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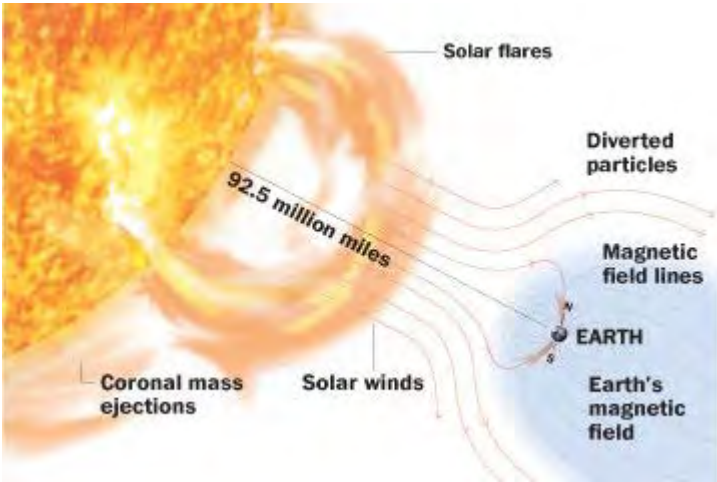
When space weather attacks!

By Brad Plumer, Published: July 13 at 9:00 am [E-mail the writer](#)

On a cool September night in 1859, campers out in Colorado were roused from sleep by a “light so bright that one could easily read common print,” as one newspaper described it. Some of them, confused, got up and began making breakfast.

Farther east, thousands of New Yorkers ran out onto their sidewalks to watch the sky glow, ribboned in yellow, white and crimson. Few people had ever seen an aurora that far south — and this one lit up the whole city.

At the time, it was a dazzling display of nature. Yet if the same thing happened today, it would



Click on the picture for a full map showing how space weather can affect the Earth.

be an utter catastrophe.

The auroras of 1859, known as the “Carrington Event,” came after the sun unleashed a large coronal mass ejection, a burst of charged plasma aimed directly at the Earth. When the particles hit our magnetosphere, they triggered an especially fierce geomagnetic storm that lit up the sky and frazzled communication wires around the world. Telegraphs in Philadelphia were spitting out “fantastical and unreadable messages,” one paper reported, with some systems unusable for hours.

Today, electric utilities and the insurance industry are grappling with a scary possibility. A solar storm on the scale of that in 1859 would wreak havoc on power grids, pipelines and satellites. In the worst case, it could leave 20 million to 40 million people in the Northeast without power — possibly for years — as utilities struggled to replace thousands of fried transformers stretching from Washington to Boston. Chaos and riots might ensue.

That’s not a lurid sci-fi fantasy. It’s a sober new assessment by Lloyd’s of London, the world’s oldest insurance market. The report notes that even a much smaller solar-induced geomagnetic storm in 1989 left 6 million people in Quebec without power for nine hours.

“We’re much more dependent on electricity now than we were in 1859,” explains Neil Smith, an emerging-risks researcher at Lloyd’s and co-author of the report. “The same event today could have a huge financial impact” — which the insurer pegs at up to \$2.6 trillion for an especially severe storm. (To put that in context, Hurricane Sandy caused about \$68 billion in damage.)

The possibility of apocalypse has piqued scientific interest in solar storms for many years. But researchers are now realizing that periodic space weather can cause all sorts of lesser mischief all the time, such as disorienting GPS satellites or severing contact between polar flights and air-traffic control.

So, in recent years, scores of businesses and government agencies have started to take space weather more seriously. Electric-grid operators are devising plans to reroute currents through their systems to brace for solar storms. Airlines such as Delta have developed plans to reroute flights in the case of emergency. The U.S. military has begun to realize that space-weather blips can disrupt communication in the heat of battle.

But preparing for disruptions isn’t easy. Just as interest in space weather is surging,

the United States is facing the loss of key monitoring satellites in the coming years, as budget cuts mean that aging systems aren't being replaced. And scientists are rushing to plug worrisome gaps in their knowledge about these storms.

The problem is far from theoretical. Last month, at a conference on space weather held by the National Oceanic and Atmospheric Administration, Daniel N. Baker of the University of Colorado told the audience that the sun had unleashed another large coronal mass ejection in July 2012 that traveled at speeds comparable to the Carrington Event of 1859. It missed the Earth by a week.

"Had that storm occurred a week earlier, it would have been a direct hit," Baker said. "And we'd probably be having a very different conversation about this today."

A year without power?

When it comes to space weather, the foremost concern is what a solar-induced geomagnetic storm might do to electric grids around the world.

At certain points in the sun's cycle, as sunspots appear and flares erupt, the sun will eject part of its outer atmosphere, a cloud of fast-moving charged particles. If one of these coronal mass ejections hits the Earth's magnetic field in just the right way, it can induce strong ground currents that travel through power lines, oil pipelines and telecom cables.



An aurora captured in Little Sturgeon Bay, Wisconsin Sunday morning at 3 a.m. on July 14, 2012. (Gary J. Meulemans, anakin1814 on Flickr and Twitter)

A truly severe geomagnetic storm could create currents powerful enough to overload electric grids and damage a significant number of high-voltage transformers, which can take a long time to repair or replace. That could leave millions without power for months or years.

"That's a key vulnerability," Smith says. "If you had a really big solar event, there just aren't enough replacement transformers available. It can take up to 12 months to build new ones."

As it turns out, most utilities don't keep lots of spares around. The largest transformers, which convert the electricity in high-voltage lines to lower voltages, are

custom-built, can cost millions of dollars and weigh up to 400 tons. Procuring a new one is a complex process that involves lining up the necessary copper and steel supplies, working with a long chain of manufacturers and arranging specialized transport. So, the Lloyd's report notes, if even 20 transformers in the Northeast were knocked out, the logistical challenges would be "extremely concerning."

Smith notes that the Northeast, with its aging power grid and peculiar geologic features, is especially at risk. Suffice it to say, it's not fun to think about what would happen to the region if 40 million people had to go without power indefinitely.

Take Pittsburgh: One 2004 study by Carnegie Mellon University found that a large number of the city's services were simply unprepared for an extended blackout. Half the city would lose water after three days if the city's electrical pumps couldn't be revived. Grocery stores, gas stations and cellphone networks would be knocked out. Police stations would go dark. Traffic lights would blink out. Most hospitals have backup systems in place, but emergency rooms would be strained if, say, the air conditioning went out during a hot summer.

"The absence of such fundamental services could lead to major and widespread social unrest, riots and theft," the Lloyd's report warns.

In theory, power utilities could try to take precautions if they had advance notice of a major solar storm headed our way. Using existing satellites, the National Weather Service's Space Weather Prediction Center in Boulder, Colo., can detect an incoming event that's about 30 minutes away.

Grid operators would have to react quickly. For example, PJM Interconnection operates a huge swath of the U.S. power grid from Illinois to the District, serving 60 million people. After receiving a warning, human operators could re-dispatch electricity to reduce the flow of current from west to east. That would minimize the grid's vulnerability to ground currents, Frank Koza, the executive director of operations support at PJM, said at the June space weather conference in Silver Spring.

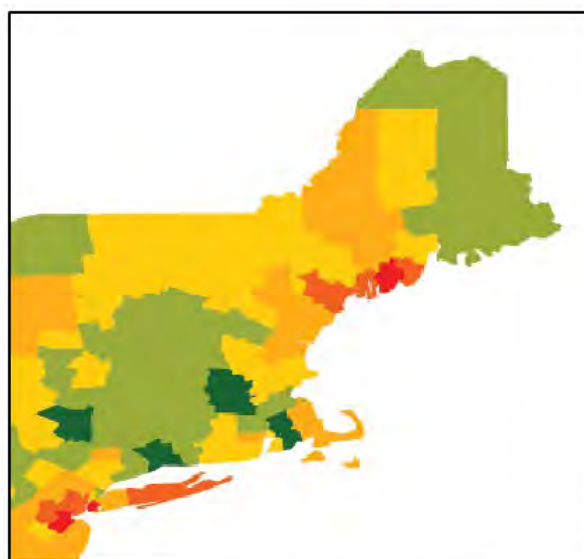
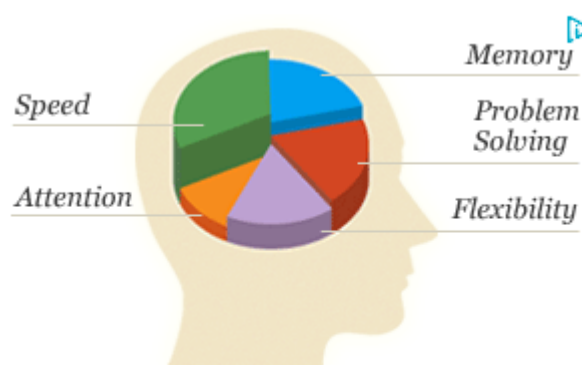


Figure 4: Relative risk of power outage by county in New England.

Credit: Lloyd's report, Solar risk in North America

For a modest solar storm, Koza said, PJM's operators could respond if voltages started to drop anywhere in the system. (Pepco, which delivers electricity to 778,000 homes and businesses in the District and Maryland, is a member of PJM.)

But there's a limit to how much these strategies can help. "The one we're really concerned about is extreme space weather, a Carrington-level event," Koza said. "What would happen in that scenario? I would have to tell you we don't really know."



For bigger storms, there are technologies that could harden the grid, such as capacitors that can help block the flow of ground currents induced by a geomagnetic event. In Quebec, the Canadian government has spent about \$1.2 billion on these technologies since the 1989 blackout.

Your brain, just *brighter*



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One problem, says Chris Beck of the Electric Infrastructure Security Council, is that many of these technologies are expensive and could make the current grid slightly less efficient in its day-to-day operations.

"We've designed our power lines to work efficiently under perfect conditions — long transmission lines, high voltages," Beck says. Unfortunately, those characteristics make the grid particularly vulnerable to a solar storm. So there's a trade-off.

Recently, the federal government decided to take a more serious look at the issue. Last fall, the Federal Energy Regulatory Commission issued an order that will eventually require grid operators to prepare both operational and technological responses to a space weather event.

Koza said he expects most grid operators to have response plans in the next year or two, but "engineered mitigation" could be another two to four years away.

Insurance companies, meanwhile, are trying to figure out how to get a handle on the risk from a solar storm. Will a major one come around once every 150 years? More often than that? "We're hoping we might one day be able to cover these risks," says Smith of Lloyd's, "but we'll need to be able to quantify them more accurately."

Policymakers have also started getting involved. For a long time, conservatives such as

Newt Gingrich were mostly interested in the risks to electric grids posed by a nuclear weapon that exploded in the atmosphere and induced ground currents. In June, Gingrich spoke to members of the Electromagnetic Pulse Caucus in the House, a group of 16 Republicans and two Democrats, about this possibility. “This could be the kind of catastrophe that ends civilization,” Gingrich said, “and that’s not an exaggeration.”

Now that the Cold War has ended, however, many of these Cassandras have switched over to warning about solar storms, which can have a similar effect, albeit on a smaller scale. Rep. Trent Franks (R-Ariz.), a founder of the EMP Caucus, has pushed a bill to protect against both “natural and man-made EMP events.” And in public, he tends to put more emphasis on solar storms.

“We’re starting to see more awareness there,” Beck says, “although we’re not quite to the point where we’re actually putting solutions in place.”

Unknown risks



(Mark Garfinkel/AP)

Setting aside apocalyptic blackouts, solar storms and space weather can create all sorts of hiccups in the global economy that scientists are only beginning to understand.

Case in point: During the Battle of Takur Ghar in Afghanistan in 2002, a U.S.

helicopter team was sent in to pick up a team of Navy SEALs. The SEALs sent a message to the helicopter warning the team not to land, but for some reason, it was never received. The helicopter landed under intense fire and four Americans were killed — an event dramatized in Sean Naylor’s bestselling account of Operation Anaconda, *Not a Good Day to Die*.

Some scientists now suspect that space weather could have been to blame for the incident.

At the space weather conference in June, Michael Kelly of the Johns Hopkins University Applied Physics Laboratory presented early evidence that a form of space weather known as “scintillation” can cause disturbances in the ionosphere and disrupt local radio communications. Researchers are working to model this phenomenon more accurately.

Airlines, too, have to take even lesser outbursts from the sun into account. Delta runs a number of commercial flights over the poles, such as routes between Detroit and Beijing and between Atlanta and Tokyo. But if they get a last-minute warning from the Space Weather Prediction Center of a geomagnetic storm, the planes often have to divert their routes away from the poles or risk losing radio contact with the ground. These diversions can cost thousands of dollars, Delta officials noted, so better predictions would help a great deal.

And those concerns only scratch the surface.

Joseph Kunches, a scientist at the Space Weather Prediction Center, says we’re still learning about activities that could be disrupted by solar weather. Satellite communications can go astray. Pipelines can corrode from ground currents. Even human space travel faces a threat.

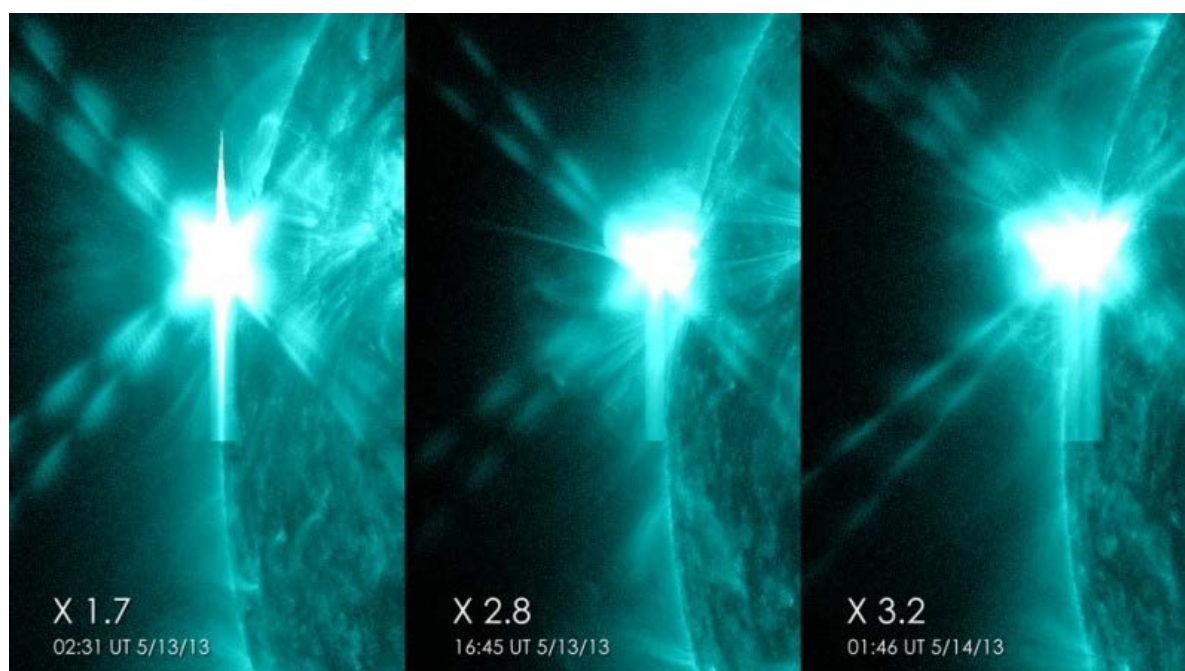
“Radiation is a big issue for space travel — particularly once you get away from the Earth’s magnetic field,” he says. Astronauts working outside the Earth’s protective shield can be particularly vulnerable to bursts of solar radiation, which can have harmful health effects. That means that if we ever want to wander around in space, it would be helpful to have a better grasp of space weather.

“In 1972, there was actually a huge eruption that fortuitously fell between two of the Apollo flights, so the radiation didn’t hurt anybody,” Kunches says. “But it’s a problem.”

And there are still plenty of unknowns. Kunches and other experts pointed to the potential impact of solar eruptions on GPS technology. Certain storms could degrade the signal as it makes its way from the satellite to the ground. GPS is built into so much of the modern economy — from navigation to geophysical exploration by oil and gas companies — that any interference with GPS signals could be quite costly.

“I call it the cyber-electric cocoon we’ve built around the Earth,” says Baker, who heads the Laboratory for Atmospheric and Space Physics at the University of Colorado. “There are all these relationships that most people don’t even have a clue are there, and we’re still trying to understand everything that’s at risk.”

Satellite fleet may shrink



These image obtained from NASA's Solar Dynamics Observatory show the three X-class flares that the sun emitted in under 24 hours on May 12-13, 2013. The Sun unleashed the three potent solar flares marking the most intense activity yet this year and causing limited interruptions to high-frequency radio communications. One of them was classified as an X3.2 flare, with X-class flares being the most intense type. (AFP PHOTO / NASA)

One big problem that businesses are having in preparing for a space weather attack is that they're still not sure, exactly, what to prepare for. Minor impacts occur fairly often. But when might we expect a Carrington event? Or even something like the Quebec storm in 1989?

“Until we know that, the industry will be limited in its response,” said Koza of PJM Interconnection.

And there's plenty more that space scientists are still trying to grasp. It's difficult to predict, for instance, whether a solar outburst will actually create a storm when it hits

Earth. A great deal depends on how a coronal mass ejection interacts with other solar winds as it moves toward us. Kunches likens it to knowing that a hurricane is coming, but not being able to measure its barometric pressure.

It would also be helpful to have more spacecraft studying the sun and giving us advance warning of storms. But, if anything, the Earth's alert systems are about to get worse, not better.

Right now, NASA operates four space satellites situated between the Earth and the sun, which together can provide roughly 30 minutes' warning of a major solar eruption. But these satellites are all reaching the end of their planned lives (and fuel tanks), and there's only one replacement satellite scheduled to launch in 2014.

At the space conference in June, various speakers discussed ways to improve our ability to watch the sun. One engineer described fantastical plans for a satellite with a 100-square-meter "solar sail" that would use be steered and pushed by the sun's photons in order to get closer and closer to the star without getting sucked in by gravity. A solar-sail satellite could, in theory, give us twice as much warning to prepare for a space storm.

But so far, these plans are all theoretical. "There's a real need for a truly operational, 24-hour-a-day, seven-day-a-week space weather observatory," Baker says. "But right now, we don't see that coming from policymakers or the agencies that would have to step up."

That means we may have to hope for a bit of luck in the years ahead. Solar activity tends to follow an 11-year cycle, with the most intense events often occurring near the peaks of the solar maximum — which, NASA says, could well arrive in late 2013 and again in 2015, although it's difficult to predict for sure.

That doesn't mean the big one will hit then. For one thing, sunspot activity has been rather muted of late, and the current maximum has been surprisingly weak. But for many experts, it's a good reason to keep the sun in mind.

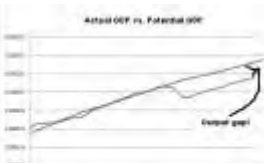
"We're really on an unknown timeline here," Beck says. "One of these could happen at any time."



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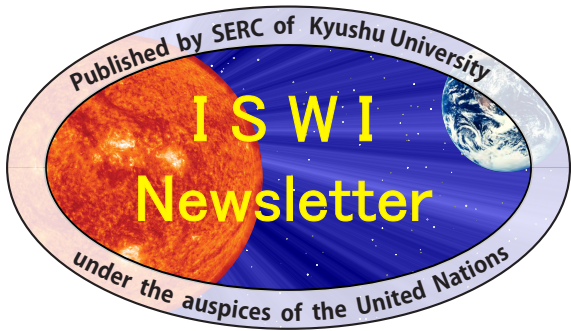
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