spacecraft.

The probe will be solar powered—it will get its electricity from liquid-cooled solar panels that can retract behind the heat shield when sunlight becomes too intense. From these near distances, the Sun will appear to be 23 times wider than it does in the skies of Earth.



Solar Probe+ will plunge more and more deeply into the Sun's atmosphere as it orbits the star.

The mysterious star

Two mysteries prompted this mission: the high temperature of the Sun's corona and the puzzling acceleration of the solar wind.

First, the corona. The temperature on the surface of the Sun is about 6,000 C. Intuition says the temperature above the surface should drop. Instead, it rises. The Sun's outer atmosphere, the corona, registers more than 1 million C, far hotter than the star below. This high temperature difference remains a mystery more than 60 years after it was first measured.

The second mystery is the solar wind. The Sun spews a hot, million-mph wind of charged particles throughout the solar system. Planets, comets, and asteroids are all subjected to it. However, there is no organized wind close to the Sun's surface. Yet out among the planets the solar wind is a veritable gale. Somewhere in between, some unknown agent gives the solar wind its great velocity.

"To solve these mysteries, Solar Probe+ will actually enter the corona," says Guhathakurta. "That is where the action is."

Fifty years in the making

A mission to provide these measurements, to probe the near-Sun particles-and-fields environment, was first recommended in 1958, at the dawn of the space age, by the National Academy of Science's "Simpson Committee." Since then, NASA has conducted several studies of possible implementations of a solar probe mission. A solar probe has remained at the top of various National Academy and NASA science priority lists. And the National Research Council's decadal survey in solar and space physics recommended in 2003 the implementation of a solar probe mission "as soon as possible."

NASA's Sun-Solar System Connection Roadmap in 2005 identified a solar probe as a "Flagship" mission that "is ready to fly and is our highest priority for new resources." The claim that such a mission was "ready to fly" was supported by a solar probe study, which was completed in 2005. Beginning in March 2004, NASA's Solar Probe Science and Technology Definition Team (STDT) had worked closely with engineers at the Johns Hopkins University APL to define a mission that could achieve those objectives.

The mission that emerged from the study followed the basic structure of several previous studies: The 2005 study used a Jupiter gravity assist maneuver to place an RTG (radioisotope thermoelectric generator)-powered spacecraft into a polar orbit about the Sun. The spacecraft was to be protected by a tall, conical carbon-carbon composite heat shield and equipped with an integrated payload comprising in-situ and remote-sensing instruments.

The baseline mission provided for two brief solar encounters, roughly five years apart. The APL engineering study demonstrated that the Solar Probe mission described in the 2005 report was technically feasible and acceptably low-risk. Moreover, the mission, as it was presented in various venues to members of the solar and heliospheric physics communities, enjoyed very broad support. Nevertheless, at a cost of $1.1 billion in FY07 dollars, the 2005 Solar Probe was found to be too expensive to implement within NASA's funding environment.

A big plus

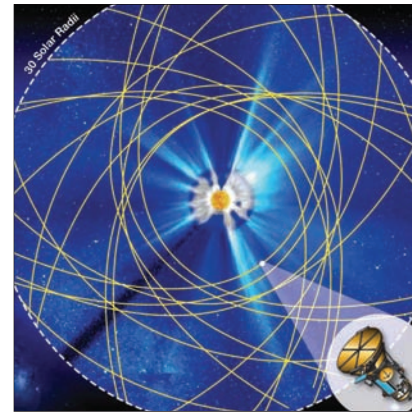
Recognizing the compelling nature of solar probe science, NASA's Science Mission Directorate (SMD) requested a new study to determine if a mission could be designed that would achieve the Solar Probe core science while costing no more than $750M in FY07 dollars. A further constraint—and a technical challenge—was the SMD's stipulation that Solar Probe not be powered by RTGs.

This new study was conducted by the same STDT that performed the 2005 investigation, again with significant support from the APL engineering staff. The study yielded a significantly redesigned mission that can be implemented within the $750M cost cap, does not require RTGs for power, and addresses the science objectives defined in the 2005 study.

In fact, the STDT found that the new mission design, with its repeated near-Sun passes, offers significant advantages in both technical implementation and science return compared with the 2005 mission. The redesigned mission was therefore christened "Solar Probe Plus."

The payload consists mainly of instruments designed to sense the environment right around the spacecraft. These include a magnetometer, a plasma wave sensor, a dust detector, and electron and ion analyzers, among others. "In-situ measurements will tell us what we need to know to unravel the physics of coronal heating and solar wind acceleration," says Guhathakurta.

Solar Probe+'s lone remote sensing instrument is the hemispheric imager. The imager is a telescope that will make three-dimensional images of the Sun's corona similar to medical CAT scans. Called coronal tomography, the technique is a fundamentally new approach to solar imaging, only possible because the photography is performed from a moving platform close to the Sun, flying through coronal clouds and streamers and imaging them as it flies by and through them.



A simulated view of the Sun illustrates the trajectory of Solar Probe+ during its multiple near-Sun passes.

With a likely launch in May 2015, Solar Probe+ will begin its prime mission near the end of solar cycle 24 and finish near the predicted maximum of cycle 25 in 2022. This time span would allow the spacecraft to sample the corona and solar wind at many different phases of the solar cycle. It also guarantees that Solar Probe+ will experience a good number of solar storms near the end of its mission.

While perilous, this exposure will be according to plan: Researchers suspect that many of the most dangerous particles produced by solar storms are energized in the corona, exactly where Solar Probe+ will be. Solar Probe+ may be able to observe the process in action and show researchers how to forecast solar energetic particle events that threaten the health and safety of astronauts.

Solar Probe+'s repeated plunges into the corona will be accomplished by means of Venus flybys. The craft will swing by Venus seven times in six years to bend the probe's trajectory deeper and deeper into the Sun's atmosphere. Although Venus is not a primary target of the mission, astronomers may learn new things about the planet when the heavily instrumented probe swings by.

"Solar Probe+ is an extraordinary mission of exploration, discovery, and deep understanding," says Guhathakurta. "We cannot wait to get started."

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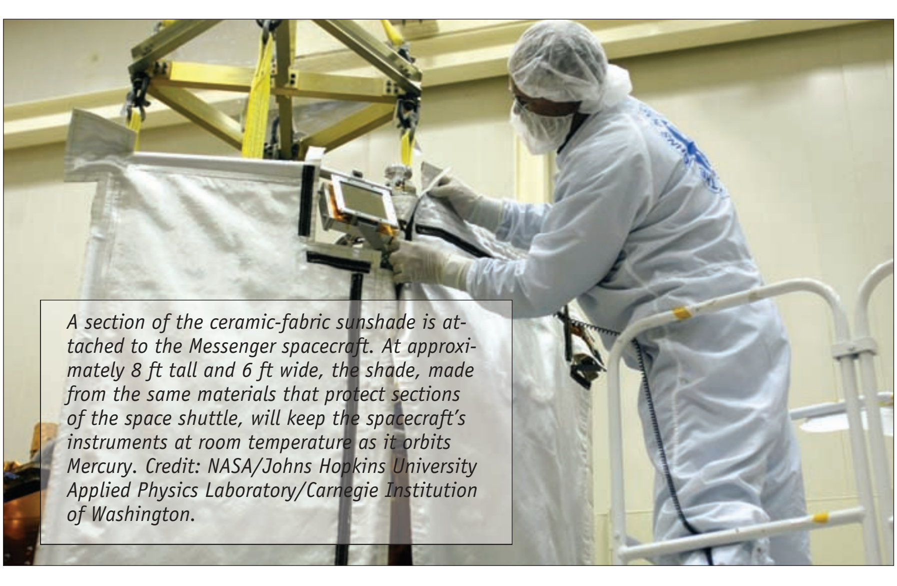

A section of the ceramic-fabric sunshade is attached to the Messenger spacecraft. At approximately 8 ft tall and 6 ft wide, the shade, made from the same materials that protect sections of the space shuttle, will keep the spacecraft's instruments at room temperature as it orbits Mercury. Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington.