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TAKING ON THE SUN

NASA's Parker Solar Probe, now on its way toward the sun, must survive the searing temperatures in the solar corona to unlock the processes driving the solar wind and coronal mass ejections that can harm satellites and electronics on Earth. Tom Risen spoke to the scientists and engineers behind Parker's thermal protection strategy.

BY TOM RISEN | @tomr@aiaa.org

When engineers got to work on NASA's Parker Solar Probe a decade ago, they needed to create a heat shield that would be lightweight, reflective and durable enough for the spacecraft to become the first to fly into the sun's outermost atmosphere, called the corona, and address the mystery of why this region is hotter than the one closer to the surface.

Parker, built by the Johns Hopkins University Applied Physics Laboratory in Maryland, is on a trajectory toward the sun, following its launch in August from Cape Canaveral, Florida. The spacecraft will complete 24 solar orbits, each gradually tightening with the aid of Venus' gravity, until Parker approaches within 6.4 million kilometers of the surface in June 2025, exposing its heat shield to temperatures of 1,377 Celsius.

The gravity of Venus and the sun will accelerate Parker to incredible speeds as the probe flies on increasingly tighter orbits. In fact, if all goes as planned, the spacecraft will become "the fastest human made object" in history when it flies at about 700,000 kilometers per hour, or "fast enough to get from Philadelphia to Washington in one second," said Nicola Fox, NASA's Parker Solar Probe mission scientist, during a pre-launch briefing with reporters.

NASA first discussed the idea of sending a probe near the sun when the agency was founded in 1958. "Every couple of decades since then, NASA sat down and said, 'OK, can we do this?'" says Adam Szabo, NASA's mission scientist for the Parker Solar Probe.

The answer was always "not yet," until 2008 when NASA chose APL to build Parker. Engineers saw that NASA's patience paid off as they drew on a range of technological advancements to build the spacecraft. Instruments on Parker will gather data about magnetic fields and particles from the shadow of a 2.43-meter-diameter, 11.4-centimeter-thick heat shield that will protect the instruments from the searing sunlight. Autonomous navigation software will ensure hydrazine thrusters keep the shield pointed at the sun to maintain a tolerable operating temperature of 30 degrees Celsius.

The autonomous navigation on the spacecraft is "absolutely critical," Szabo says, because NASA won't always be able to maintain contact with Parker to keep the shield focused. "The light pressure is so intense that communications would be a problem," he says. The shield consists of a carbon foam core sandwiched between two panels of a composite derived from the same kind of reinforced carbon-carbon that protected the leading edges of the space shuttle wings. The shield sits atop a truss made of titanium, a metal that can endure the 315-degree Celsius heat it is expected to face.

Testing the heat shield for durability was "very difficult," says Betsy Congdon, the lead engineer at APL for the thermal protection system. "The difficulty is testing for those high temperatures in vacuum, so we tested at a variety of facilities all over the [U.S.]," including at NASA Goddard Space Flight Center's thermal vacuum chamber in Maryland.

Designers simulated the temperature fluctuations the probe will face on each orbit, as it flies toward the sun and then away from it. In fact, Parker will fly by Venus seven times through 2024, a series of gravity assists whose momentum will send the probe deeper and deeper into the sun's atmosphere.

The shield's carbon foam supplied by secondary contractor Ultramet of California is a stronger version of a foam the company has sold as a bone replacement material, though it is 97 percent air.

The shield panels, built by secondary contractor Carbon-Carbon Advanced Technologies of Texas, are made from a "thinner, next generation version" of the shuttle's reinforced carbon-carbon, Congdon says. To reflect as much light from the sun as possible, researchers at Johns Hopkins' main campus created the recipe for a ceramic-based white coating that was sprayed evenly across the outer shield panel by aerospace materials contractor Plasma Processes of Alabama.

Designers also had to find a way to protect the probe's electricity-generating solar arrays during the hottest part of each orbit. As Parker approaches the sun, the arrays will be folded to a shallow angle to reduce exposure to sunlight, "otherwise they could melt," Szabo says. They will extend again as Parker heads away from the sun.

Pipes beneath the solar arrays will also pump water back and forth from a radiator within the titanium truss to shed heat into space.

"Space is dark, so you can keep the water cool if you keep it out of the sunshine," Szabo says.

Scientists hope to learn about the acceleration and origin of solar wind, charged particles that course through our solar system after emanating from the corona, and how to better predict more intense blasts of magnetic energy from the sun that could disrupt electronics on satellites. The probe's namesake, heliophysicist Eugene Parker, 89, a professor emeritus at the University of Chicago, predicted the existence of the solar wind in 1958.

The equations Parker published in his 1958 paper predicting the supersonic flight of solar winds "taught us about the threats that come from this plasma," said NASA's Thomas Zurbuchen, the associate administrator in charge of the Science Mission Directorate, during the pre-launch briefing. The spacecraft will gather data about the solar wind by extending a metal solar probe cup just beyond the diameter of the heat shield to determine the velocity, density and temperature of the ionized gas. Pieces of sapphire will create an electric field to make what's called a Faraday cup that will ensure only charged particles can enter the cup.

Also, five electric antennas and three magnetometers will measure fluctuations in the intensity of magnetic fields and detect the shock waves that blow through the corona and are associated with coronal mass ejections, bursts of plasma and magnetic energy that can reach Earth in 18 hours. Four of the antennas will be exposed beyond the heat shield. These are built from niobium alloy, which can endure extreme heat. A mass spectrometer will also weigh ions within the solar wind, and a white light telescope will make 3D images of the wind as it passes.

Lessons learned from designing and constructing the heat shield "can change the way we look at a lot of our re-entry problems, and we can develop and use heat shielding in new ways potentially on missions like interstellar probes as well," Congdon says. ★

◀▲ Employees of the Johns Hopkins University Applied Physics Laboratory work at Astrotech Space Operations in Titusville, Fla., on the thermal protection system for the Parker Solar Probe.

NASA