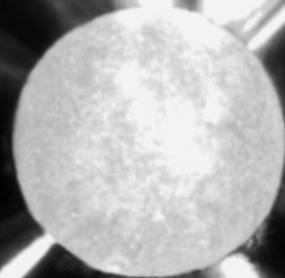


National Aeronautics and Space Administration
www.nasa.gov



STEREO

SCIENCE WRITER'S GUIDE

A guide for reporters to understand the mission and purpose of NASA's STEREO observatories

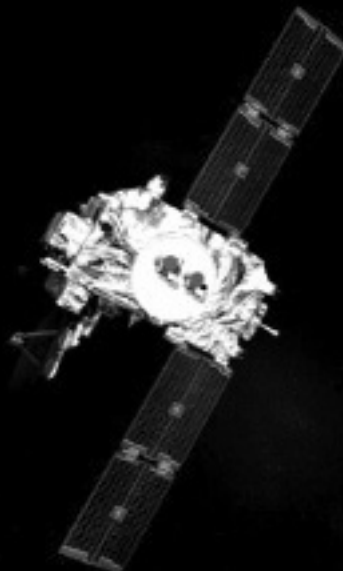


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STEREO Quick Reference Guide

STEREO (Solar TERrestrial RELations Observatory) is a 2-year mission employing two nearly identical observatories to provide 3-D measurements of the sun to study the nature of coronal mass ejections. These powerful eruptions are a major source of the magnetic disruptions on Earth and a key component of space weather, which can greatly affect satellite operations, communications, power systems, and the lives of humans in space.

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STEREO Fact Sheet: http://www.nasa.gov/pdf/113365main_factsheet.pdf
STEREO Booklet: http://www.nasa.gov/pdf/136031main_STEREObooklet.pdf
STEREO Products: <http://stereo.gsfc.nasa.gov/classroom/products.shtml>

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STEREO WEB SITES FOR MORE INFORMATION:

<http://www.nasa.gov/stereo>
<http://stereo.gsfc.nasa.gov>
<http://www.stereo.jhuapl.edu>
<http://stereo.gsfc.nasa.gov/classroom/faq.shtml>
<http://stereo.gsfc.nasa.gov/classroom/definitions.shtml>

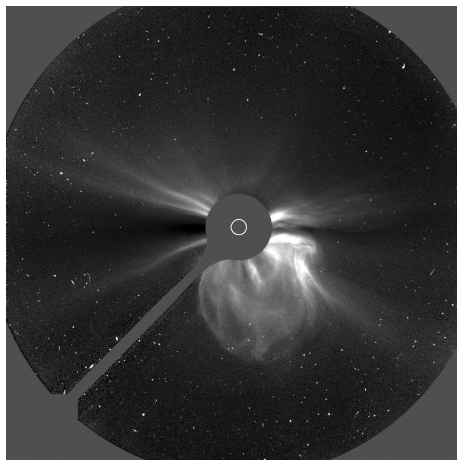
STEREO INSTRUMENT WEB SITES:

IMPACT: <http://sprg.ssl.berkeley.edu/impact>
PLASTIC: <http://stereo.sr.unh.edu>
SECCHI: <http://www.solar.nrl.navy.mil/STEREO>
S/WAVES: <http://ssed.gsfc.nasa.gov/swaves>

STEREO SCIENCE CENTER:

<http://stereo-ssc.nascom.nasa.gov>

RIGHT: Coronal Mass Ejection (CME)
leaving the sun on March 29, 1998.
Credit: NASA/ESA



How NASA Is Structured To Seek Solar Answers

HELIOPHYSICS DIVISION

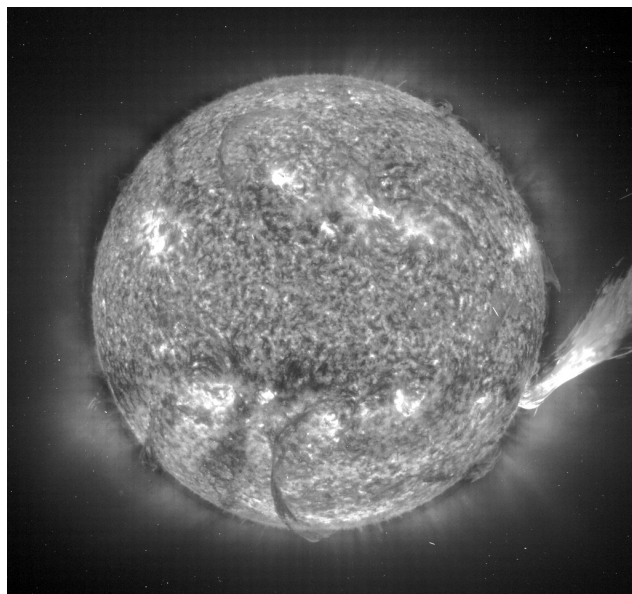
NASA's goal for future research and exploration within its Heliophysics Division is to observe and understand the complex phenomena associated with space weather by studying the sun, the heliosphere, and planetary environments as a single, inter-connected system. Such an understanding will represent not just a grand intellectual accomplishment for our time, it will also provide knowledge and predictive capabilities essential to future human and robotic exploration of space and will serve key societal objectives in important ways.

THE SOLAR TERRESTRIAL PROBES PROGRAM

The Solar-Terrestrial Probe (STP) missions address fundamental science questions about the physics of space plasmas and the flow of mass and energy through the solar system. The STEREO mission will provide an unprecedented view of the three-dimensional distribution of magnetic fields and particle flows throughout the heliosphere. And the Magnetospheric Multiscale Mission, to be launched in 2011, will explore the fundamental microphysical processes responsible for the transfer of energy from solar wind to Earth's magnetosphere and the explosive release of energy during substorms. Solar-B, a partnership mission led by Japan, will be launched in 2006 to observe how magnetic fields on the sun's surface interact with the sun's outer atmosphere, which extends millions of miles into space.

INTRODUCTION TO STEREO

Solar TERrestrial RELations Observatory (STEREO) is the third mission in NASA's STP program. This two-year mission will employ two nearly identical space-based observatories—one ahead of Earth in its orbit, the other trailing behind—to provide the first-ever stereoscopic measurements to study the sun and the nature of its coronal mass ejections, or CMEs.



ABOVE: Erupting prominence from June 15, 1998, captured by the Solar & Heliospheric Observatory (SOHO).
Credit: NASA/ESA

Q&A on the STEREO Mission

WHAT IS STEREO'S PURPOSE AND MISSION?

The purpose of STEREO's mission is to discover and communicate new scientific knowledge about space processes and conditions. In an effort to understand the nature of coronal mass ejections (CMEs), the most energetic eruptions on the sun, STEREO will provide the first-ever stereoscopic measurements to study the sun and space weather.

HOW LONG WILL THE MISSION LAST?

STEREO is expected to operate for a minimum of two years. An additional one year of data analysis will be supported by STEREO's science team and by the mission's science center, located at NASA's Goddard Space Flight Center (GSFC), Greenbelt, Md.

HOW WILL STEREO HELP THE AVERAGE PERSON?

It will provide a better understanding of space weather and will help protect space assets like satellites and astronauts in space.

WHAT DOES STEREO COST?

STEREO costs about \$460 million plus approximately \$60 million from European contributions. That figure includes all development costs, launch costs, two years of operation, and three years of data analysis.

HOW MANY INSTRUMENTS ARE ONBOARD THE OBSERVATORIES?

Each twin STEREO observatory will carry two instruments and two instrument suites. This combination provides a total of 16 instruments per observatory. The Johns Hopkins University Applied Physics Laboratory, in Laurel, Md., has designed and built the spacecraft platform that house the instruments.

WHAT ARE THE NAMES OF THE STEREO INSTRUMENTS*?

- 1) Sun-Earth Connection Coronal and Heliospheric Investigation (SECCHI)
 - 2) STEREO/WAVES (SWAVES)
 - 3) *In-situ* Measurements of Particles And CME Transients (IMPACT)
 - 4) PLAsma and SupraThermal Ion Composition (PLASTIC)
- (*See STEREO Instrument page for details on each instrument)

WHAT IS THE MAIN MISSION OBJECTIVE?

The principal mission objective for STEREO is to understand the origin and consequences of CMEs, the most energetic eruptions on the sun.

WHAT ARE THE OTHER MISSION OBJECTIVES?

Specific science objectives are to:

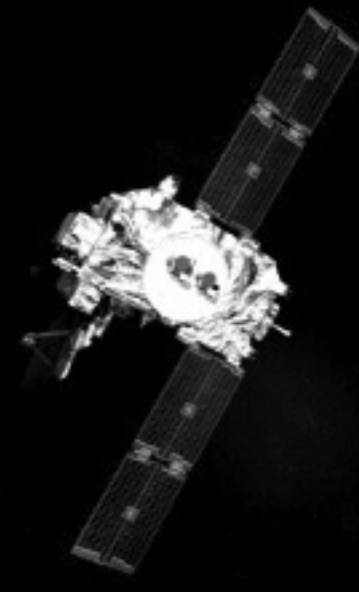
- 1) Understand the causes and mechanisms that trigger CMEs.
- 2) Characterize how CMEs move through the heliosphere.
- 3) Discover the mechanisms and sites of solar energetic particle acceleration.
- 4) Develop a three-dimensional, time-dependent model of the magnetic topology, temperature, density, and velocity structure of the ambient solar wind.

WHAT IS NEW AND REVOLUTIONARY ABOUT THE STEREO MISSION?

For the first time we will be obtaining 3-D information about the sun and solar wind with two nearly identical space-based observatories, using imaging, measurements of conditions at the spacecraft, and radio astronomy experiments.

WHY ARE STEREO'S TWIN OBSERVATORIES CALLED "NEARLY IDENTICAL"?

The twin STEREO observatories orbit the sun such that one spacecraft is ahead of the Earth and the other is behind it. Because the high-gain dish antennas need to be pointed at Earth for command



Q&A



and telemetry, one spacecraft must fly "upside down" relative to the other. This requires the identical instruments on each craft to be placed in slightly different locations. Also the "B" observatory's main structure is a little thicker so that it can support the weight of the "A" observatory during launch. The "B" observatory will retain a portion of the separation fitting or ring used to connect the two during their ride into space.

HOW FAR ARE THE STEREO SATELLITES SPACED APART?

Both are almost in Earth's orbit but one is a little closer to the sun, and the other a little further from the sun. Spacecraft "A" orbits the sun every 346 days, while "B" orbits every 388 days. From the perspective of the sun, the observatories separate by 45 degrees every year.

HOW WILL STEREO OBTAIN THE "STEREO" VIEWS OF THE SUN?

The STEREO mission will offer a totally new perspective on solar eruptions by imaging CMEs and background events from two nearly identical observatories simultaneously. To obtain unique views of the sun, the twin observatories must be placed into a rather challenging orbit where they will be offset from one another. One observatory will be placed ahead of Earth in its orbit and the other behind. Just as the slight offset between your eyes provides you with depth perception, this placement will allow the STEREO observatories to obtain 3-D images of the sun.

WHAT PREVIOUS MISSIONS DOES STEREO CONTINUE AND IMPROVE UPON?

The SOHO, ACE, and WIND missions.

THE FEATURE SECTION OF THE WRITER'S GUIDE WILL EXPLORE:

1) WHY SEEING THE SUN IN 3-D IS IMPORTANT IN FORECASTING

One point of view is not enough to really understand the trajectory and structure of a large moving feature. In order to really understand CMEs and related phenomena we need to see them from more than one point of view at once. Then we may be able to understand the processes at work and predict how CMEs will affect Earth and human endeavors in space.

2) SPACE SUPERSTORM COULD TAKE HEAVY TOLL

Our satellites and space assets are affected by space weather, almost like a boat on the ocean.

3) SICKENING SOLAR FLARES

The biggest solar proton storm in 15 years erupted in January 2005. NASA researchers discuss what it might have done to someone on the moon.

HOW WILL STEREO IMPROVE OUR KNOWLEDGE OF THE SUN AND SPACE WEATHER?

CMEs are one of the primary drivers of space weather. This mission will help us understand how and why these occur and how they move through space—key information for predicting them and mitigating their effects. The mission will also help us better understand the general structure of the solar wind and interplanetary magnetic field, which are also key to understanding how the sun affects us.

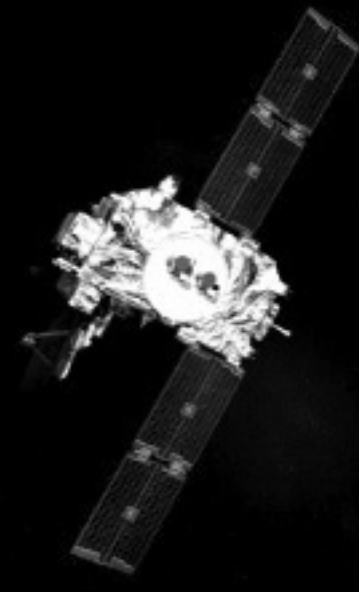
WHAT EXACTLY IS "SPACE WEATHER"?

At the center of the solar system is the sun, a magnetic variable star that drives the Earth and all the planets of the solar system. The modulation of the sun on space conditions is the result of the interplay of three forces, pressure, gravity, and magnetic forces. In the case of short term variation, particularly ones that have impact on human systems or environmental conditions, the effects are collectively referred to as "space weather." Solar flares and coronal mass ejections (CMEs) originate at the sun and can cause disturbances near Earth and throughout the solar system. There are several examples of space weather effects: this solar activity, as well as its interaction with Earth's magnetic fields, can produce dangerous radiation in the forms of high-speed particles or electromagnetic radiation and can affect spacecraft, communications and power systems, and present a hazard to astronauts.

WHAT ARE CORONAL MASS EJECTIONS AND WHY IS IT IMPORTANT TO STUDY THEM?

CMEs are powerful eruptions that can blow up to 10 billion tons of the sun's atmosphere into interplanetary space. Typically, CMEs eject about one billion tons of solar particles into space and travel at about one million miles per hour. They can create major disturbances in the interplanetary medium (dust, gas, and plasma in the space between the planets), and if they reach Earth, trigger severe

Q&A



.....

magnetic storms that affect satellites, communications, power grids, and airlines. CME-driven shocks also play a significant role in accelerating solar energetic particles that can damage spacecraft and harm astronauts. Despite their importance, scientists don't fully understand the origin and evolution of CMEs; STEREO's unique 3-D measurements should help with those answers.

WHEN WILL THE FIRST DATA BE RELEASED?

The S/WAVES and IMPACT instruments will transmit data within the first day or two, while the PLASTIC instruments will start to operate within two to three weeks. The first 3-D images will be obtained and released approximately three months after launch as STEREO gets into an appropriate orbit. The STEREO Project Scientist, the STEREO Science team, and NASA Headquarters will coordinate all releases.

WHAT WILL THE 3-D IMAGES LOOK LIKE?

The images will be similar to that of the Extreme Ultraviolet Imaging Telescope (EIT) on the Solar and Heliospheric Observatory (SOHO), but with significantly greater resolution (2k) and frequency (one image every few minutes). The EIT instrument takes images approximately every 12 minutes.

HOW WILL THE DATA BE DISTRIBUTED?

The data will be available over the Internet from the STEREO Science Center:
<http://www.nasa.gov/STEREO>

HOW AND WHERE WILL THE DATA BE PROCESSED?

The regular data will be processed by the instrument teams, while the space weather beacon data to be used for space weather is processed at NASA Goddard Space Flight Center.

WHO CAN HELP WITH PRESS RELEASES, INTERVIEWS, OTHER RESOURCES? VIDEO?

NASA Public Affairs officers can provide the latest press releases, breaking news, video and arrange interviews. At Goddard Space Flight Center, contact: Rachel Weintraub, Public Affairs Officer and NASA-TV Producer, Tel. 301-286-0918 or 301-286-8955 or by e-mail Rachel.A.Weintraub@nasa.gov

WHAT ARE NASA'S MISSION MANAGEMENT RESPONSIBILITIES?

During the mission development phase, STEREO was managed by NASA GSFC Solar Terrestrial Probes Program Office in Greenbelt, Md., which provided science instrument management, systems engineering, mission assurance, and reliability. During the post-launch phase, STEREO is managed by the Goddard Science and Exploration Directorate, which is responsible for dissemination of telemetry, processed data, and real-time space weather data as well as data archiving, overall science coordination, and coordination of Education and Public Outreach (EPO) efforts.

WHAT ARE JOHNS HOPKINS MISSION MANAGEMENT RESPONSIBILITIES?

During the mission development phase, The Johns Hopkins University Applied Physics Laboratory (JHU/APL) in Laurel, Md., was responsible for the design, construction, integration, and testing of the twin observatories. Post-launch, JHU/APL is responsible for mission operations of the observatories as well as the ground data collection during the two-year mission.

WHO ARE THE PARTNERS ON THE STEREO MISSION? WHAT ROLE DO THEY HAVE?

- 1) Johns Hopkins University Applied Physics Laboratory (mission operations)
- 2) NASA GSFC (STEREO Science Center (SSC)/data archiving; space weather)
- 3) Naval Research Laboratory (NRL), Washington, DC (SECCHI instrument)
- 4) *Paris-Meudon-Nancay Observatory*, France (SWAVES instrument)
- 5) University of California, Berkeley (UCB) (IMPACT instrument)
- 6) University of New Hampshire (UNH) (PLASTIC instrument)

HOW DOES STEREO FIT IN WITH NASA'S SUN-SOLAR SYSTEM CONNECTION OBJECTIVES?

STEREO contributes to all three of NASA's sun-Solar System Connection theme's scientific objectives: (1) understanding the changing flow of energy and matter throughout the sun, heliosphere, and planetary environments; (2) exploring the fundamental physical processes of space plasma systems; and (3) defining the origins and societal impacts of variability in the sun-Earth connection.

Q&A

Why Seeing The Sun In 3 Dimensions Is Important In Forecasting

by Rachel A. Weintraub

Stay Tuned for a STEREO View of Stormy Space Weather

Original story found at: <http://www.nasa.gov/vision/universe/solarsystem/stereo.html>

The thrills! The chills! Soon you'll be able to see for the first time ever, in dazzling three dimensions ... the sun. Imagine solar prominences looping out into space for thousands of miles. Now picture a billion megaton blast of solar plasma flying toward Earth and the effect it would have on astronauts, satellites in orbit, airplanes, and power grids, which are vulnerable to such a burst. Now you're starting to see why we need a better understanding of that powerful and dynamic star.

The upcoming Solar TERrestrial RELations Observatory (STEREO) mission will help provide the big picture by using two nearly identical spacecraft to image the sun and track its activity in high definition 3-D. Particularly crucial will be its observations of coronal mass ejections, or CMEs, the most powerful explosions in the solar system. Related to solar flares (scientists still don't really know which comes first), CMEs can pack the force of a billion megaton nuclear bombs.



LEFT: STEREO spacecraft observing a CME in 3-D.
Credit: NASA/Walt Feimer.

"In terms of space weather forecasting, we're where weather forecasters were in the 1950s. They didn't see hurricanes until the rain clouds were right above them; in our case, we can see storms leaving the sun but we have to make guesses and use models to figure out if and when it will impact Earth," said Dr. Michael Kaiser, Project Scientist for STEREO at NASA Goddard Space Flight Center.

RIGHT: A view of the sun-Earth Connection Coronal and Heliospheric Investigation (SECCHI) instrument being built at the Naval Research Laboratory in Washington, DC. The spacecraft are being assembled in the APL Cleanroom.

Credit: NRL/NASA/Chris Gunn.

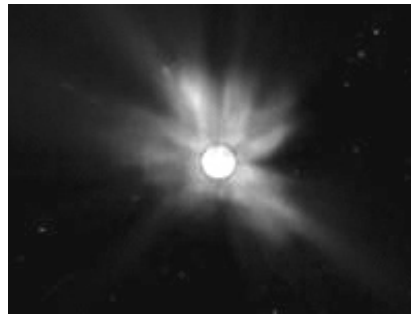


There's a strong fleet of satellites observing the sun right now, but even with missions like SOHO, which images the sun every 10 to 15 minutes, scientists still can't definitively say if a CME is coming toward Earth or traveling away from it—for that we need to see the third dimension.

"When you're trying to figure out what really makes a CME go, knowing where it is in space is crucial. At this point we don't quite know where it is, how fast it's traveling, or how one structure interacts with another," said Dr. Terry Kucera, Deputy Project Scientist for the mission.

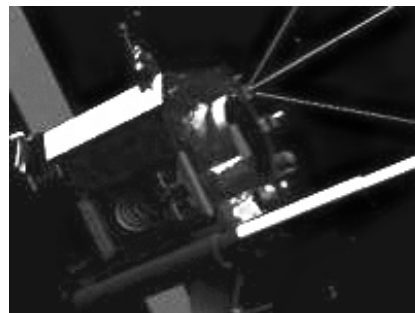
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RIGHT: A 3-D rendering of the sun's corona, the wispy outer atmosphere where solar flares thrive.
Credit: NASA/Tom Bridgman



"If you only saw stuff with one eye you lose the ability to judge perspective and depth," said Dr. Alex Young, a NASA scientist. "Basically we're looking at the sun with one eye. With STEREO, we're finally going to have the ability to gain this extra dimension, or this depth perception we didn't have before."

STEREO's spacecraft are just as unique and groundbreaking as its mission. It marks the first time that two spacecraft will launch on the same rocket, and then swing around the moon to get into separate orbits. Once there, STEREO 'A' will fly ahead of the Earth and STEREO 'B' will fly behind it. When the solar arrays are deployed, the spacecraft will be about the length of a large school bus.

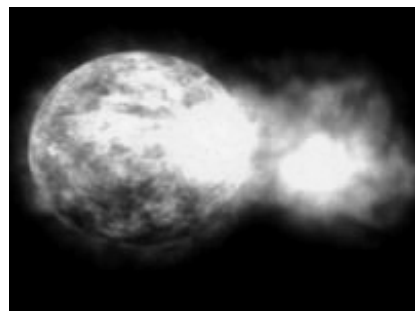


LEFT: Preview of STEREO spacecraft. The two spacecraft will be launched on the same spacecraft in Spring 2006.
Credit: NASA/Chris Meaney

Building two spacecraft at the same time "requires twice the amount of effort, but isn't that much harder with the right team," said Jim Adams, the Deputy Project Manager.

Each STEREO observatory has a total of 16 instruments, all of which have been assembled in labs throughout the world. The instruments were delivered to The Johns Hopkins Applied Physics Lab for assembly and initial testing, and then went to NASA Goddard Space Flight Center for final testing. STEREO launches in the spring of 2006 from the Cape Canaveral Air Force Station in Florida.

Besides improving space weather forecasting and understanding for Earth systems, STEREO is also an important key to understanding the sun's influence throughout the solar system.

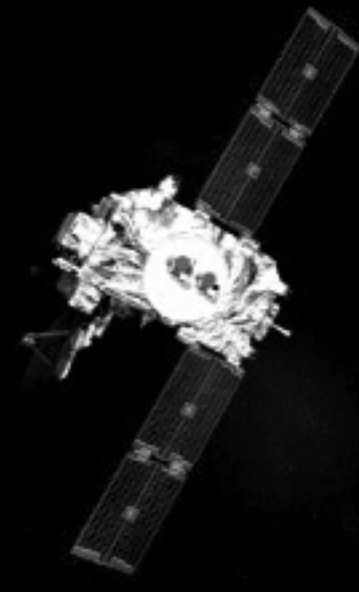


LEFT: This artist's concept shows a CME leaving the sun and being buffeted by Earth's magnetic fields until it finally results in a spectacular aurora at the poles. Scientists still don't fully understand the origins and evolution of these massive storms.
Credit: NASA/Walt Feimer

Here on Earth we're protected by the atmosphere and magnetic fields from the sun's radiation. But as NASA gears up to send astronauts to the moon and beyond, we're going to need a better understanding of the dangerous solar particles accelerated by shock waves from CMEs. One of the biggest mysteries confronting scientists: why does one CME produce a major storm and another one does not?

"To some degree, we're getting knocked around and seeing bits and pieces. With STEREO, we'll get a chance to step back and see a CME from the outside in all its glory. ... We're not just going to see CMEs coming toward us, but we'll see how they move through the solar system," said Young.

STEREO FEATURES: 1





Safeguarding Our Satellites From The Sun

by Bill Steigerwald & Rachel A. Weintraub

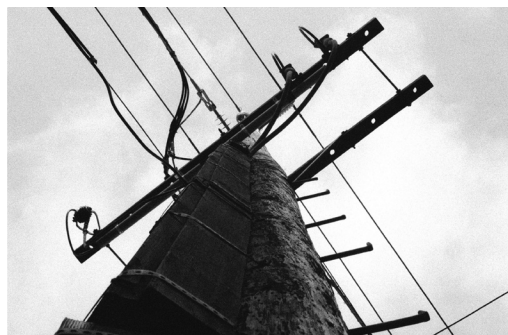
How much do we need to worry about the sun? Solar blasts from the past reveal some expensive consequences and important incentives to improve our understanding.

A direct hit from a giant solar storm similar to the historic 1859 storm could take a heavy toll on our satellite fleet, according to new research.

"A worst-case solar storm could have an economic impact similar to a category 5 hurricane or a tsunami," said Dr. Sten Odenwald of NASA's Goddard Space Flight Center, Greenbelt, Md. "There are more than 900 working satellites with an estimated replacement value of \$170 billion to \$230 billion, supporting a \$90 billion-per-year industry. One scenario showed a 'superstorm' costing as much as \$70 billion due to a combination of lost satellites, service loss, and profit loss."

RIGHT: Telegraph pole in San Francisco, Calif.
Credit: Damon Hart-Davis

The 1859 storm was more severe than any encountered during the space age, according to a review of ice core data by Odenwald, and an analysis of geomagnetic data and eyewitness accounts by Dr. Jim Green of NASA Goddard, and his team. "The 1859 storm was the granddaddy of all solar storms—there has been nothing like it since," said Green. "It disrupted telegraph lines all over the world and generated aurora as far south as Panama. It enthralled the public—news reports were everywhere."



Solar storms begin with tangled magnetic fields generated by the sun's churning electrified gas (plasma). Like a rubber band that has been twisted too far, solar magnetic fields can suddenly snap to a new shape, releasing tremendous energy as a solar flare or a coronal mass ejection (CME). Solar flares are explosions in the sun's atmosphere, with the largest equal to billions of one-megaton nuclear bombs. Solar magnetic energy can also blast billions of tons of plasma into space at millions of miles (kilometers) per hour as a CME. This violent solar activity often occurs near sunspots, dark regions on the sun caused by concentrated magnetic fields.

Sunspots and stormy solar weather follow an eleven-year cycle, from few sunspots and calm to many sunspots and active, and back again. The most powerful solar storms have occurred within a few years of the peak in sunspot number, which was in the year 2000 for the last solar cycle.

Recent Record-Breaking Storms

We've seen some pretty fantastic solar storms in the last few years too, despite the sun entering into the solar minimum. And we've been very lucky. The last few major storms were more like glancing blows rather than full impact in terms of affecting Earth's many satellites and space systems. For example, just last September as the nation was reeling from Hurricane Katrina, forecasters at the National Oceanic and Atmospheric Administration (NOAA) issued warnings that some of the largest solar flares ever recorded had erupted and had the potential to disrupt spacecraft operations, electric power systems, high frequency communications, and low frequency navigation systems. In particular they were concerned about communications between rescue workers.

The event created "a complete blackout of high frequency communications on the daylit side of Earth, which included the entire U.S. and basically anywhere the sun was shining" at the time, said Larry Combs, a solar forecaster at the NOAA Space Environment Center.



LEFT: An APL technician secures the electrical harness routed to the high-gain antenna on the STEREO "A" observatory.
Credit: Johns Hopkins University / Applied Physics Laboratory

Perhaps the best-known disruption of service occurred in March 1989, when a powerful solar blast disturbed at least 200 different components of electric power systems in Maryland, California, New York, New Mexico, Arizona, and Pennsylvania. In Sweden, five power transmission lines were tripped by large voltage fluctuations and fire alarms went off. Meanwhile a \$10 million transformer was damaged beyond repair in New Jersey.

But the Hydro-Quebec power company suffered the brunt of the storm: a chain reaction collapsed an entire power grid in 90 seconds leaving more than six million people in Quebec City, Montreal, and surrounding areas without power and heat. Morning rush hour was snarled without traffic lights, the subway system and airport were shut down, and schools and businesses were forced to close. It took nine hours to restore power to most of the region and cost Hydro-Quebec at least \$10 million.

Satellites were also affected: geostationary communication satellites had to be re-pointed manually and doctors never received pages. Some satellites in polar orbits tumbled out of control for several hours and some weather images were lost when the GOES weather satellite communications were interrupted.



Next Steps: Understanding and Predicting

LEFT: Artist concept of STEREO doing its lunar swingby.
Credit: Johns Hopkins University / Applied Physics Laboratory

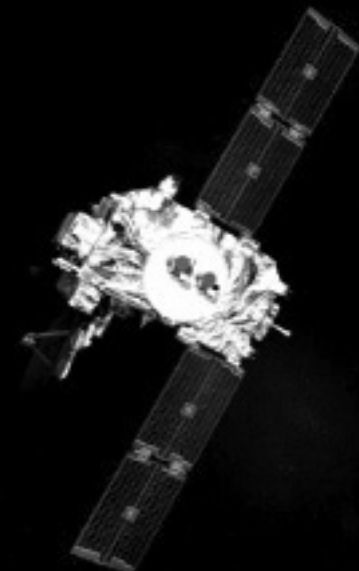
NASA's upcoming Solar Terrestrial Relations Observatory (STEREO) will help researchers better understand space weather in order to make more accurate predictions and take better precautions. While a fleet of spacecraft already fly between the sun and Earth trying to gain a better perspective on the sun's powerful blasts, STEREO will be the first to provide a three-dimensional view. This additional information will help

us understand how and why CMEs, the primary driver of space weather, occur and how they move through space.

Better prediction means more warning time for satellite and power grid operators to put their assets into a "safe mode" to weather the storm while a better understanding will help engineers figure out how to build better and more resilient systems.

"Every year we become more and more reliant on space technologies in our everyday lives, and we expect things to work," said Dr. Michael Kaiser, STEREO Project Scientist at NASA Goddard Space Flight Center. "But nature has a mind of its own and STEREO is going to help us figure out how to avoid those expensive and inconvenient surprises the sun tends to throw at us."

STEREO FEATURES: 2



Sickening Solar Flares

by Dr. Tony Phillips

This article is excerpted from Science@NASA (<http://science.nasa.gov>)

When the biggest solar proton storm in 15 years erupted in January, many were left wondering: what would have happened if astronauts were on the moon?

NASA's new plans include returning to the moon—not just with robots, but with people too. In the decades ahead we can expect to see habitats, greenhouses, and power stations up there. Astronauts will be out among the moon dust and craters, exploring, prospecting, and building.

On Jan. 20, 2005, there were no humans walking around on the moon. Good thing.

On that day, a giant sunspot named "NOAA 720" exploded. The blast sparked an X-class solar flare, the most powerful kind, and hurled a billion-ton cloud of electrified gas (a coronal mass ejection, or CME) into space. Solar protons accelerated to nearly light speed by the explosion reached the Earth-moon system minutes after the flare—the beginning of a days-long "proton storm."

Proton storms cause all kinds of problems. They interfere with ham radio communications. They zap satellites, causing short circuits and computer reboots. Worst of all, they can penetrate the skin of space suits and make astronauts feel sick.

January 2005 was a stormy month in space. With little warning, a giant spot materialized on the sun and started exploding. From Jan. 15 through Jan. 19, sunspot 720 produced four powerful solar flares. When it exploded a fifth time on Jan. 20, onlookers were not surprised.

The sunlit side of the moon is totally exposed to solar flares. It has no atmosphere or magnetic field to deflect radiation. Protons rushing at the moon simply hit the ground—or whoever might be walking around outside. An astronaut on the moon, caught outdoors on Jan. 20, would have had almost no time to dash for shelter, and would have become sick. At first, he'd feel fine, but a few days later, symptoms of radiation sickness would appear: vomiting, fatigue, low blood counts. These symptoms might persist for days.

Improving Space Weather Forecasts

When the Solar Terrestrial Relations Observatory (STEREO) launches in Spring 2006, scientists expect to gain a better understanding of these events and improve warning time. The two STEREO spacecraft will image the sun and CMEs in 3-D for the first time ever to give scientists a better and more complete view of these events. In fact our current two-dimensional view even makes it hard sometimes to predict which direction the events are heading in!

STEREO's task is to learn more about what triggers these storms, how they move through the solar system, and what makes them tick. In particular, it will take a hard look at how and where these proton storms are triggered and how the solar activity that causes them builds up in the sun's atmosphere before exploding out into space.

This January storm came fast and "hard," with proton energies exceeding 100 million electron volts. These are the kind of high-energy particles that can do damage to human cells and tissue.



Credit: NASA

Here on Earth, however, no one suffered. Our planet's thick atmosphere and magnetic field protects us from protons and other forms of solar radiation. In fact, the storm was good. When the plodding CME arrived 36 hours after the initial blast and hit Earth's magnetic field, sky watchers in Europe saw the brightest auroras in years.

Dangerous Solar Storms

According to space weather theory—soon to be revised—this is how a proton storm develops: It begins with an explosion, usually above a sunspot. Sunspots are places where strong magnetic fields poke through the surface of the sun. For reasons no one completely understands, these fields can become unstable and explode, unleashing as much energy as 10 billion hydrogen bombs.

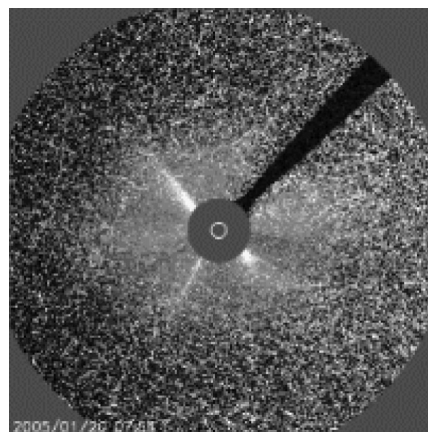
From Earth we see a flash of light and x-rays. This is the "solar flare," and it's the first sign that an explosion has occurred. Light from the flare reaches Earth in only 8 minutes. High energy protons can follow in another 10 to 20 minutes, although sometimes they take longer.

The Jan. 20 proton storm was by some measures the biggest since 1989. It was particularly rich in high-speed protons packing more than 100 million electron volts (100 MeV) of energy. Such protons can burrow through 11 centimeters of water. A thin-skinned spacesuit would have offered little resistance.

Astronauts on the International Space Station (ISS), by the way, were safe. The ISS is heavily shielded, plus the station orbits Earth inside our planet's protective magnetic field. "The crew probably absorbed no more than 1 rem," said Francis Cucinotta, NASA's radiation health officer at the Johnson Space Center.

One rem, short for Roentgen Equivalent Man, is the radiation dose that causes the same injury to human tissue as 1 roentgen of x-rays. A typical diagnostic CAT scan, the kind you might get to check for tumors, delivers about 1 rem. So for the crew of the ISS, the Jan. 20 proton storm was no worse than a trip to the doctor on Earth.

On the moon, Cucinotta estimates, an astronaut protected by no more than a space suit would have absorbed about 50 rem of ionizing radiation. That's enough to cause radiation sickness. "But it would not have been fatal," he adds.



LEFT: The Jan. 20 proton storm photographed from space by the Solar and Heliospheric Observatory (SOHO). The many speckles are solar protons striking the spacecraft's digital camera.

Credit: NASA/ESA

To die, you'd need to absorb, suddenly, 300 rem or more.

The key word is *suddenly*. You can get 300 rem spread out over a number of days or weeks with little effect. Spreading the dose gives the body time to repair and replace its own damaged cells. But if that 300 rem comes all at once ... "we estimate that 50% of people exposed would die within 60 days without medical care," said Cucinotta.



Previous Close Calls

The solar storm of August 1972 is legendary at NASA because it occurred in between two Apollo missions: the crew of Apollo 16 had returned to Earth in April and the crew of Apollo 17 was preparing for a moon landing in December.

Cucinotta estimates that a moonwalker caught in the August 1972 storm might have absorbed 400 rem. Deadly? "Not necessarily," he says. A quick trip back to Earth for medical care could have saved the hypothetical astronaut's life.

Surely, though, no astronaut is going to walk around on the moon when there's a giant sunspot threatening to explode. "They're going to stay inside their spaceship (or habitat)," according to Cucinotta. An Apollo command module with its aluminum hull would have attenuated the 1972 storm from 400 rem to less than 35 rem at the astronaut's blood-forming organs. That's the difference between needing a bone marrow transplant ... or having a headache.

Modern spaceships are even safer. "We measure the shielding of our ships in units of areal density—or grams per centimeter-squared," says Cucinotta. Big numbers, which represent thick hulls, are better.

The hull of an Apollo command module rated 7 to 8 g/cm². A modern space shuttle has 10 to 11 g/cm². The hull of the ISS, in its most heavily shielded areas, has 15 g/cm². Future moonbases will have storm shelters made of polyethylene and aluminum possibly exceeding 20 g/cm². A typical space suit, meanwhile, has only 0.25 g/cm², offering little protection. "That's why you want to be indoors when the proton storm hits," said Cucinotta.

But space beckons and NASA has a lot to learn about the sun's hazards—in terms of protecting astronauts and learning how to better shield spaceships, satellites, and other space assets. Upcoming missions like STEREO should go a long way toward those goals.

STEREO Satellites, Launch, and Operation Quick Facts

WHAT KIND OF INSTRUMENTS DO THE SATELLITES CARRY?

STEREO consists of several instrument suites. All the imaging telescopes are part of the SECCHI suite, while IMPACT and PLASTIC measure the solar wind particles that reach each spacecraft, and SWAVES does radio triangulation. The SECCHI instruments are designed to take their images within one second of each other, including a small correction for the difference in light travel time from the sun to each spacecraft.

HOW BIG ARE THE STEREO SPACECRAFT?

Each observatory is 3.75 ft (1.14 m) high, 4 ft (1.22 m) wide, and 21.24 ft (6.47 m) wide with solar arrays deployed. Each observatory also weighs about 1,364 lbs (620 kg) fully fueled, although the bottom spacecraft, 'B' is slightly heavier. Generally the observatories are each about the size of a commercial refrigerator and the solar arrays extend to the length of a soccer net.

STEREO Capabilities:

First stereo imaging and tracking of space weather disturbances from sun to Earth.
First continuous determination of interplanetary shock positions by radio triangulation.

Key Characteristics of Each of the Twin Observatories:

Mass: 1,364 pounds (620 kilograms)

Dimensions:

3.75 feet (1.14 meters)

4.00 feet (1.22 meters) wide (launch configuration) 21.24 feet (6.47 meters) wide (solar arrays deployed) 6.67 feet (2.03 meters) deep

Power consumption 475 watts

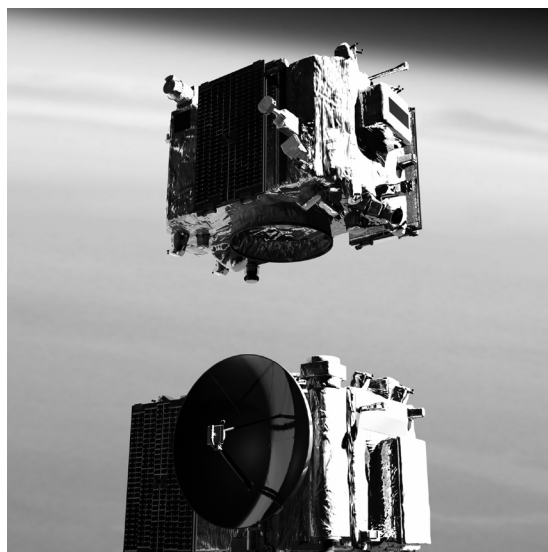
Data downlink 720 kilobits per second

Memory 1 gigabyte

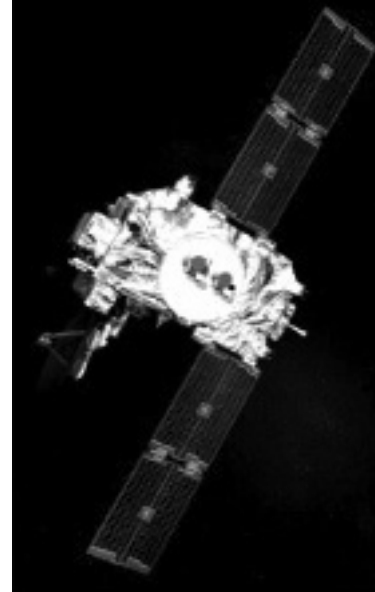
Launch Site: Cape Canaveral Air Force Station, Fla.

Expendable Launch Vehicle: Delta II 7925-10L rocket

Launch Date and Time: Spring 2006



ABOVE: Separation of twin STEREO Observatories
Credit: Johns Hopkins University/Applied Physics Laboratory

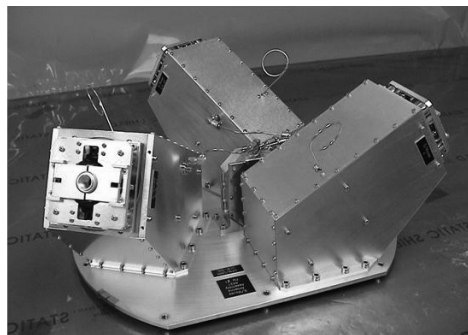
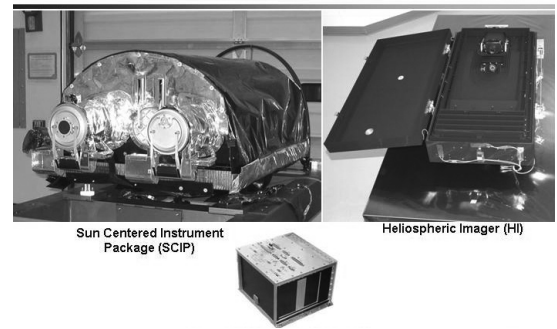


STEREO Instruments

The following four instrument packages are mounted on each of the two STEREO spacecraft:

Sun-Earth Connection Coronal and Heliospheric Investigation (SECCHI) will have four instruments: an extreme ultraviolet imager, two white-light coronagraphs, and a heliospheric imager. These instruments will study the 3-D evolution of CMEs from birth near the sun's surface through the corona (its outer atmosphere) into the interplanetary medium and to their eventual impact at Earth. Principal Investigator: Dr. Russell Howard, Naval Research Laboratory, Washington, D.C.

SECCHI Elements

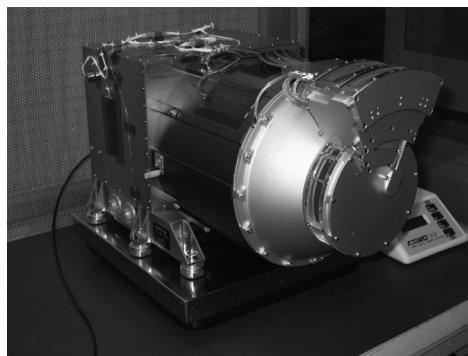
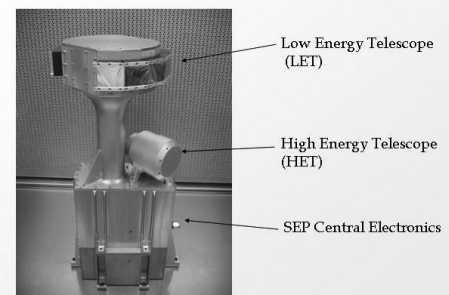


STEREO/WAVES (SWAVES) is an interplanetary radio burst tracker that will trace the generation and evolution of traveling radio disturbances from the sun to the orbit of Earth. Principal Investigator: Dr. Jean Louis H. Bougeret, *Centre National de la Recherche Scientifique, Observatory of Paris*, and Co-Investigator Mr. Michael Kaiser of Goddard, lead the investigation.

In-situ Measurements of Particles and CME Transients (IMPACT) will sample the 3-D distribution and provide plasma characteristics of solar energetic particles and the local vector magnetic field. There are 6 instruments on IMPACT: SEP, HET, LET (pictured) MAG, SWEA and SEPT (not pictured). Principal Investigator: Dr. Janet G. Luhmann, University of California, Berkeley.



SEP/HET/LET



PLAS-TIC will provide plasma characteristics of protons, alpha particles and heavy ions. This experiment will provide key diagnostic measurements of the form of mass and charge state composition of heavy ions and characterize the CME plasma from ambient coronal plasma. Principal Investigator: Dr. Antoinette Galvin, University of New Hampshire.

Important STEREO Science Concepts

If you are reading through the STEREO Web pages you may come across a number of terms that are not exactly household words, but are central to a real understanding STEREO science.

Here are brief discussions of a few of important STEREO science concepts:

- Corona
- Solar Wind
- Coronal Mass Ejections
- Solar Flares
- Solar Energetic Particles
- Space Weather

CORONA



LEFT: This picture of a corona is a combination of 22 photographs that were digitally processed to highlight faint features of a total eclipse that occurred in August of 1999.

Credit & Copyright: Fred Espenak

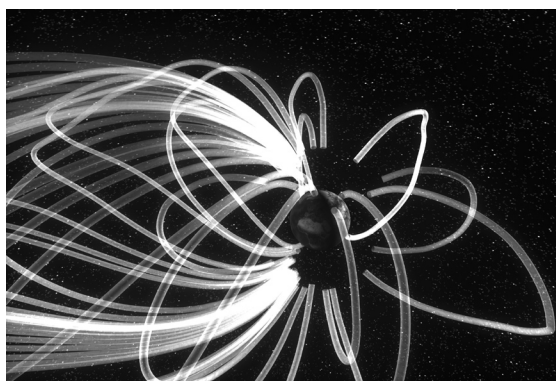
The corona is the sun's hot, thin outer atmosphere. From Earth it is most easily seen during a total solar eclipse in which the sun's bright disk is covered by the moon, revealing the much fainter corona.

The highly structured corona is shaped by

the sun's complex magnetic field, and is very active, exhibiting coronal mass ejections and flares among other solar magnetic phenomena. The corona is so hot at over a million degrees Celsius that it produces ultraviolet light and X-rays.

STEREO's SECCHI imaging suite will show us the corona in two ways. Its coronagraphs imitate a solar eclipse in space by covering the disk of the sun with an occulting disk, so that we can see scattered light from the corona. The SECCHI Extreme-Ultraviolet Imager (EUVI) will let us observe the ultraviolet light produced by the corona.

SOLAR WIND



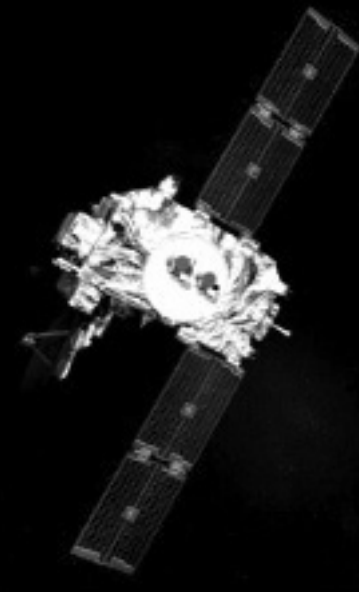
Artist's rendition of the Earth's magnetic field.
Credit: NASA

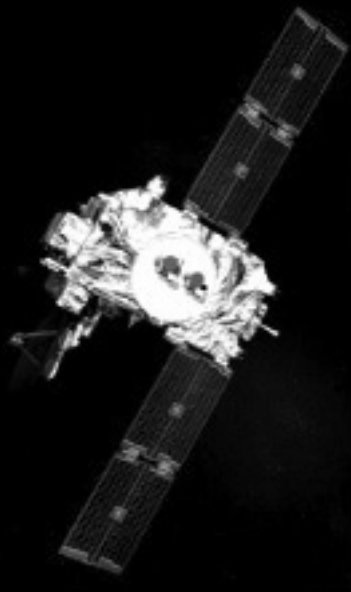
The sun's super hot atmosphere expands out into the solar system, flowing past Earth and the other planets. In fact, you could say that Earth is inside the outermost layer of the sun.

This flow is called the solar wind and it consists mostly of hydrogen, with some helium and small amounts of heavier elements.

It is exceedingly thin — just a few particles per cubic centimeter—and moves at velocities from 200 to 800 km/s, or even faster if you count the fastest CMEs which can move outwards at over 1000 km/s (two million mph). However, this is still far slower than the speeds of solar energetic particles, which can shoot out at over 100,000 km/s, nearly the speed of light.

SCIENCE CONCEPTS

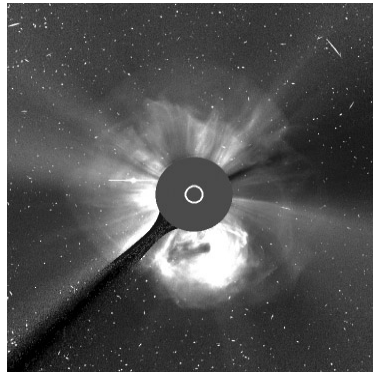




The solar wind varies in time and location, with higher speed, lower density streams flowing out of areas known as coronal holes, where the sun's magnetic field opens out into the solar system. The solar wind carries the sun's magnetic field outwards to form the interplanetary magnetic field (or IMF). The area affected by the solar wind and IMF extends beyond the orbit of Pluto and is known as the heliosphere.

The STEREO PLASTIC and IMPACT instruments sample the solar wind as it passes by the two spacecraft.

CORONAL MASS EJECTION (CME)



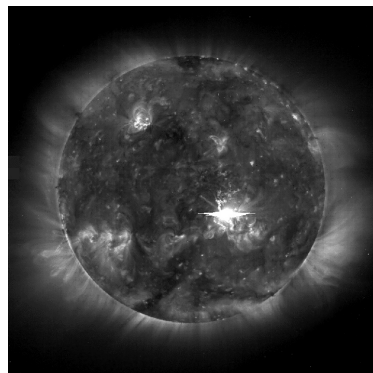
LEFT: The SOHO/LASCO coronagraph observes a CME. Similar images will be produced by STEREO's SECCHI coronagraphs.
Credit: NASA/ESA

A billion tons of matter traveling at a million miles an hour, these giant magnetic structures blast off the sun into the solar system and can create major disturbances in Earth's magnetic field, resulting in the beautiful aurora but also problems with spacecraft and power systems. They are also a source of Solar Energetic Particles (SEPs), which are a hazard to astronauts.

Although CMEs are huge and powerful, they are very thin and spread out, with just a few particles per cubic centimeter. Much of the power they have to affect us comes from their magnetic fields, which are part of the interplanetary magnetic field and can disturb the magnetic field of Earth. It usually takes a CME two to four days to reach Earth, although extremely fast ones have been known to reach here in just over a day.

Understanding what causes CMEs and how they move through the solar system is one of the chief goals of the STEREO mission. The CMEs are imaged by the different telescopes in the SECCHI instrument suite. The actual material in CMEs is measured as they pass the spacecraft using the IMPACT and PLASTIC instruments, and IMPACT measures their magnetic fields. The SWAVES instruments observe radio signals produced by shock waves formed as the CMEs plow through the solar wind.

SOLAR FLARES



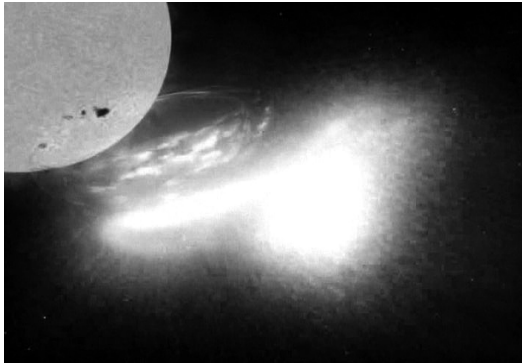
LEFT: The sun unleashed a powerful flare on Nov 4, 2003 as captured here by SOHO.
Credit: NASA/ESA

Solar flares are bright, explosive events that take place in the sun's lower corona. They can be associated with CMEs, but are not the same thing. Scientists will use the SECCHI imaging instruments aboard STEREO to improve our understanding of how flares are related to CMEs.

Although most of what is called a solar flare occurs relatively low in the sun's atmosphere, flares do release charged particles which travel along the magnetic field lines of the interplanetary magnetic field (IMF). Electrons emitted in this way by flares produce radio waves detected by the SWAVES instruments and allow researchers to map the IMF.

Sometimes these charged particles may be high enough in energy to qualify as solar energetic particles (SEPs). SEPs along with the x-rays and gamma-rays produced by flares can be harmful to astronauts.

SOLAR ENERGETIC PARTICLES (SEPs)



LEFT: A still from an animation shows the SEPs preceding the CME blast.
Credit: NASA

Particles, especially protons, moving at super high speeds can be a deadly hazard to astronauts and spacecraft. These are frequently emitted during solar activity and are thought to be caused by CMEs and/or solar flares. Here on Earth's surface, we are shielded from their damaging effects by Earth's magnetic field.

Most SEPs are protons and electrons, but there are also other heavier particles, all of which are measured by STEREO's IMPACT and PLASTIC instruments. The electrons give off radio signals which are measured by the SWAVES instruments.

SEPs move at relativistic speeds (30–90% of the speed of light), far faster than the regular solar wind or CMEs. Since they are charged particles they move along the interplanetary magnetic field's spiraling magnetic field lines. Because of this, SEPs are often detected far eastward of where they are thought to originate.

SEPs usually arrive at Earth from 20 minutes to several hours after the start of a flare or CME. The time it takes for the particles to get here depends on how fast they are going, where and when the protons are accelerated, and the path they take.

It is still not entirely clear if SEPs are emitted by CMEs as they plow through the solar wind, by solar flares low in the sun's atmosphere, or both. The instruments aboard STEREO will be used to better understand their origins.

SPACE WEATHER

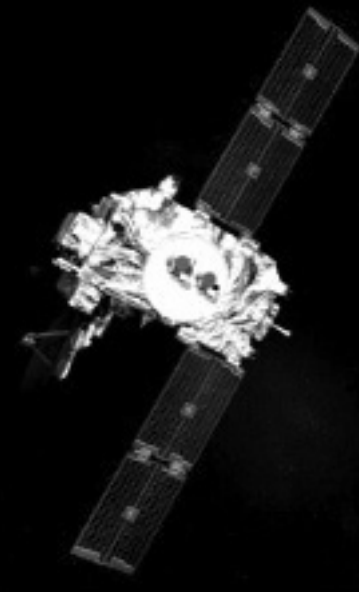


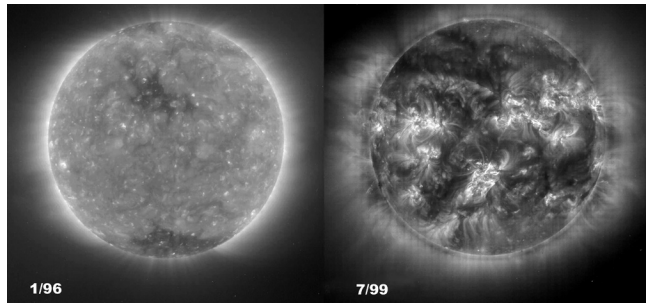
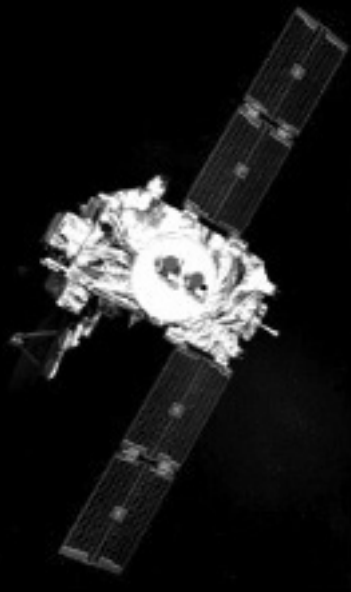
LEFT: This aurora was captured at dusk on May 19, 2000 over Alaska. It sported a typical green glow.
Credit & Copyright: Jan Curtis (U. Alaska), ACRC

"Space weather" describes changes in the solar system environment caused by variations in the sun and solar wind. These include CMEs and solar flares, and changes in the interplanetary magnetic field due to solar surface features like coronal holes. Space weather phenomena cause the beautiful aurora (northern and southern lights) and can also affect communications, power systems, aviation, and spacecraft. Some space weather occurrences, such as solar energetic particles can present grave dangers to astronauts.

Like Earth weather, space weather varies substantially in space and time. A CME headed towards Earth may completely miss Mars or Venus and vice versa. Spacecraft deployed around the solar system, like STEREO, will give us a better, solar-system-wide view of what is happening.

SCIENCE CONCEPTS



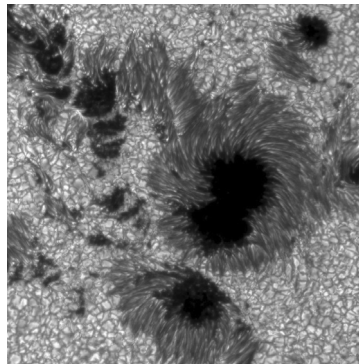


LEFT: A SOHO image of the sun in solar minimum (1996) and solar maximum (1999).
Credit: NASA/ESA

Solar Minimum/Solar Maximum

The sun has an 11-year cycle of activity determined by the reversal of its magnetic poles. During the solar minimum, the sun may churn out a strong CME every two days; that's approximately 180 CMEs per year through only about 10–15 CMEs are directed at Earth. During solar maximum, the sun averages five CMEs daily, and sends about 100 Earthward CMEs per year. The last solar maximum was approximately 2000-2001. We are now entering a quiet period which will provide STEREO with a unique perspective.

Sunspots

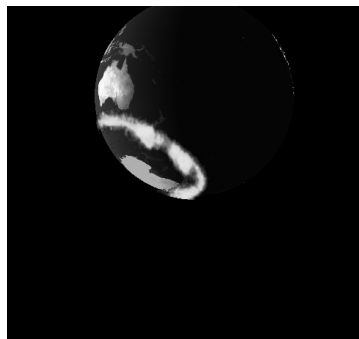


LEFT: A close-up view of a sunspot as taken by the Swedish Solar Telescope on La Palma in the Canary Islands.
Credit: SST/Royal Swedish Academy of Sciences

Sunspots are disturbed areas in the solar photosphere that appear dark because they're cooler than the surrounding areas. They range in size from 1,500 miles to several times Earth's size (a very large one could fit 20 Earths!). Sunspots are made from strong magnetic fields and usually occur in pairs or groups of opposite polarity that move together across the surface of the sun. Sunspots are the footprints of magnetic loops: the loops hold or push plasma through the surface of

the sun from below the surface and have the potential to become so tangled and outstretched that they snap and create solar flares. Scientists track solar cycles by counting sunspots; quiet times on the sun mean there are few to no sunspots visible.

Auroras



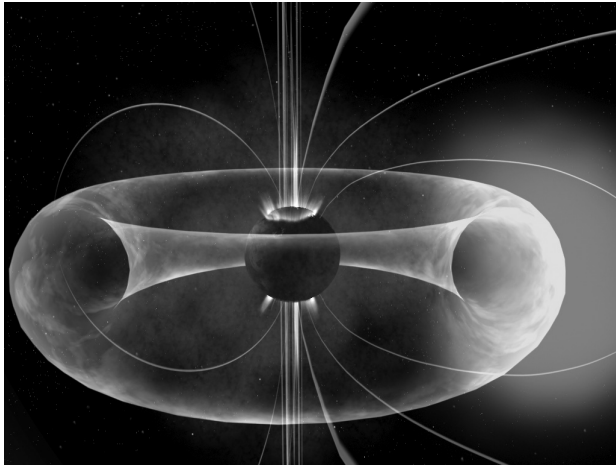
LEFT: The Polar spacecraft got a great view of the aurora australis (southern lights) expanding and brightening in 2004. Credit: NASA/The University of Iowa

Auroras are light displays that can sometimes be seen in the night sky, especially at extreme northern and southern latitudes. Auroras are caused by energetic particles from the magnetosphere. Coronal mass ejections can bring about intense auroral displays.

Ordinarily, the magnetosphere deflects most of the particles of the solar wind. However, some solar wind particles do manage to leak in. These enter the Earth's atmosphere along the magnetic field lines; that is, at the North and South Poles.

When these particles (mainly electrons) collide with gas molecules (mainly oxygen and nitrogen) in the upper atmosphere, they excite the gas particles to higher energy states. As these gas molecules "de-excite" back down to lower energy levels, they release light. This light produces the often gorgeous auroras, which can be green, red, or purple, and appear as curtains, arcs, or clouds.

Magnetosphere



LEFT: When the solar blasts head toward Earth, they're filtered through Earth's protective magnetic fields, almost like a pinball. Some particles make it through the fields and interact with particles in our atmosphere to create colorful auroras.
Credit: NASA

Earth's magnetic field stretches way out into space—at least 37,000 miles (60,000 kilometers)—to form a protective bubble known as the magnetosphere. The magnetosphere is important because it shields us from interplanetary space weather. Charged particles cannot easily cross the lines of a magnetic field. The result is that most of the particles in the incoming solar wind are deflected around the Earth by its magnetic field.

However, charged particles are not the only component of the solar wind. The solar wind also carries with it interplanetary magnetic field, or IMF, which is a magnetic field from the sun. The IMF can influence solar weather by disrupting the earth's magnetosphere. How?

The Earth's magnetic field and the IMF connect at the polar caps, and it's here that energy and particles can and do enter the magnetosphere. If the incoming IMF points south, its interconnection with the Earth's magnetic field becomes especially strong. The effect is like widening a hole: suddenly more energy and particles enter the magnetosphere. Auroras intensify, and geomagnetic storms become likely. For this reason, scientists pay careful attention to not only the strength but also the orientation of incoming magnetic fields from the sun. South-pointing magnetic fields can spell trouble, while north-pointing fields usually coincide with calmer conditions.

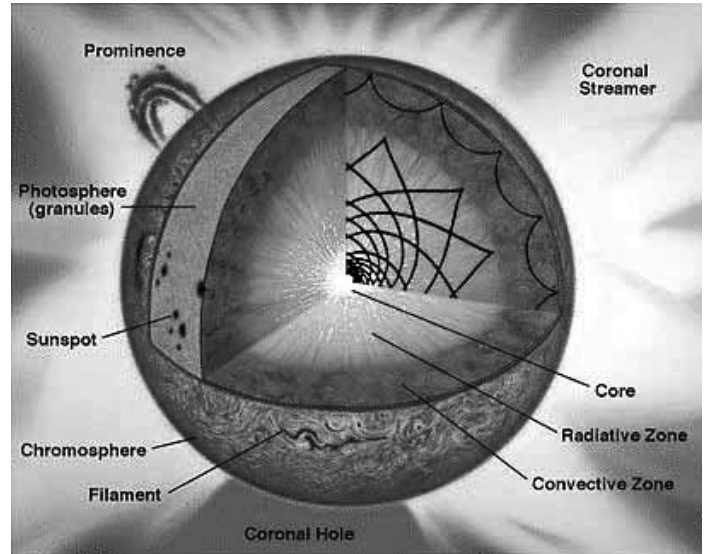




Sun Science Basics

This section was compiled to help science writers understand the science behind studying the sun and solar events. It is organized into several sections:

- 1) Sun Facts
- 2) Q&A on coronal mass ejections and space weather
- 3) Solar Science Glossary

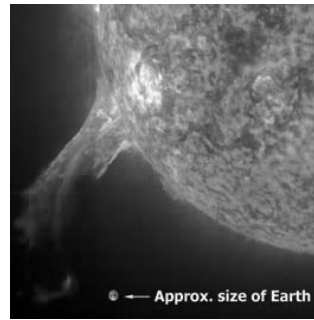


SUN FACTS

- The sun has an 11-year cycle of activity determined by the reversal of its magnetic poles (north pole becomes south pole).
- The sun is 4.6 billion years old.
- 1 million Earths would fit inside the sun.
- 20 planet Earths could fit in one very large sunspot.
- Sunbeams reaching Earth today began in the sun's center hundreds of thousands of years ago.
- Plasma pushes the loops through the sun's surface.
- Light takes 8 minutes to travel the 93 million miles from the photosphere to Earth.
- Filaments are formed in magnetic loops that hold relatively cool, dense gas suspended above the surface of the sun.
- When we see a filament in profile against the dark sky it looks like a stretched out, glowing loop. These are called prominences.
- Our sun is a "Type G star." A Type "G" star is known as a yellow dwarf, and is a very common star.
- The sun's energy varies no more than one-tenth of one percent over a decade.
- Sun's composition: 70% hydrogen; 28% helium; 2% heavier elements by mass.
- The sun has no solid surface, just layers of atmosphere which extend beyond Earth, thinning as it goes.
- Different layers and latitudes of the sun's atmosphere rotate at different speeds.
- Sun's equator takes 26 days to rotate, while the sun's poles rotate every 36 days.
- Sun's inner 70% rotates like a solid body, once every 27 days, just 1 day slower than outer layers at the equator.
- Differential rotations twist and create sun's magnetic field from north to south. The twisted fields can rise and poke through surface as the loops seen above sunspots or as solar prominences.

Solar Science Glossary

Source: <http://sohowww.nascom.nasa.gov/explore/glossary/>



ACE — Advanced Composition Explorer satellite (measures CMEs)

Aurora — A display of colored light given off by collisions between charged particles in a planet's magnetic field and atoms of atmospheric gases near the planet's magnetic poles. Auroras are visible on Earth as the aurora borealis or northern lights and the aurora australis or southern lights.

Chromosphere — 1,500 mile thick layer of plasma above the photosphere (with temperatures from 10000 to 60000 degrees Celsius).

CME (Coronal Mass Ejection) — A huge magnetic bubble of plasma and magnetic field lines that erupts from the sun's corona over a course of several hours and travels through space at high speed. Usually accompanied by a solar flare. The charged particles and magnetic fields associated with CMEs can cause power and communications outages, loss of satellites, and health problems for astronauts. They usually take about three days to reach Earth, but very fast ones can arrive in under a day.

Convection — The movement of matter due to changes in temperature and therefore density. Warm material rises because it is less dense (lighter) and cool material sinks because it is more dense (heavier).

Convective Zone — In the sun, the convection zone extends from just below the photosphere to the radiative zone. In this region convection currents circulate the sun's energy to the surface.

Core — In solar astronomy, the innermost part of the sun, where energy is generated by nuclear fusion (fusion of one atom to another).

Corona — The outermost layer of the sun's outer atmosphere, a halo of ions extending millions of miles into space. The corona consists of a gas that is much thinner than the Earth's atmosphere. The temperature is greater than one million degrees centigrade. It is visible to the naked eye during a solar eclipse.

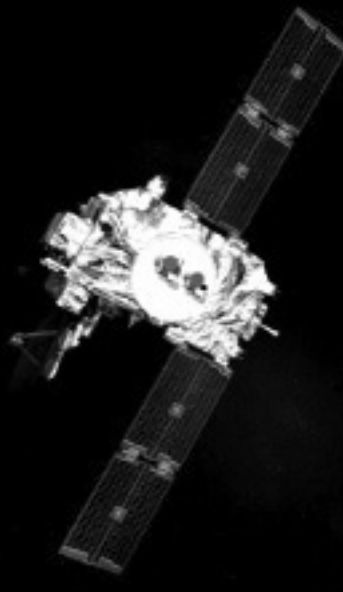
Coronagraph — An instrument which studies the sun's outer atmosphere, the "corona." From Earth this is most easily seen during a total eclipse. Each STEREO observatory has two coronagraphs which study the sun from space. These allow us to observe the corona by covering the bright disk of the sun. This creates a sort of false eclipse and allows us to see the sun's fainter outer atmosphere.

Coronal Hole — An area of the corona which appears dark in ultraviolet light. They are usually located at the poles of the sun, but can occur other places as well. The magnetic field lines in a coronal hole extend out into the solar wind rather than coming back down to the sun's surface as they do in other parts of the sun. Because the magnetic field lines go out into space they take hot material with them making the area cooler than the rest of the bright, hotter surface.

Electromagnetic Spectrum — The entire range of all the various kinds or wavelengths of electromagnetic radiation, including (from short to long wavelengths) gamma rays, x-rays, ultraviolet, optical (visible), infrared, and radio waves.

Energetic Particles — The atoms and molecules of a gas are in constant motion, colliding rapidly and filling all available space. The hotter the gas, the faster they move, and the more energy each of them hold. The free ions and electrons in a plasma behave the same way. Ions and electrons actually observed in space are often much, much more energetic and may move at a large fraction of the velocity of light (300,000 km/sec or 186,000 miles/sec). Researchers think that high-energy particles in the solar wind are not merely heated, but are accelerated by shocks in front of CMEs and by electric and magnetic processes in flares.

GLOSSARY



Faculae — Bright blotches on the surface of the sun that put out more radiation than normal and increase the solar irradiance.

Filament — A structure in the corona consisting of cool plasma supported by magnetic fields. In visible light filaments are dark structures when seen against the bright solar disk, but appear bright when seen over the solar limb. Filaments seen over the limb are also known as prominences. Filaments may become parts of CMEs if they lift off of the sun.

Flare — Rapid release of large amounts of energy from a small region on the sun in the form of electromagnetic radiation and energetic particles.

Gamma Rays — Created from nuclear reactions. The most energetic wavelengths of electromagnetic radiation.

Geomagnetic Storm — A worldwide disturbance of the Earth's magnetic field, associated with solar activity. These storms can cause power outages, communications blackouts, health risks for astronauts, loss of satellites, and auroras.

Granules — Short-lived cells of plasma that carry heat to the sun's surface via convection rising and falling.

Infrared — Of or relating to the range of invisible radiation wavelengths from about 700 nanometers, just longer than red in the visible spectrum, to 1 millimeter, on the border of the microwave region.

Ion — An atom or molecule that has lost or gained one or more electrons and has become electrically charged as a result.

Ionization — The process by which ions are produced, typically occurring by collisions with atoms or electrons, or by interaction with electromagnetic radiation.

Irradiance — Radiant energy per unit time per unit area incident on a surface.

Magnetic Loop or Field Lines — Imaginary lines that indicate the strength and direction of a magnetic field. The orientation of the line and an arrow show the direction of the field. The lines are drawn closer together where the field is stronger. Charged particles move freely along a magnetic field line, but are kept from moving to other lines.

Magnetism — A force generated by currents and changing electric fields. Magnetism is responsible for almost every feature in the solar atmosphere, from sunspots to CMEs to flares.

Magnetosphere — Area around a planet in which the planet's magnetic field is stronger than the magnetic field carried by the solar wind.

Maunder Minimum — During the coldest part of the Little Ice Age, from 1645 to 1715, there is believed to have been a decrease in the total energy output from the sun, as indicated by little or no sunspot activity. Astronomers of the time observed only about 50 sunspots for a 30-year period as opposed to a more typical 40,000-50,000 spots.

Nanometers (nm) — A billionth of a meter.

Plasma — Plasma is often considered the fourth state of matter (besides solid, liquid, and gas). Plasmas consist of a gas heated to sufficiently high temperatures (in other words, with so much energy) that the atoms ionize (lose electrons). Because plasmas are dominated by charged particles they interact strongly with electric and magnetic fields. Most of the matter in the universe is in the plasma state. Lightning and fluorescent lights are plasma.

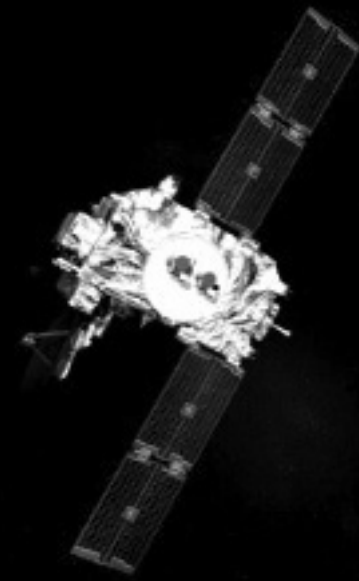
Photosphere — Sun's surface (5,700 degrees Celsius). The layer of the sun from which the light we actually see (with the human eye) is emitted.

Prominence — A structure in the corona consisting of cool plasma supported by magnetic fields. In visible light, prominences are bright structures when seen over the solar limb, but appear dark when seen against the bright solar disk. Prominences seen on the disk are also known as filaments. Prominences may become parts of CMEs if they lift off of the sun.

Radiation (electromagnetic radiation) — Energy that travels through space at the speed of light and moves by the interaction of electric and magnetic fields. This radiation transports energy.

Radiative Zone — An interior layer of the sun, lying between the core and the convection zone, where energy travels outward through the slow radiation, absorption, and re-radiation of energy by tightly packed atoms.

Radio Waves — A kind of electromagnetic radiation, like light, but far beyond the red or even the infrared portion of the spectrum. When a solar flare or coronal mass ejection erupts, hot, charged particles are accelerated away from the sun. When this happens, a radio signal is emitted that reaches Earth in a little over 8 minutes.



SOHO — Solar and Heliospheric Observatory spacecraft.

Solar Cycle — The approximately 11-year pattern in the number of sunspots, coronal mass ejections (CMEs), solar flares, and other solar activity. About every 11 years the sun's magnetic field changes from north to south. Eleven years later it will flip back. People may have heard of this as the 22-year cycle because after two 11 year cycles the sun's magnetic field will be back the way it was at the start of the 22 years.

Solar Flare — A small area above the solar surfaces suddenly roars to tens of millions of degrees. A flare is caused by tremendous releases of magnetic energy in a sunspot region. The resulting radiation surge can cause blackouts of communication and loss of satellites. Although flares can produce dangerous X-rays and gamma-rays, CMEs produce even more dangerous radiation in the form of high-energy protons.

Space Weather — Space weather refers to conditions on the sun and in the solar wind, and the Earth's magnetosphere, ionosphere, and thermosphere that can influence space and ground-based technological systems and can endanger human life or health. Adverse conditions in the space environment can cause disruption of satellite operations, communications, navigation, and electric power distribution grids, leading to a variety of socioeconomic losses.

Solar Wind — Solar wind is the plasma coming out of the sun in all directions at very high speeds—an average of about 400 km/s, almost a million mph! Solar wind is responsible for the tails of comets pointing away from the sun and the shape of the magnetic fields around the planets. Solar wind can also have a measurable effect on the flight paths of spacecraft.

Spectral Solar Irradiance (SSI) — Irradiance per unit wavelength, for a particular chosen band of wavelengths.

Spectrograph — A device that separates light by wavelength (color) in order to produce a spectrum that allows for the identification of elements within the light source.

Solar Ultraviolet Irradiance — The amount of energy in the ultraviolet portion (or part) of the spectrum from 120 to 300 nanometers (nm).

Sunspots — Cool, dark areas on the sun generated by strong magnetic fields beneath the sun's surface. Temporary disturbed areas in the solar photosphere that appear dark because they are cooler than the surrounding areas. They range in size from 1,500 miles to several times Earth's size. Sunspots are caused by strong magnetic fields. They usually occur in pairs or groups of opposite polarity that move together across the surface of the sun. Sunspots are the footprints of magnetic loops. The loops push through the surface of the sun. The magnetic loops push or hold plasma below the surface.

Transition Region — Area of the sun's atmosphere with temperatures in between those of the chromosphere and the corona, 20,000 - 1,000,000 degrees Celsius.

Ultraviolet — Electromagnetic radiation from about 10 to 400 nm, just shorter than violet in the visible spectrum.

Visible light — Electromagnetic radiation from 400 to 700 nm, which is detectable by the eye.

Wavelength — The distance between one peak or crest of a wave of light, heat, or other energy and the next corresponding peak or crest. (Wavelengths of light from the sun range from radio waves to gamma rays).

STEREO Acronyms

ACE	Advanced Composition Explorer	MAG	Magnetometer
ACR	Anomalous Cosmic Ray	Mb	Megabit
Ah	Amp-Hours	MB	Megabyte
APL	Applied Physics Laboratory	MHz	Megahertz
AU	Astronomical Unit	mm	millimeters
CalT	California Institute of Technology	m/s	meters per second
CIR	Corotating Interaction Region	MOC	Mission Operations Center
CESR	<i>Centre d'Etudes Spatiale des Rayonnements</i>	MPE	Max Planck Institute for Extraterrestrial Physics (Germany)
cm	Centimeters	MSFC	Marshall Space Flight Center
CME	Coronal Mass Ejection	N	Nitrogen
CNRS	<i>Centre Nationale de la Recherche Scientifique</i>	NASA	National Aeronautics & Space Administration
Co-I	Co-Investigator	Ne	Neon
COR	Coronagraph	NRL	Naval Research Laboratory
dB	Decibel	NSSDC	National Space Science Data Center
DPU	Data Processing Unit	PAC	Post-acceleration
DSAD	Digital Solar Attitude Sensor	PI	Principal Investigator
DSMS	Deep Space Mission Services	PLASTIC	Plasma and Suprathermal Ion Composition
DSN	Deep Space Network	Psi	Pounds per square inch
DSP	Digital Signal Processor	O	Oxygen
EA	Earth Acquisition (mode)	Re	Radius of Earth
EMI	Electromagnetic Interference	RF	Radio Frequency
E/Q	Energy per charge	S	Sulfur
ESA	Electro Static Analyzer	SA	Solar Array
ESA	European Space Agency	S/C	Spacecraft
ESOC	European Space Operations Centre	SDO	Solar Dynamics Observatory
ESTEC	European Space Research & Technology Centre	SECCHI	sun–Earth Connection Coronal and Heliospheric Investigation
EUV	Extreme Ultraviolet	SEB	SECCHI Electronics Box
EUVI	Extreme Ultraviolet Imager	SEP	Solar Energetic Particles
FUV	Far Ultraviolet	SEPT	Solar Energetic Proton Telescope system
G	Unit of gravitational acceleration	SEPT-E	SEPT Telescope with FOV in the ecliptic plane
Gbits	Giga bits	SEPT-NS	SEPT Telescope with FOV out of the ecliptic plane
GSFC	Goddard Space Flight Center	Si	Silicon
H	Hydrogen	SIT	Suprathermal Ion Telescope
He	Helium	SOHO	Solar & Heliospheric Observatory
HF	High Frequency	SPE	Sun Probe Earth Angle
HET	High Energy Telescope	sqm	square meters
HFR	High Frequency Receiver	SSC	STEREO Science Center
HGA	High Gain Imager	SSMO	Space Science Mission Operations
HI	Heliospheric Imager	STEREO	Solar TERrestrial RELations Observatory
HMF	Heliospheric Magnetic Field	SW	Solar Wind
Hz	Hertz, cycles per second	S/WAVES	STEREO/WAVES
ICME	Interplanetary Coronal Mass Ejection	SWEA	Solar Wind Electron Analyzer
IFOV	Instantaneous Field-Of-View	SWS	Solar Wind Sector
IMPACT	<i>In-Situ</i> Measurements of Particles	UBIRM	University of Birmingham
ISM	Interstellar Medium	Ube	University of Bern
JHU	Johns Hopkins University	UCB	University of California, Berkeley
JPL	Jet Propulsion Laboratory	UFOV	Unobstructed Field of View
K	Kelvin	UNH	University of New Hampshire
Kb	kilobit	UTC	Universal Time Coordinated
KB	kiloByte	UV	Ultraviolet
Kbps	kilobits Per Second	XUV	Solar Soft X-ray
kg	kilogram	W	Watt
LET	Low Energy Telescope	W/m2	Watt per meter squared
LGA	Low gain antenna	WAP	Wide Angle Partition of PLASTIC Instrument
LV	Low Voltage		
m	meters		

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