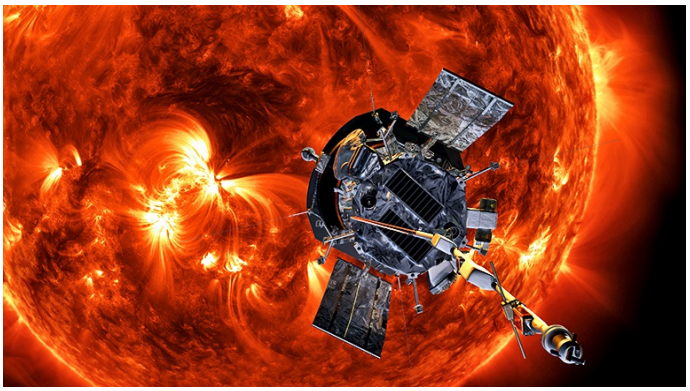
How to shield the solar probe from extreme heat
The Parker Solar Probe will get closer to the Sun than any spacecraft in human history. How will the spacecraft withstand the heat?
A heat shield you can scorch with a blowtorch until it glows red on one side and still comfortably touch on the other will protect a NASA probe flying to within 4 million miles (6.4 million km) of the Sun's surface.
The shield is the culmination of years of work by engineers to solve what they call the "thermal problem" of the soon-to-launch Parker Solar Probe. "Thermal problem" is a shorthand way of referring to the extraordinary complications of a record-breaking dive directly into our star's outer atmosphere, or corona.


Artist's concept of the Parker Solar Probe spacecraft approaching the Sun

SOLAR EXPLORER
NASA's Parker Solar Probe is on its way for a rendezvous with the Sun. A United Launch Alliance Delta IV Heavy rocket, carrying the spacecraft, lifted off at 3:31 a.m. EDT, from Space Launch Complex 37 on Cape Canaveral Air Force Station in Florida, its engines blazing golden in the clear night sky during ascent.
During its seven-year mission, the probe will explore some of the Sun's greatest mysteries: Why is the solar wind a breeze closer to the Sun but a supersonic torrent farther away? Why is the corona itself millions of degrees hotter than the surface? What are the mechanisms behind the astoundingly fast-moving solar energetic particles that can interfere with spacecraft, disrupt communications on Earth, and endanger astronauts?
Engineers have spent more than a decade creating the heat shield to deflect the worst of the Sun's energy. The front and back faces are made of sheets of carbon-carbon, a lightweight material with superior mechanical properties especially suited for high temperatures.


The mission will provide new data on solar activity and make critical contributions to our ability to forecast major space-weather events that impact life on Earth.

During its mission to "touch" the Sun, Parker Solar Probe will use gravity assists from Venus seven times over nearly seven years to gradually bring its orbit closer to the Sun. It will fly directly through the Sun's atmosphere, as close as 3.8 million miles from its surface, closer to the surface than any spacecraft before it. The spacecraft will hurtle around the Sun at speeds up to 430,000 miles per hour. That's 15 times faster than a speeding bullet.

For more than 60 years, scientist have wondered how energy and heat move through the solar corona and what accelerates the solar wind as well as solar energetic particles. Now, with the help of cutting-edge thermal technology that can protect the mission on its dangerous journey, the spacecraft's four instrument suites will study magnetic fields, plasma and energetic particles, and image the solar wind.
Parker Solar Probe will revolutionize our understanding of the Sun's corona. Facing brutal heat and radiation, the spacecraft will fly close enough to watch the solar wind speed up from subsonic to supersonic, and fly through the birthplace of the highest-energy solar particles. Parker


Dr. Eugene Parker, a pioneer in heliophysics and distinguished service professor emeritus for the Department of Astronomy and Astrophysics at the University of Chicago, watches the launch of NASA's Parker Solar Probe. This is the first agency mission named for a living person.

Solar Probe and its instruments will be protected from the Sun's heat by a 4.5-inch-thick, carbon-carbon composite heat shield.
Carbon itself conducts heat, but carbon foam is 97 percent air. There's just not that much material for heat to travel through. But even the carbon foam's impressive heat-dispersing properties weren't enough to keep the spacecraft at its required temperature. Because there's no air in space to provide cooling, the only way for material to expel heat is to scatter light and eject heat in the form of photons. For that, another layer of protection was necessary: a white coating that would reflect heat and light. After extensive testing, the team settled on a coating based on bright white aluminum oxide. That coating could react in high temperatures, however, with the carbon of the heat shield and turn gray, so the engineers added a layer of tungsten, thinner than a strand of hair, between the heat shield and the coating to stop the two from interacting. They added nanoscale dopants to make the coating whiter and to inhibit the expansion of aluminum oxide grains when exposed to heat.

While the probe orbits the Sun and records data with onboard instruments, its thermal protection system will shield the spacecraft from heat more intense than any spacecraft has ever experienced. Combined with a water-powered cooling system, the thermal protection system will keep the majority of the probe's instruments at about 29 degrees C – the equivalent of a nice summer day – while the TPS itself endures a temperature of 1,370 degrees C). Without the thermal protection system, there would be no probe.

Elisabeth Abel, TPS thermal lead at the Johns Hopkins University Applied Physics Laboratory, said:

> *This was the technology that enabled us to do this mission – to enable it to fly. It is incredibly exciting to see something you put a lot of energy and hard work into, actually fly*.

On its seven-year mission, the Parker Solar Probe will whip through the Sun's sizzling outer atmosphere, or corona, swooping to within 6.4 million km of the Sun's surface. This craft will face heat and radiation like no spacecraft before it. Scientists hope that – if it does survive its fiery journey so close to our local star – the Parker Solar Probe's instruments will provide data leading to better predictions of space weather, which begins at the Sun and ultimately can wreak havoc on human technologies on Earth and in space.

A spacecraft to touch the Sun

The scientists also hope the Parker Solar Probe will help them address fundamental questions about the Sun's dynamic and mysterious corona. The Sun's corona is one of the Sun's biggest secrets. It is hundreds of times hotter than the surface below. That's counterintuitive, like if you got warmer the farther you walked from a campfire, but scientists don't yet know why that's the case. Some think the excess heat is delivered by electromagnetic waves called Alfvén waves moving outwards from the Sun's surface. Others think it might be due to nanoflares – bomb-like explosions that occur on the Sun's surface, similar to the flares we can see with telescopes from Earth, but smaller and much more frequent. Either way, Parker Solar Probe's measurements direct from this region itself should help us pin down what's really going on.
We also hope to learn more about space weather and its effects on our earthly technologies. What exactly is the solar wind – the Sun's constant outpouring of material that rushes out at a million miles per hour and fills the solar system past the orbit of Pluto. The solar wind can cause space weather when it reaches Earth – triggering things like the aurora, satellite problems, and even, in rare cases, power outages.
We know where the solar wind comes from, and that it gains its speed somewhere in the corona, but the exact mechanism of that acceleration is a mystery. By sampling particles directly at the scene of the crime, scientists hope Parker Solar Probe can help crack this case.

The Parker Solar Probe will carry a suite of four instruments that will measure the Sun's particles, magnetic and electric fields, solar wind and more. It is hoped, that by helping scientists understand our local star, the Parker Solar Probe will provide insights on stars everywhere in the universe.

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