TROY: I'm Troy Cline bringing you another Sun-Earth Day connection.
As a reminder Sun-Earth Day happens on or near the Spring Equinox; however many people celebrate Sun-Earth Day throughout the year. I'm here with my friends at the Nasa Edge Studio, hey.
CHRIS: Hey Troy, How are you doing?
TROY: I'm doing great.
BLAIR: Great to have you here.
CHRIS: And the letter of the day is... "H" for
BLAIR: Hinode
TROY: Hinode, and what does Hinode mean?
BLAIR: It means Sunrise.
TROY: I've always been impressed with your ability to do amazing graphics like that.
BLAIR: We're going retro graphics. As much fun as we are having with this, we wouldn't have these cool images if it weren't for the series of Sun satellites of which Hinode is one to send back incredible data
TROY: That's right
CHRIS: Now we saw two cool videos of Hinode already. And we're going to be seeing this third one. What's on tap for this third video?
TROY: In this one we'll be talking about how Hinode explores the atmosphere of the Sun and how it's helping us improve our understanding of the Solar Atmosphere. Which I find really facinating because most people don't realize that we live within the atmosphere of the Sun.
BLAIR: That is what space weather is all about too.
TROY: Exactly.
CHRIS: I think it's also improtant, that a lot of people out there, and I could be totally wrong, but they see us as taking satellites and putting them up in low earth orbit and studying the earth. We have a "train" of satellites studying the Sun as well.

TROY: That's right. And this video is exceptional. I can't wait for you to see what's inside this one.
BLAIR: And plus you have that viewer on the website and you see all of these different images you wouldn't, if you didn't have all these different satellites that can take different analytical looks.
TROY: That's right. And that is the Space Weather Media Viewer which is new and improved and was just released and it's awesome.
BLAIR: It is awesome. I actually witnessed some solar activity earlier.
TROY: All of the data that comes in is near real time. So it's no more than about 2 hours old usually.

[BEGIN MOVIE]
Our sun provides us with the light and heat we need to keep warm and grow the crops we need to survive. It makes possible the very existence of life on this planet. It is the ultimate battery that drives our climate, and our energy needs. And, like an electric current, it’s overload can plunge us into darkness.

On Friday, March 10th, a powerful explosion on the Sun launched a cloud of gas from Active Region 5395- a sunspot group nearly dead center on the Sun, and over 3 Earths in diameter. The storm cloud rushed out from the Sun at a million miles an hour, and on the evening of Monday, March 12 it struck

Earths magnetic field. Millions of people in Alaska, Canada and Scandinavia were treated to a spectacular auroral display that night that lasted from sunset until midnight.

A spectacular light show took the skies as far south as Florida and Cuba. The vast majority of people in the Northern Hemisphere had never seen such a spectacle in recent times. Some even worried that a nuclear first-strike might be in progress. Silently, the storm had impacted the magnetic field of the Earth and caused continent-wide electrical currents to flow in the ground.

The expanding ring of storm currents created by the northern lights swooped downwards in latitude, deep into North America. This caused continent-wide electrical currents to flow in the ground beneath the gawker's feet. The currents eventually found harbor in the electrical systems of the United Kingdom, the United States and Canada.

At 2:44:16 AM on March 13, all was well as power engineers operated the Hydro-Quebec power grid. They had resigned themselves to yet another night of watching power loads come and go during the off-peak hours. The engineers didn't know, however, that for the last half-hour, their entire system had been under attack by powerful Earth currents.

A power grid consists of hundreds of electrical generation plants… Thousands of transformers that boost the voltages to send the current on transmission lines. Tens of thousands of sub-stations that step-down the voltages and millions of power poles that serve to connect the substations to the customers. This entire network must be maintained or 'regulated' to a fixed voltage so that the power is moved efficiently. The large transformers are grounded to the Earth, and this provides a pathway for magnetic storm 'earth currents' to enter the network If the storm is strong enough, the network loses its regulation and this can cause damage to costly transformers that take weeks to repair or even years to replace. Since magnetic storms cover millions of square kilometers, entire power grids can be shut down causing major blackouts.

At 2:44:17 AM, these currents found a weak spot in a sprawling North American power grid located in Quebec.

A 100-ton, static VAR capacitor Number 12 at the Chibougamau sub-station tripped and went off-line as harmonic currents caused protective relays to sense overload conditions.

At 2:44:19 AM, two seconds later, the loss of voltage regulation at Chibougamau caused power swings and a reduction of power generation in the 735,000-volt La Grande transmission network.

At 2:44:46 AM, and 150 kilometers away at the Albanel and Nemiskau stations, four more capacitors went off-line.

The last station to fall at 2:45:16 AM was the Laverendrye complex to the south of Chibougamau.

The fate of the network had been sealed in barely 59 seconds as the entire 9,460-megawatt output from Hydro-Quebec's La Grande Hydroelectric Complex found itself without proper regulation. Lasting 75 seconds from start to finish, the cascading events traveled much too fast in space and time for human operators to react, but it was more than enough time for 21 billion watts of badly needed electrical power to suddenly disappear from service.

The nighttime temperature in Toronto was 19 F, or -7 degrees Celsius, so the loss of electric power was felt very dramatically as most people woke up to cold homes for breakfast.

Over 3 million people live near Montreal, the second largest metropolitan area in Canada, where nearly half of the population of Quebec resides. Montreal is famous for its 30 kilometers of underground walkways linking 60 buildings, two universities and thousands of shops and businesses. Over 500,000 people use this system each day to avoid the freezing cold winter air. Pedestrians suddenly found themselves plunged into complete darkness, with only the feeble battery-powered safety lights to guide them to the surface.

The presses at the Montreal Gazette had been rolling at break-neck speed that night to print the Monday newspaper for its 195,000 subscribers. The sudden loss of power caused the huge rolls of paper – each weighing several tons - to come to a sudden halt, shredding paper in a storm of debris, and jamming the presses.

The blackout also closed schools and businesses, kept the Montreal Metro shut down during the morning rush hour …and paralyzed Dorval Airport, delaying dozens of flights. Without their navigation radar in operation, no flight could land or takeoff until power had been restored. People ate their cold breakfasts in the dark and left for work. They soon found themselves stuck in congested traffic. Motorists tried to navigate darkened intersections without any streetlights or traffic control systems operating. Thanks to working emergency generators, no major problems were reported from most of Montreal's hospitals, although the Montreal Children's Hospital cancelled all elective surgery. A more urgent situation did arise at the St. Luc Hospital when four patients in intensive care had to have air pumped into their lungs manually.

Like most modern cities, people work round the clock, and in the early morning hours of March 13, the Swing Shift staffed many office buildings in the caverns of Downtown Montreal.
All these buildings were now pitch dark, stranding workers in dark offices, stairwells and elevators.

The Quebec blackout cost businesses tens of millions of dollars as it stalled production, idled workers and spoiled products.

By 10:00 AM, power had been restored to most of the customers in Quebec, and by 11:00 AM on March 14, all but 3,500 of the 842,000 customers were back in business. Almost immediately, in the daily papers on March 14th, the cause was attributed by scientists and engineers to a magnetic storm, and the cause of the blackout switched to an ‘Act of God’ event for which Hydro-Quebec could not be held entirely responsible.

I recently spoke with electric power engineer Jean Beland at Hydro-Quebec about the 1989 blackout.

In the following weeks after the 1989 event, the corrective action has been to use space weather forecasting services. This service will alert the online operator that something is coming or might be coming which will give them probability or the given severity. And then the operator will be able to take corrective action against the geomagnetic storm.

The National Research Council in Ottawa issued a warning to the utility about the impending magnetic storm 6 days before the event arrived. To its credit, Hydro-Quebec heeded these warnings and recommendations and reduced the power load over by 10% as a precaution.
Yet pointing a finger at the Sun was not considered a credible explanation by a population unfamiliar with the effects that solar storms are capable of.

Although this historic blackout was largely a local political and economic event for Quebec, it served as a major wakeup call for… the United States.
[END MOVIE]

TROY: We have Dr. Sten Odenwald on line with us right now, who is not only the producer of the Hinode Vodcast series but he is also one of our NASA astronomers.
STEN: Thank you for that wonderful glowing introduction.
CHRIS: And a long time friend of NASA Edge and formerly of NASA Connect and NASA Sci-Files.
BLAIR: And certainly when I can't answer a question he is the goto guy. We send emails along to the guy with knowlege.
TROY: So between the two of you, you know everything [LAUGHTER]
CHRIS: Every time we get an astronomy question on the Edge I send it straight to Sten.
TROY: So do I. Hey Sten what can you tell us about this satellite. There is so much about it that is new that we're waiting to hear about.
STEN: I've been doing these vodcasts to re-kindle the interest in Space Weather issues because we're in sunpot minimum right now. So I thought that with Hinode, which is a solar observing satellite looking at flarese and things, that it made sense to talk about extreme space weather events. Like the extreme sports and the extreme eating habits of the rich and famous [laughter]. Well this is sort of like extreme space weather events. [pause] This one is about the great Quebec blackout in 1989, March 13. We've learned a lot about what Space Weather can do to clean our clocks in the last 20 years.
CHRIS: Yeah, I remember reading about that in your book "The 23rd Cycle"
BLAIR: It's interesting because that's what magnetospherence comes out of; being able to monitor these kinds of things and better prepare so that we don't have the same kind of consequence that we had back in 1989.
TROY: That's right, and if everybody remembers, magnetospherence is a term coined by very own Blair.

STEN: It really is interesting. I'm more impressed that we haven't had more blackouts from solar storms. But we've learned quite a lot about how to build electrical systems and satellites in the space of three space weather events.
TROY: Now I see here that you said the Quebec blackout solar storm is not one of the biggest ones we experienced in the last 100 years. Is that correct?
STEN: That's correct; the deal is though that we've had different types of technologies in the past and some of them were sufficiently primitive. You would really have to whack the part in order for them to do anything. For instance telegraph systems. We don't use telegraphs anymore but for 100 years it was the popular mode for communication. It turned out to be rather sensitive to geomagnetic storms. You would typically have several hunderd volts of voltage on these telegraph lines, shorting out telegraph sets and giving people nasty burns while sending messages to grandma on halloween [Laughter] Now we don't have that technology but we have other kinds of technology that have proved itself to be sensitive to space weather. Of course all of our communication satellites rock and roll when there is a big space weather event.
BLAIR: Isn't that one of the things this data will do, in better understanding the solar activity and how we're impacted by it?
STEN: Absolutely. The deal is that we can't get out of the way from this garbage. We can't move the planet out of the way of a coronal mass ejection. So the only hope that we have is to be able to forecast these things; you know, look at the Sun, see what's going on there and plug all the data into the model to forecast what's going to happen in 3 or 4 days. That gives us enough time to deal with satellites and put them into safe modes, and handle our electrical power grids and all of that. That is why so much of the emphisis is on understanding the basic physics of Space Weather. Only after you understand how the dominos fall can you actually set up and create a predictive model.
CHRIS: Couldn't essentially this be a security threat; let's say we had a major storm hit us and it effected the communications for airlines and have to shut everything down. Could you imagine having 4 or 5 thousand planes up at once and then all of the sudden a blackout.
STEN: That is absolutely true. These are not theoretical issues, these are all identified hazards. We had in world war 2 shortwave blackouts all the times due to solar storms. So the Allied forces had to work around losing shortwave communications with headquarters as part of handling the war. For airline crews and flights, the next 10 years we're going to go to almost all GPS on almost all commercial airlines on takeoff and landings. Now GPS satellites and position information is terribly sensitive to space weather events because the ionisphere gets disturbed. It's something to consider as a hazard. And that's why predicting when bad things are going to happen is so vitally important. That is why satellites like Hinode are up there digilantly working gathering data.
BLAIR: How would you rate the predictability we have right now. It seems that we have a 2 or 3 day heads-up. Is that accurate?
STEN: Yes. We have gotten really good at that. Mainly because we can actually photograph or image the plasma as it's coming off the Sun.
TROY: Now given the information you have especially with some of the books you've written, I understand there is some debate with this next solar cycle, or the next solar maximum. What do you think is going to happen?
BLAIR: And when does it begin?

STEN: Technically is has already started. We are in sunspot minimum and starting to slowly and sluggisly come out of it. It's been an unusually long sunspot minimum which is what is giving the forecasters the idea that the next cycle isn't going to be nearly as strong as the past one was that we just went through. Predicting how big the next cycle is going to be is more an artform than it is a hard and fast prediction at this point.

CHRIS: It's like predicting the weather here on earth.

STEN: That's exactly right except in New England you wait 5 minutes and it's a new pattern. Here you have to wait 11 years.

TROY: Plus you can't go out and say eye-witness weather [roaring laughter].

BLAIR: But there is something interesting about getting the imagery from the Sun, from these satellites in any kind of advanced format. That's going to be beneficial. So having these satellites certainly helps out in our ability to prepare. Which sounds like something we really need to pay attention to.

STEN: Absolutely. And understanding a lot about how flares work, how magnetic energy is converted into particle energy which then becomes radiation that satellites are effected by. It's all a very complicated thing. We're still decades away from really understanding the subtleys mainly because the Sun is a chaotic system fundamentally. It's not one that works well with predictive models and there is always element of randomness in how things work.

CHRIS: In fact, by 2020 when we go back to the moon, Blair wants to be the first media-naught on the lunar surface; so I have a feeling we're going to have our first solar-Blair.

TROY: Causing quite a bit of magnetospherence [Laughter]

CHRIS: Which might be a hazzard to earth since it's only 2 or 3 days away.

BLAIR: I create the term magnetospherence but I actually generate legitimate magentospherence. The convergence of thoughts here is frightening [Laughter]. My hair is the same color as the Sun. I'm truely heat miser.

STEN: Changing shampoo can fix that [Laughing]

TROY: Can you tell us how to learn more about the Hinode Mission. I always love to tell people to go to the Sun-Earth Day web site where we have links to you but where specifically can they go?

STEN: Specifically, the Marshall Space Flight Center has the official Hinode web site which is maintained by the program office. There you can find the education resources under the educator tab. You can also find, under science materials, a number of resources I've developed on the human impact of space weather.

TROY: I'd also like to remind everybody that you can see a beautiful image from the Hinode space craft on our new Space Weather Media Viewer.

STEN: It's an incredible thing. Some of these Hinode images look at the full Sun. You see all of these freckles all over the place; and those are what we call nano-flares. These are individual little flares that pop off every day by the thousands across the solar surface. We think that those are the guys that are responsible for heating up the corona and causing solar wind ultimately. It's very exciting to see this new data coming in at the resolutions where you can actually start seeing the relative physics.

TROY: Now that's cutting edge. Hey Sten, do we have several more of these videos to look forward to?

STEN: We have the compainion video coming up to the one on Quebec. Basically what happened in the US due to that blackout. Following that we're going to do a vodcast that talks about the radiation component to solar flares and how those affect satellites. And then finally for next academic year we're going to kick off by creating a 20 minute NASA TV program for the 150th anniversary of the 1859 super storm. So we have little things stacked all along the year.

BLAIR: If you need a solar spokesman, Solar Blair is your man.

TROY: I can't come up with one quick enough for me [Laughter] But I will.

CHRIS: I'm looking at a fact sheet on Hinode. The backside of the sheet has two of your math problems, which looks pretty good.

STEN: Yeah, I'm a big proponent of math education within NASA. As are you Chris, and you know it's that kind of a thing that has been an un-touched subject for way too long for NASA. I'm trying to amp up the volume on why math education is so important. You can't do astronomy and predict the Sun without mathematics.

CHRIS: I say that to Blair every day. I'm trying to get him to learn Algerbra. [Laughter]

BLAIR: Yeah, it's been trying.

STEN: Algerbra is sweet. When you get into calculus the beat starts picking up and you can start doing some really fun things.

BLAIR: Nothing says I love you like Algerbra [Laughter].

CHRIS: Well hey Sten I just want to thank you for all the great information and for having a chance to talk with us today.

STEN: Thanks a lot, it's been a lot of fun.

BLAIR: Thanks for the math rehabilitation.

STEN: Hey, anything I can do to raise math visibility I'll always do.

TROY: Well this is Troy Cline with the NASA Edge team saying thanks for joining us for another Sun-Earth Day connection.

[Fading off chatter]