Spacecraft dare to fly close to the sun

Stephen Ornes, Science Writer

A wide swath of North America was reminded during last summer’s eclipse that you can’t stare at the sun without protection. But to study the sun, space probes have to do much more than stare. They have to get extremely close to the sun’s unforgiving environs. Next year, two solar missions will do exactly that—traveling tens of millions of miles to study the sun’s outer atmosphere, its corona, in hopes of understanding why it’s dramatically hotter than the sun’s surface.

Normally, the temperature drops as you move farther from a source of heat. Not so near the sun. Although the sun’s temperature falls from ~15 million degrees Celsius at its core to ~6,000 °C at the surface, the corona heats up again to more than one million degrees Celsius, thus creating an aura of ionized gas, or plasma, around the sun.

The corona accelerates ionized particles near the sun to nearly 1,000 times the speed of sound—creating a solar wind. Over the last few decades spacecraft, from NASA’s Pioneer explorations in the 1960s to the latest Solar and Heliospheric Observatory (SOHO), have ventured closer and closer to peek at this high-temperature plasma (1). SOHO, which will continue to make precise measurements of the solar wind at least until the end of 2018, is the same distance from the sun as Earth and follows the same orbit. Scientists have argued for decades that the best way to study the corona is to send probes closer—much closer (2).

Double Take

Technology has finally caught up to that vision. The first spacecraft to get up close and personal with the sun will likely be NASA’s Parker Solar Probe, which has a launch window that opens in July 2018. The Probe will be slung toward the sun on the top of a Delta IV Heavy rocket, reaching speeds of 430,000 mph—the...
fastest of any spacecraft in history. At its nearest point to the sun, the Probe will be only 3.7 million miles out, closer than any previous solar probe has ventured. It will face temperatures nearly high enough to melt iron (3).

That neighborhood is home to streams of energetic particles, the sun’s shifting magnetic field, and powerful solar flares. But physicist Nicky Fox, the mission project scientist at the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, MD, doesn’t see those factors as only hazards. They’re opportunities for understanding how a solar storm is born. “We want to see a huge flare and experience supersonic shocks,” she says. “We want to see huge amounts of high-energy particles and be right there when it happens.”

The launch window for the other mission, the Solar Orbiter, a collaboration between NASA and the European Space Agency (ESA), opens in February 2019. It will get to within 26 million miles of the sun, inside the orbit of Mercury, and will observe the sun and detect the energetic particles and magnetic fields in its vicinity (4). Both teams have had to develop strategies for studying the sun without their spacecraft being destroyed by the heat or the high-energy particles.

**Hide and Seek**

Protection begins with the heat shield. The Probe’s shield is made of 4.5 in of super-light carbon foam sandwiched between thin sheets of a light carbon-composite material. The sun-facing side is coated with alumina, a reflective ceramic insulator.

The Parker Solar Probe’s instruments will study the electric and magnetic fields around the sun, count solar wind particles, match the behavior of the solar wind with the observed populations of high-energy particles, and use telescopes to image the sun’s atmosphere and solar wind. Most of these instruments will hide behind the shield.

The biggest challenges, says Fox, are for devices that will stare directly at the sun. One is the Fields instrument, which includes four antennas that stick out of the sides of the shield. Each antenna is made of a rolled-up tube of niobium-13, called the “whip,” which can withstand the coronal temperature and sends its signal through a molybdenum wire to a computer inside. The other instrument is the Faraday cup, which “peeks around the heat shield,” says Fox.

**The Orbiter’s shield, on the other hand, comprises several layers of titanium separated by an insulator. The outermost titanium layer is treated with a material called Solar Black, a black calcium phosphate made from burnt bone charcoal that absorbs more than 99% of incident sunlight and radiates it back into space as heat. The shield has small, sliding trapdoors that protect the apertures of Solar Orbiter’s sun-pointed cameras when they are not performing any observations.**

**Hide and Seek**

Protection begins with the heat shield. The Probe’s shield is made of 4.5 in of super-light carbon foam sandwiched between thin sheets of a light carbon-composite material. The sun-facing side is coated with alumina, a reflective ceramic insulator.

The Parker Solar Probe’s instruments will study the electric and magnetic fields around the sun, count solar wind particles, match the behavior of the solar wind with the observed populations of high-energy particles, and use telescopes to image the sun’s atmosphere and solar wind. Most of these instruments will hide behind the shield.

The biggest challenges, says Fox, are for devices that will stare directly at the sun. One is the Fields instrument, which includes four antennas that stick out of the sides of the shield. Each antenna is made of a rolled-up tube of niobium-13, called the “whip,” which can withstand the coronal temperature and sends its signal through a molybdenum wire to a computer inside. The other instrument is the Faraday cup, which “peeks around the heat shield,” says Fox.
and measures the temperature, velocity, and abundance of electrons, protons, and helium ions in the solar wind.

**Feeling the Heat**

Scientists on both teams are wrapping up the tests and simulations. Last year, the Orbiter’s shield survived its trial in the Large Space Simulator at ESA’s Test Centre in The Netherlands. The facility has a vacuum chamber that mimics space and an array of powerful xenon bulbs that produces an intensity that rivals the sun. “We want to make sure all components can maintain their material properties for all 10 years of the mission,” says solar physicist Daniel Müller, the project scientist for the ESA’s Solar Orbiter mission in The Netherlands. Early next year, he says, the fully assembled spacecraft will be tested at a testing facility in Munich. “It’s like a huge puzzle, and we’re integrating the pieces,” says Müller.

In early October, the two research teams met at APL. Müller says that even though they’re working in different regimes, the science goals of the Probe and the Orbiter have an “almost ideal synergy.” The combined observations will provide a richer dataset about the sun’s environment than either can individually. For example, Solar Orbiter’s observation of the solar surface from afar will provide context to the Probe’s simultaneous, up-close measurements of the corona and provide key measurements to link the sun to the heliosphere. Taken together, the observations will give a more detailed view of the evolution of the solar wind from the sun to Earth and beyond.

Scientists already know that large solar eruptions are more likely when the sun is at peak radiance during its 11-year cycle. They also know that the structure of the corona depends on the sun’s shifting magnetic field. When the corona expels the solar wind, it flows along the magnetic field lines; the wind becomes disordered the farther it gets from the sun.

But researchers still don’t know the exact mechanisms that lead to the formation of the solar wind or how the sun’s turbulent magnetic field drives the flow of coronal plasma. A deeper understanding of those processes will help researchers predict solar weather, prepare for massive solar flares, and even shed light on how stars such as the sun are born, live, and die.

Ultimately, says Fox, the goal of the two missions is to create a coherent picture of the sun’s corona. “That’s the whole reason we’ve gone to all of this trouble,” she says. “We’ve learned so much about the sun with remote sensing techniques, but you can only learn so much by looking at something. You really do have to go.”

“We’ve learned so much about the sun with remote sensing techniques, but you can only learn so much by looking at something. You really do have to go.”
—Nicky Fox

---