The City Edition

Sunspot Cycle vs. the Power Grid

In 1859 a massive solar flare struck the Earth's atmosphere, disabling the telegraph system. Now that modern infrastructure is dependent on lightweight satellites and centralized power grids, a similar event could cripple entire countries for years. So with the next peak in the sunspot cycle due to start in 2013, what's the plan?

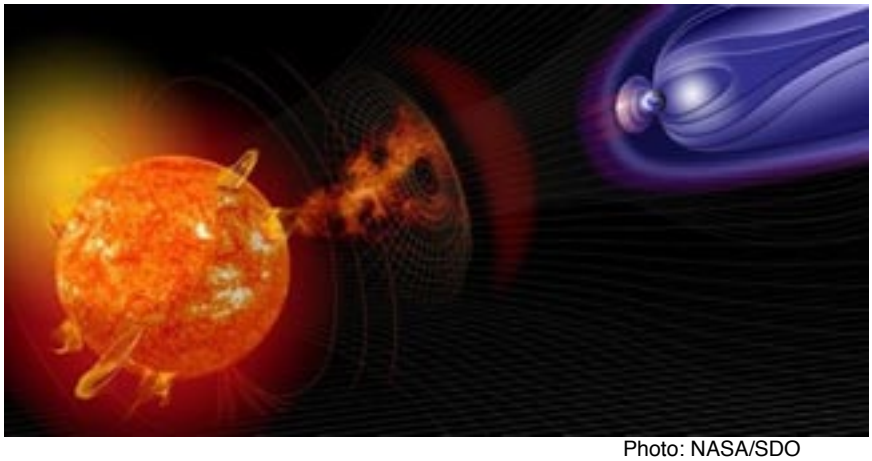

Photo: NASA/SDO

Visualization of a CME on its way to hitting the earth's magnetosphere. The planet is the white sphere in the upper right corner, surrounded by a protective magnetic field that absorbs and deflects the sun's radiation.

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BY ROSEMARY REGELLO

Whatever happens on the ground, in the coming years solar phycisists expect the Sun's behavior to impact the planet in ways rarely (if ever) experienced by modern man.

On July 11th, an X-class solar flare shot out from our home star with a vengeance, shelling the earth with a billion hydrogen bombs' worth of X-ray and ultraviolet radiation. Some radio frequencies near the North Pole were jammed for about an hour. Then, early in the morning of July 15th, a brilliant display of northern lights could be seen in the northern United States. It was the biggest space weather event so far in 2012. Scientists are bracing for more of the same, maybe even worse as the next peak in the sunspot cycle arrives in 2013.

Likewise, the year 2011 was a memorable one for solar activity. In June, a medium-sized corona mass ejection, or CME, had NASA officials plenty worried. While its eventual impact proved inconsequential, another CME emitted on the far side of the Sun was packing considerably more heat.

"If this [second] event was on a collision course with the U.S., we would have had a major space weather event," Antti Pulkkinen of the Goddard Space Flight Center told the New York Times. "In this regard, we got lucky."

On Valentines Day (also in 2011), a trio of solar flares caused minor disruptions to radio transmissions in China and produced auroras that were visible in the United Kingdom. Incredibly, Earth dodged a bullet on that occasion as well. That's because the CME that followed the flares to Earth was much weaker than expected.

In 2010, dire forecasts for the anticipated 2013 peak in Sunspot Cycle 24 led the House Committee on Energy and Commerce to authorize $100 million to upgrade the nation's power grids. It wasn't much of a debate, either. The vote was 47-0, and many legislators acknowledged that a big enough solar event will likely knock out nationwide grids, satellites, microchip circuitry and thousands of pole transformers, all in a single blow.

A NASA-funded study published in 2009, "Severe Space Weather Events--Understanding Societal and Economic Impacts," went so far as to suggest that electric power and communications to tens of millions of people could disappear for months.

Despite the warning, the Grid Act failed to pass in the Senate, leaving the country's aging infrastructure to fend for itself. The North American Electric Reliability Corporation, a self-regulatory body managed by utility companies, formed a Geomagnetic Disturbance Task Force in 2010 to craft new standards and regula-

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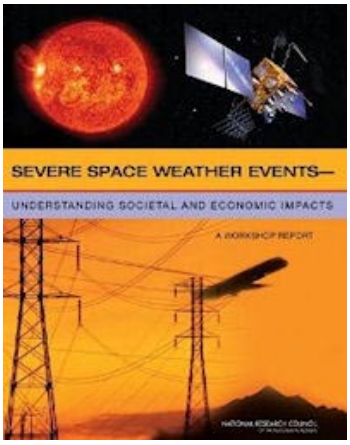
tions to protect the grid from cataclysmic space-weather-induced failures. To date, the task force has generated a lot of documents, (like a white paper) but not many changes.

Understanding Solar Flares and CME's



A perfect storm of radioactive particles striking and disabling our modern infrastructure has been forecast for some time. Solar physicist Sami Solanki warned in 2005 that an unusually high output of solar flares since the 1940's may be the prelude to record activity by 2013. "Except possibly for a few brief peaks, the Sun is more active currently than at any time in the past 11,000 years," he told a conference of his peers in Boulder, Colorado.

Solanki directs the Max Planck Institute for Solar System Research.

Typically, the warning sign of a solar flare about to fire is an expanding bubble of plasma on the Sun's surface that appears one or two days before the flare. To the naked eye, it looks like a black blotch on a bright canvass. Hence the term "sunspot" was coined. The darker color is due to a much lower surface temperature. This decrease comes in advance of a huge burst of plasma that erupts deep within the sun. A magnetic field line then directs the plasma outward into space.

Beside sunspots, a few other terms used by solar scientists are worth remembering, since journalists recite them (not always accurately) when reporting space weather events:

Solar Flare - This is a bundle of X-rays and gamma rays that reach the earth 8-120 minutes after exploding out of a sunspot. Because multiple atoms are involved, different parts of the flare arrive at different speeds. The rays are capable of disabling radio transmissions and causing other magnetic disturbances. Solar flares, when reported, are linked to an already identified "active region" of sunspots (e.g. "AR 1339"), and a time date (e.g. "1549 UTC"). UTC stands for Coordinated Universal Time, (formerly GMT). In this example, 15:49 is 3:49 p.m. in the U.K., and 10:49 a.m. in New York.

CME - This is short for "coronal mass ejection", a fiery mass of charged particles (aka plasma) propelled through space by solar wind. The word corona refers to the sun's outermost layer, which remains visible during a total solar eclipse.) A CME's trip to earth takes a lot longer than the initial solar flare, typically 48-36 hours.

On videos, it's the CME that you see splitting away from the sun. While the ejection packs a lot more punch than the initial flare, NASA and other space agencies at least have time to warn satellite and power grid operators of any potential risks.

X-Class, M-Class, etc. - Solar flares are divided into several classes of intensity. As a memory aid, just think of C-class flares as Common, M-class as Moderate and X-class as eXtreme events. (There are also much weaker A and B-class solar flares.) A number attached to the letter, e.g. M 5, rep-

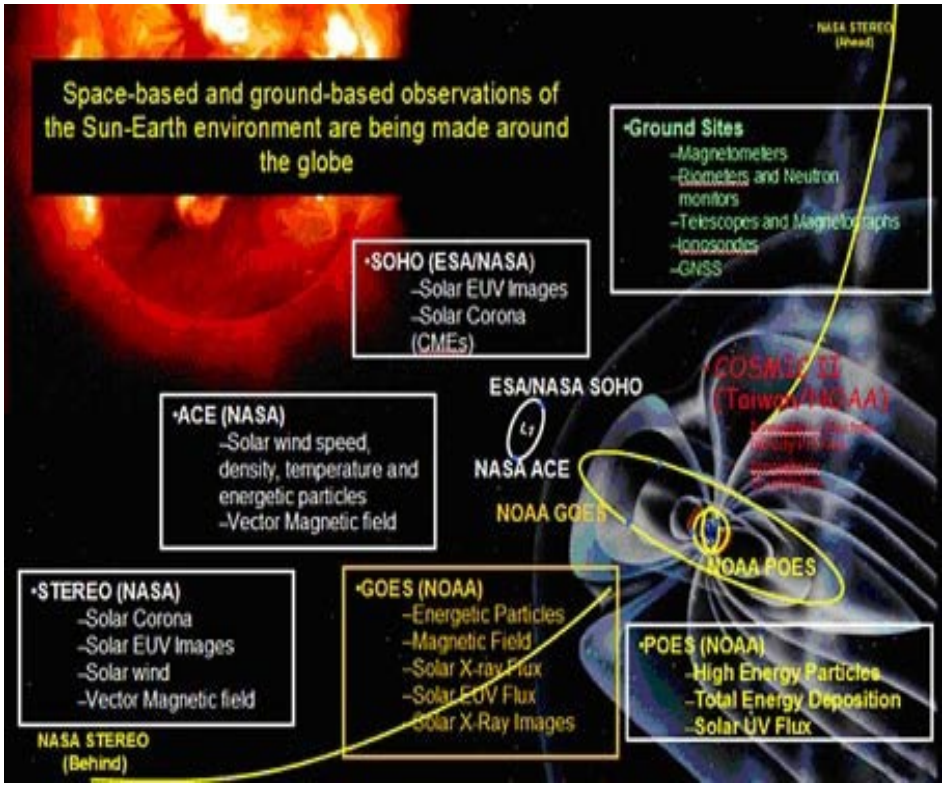


Photo: NASA/SDO

A graphic rundown of some of the satellite probes and ground-based monitoring of the Sun, radioactive particles and magnetism. Unfortunately, none of this equipment can stop a CME, just give us a little warning as it barrels toward us.

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resents a standard measurement of X-ray energy. Scientists refer to it as "peak flux". An X2 flare is twice as powerful as an X1 flare, but four times more powerful than an M5 flare. The strongest solar flare ever measured was an X28 in 2003.

Trajectory - It's important to remember that the sun is a massive object located far, far away. This makes the angle in which a solar flare/CME shoots outward just as critical as the intensity.

Most inbound CME's register only a glancing blow against the earth's outer layer, or magnetosphere, so predicting the strength of an impact remains a challenge. Complicating matters further, a solar wave of radiation striking the earth has a bow shock effect. This must also be assessed before scientists can determine which parts of the planet (if any) are at risk.

Geomagnetic Storm - Whenever large amounts of radiation in space strike the outer atmosphere, the event is referred to as a "storm". (The layman's term for it is "space weather".) The direction of a compass needle may be affected by a geomagnetic storm, and radio communications may be disrupted for a period of time.

In a worst-case scenario, satellites, electrical power grids, airplane navigation equipment and sensitive electronic circuitry on the ground could all be disabled. More often, however, a magnetic storm is simply reported in conjunction with the auroras it produces near the North and South Poles.

Solar Cycle - First documented by astronomer Richard Carrington in the 19th century, the sun appears to repeat 22-year cycles of magnetism and sunspot activity over and over. The cycle is divided into two matching 11-year intervals, each containing a trough (no sunspots) and a peak (lots of sunspots). The only difference between the two 11-year cycles is the polarity of the magnetic fields, which reverses each time. In any case, each 11-year interval is counted as one "sunspot cycle". We're now in Cycle 24, which began in 2008.

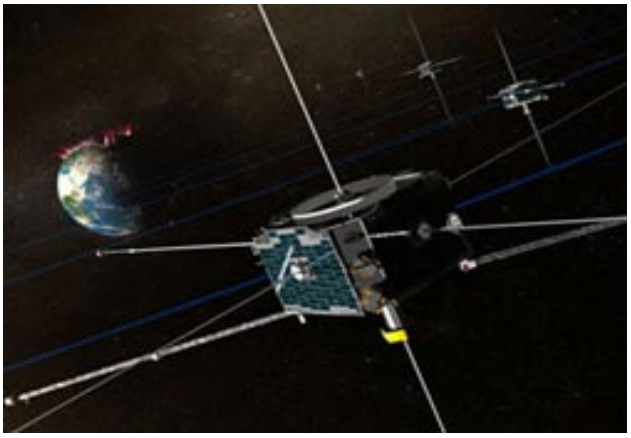

Image: NASA

Artist's conception of the five THEMIS probes tracking a solar storm.

Watching and Waiting

To keep tabs on a potential doomsday scenario unfolding, the European Space Agency and NASA launched the Solar and Heliospheric Observatory (SOHO) in 1995. In 2006, the Solar Terrestrial Relations Observatory (STEREO) was sent up to join the vigil. STEREO's two satellites are positioned on opposite sides of the space, between the Sun and Earth, providing a fully three-dimensional view of CME's.

Nearly 20 other satellites managed by multiple space agencies, including Japan and India, are monitoring the Sun. On the ground, NASA's Space Environment Center tracks the data transmissions of most of these probes. In the event that a strong CME starts heading towards our planet, it's the center's job to alert power grid operators and satellite controllers worldwide.

In 1859, the radiation spike from a powerful CME known as the Carrington Event (named after Richard Carrington) shut down the world's rudimentary telegraph network for a short time. It's considered the biggest CME to hit the earth in its recorded history. Moreover, had an event of that size struck in modern times, damage would have been catastrophic.

Curiously, the solar storm in

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1859 occurred during a lowpoint (i.e. trough) in the sunspot cycle. The event was credited with ending the Little Ice Age, a period between 1300 and 1859 AD when few sunspots were seen. An epoch of intense cold gripped the northern hemisphere, destroying crops and causing the River Thames to freeze over every winter. Nowadays, solar phycisists attribute the Little Ice Age on the so-called Maunder Minimum, a lull in solar activity between 1645 and 1715.

By reducing electrical current on the grid and shutting down satellites, sensitive circuitry and transformers, it's possible to avoid serious damage from a geometric storm. But if the circuitry and equipment does get overloaded, it could take months or years to make all the repairs.

Regardless, such counter-measures in the face of powerful solar glare would come at a huge cost. As California's rolling blackouts of 2000 proved, cutting power to a grid without warning customers can cause life-threatening outages. Officials will have to make a risk assessment, pitting deaths from traffic light failures, elevator stoppages and other communication failures against the possibility of a power grid overload. In 2006, the Discovery Channel took a closer look at this quandary in the docudrama *Solar Storm - Perfect Disaster*.

It doesn't help that the Earth's magnetic field appears to be petering out, according to the phycisists who monitor it. They estimate that it has lost 10 percent of its charge since measurements were first taken by Carl Gauss in 1835. Some of the experts (and more than a few doomsday proponents) believe a periodic magnetic pole reversal is in the works.

Such events happen rarely on the planet, but when they do, they're accompanied by the kind

Electricity transformers take a long time to manufacture. Replacing two thousand of them on the ground, and 140 million of them on electric poles, would cost about a trillion dollars and take up to ten years.

of rapid decline in magnetism that has been observed in recent decades.

There are several areas in the South Atlantic Ocean where a north-south magnetic pole flip may already be underway. While a reversal carries its own consequences for all electric devices (including computer hard drives), what worries scientists even more is the loss of a critical shield against space radiation at a time when it's needed most.

In 2007, a set of five satellite probes known as the THEMIS mission stumbled onto a breach of Earth's daylight side during a solar storm. Specially designed instruments were able to track a deluge of radioactive particles as they became trapped inside the magnetosphere. Had it been a more significant event, the radiation would have sent electrical current downward in an arc. The arc would have likely triggered a cascading failure of power grids around the world.

As it was, solar physicists were astonished by the data they collected. "At first I didn't believe it," David Sibeck of the Goddard Space Flight Center said in a NASA press release.

Project physicist Jimmy Raeder explained, "1027 particles per second were flowing into the magnetosphere — that's a 1 followed by 27 zeros. This kind of influx is an order of magnitude greater than what we thought was possible."

Defying a standard premise of physics, the event demonstrated that a CME has a far worse impact when the magnetic lines of the Earth and the Sun are both aligned to the north. And the scientists expect this same situation to reach white-knuckle stage when Sunspot Cycle 24 peaks in 2013. The press release continued:

"For reasons not fully under-

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stood, CMEs in even-numbered solar cycles tend to hit Earth with a leading edge that is magnetized north. Such a CME should open a breach and load the magnetosphere with plasma just before the storm gets underway. It's the perfect sequence for a really big event."

NASA's Sibeck added: "The sequence we're expecting … is just right to put particles in and energize them to create the biggest geomagnetic storms, the brightest auroras, the biggest disturbances in Earth's radiation belts."

THEMIS, by the way stands for a mouthful: Time History of Events and Macroscale Interactions during Substorms. The mission merged with other satellites in 2010 and became known as ARTEMIS: Acceleration, Reconnection, Turbulence and Electrodynamics of the Moon's Interaction with the Sun".

Back in 2009, NASA funded a study and report from the National Academy of Sciences called "Severe Space Weather Events--Understanding Societal and Economic Impacts." The workshop group of scientists concluded that the interdependent nature of high-tech society might prove our unraveling should a strong enough solar flare or CME broadside the planet.

With communications satellites disabled and the power grid inoperative, everything from water coming out of your tap to the public transit system would go out of service indefinitely. Gasoline could no longer be pumped from underground tanks, since that requires electricy. Stoplights would fail, causing a transportation nightmare and disrupting deliveries of food and other essential commodities. Consumers wouldn't be able to shop in any case, since banking and most retail transactions depend on electricity and the internet. Hospitals would also quickly bcome inaccessible, while police and other emergency responders would have no way to communicate in the field.

So while NASA continues to insist there's no looming catastrophe on the horizon, plain facts clearly suggest otherwise. In February 2010, the space agency launched the Solar Dynamics Observatory, a bigger and more elaborate probe than its predecessors. But like the others, this one can do nothing to thwart the impact of a CME, just film its spectacular and apocalyptic approach in living 3-D color.