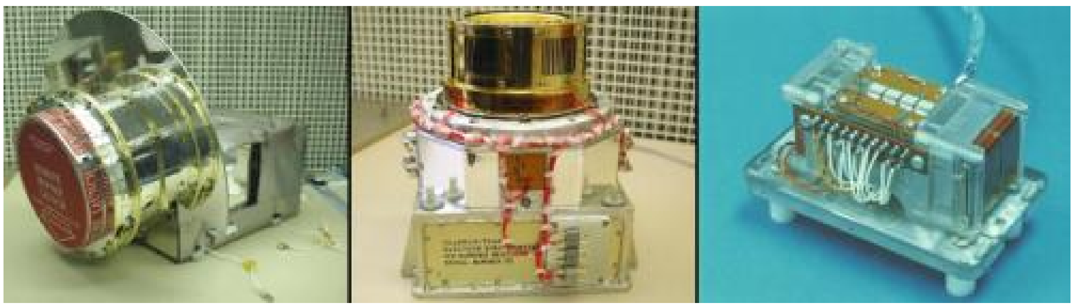
NOAA's DSCOVR: Offering a new view of the solar wind

February 6 2015



Three instruments will help measure the solar wind on the DSCOVR mission: (shown from left to right), the Faraday cup to monitor the speed and direction of positively-charged solar wind particles, the electron spectrometer to monitor electrons, and a magnetometer to measure magnetic fields. Credit: NASA/NOAA/DSCOVR

There's a fascinating spot some 932,000 miles away from Earth where the gravity between the sun and Earth is perfectly balanced. This spot captures the attention of orbital engineers because a satellite can orbit this spot, called Lagrange 1 just as they can orbit a planet. But the spot tantalizes scientists as well: Lagrange 1 lies outside Earth's magnetic environment, a perfect place to measure the constant stream of particles from the sun, known as the solar wind, as they pass by.

In early February, the United States Air Force will launch a National Oceanic and Atmospheric Administration (NOAA) satellite called Deep

Space Climate Observatory, or DSCOVR, into orbit around this spot. NOAA will use DSCOVR to monitor the solar wind and forecast space weather at Earth—effects from the material and energy from the sun that can impact our satellites and technological infrastructure on Earth.

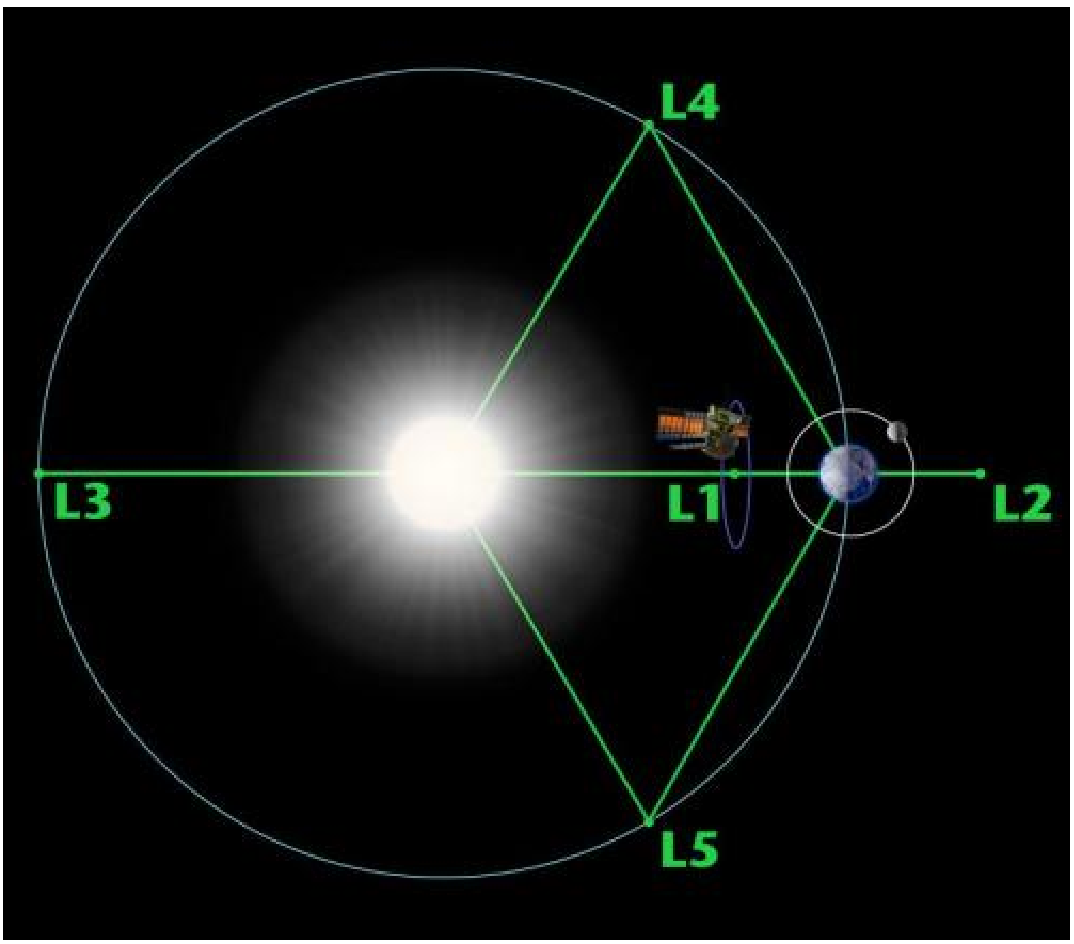
However, the three solar wind instruments on board are also exciting researchers with the hope of untangling some unsolved science mysteries about the solar wind. Two of the instruments were built at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and one at the Massachusetts Institute of Technology and the Harvard-Smithsonian Center for Astrophysics, both in Cambridge, Massachusetts.

"One of our main questions about the solar wind is based on the fact that it cools down as it moves toward Earth but not as fast as we'd expect," said Adam Szabo, NASA's DSCOVR project scientist at NASA Goddard. "There must be some heating mechanism that slows down the cooling. The solar wind instruments on DSCOVR will help us determine what's providing that extra heat."

To explore the various theories about what heats the solar wind, one must immerse oneself in the physics of very hot, charged gases called plasmas. On Earth, plasmas are found almost exclusively in laboratories and neon signs. However, plasmas dominate most of the universe, filling up space and fueling stars. Because the particles are charged, the gas is ruled by the laws of electromagnetism, in which charged particles help maintain magnetic fields and those same fields help guide the way the particles can move. The constant feedback between these phenomena creates a complex system where small events can have big consequences.

There are two broad categories of theories as to what heats the plasma in the solar wind. The first set of theories posits that some kind of electromagnetic wave coursing through the plasma provides heat, kicking individual particles into faster movements simply because their movements are in sync with the particles, like the perfectly timed push of a swing.

The second set of theories rely on grand scale movements - think giant ocean waves of moving particles - that cascade down to ever smaller scales of motion eventually providing energy and heat to the individual particles themselves. In the ocean wave analogy, this might be like how the energy of a large wave incites smaller motions such as the froth riding at its crest.



This is a diagram of the five Lagrange points associated with the sun-Earth system, showing DSCOVR orbiting the L-1 point. Image is not to scale. Credit: NASA/WMAP Science Team

Distinguishing between these two broad camps—not to mention hammering out the details of what plasma waves might be present or how the turbulence cascade actually works - require monitoring three facets of the solar wind: The movement of the positive particles, the movement of the negatively-charged electrons, and the alignment of the magnetic fields present in the plasma and its electric fields.

DSCOVR carries an instrument for each of these measurements. The velocity and direction of the positively-charged particles are measured by something called a Faraday cup, built by the Massachusetts Institute of Technology and operated by the Harvard-Smithsonian Center for Astrophysics and the University of Michigan in Ann Arbor. Faraday cups were one of the first plasma instruments ever developed - there are Faraday cups on the two Voyager spacecraft, launched in 1977—however they are improved with every incarnation. The one on DSCOVR will be able to profile the energies of the protons in the solar wind at least once a second. Compare this to the Faraday cup on the Wind spacecraft, which launched in 1994 and gathers one profile every 92 seconds.

"Profiling the number and velocity of the particles every second, takes us down to scales where we can analyze wave particles," said Szabo. "This is exactly what we need to help determine what's heating the solar wind. This is revolutionary."

The Faraday cup on DSCOVR plays another important role. It is a precursor to a similar instrument—led by Justin Kasper at the University of Michigan—for NASA's Solar Probe Plus, planned for a 2018 launch. Solar Probe Plus will study the solar wind much closer to the sun. It will fly almost ninety times closer to our sun than DSCOVR and plunge repeatedly into the sun's atmosphere. There the solar wind is denser and its physical processes faster, so the Faraday cup will be built to measure at a rate of 100 times per second. Feedback from the instrument on DSCOVR should help with design of the one being built for Solar Probe Plus. Moreover, once both are in space, the similarity between the instruments will ensure the validity of comparisons between the measurements at the sun and near Earth.

"When we proposed the DSCOVR Faraday cup we saw it as a pathfinder for the Solar Probe Plus mission," said Kasper, who is also the instrument lead for the Faraday cup on Solar Probe Plus. "We are extremely excited to be able to see how such a fast instrument behaves, and what we discover will feed right into our plans for Solar Probe Plus."

The magnetic field and electron instruments on DSCOVR were both built at NASA Goddard. These, too, are fairly well-tested instrument types at this point. A similar magnetic field instrument, called a magnetometer, is on Wind, Voyager and the Advanced Composition Explorer, or ACE. This type of magnetometer will also be on Solar Probe Plus.

DSCOVR's magnetometer will gather data at the rate of 50 times per second, which is the fastest speed so far accomplished. Compare that to Wind's 11 times per second and ACE's 6 times per second. The goal for Solar Probe Plus is to reach 256 times per second.

Such instrumentation, of course, is also key to DSCOVR's primary job as a NOAA operational space weather satellite. NOAA is the U.S. government's official source for space weather forecasts and warnings. Since 1997, NOAA has incorporated crucial data from NASA's ACE, in order to monitor the solar wind in real time. DSCOVR will provide a new set of input to succeed that solar wind workhorse.

DSCOVR's orbit at Lagrange 1 also makes it ideal as an Earth observer:

It includes two instruments to support Earth science.

The DSCOVR mission is a partnership between NOAA, NASA and the U.S. Air Force. NOAA will operate DSCOVR from its NOAA Satellite Operations Facility in Suitland, Maryland, and process data at the Space Weather Prediction Center in Boulder, Colorado, for distribution to users within the United States and around the world. The data will be archived at NOAA's National Geophysical Data Center in Boulder, Colorado.

NASA received funding from NOAA to refurbish the DSCOVR spacecraft and its solar wind instruments, develop the ground segment and manage launch and activation of the satellite. The Air Force funds and oversees the launch services for DSCOVR. DSCOVR also hosts NASA-funded secondary sensors for Earth and space science observations. NASA provided funding for the refurbishment of the Earth-viewing instruments. The Earth science data will be processed at NASA's DSCOVR Science Operations Center and archived and distributed by NASA's Atmospheric Science Data Center.

Provided by NASA's Goddard Space Flight Center