PREPARING FOR THE NEXT SOLAR MAX[1]

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4 APPENDIX: ToC OF THE SEVERE SPACE WEATHER EVENTS REPORT 9

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[1] The original articles on which this paper is based appeared in the *Network World Security Strategies* newsletter as the following items, all by this author:

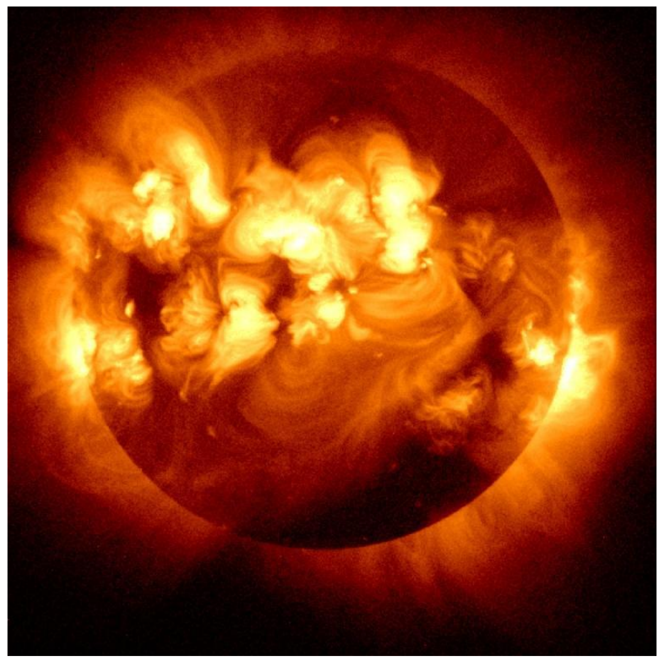
- Solar storms are more than a curiosity. (Jul 17, 2009). < http://www.networkworld.com/newsletters/sec/2009/072009sec1.html >
- Solar storms have caused serious disruptions. (Jul 22, 2009). < http://www.networkworld.com/newsletters/sec/2009/072009sec2.html >
- Preparing for the next solar max. (July 27, 2009) < http://www.networkworld.com/newsletters/sec/2009/072709sec1.html >

1 Solar Storms are More than a Curiosity: NRC Report Warns of Severe Impacts on Infrastructure

As if the growing instability of atmospheric weather resulting from anthropogenic greenhouse gas emissions[2] were not enough to worry infrastructure security professionals, a growing concern centers on geomagnetic storms resulting from cyclical storms in the outer layers of our sun.

Most people know that our sun cycles through eleven year cycles of solar storms in its outer layer, the chromosphere.[3] The solar storms are associated with cooler vortices of incandescent plasma (the form of matter in which electrons and nucleons are so energetic that they are ripped apart from their normal association into atoms) called sunspots[4] and solar flares,[5] huge jets of plasma that arc upwards into the corona for thousands of miles. The composite photograph below from NASA shows several solar flares.[6]

Solar flares generate immense pulses of electromagnetic interference (EMI); indeed, as recounted by Richard E. Kerr in the 26 June 2009 issue of *SCIENCE* magazine,[7] the intense solar storm of August 28, 1859 had devastating effects even on the relatively primitive electrical communication system of the time: "The sun had blasted a billion-ton magnetic bubble of protons and the like right at Earth. On smashing into the planet's own magnetic cocoon at several million kilometers per hour, the bubble dumped its energy, pushing the solar-driven aurora from its customary arctic latitudes to overhead of Cuba. This once-in-500-years 'solar superstorm' crippled telegraph systems for a day or two across the United States and Europe but otherwise was mainly remembered for its dramatic light show."



Solar Flares shown in compositie photograph

Today, the effects of such a solar storm will be potentially devastating.

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2 EPA (2009) Greenhouse Gas Emissions. < http://www.epa.gov/climatechange/emissions/index.html >

3 Raw, S. (2007). The Solar Chromosphere. < http://www.chromosphere.com/ >

4 NASA (2009). The Sunspot Cycle. < http://solarscience.msfc.nasa.gov/SunspotCycle.shtml >

5 NASA (undated). What is a Solar Flare? < http://hesperia.gsfc.nasa.gov/sftheory/flare.htm >

6 Image from < http://mynasa1.nasa.gov/images/content/158270main_solarflare.jpg >

7 Kerr, R. A. (2009). Are We Ready for the Next Solar Maximum? No Way, Say Scientists. Science 324(5935):1640-1641 (Jun 26, 2009).
Abstract < http://www.sciencemag.org/cgi/content/summary/324/5935/1640 >; full article requires membership in AAAS or access through library databases.

2 National Academies Report

The National Academies Press has published a report that should concern everyone involved in the critical infrastructures at the planetary and national scales: *Severe Space Weather Events – Understanding Societal and Economic Impacts: A Workshop Report.*[8] The entire report is available online free as a single PDF file with a simple registration of e-mail address, ZIP code and economic sector. Alternatively, the executive summary[9] is available without registration and the entire text is freely readable through a Web browser.[10]

The Preface of the report includes this description of the effects of a solar storm in "late October and early November 2003 [which] produced intense solar energetic particle events and triggered severe geomagnetic storms, the wide ranging effects of which were described [in a National Oceanic and Atmospheric Administration (NOAA) report published in April 2004][11] as follows:

> The Sydkraft utility group in Sweden reported that strong geomagnetically induced currents (GIC) over Northern Europe caused transformer problems and even a system failure and subsequent blackout. Radiation storm levels were high enough to prompt NASA officials to issue a flight directive to the ISS astronauts to take precautionary shelter. Airlines took unprecedented actions in their high latitude routes to avoid the high radiation levels and communication blackout areas. Rerouted flights cost airlines $10,000 to $100,000 per flight. Numerous anomalies were reported by deep space missions and by satellites at all orbits. GSFC Space Science Mission Operations Team indicated that approximately 59% of the Earth and Space science missions were impacted. The storms are suspected to have caused the loss of the $640 million ADEOS-2 spacecraft. On board the ADEOS-2 was the $150 million NASA SeaWinds instrument. Due to the variety and intensity of this solar activity outbreak, most industries vulnerable to space weather experienced some degree of impact to their operations.

The Summary points out that in March 1989, a solar storm caused, "the collapse within 90 seconds of northeastern Canada's Hydro-Québec power grid during the great geomagnetic storm of March 1989, which left millions of people without electricity for up to 9 hours." Kappenman and colleagues provide additional explanations and warnings:

> Disturbances caused by solar activity can disrupt these complex power grids. When the Earth's magnetic field captures ionized particles carried by the solar wind, geomagnetically induced currents (GIC) can flow through the power system, entering and exiting the many grounding points on a transmission network. GICs are produced when shocks resulting from sudden and severe magnetic storms subject portions of the Earth's surface to

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8 NRC (2008). Severe Space Weather Events--Understanding Societal and Economic Impacts: A Workshop Report (2008). Committee on the Societal and Economic Impacts of Severe Space Weather Events: A Workshop. Space Studies Board, Division on Engineering and Physical Sciences, National Research Council of the National Academies. National Academies Press (ISBN 978-0-309-12769-1). Also available free online in PDF & HTML < http://www.nap.edu/catalog.php?record_id=12507 >

9 Executive Summary for reference [8] < http://www.nap.edu/nap-cgi/report.cgi?record_id=12507&type=pdfxsum >

10 HTML version for reference [8] < http://www.nap.edu/catalog.php?record_id=12507#toc >

11 NOAA (2004). Intense Space Weather Storms, October 19 – November 07, 2003 < http://www.weather.gov/os/assessments/pdfs/SWstorms_assessment.pdf >

> fluctuations in the planet's normally stable magnetic field. These fluctuations induce electric fields in the Earth that create potential differences in voltage between grounding points—which causes GICs to flow through transformers, power system lines, and grounding points. Only a few amps are needed to disrupt transformer operation, but over 100 amps have been measured in the grounding connections of transformers in affected areas….
>
> Recent storms associated with Solar Cycle 22 (the 11-year sunspot cycle that began in 1986) have had an unprecedented impact on electric power systems. The great geomagnetic storm of March 13, 1989, plunged the entire Hydro Quebec system, which serves more than 6 million customers, into a GIC-triggered blackout. Most of Hydro Quebec's neighboring systems in the United States came close to experiencing the same sort of outage.
>
> Less severe geomagnetic storm events in September 1989, March 1991, and October 1991 also hampered utility operations. GIC interactions with new technological devices such as large electric power controllers affected voltage regulation and caused undesired relay operations in the system equipment.
>
> In contrast to today's more severe solar storm cycle, the preceding, relatively quiet 30-year period led designers of electrical systems to overlook the possible influences of GICs. Conventional threats—such as high winds, ice loading, or lightning—did not cause the Hydro Quebec collapse. Rather, it was the consequence of a threat that had never been considered on a system-wide scale across the continental network.
>
> Many portions of the North American power grid are vulnerable to geomagnetic storms. Much of the grid is located in northern latitudes, near the north magnetic pole and the auroral electrojet current and in regions of igneous rock, a geological formation with high electrical resistivity…. Systems in the upper latitudes of North America are at increased risk because auroral activity and its effects center on the magnetic poles, and the Earth's magnetic north pole is tilted toward North America.[12]

Additional examples of space-weather effects include (quoting directly from the NOAA Report Summary)

- The outage in January 1994 of two Canadian telecommunications satellites during a period of enhanced energetic electron fluxes at geosynchronous orbit, disrupting communications services nationwide. The first satellite recovered in a few hours; recovery of the second satellite took 6 months and cost $50 million to $70 million.
- The diversion of 26 United Airlines flights to non-polar or less-than-optimum polar routes during several days of disturbed space weather in January 2005. The flights were diverted to avoid the risk of HF radio blackouts during PCA events. The increased flight time and extra landings and takeoffs required by such route changes increase fuel consumption and raise cost, while the delays disrupt connections to other flights.
- Disabling of the Federal Aviation Administration's recently implemented GPS-based Wide Area Augmentation System (WAAS) for 30 hours during the severe space weather events of October-November 2003.

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12 Kappenman, J. G., L. J. Zanetti, & W. A. Radasky (1997). Geomagnetic Storms Can Threaten Electric Power Grid. *Earth in Space* 9(7):9-11 (Mar 1997). < http://www.agu.org/sci_soc/eiskappenman.html >

Some of the other key points about the threat to critical infrastructure from other parts of the report are summarized in the following bullet points (occasional quotes and paraphrasing, with a pointer to the pages in the PDF file):

- Solar storms can disable communications, surveillance and geopositioning satellites; e.g., the Telesat Anik E2 satellite was disabled in 1994 at a potential direct loss of U$290M for the satellite and indirect costs to about "100,000 home satellite dish owners [who] were required to manually re-point their dishes to E1 and other satellites. The satellite was restored following a US$50 million-C$70 million 6-month recovery effort." [p 25]
- Interference with satellites affects infrastructure directly but also indirectly because of the interconnectedness of our modern society[p 30]; Figure 3.1[13] reproduced from the report illustrates this view particularly clearly.

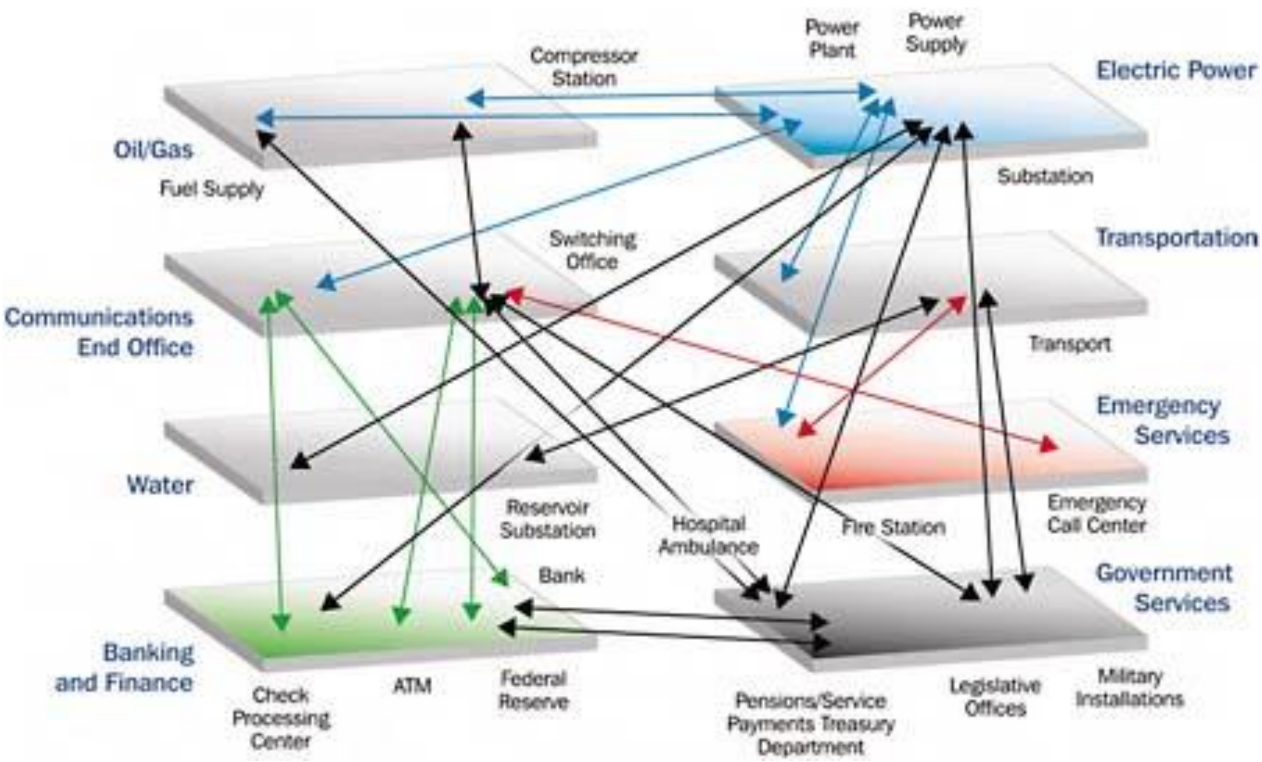

Figure 3.1 from NOAA Report showing interconnections in modern society infrastructure; see footnote [11]

- Polar routes have become cost-effective for commercial airlines because they are often shorter and have fewer headwinds than conventional routes; [p 51] however, aircraft are required to maintain constant radio communications with their parent company and with air-traffic control. Normally, the aircraft use geosynchronous satellites as relays, but those are not accessible above 82°N. Thus in the northern extremes, aircraft must use high frequency (HF) radio, which is blacked out by strong solar radio emissions.
- Unpredicted pulses caused by solar storms can actually fry transformers in electric power-generation grids, [p 54] causing major disruption to power distribution – and with costs at a

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13 Figure from < http://books.nap.edu/books/12507/xhtml/images/p200168f2g30001.jpg >

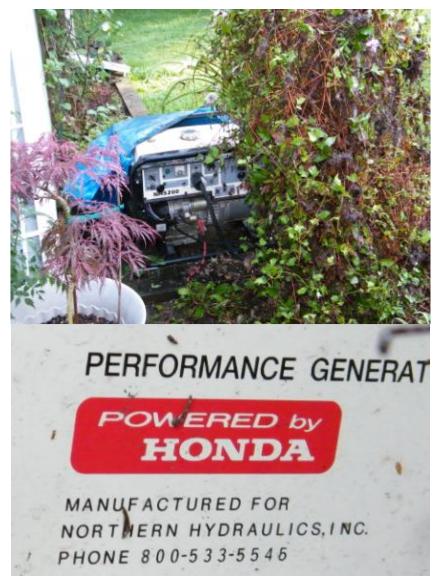
potentially staggering level.[14]

- "Recent analysis by Metatech estimates that more than 300 large EHV transformers would be exposed to levels of GIC sufficiently high to place these units at risk of failure or permanent damage requiring replacement. Figure 7.2 shows an estimate of percent loss of EHV transformer capacity by state[15] for a 4800 nT/min threat environment such as might occur during a storm of the magnitude of the May 1921 event.[16] Such large-scale damage would likely lead to prolonged restoration and long-term shortages of supply to the affected regions."
- Radio-frequency interference with U.S. Air Force satellite and communications equipment caused by solar activity poses a significant threat to U.S. national security.[p 65]

3 Preparing for the Next Solar Max

The next solar maximum is expected around between 2010 and 2012 and that is expected to be "the most intense solar maximum in fifty years,"[17] infrastructure managers should be preparing to cope with power interruptions, communications disruptions, and interference with geopositioning systems. After reading the report, which I strongly recommend to all infrastructure technology managers and their colleagues involved in business continuity planning (BCP), I have some obvious recommendations which I hope will stimulate readers to dig into this issue for themselves:

- Assign a specific named function (an employee and a backup) in your BCP team to monitor the National Oceanographic and Atmospheric Administration (NOAA) Space Weather Prediction Center[18] every day to get a sense of when a large solar event is threatened.
- Electric power utilities should be preparing for emergency shutdowns to reduce voltage spikes that could damage their equipment.
- High-tech equipment users (that's essentially everyone reading this column) should be prepared for interruptions to power from the grid; the usual calculations about the costs and benefits of standalone or shared power-generation units will determine whether organizations can realistically power themselves off the grid and for how long. (I have a 7.5 KVA gasoline generator that runs my entire house and office for 18 hours on three gallons of gasoline – and I keep a supply of 30 gallons of gasoline for the generator and my tractor at all times).



Backyard emergency electric generator

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[14] See photograph at < http://books.nap.edu/books/12507/xhtml/images/p200168f2g54002.jpg >

[15] See figure at < http://books.nap.edu/books/12507/xhtml/images/p200168f2g78001.jpg >

[16] Silverman, S. M. & E. W. Cliver (2001). Low-latitude auroras: the magnetic storm of 14-15 May 1921. Journal of Atmospheric and Solar-Terrestrial Physics 63(5):523-535. Abstract at < http://adsabs.harvard.edu/abs/2001JATP...63..523S > Cited in NOAA study, footnote [11].

[17] Cain, F. (2006). Next Solar Max Will Be A Big One. *Universe Today* (Mar 14, 2006). < http://www.universetoday.com/2006/03/14/next-solar-max-will-be-a-big-one/ >

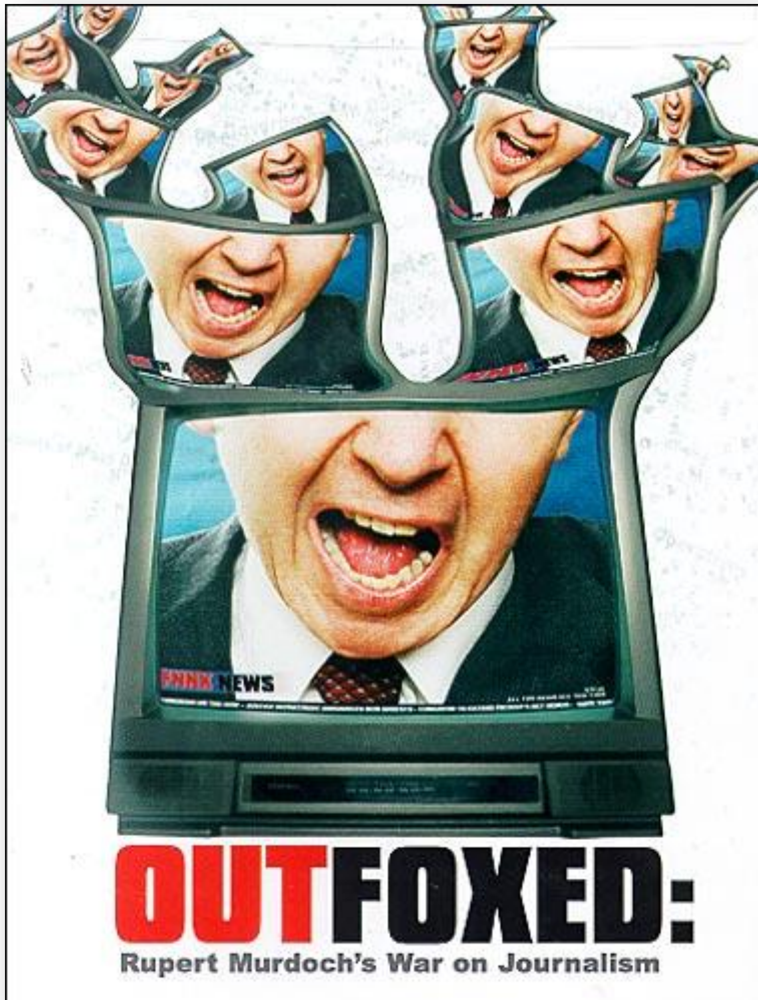
[18] NOAA / Space Weather Prediction Center < http://www.swpc.noaa.gov/SWN/ >

- All critical computer and communications equipment must be adequately buffered against electric voltage fluctuations by installation of suitable surge protectors (remember your telephone equipment too).
- Individual critical equipment units must be equipped with appropriate uninterruptable power supplies (UPS) allowing for data protection (immediate backups of changed files) and acceptable time for orderly shutdown. (I just upgraded my own UPS equipment by adding a second 1.5KVA unit, which includes power regulation, so that my main tower and my backup tower are on separate power supplies allowing for 20 to 30 minutes of operation off the grid.) The image below shows the three devices in my office.

APC Power Conditioner & Uninterruptable Power Supplies in Author's Office

If you want to kick-start your discussions with your senior management on this topic, you may find a useful tool in a Fox TV interview[19] with astrophysicist Prof Michio Kaku[20] of City College of New York. The clip unfortunately includes the subtitle, "Solar Flares Could Mean the End of Life As We Know It;" I unrespectfully point out that improving Fox News' quality of journalism would also change life as we know it.[21]

But that's a topic for a different venue.



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19 Fox News (2009). Nasa Warns of Super Solar Storm 2012. Available through YouTube. < http://www.youtube.com/watch?v=4_TzIUlaQok >

20 Kaku, M. (2009). Welcome to Explorations in Science with Dr. Michio Kaku. < http://mkaku.org/ >

21 Greenwald, R. (2004). Outfoxed: Rupert Murdoch's War on Journalism. Documentary film available on DVD (e.g., from DVD Empire at < http://www.dvdempire.com/Exec/v4_item.asp?item_id=613631 >) or free on Google Video < http://video.google.com/videoplay?docid=6737097743434902428 >

4 APPENDIX: TABLE OF CONTENTS OF THE SEVERE SPACE WEATHER EVENTS REPORT

http://www.nap.edu/catalog.php?record_id=12507

The 144-page report (there's a National Academies Press flier inserted before the cover page) includes the following sections and chapters:

Preface

Acknowledgement of Reviewers

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APPENDICES

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C. Abstracts Prepared by Workshop Panelists
D. Biographies of Committee Members and Staff
E. Select Acronyms and Terms

