NASA spacecraft launched for close-up study of the Sun

By Bryan Dyne
13 August 2018

The Parker Solar Probe was launched early Sunday morning and has begun its three-month journey to get closer to the Sun than any previous spacecraft.

For the first time, a spacecraft will venture into the Sun's outer atmosphere, the corona, to take measurements of the complex thermal and magnetic interactions that have been observed from afar in different forms for more than one and a half centuries. The probe will study the flow of heat into the corona, examine the structure and motion of the solar wind and investigate the mechanisms that transport and accelerate particles from the Sun's surface to Earth's orbit and beyond.

Once it is fully deployed, the Parker Solar Probe will join the ten other spacecraft that are currently studying different aspects of the Sun and its influence on Earth and the solar system in general. The total cost is estimated at $1.5 billion over the lifetime of the mission, about a tenth of the US Navy's new Gerald R. Ford-class supercarrier.

During its first week of operations, the spacecraft will deploy its high-gain antenna for ship-to-Earth communications and its magnetometer boom, which will study changes in the solar magnetic field.

Later, the craft's hundreds of researchers, engineers and technicians will begin the four-week process of calibrating five main scientific instruments and ensuring that all flight systems are ready to face the extreme heat that the probe will experience when it is studying the Sun at a distance of 24 million kilometers, half the distance of Mercury's orbit. The first close-up observations are expected to begin in December.

The mission is slated to last until 2024, using a series of seven flybys of Venus to get progressively closer to the Sun. At its closest approach, the probe will dive to just 6 million kilometers away from the Sun and will whip around the star at 692,000 kilometers per hour. For comparison, the New Horizons mission to Pluto is only traveling out of the Solar System at just under 51,000 kilometers per hour.

To survive the intense radiation so close to the Sun, the Parker Solar Probe uses a specially designed heat shield that has to resist radiation that is 475 times the intensity Earth receives. The heat shield consists of a layer of highly reflective aluminum oxide, a carbon-carbon composite and a carbon foam, which reduces temperatures of 1,370 degrees Celsius (hotter than lava erupting from a volcano) to about 30 degrees Celsius (slightly above room temperature).

While this technology is not new, it places enormous constraints on the operations of the instruments because they must study the corona and magnetic field while avoiding direct sunlight, under conditions where the sun's apparent disk is 30 times as large as it appears from Earth.

The protection of the instruments also depends on onboard algorithms to constantly correct the spacecraft's orientation. As the spacecraft flies around the Sun, it is too far away to be controlled by anyone on Earth and so must correct the probe's orientation without any human aid. And unlike a landing on Mars, which requires computer guidance and correction for about seven minutes, Parker Solar Probe will have to correct its course by itself for seven years.

Once the spacecraft begins to collect data, it will provide critical insights into solving two problems in solar physics that have puzzled astronomers for decades: the hot temperatures of the corona and the fast speeds of the solar wind.

The corona is the thin outer layer of the Sun's atmosphere. It consists of free electrons and ions that flow around the Sun and out from it in patterns guided by the Sun's myriad and constantly fluctuating magnetic fields. Much of the solar activity that reaches Earth originates in the corona and can interfere with radio communications, harm satellites and astronauts and even break power grids and oil pipelines. A full understanding of the corona is similar to understanding climate patterns on Earth, both interesting from a pure research standpoint and essential to ensure the continued functioning of society.

While the first scientific observations of the corona were made in 1869, the results were not understood until 1940, when Swedish physicist Bengt Edlén determined that the light from the corona revealed the presence of iron atoms that had 13 out of their 26 electrons stripped off. Using the developments in quantum mechanics in the preceding three decades, Edlén calculated that the energy required to remove so many electrons from iron meant that the temperature of the corona had to be at least one million degrees Celsius.

There was immediate skepticism of the result. Temperatures in the core of the Sun, the source of the star's energy, reach fifteen million degrees Celsius, but they steadily decrease to about six thousand degrees Celsius on its surface. It was counterintuitive that the temperature further from the Sun's core would increase. As every observation since then has confirmed, however, going from the surface of the Sun into the corona, the temperature spikes to between one and ten million degrees Celsius, akin to moving away from a fire and yet getting hotter.

There are currently three main hypotheses to explain this transfer of heat, including slow-moving sound waves that travel between different layers of the Sun's atmosphere, energy stored and transferred via magnetic fields and small jets of particles originating from just above the Sun's surface. None of them have been wholly rejected or confirmed and in fact all may play a role in powering the corona.

The speed of the solar wind is related to the high coronal temperature. In 1958, the spacecraft's namesake Eugene Parker (1927-) predicted that material in the corona is so hot that it can escape the Sun's gravity and accelerate into the Solar System. This was confirmed a year later by data collected by the Soviet spacecraft Luna 1 and analysis done by Konstantin Gringauz. The results were replicated by the Soviet Luna 2, Luna 3, and Venera 1, and the NASA spacecraft Mariner 2.

Continued work predicted that these particles begin accelerating 2.8 million kilometers above the surface of the Sun. This was the accepted theory until the 1990s when observations by the Solar and Heliospheric Observatory spacecraft showed that the acceleration of the solar wind occurred four times closer to the Sun than Parker's prediction. Given that, there must be something more than the heat of the corona driving the solar wind.

There have been several ground- and space-based experiments to try to resolve this discrepancy, but none have been so far successful. The leading hypotheses involve still unknown magnetic and gravitational interactions between particles in the corona and the Sun as a whole.