Geomagnetic Storms

The Natural Threat to Our Energy Infrastructure

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Executive Summary

Solar storms and their resulting geomagnetic events on earth have always been around. They are not new. So why are they suddenly of concern to us? After all, we have not been greatly affected by them before. It has been about 153 years since what was probably the last extreme (G5) solar storm that struck Earth (in 1859) and 82 years since the last (G4) severe one (in 1928). These happened when there was hardly an infrastructure in place. Space weather science is still too young to make valid predictions but, even though they can happen at any time, the Sun's 11-year "Saros Cycle" is now entering into a phase that is expected to generate increased solar activity during 2012 or 2013.

Modern societies are developing technologies and relying on energy at an exponential rate, especially during the past few decades. People and businesses have come to rely on electrified buildings, factories and transportation; and on computers, satellites, land and radio telephones, and GPS, for example; without a second thought. But these same systems also place us in peril of a widespread, prolonged crises as a result of GMS-generated geomagnetic induced currents (GICs)–like unfathomable power surges—that will course through vast networks of subterranean pipelines, long telephone and electricity wires, and other conductors.

Energy systems are vulnerable, by many scientific accounts. An extreme or severe GMS today has the potential to destroy or incapacitate entire energy grids and communications systems across much of the United States for months. (And this holds true to most any modern society.) And we may not be ready. One recent poll in South Florida suggests that less than 4% of the business community, including emergency managers (EM), are aware of this threat. The anecdotal evidence suggests that the equipment shielding and crisis management procedures of energy and communications providers are questionable. Much more can and needs to be done, but we are not standing still; there are actions being taken to avert or mitigate a severe GMS crisis. For example:

- The federal government has provided grants to the states to prepare for such events, even though the majority of them have been slow to start energy assurance programs to counter the threat. The State of Florida is among the early promoters of GMS awarenes and training, but few of the states in the northern latitudes or along the congested Eastern Seaboard—the states at greatest risk—are doing so.

- Agencies like NASA and NOAA are on guard with surveillance systems aimed at the Sun to provide an early warning, but the channels and procedures to disseminate such critical information to the energy and communications companies and to government first responders in a timely manner is a weak link in the system.

The challenge we face to avert or mitigate an energy catastrophy lies in three general areas of work:

1. **Education**. As Florida is already doing, the states must first raise GMS awareness among the general public, the EM community and among the greater public sector. The public sector also needs to assure that their procedures are relevant to GMS events.
2. **Engineering**. This falls primarily on the energy producers and communications companies. First responders will be overwhelmed if the managers of these networks do not take the procedural and engineering measures to shield equipment so they may survive GICs.
3. **Centralization**. The federal space weather watchdogs need to build fast dissemination channels to state emergency operations centers (EOCs) so GMS procedures can be implemented in time by the private sector and first responders.

Geomagnetic Storms

The Natural Threat to Our Energy Infrastructure

> *"An unmitigated G5 geomagnetic storm in the U.S. will thrust our country into a protracted, chaotic recovery…"*

Among the natural events that could have catastrophic consequences in our nation, and that could affect many countries at once, is a category G5 (extreme) solar storm aimed at Earth. Such an event has the potential of destroying America's energy infrastructure. The United States could be left without power for months, not days or weeks. How many of us can internalize the magnitude of such an event when we're flabbergasted at the relatively minor, localized destruction of a Hurricane Katrina…or a California earthquake?

Once a solar storm reaches Earth it can become a geomagnetic storm. An *unmitigated* G5 geomagnetic storm in the U.S. will likely thrust our country into a protracted, chaotic recovery that would unfold slowly at first. The likely consequence after many days of no electricity, as emergency generators run out of fossil fuel, is that panic will sow anarchy and public safety resources will be stretched to a breaking point. It is hard to imagine what government agency, commercial enterprise, industry, or human activity will go untouched. Cell phones, GPS (Global Positioning System) devices, electrical power, aviation, and day-to-day activities can be affected, or halted.

Scientists who have studied solar cycles see patterns that are believed to be predictive. And we are rapidly approaching 2013, the year that is expected to be the high point of the Sun's eleven-year cycle; but more troublesome is the fact that we are also reaching the end of another, longer solar cycle that occurs every few decades and could be similar to the cycles that peaked in 1859 and 1921. When it happens, there may be extraordinary solar activity that may be capable of producing a catastrophic Category 5 magnetic storm on Earth. But we should not become complacent if this solar maximum goes uneventfully as extreme solar storms can occur at any time.

About Solar Storms

Solar storms are not new.[1] They are a product of our Sun's natural behavior as explosions composed of atomic particles from its corona shoot out into space bombarding every other object in the Solar System under the powerful gravitational pull of the Sun. Solar storms are a part of "space weather."

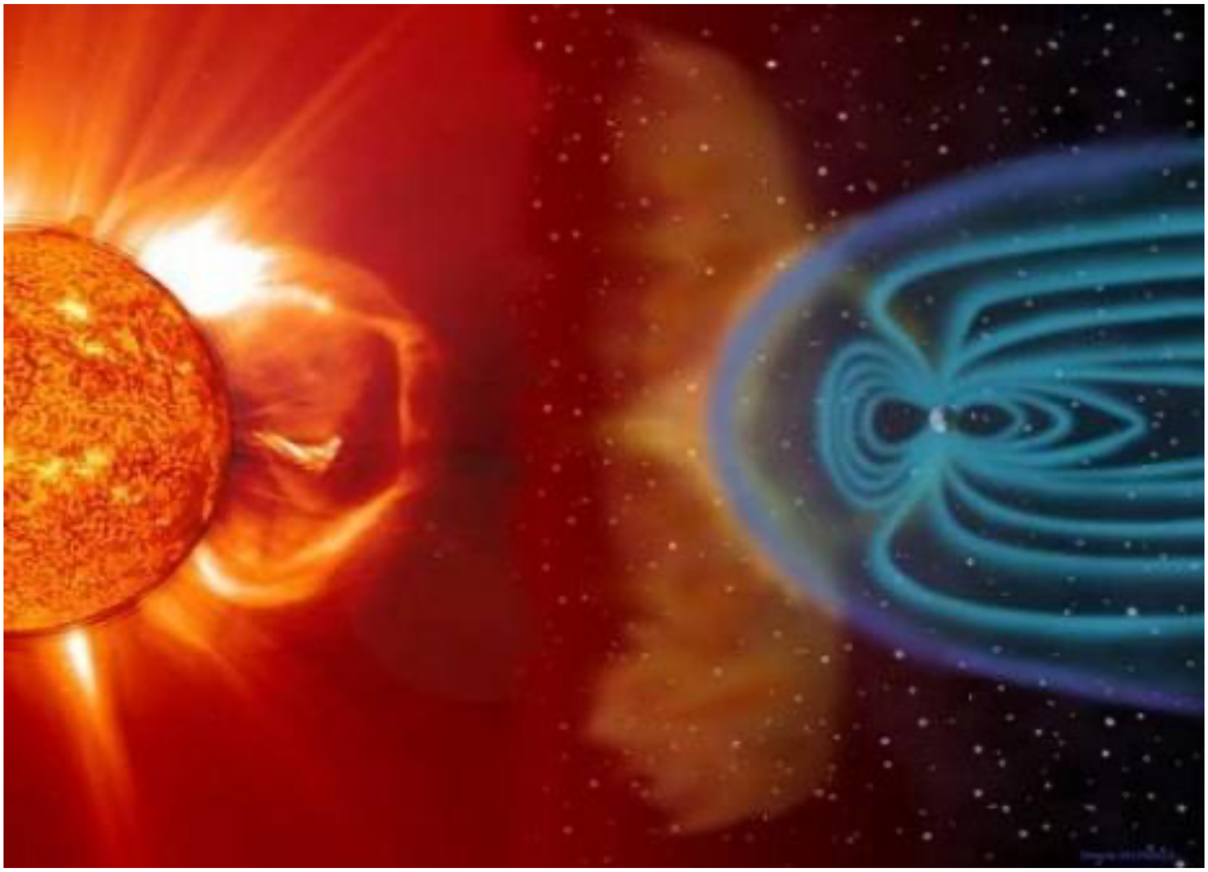

Figure 1: NASA rendition of a solar ejection of plasma into space and its effect on Earth, the small blue planet

Space weather is the concept of varying conditions that exist in the space between the Sun and our planet's atmosphere. Therefore, space weather is the forecast of changes in the ambient plasma, magnetic fields, radiation, and other particles in space. Much of the space weather is carried by "solar wind" generated from the Sun's upper atmosphere.

[1] What is new is our exponentially increasing dependence on electricity and modern conveniences that may be susceptible to the effects of geomagnetic events. What was relatively inconsequential only a few decades ago has become an Achilles heel to our technology-driven society.

The term *space weather* was not recognized until the 1990s. Prior to that time, conditions related to this area were considered to be part of physics or space exploration. During the 1990s, it became clear that the space environment's impact has a considerable effect on our planet and its *biosphere* as well as technological systems developed by humans. As a result, NASA and other agencies responsible for developing satellite and communication technology that could be severely impacted by these conditions funded intense research.

So where did it all begin? Perhaps to better understand the threat we face, we need to understand how, why, what, and when these events occur.

Our Sun's Origins

The Sun began as a massive cloud of gas and dust, which began to contract as a result of its own gravity. This inward contraction generated considerable amounts of pressure and heat.

As the Sun became hotter, it reached an estimated one million degrees and its core ignited and started a process known as *thermonuclear fusion*—how a star produces light, heat, and energy. The main ingredients of this fuel are hydrogen and helium. Since hot gases rise, they move from the "core" to the much cooler surface. When the gasses cool they fall again. This is a convection model that goes on continuously.

Figure 2: Northern Lights, or aurora borealis

The Sun's temperature on the surface is not equally distributed. Some areas of the Sun's surface, known as "sunspots," are somewhat cooler than others. This does not mean that sunspots are not hot; they are just less so. As a result they are seen on the surface of the Sun as dark spots when observed from a distance.

Sunspots are very important in our understanding of solar storms because they reveal periods of intense or lesser activity. Generally, there is an increase and decrease in solar activity over a period of 11 years. This 11-year cycle is known as the "Saros Cycle."

Solar Flares, Storms and Winds

During periods of increased solar activity, massive amounts of gas and plasma (particles) are discharged from the Sun to its atmosphere.

> *"…[a geomagnetic storm can] cause a secondary (internal) magnetic field in the ground…referred to as (unwanted) 'geomagnetic induced currents' (GIC)."*

Solar wind is a flow of particles powered by the million-degree temperature of the Sun's *corona*, the region above the Sun's surface that is a total enigma because the temperature of the corona is 100 times hotter than at the surface of the Sun.

The location of a solar flare affects the effect it will have on Earth: If the flow of particles is away from the Earth's orbit, it will have no effect. What is more, our planet's magnetic field protects us from the effects of solar wind by deflecting most of the particles that would penetrate our atmosphere.

While some of the particles eventually become trapped in Earth's *Van Allen Radiation Belts*, some manage to enter our outer atmosphere, distorting our magnetic field and producing interactions with electrical and communications infrastructures on Earth and its orbiting satellites.

The Van Allen Radiation Belts are made of charged particles (plasma) around the Earth that are held in place by the Earth's magnetic field. These belts pose a threat to satellites and their sensitive components as they fly into them, and if they stay in those affected areas for any prolonged periods of time.

Effects of Magnetic Variations on Earth

When space weather occurs electric currents in our upper atmosphere experience abnormal variations and induce a secondary (internal) magnetic field on the ground. Faraday's law of induction explains how these external magnetic fields act on internal fields to create what is referred to as (unwanted) "geomagnetic induced currents" (GIC).

In simpler terms, space weather's effects on Earth's magnetic field in turn affect our long electrical conductor systems as GICs flow through any conducting structure, such as electric transmission grids, subterranean pipelines, undersea communication cables, telephone and telegraph networks, oil and gas pipelines, and railways.

The largest current variations of the magnetosphere and ionosphere—resulting in the largest external magnetic field variations—occur during geomagnetic storms and it is then that the largest and potentially most active GICs occur.

Because the largest and most powerful magnetic field variations are observed at higher latitudes, GICs have been measured for decades in power grids and pipelines in Canada, Scandinavia, and near the two polar regions. We have learned that even relatively minor GICs can cause severe damage by corroding those lines and damaging high-voltage power transformers (Fig. 3).

Geomagnetic storms also affect our upper atmosphere (ionosphere) where they can affect radio transmissions and could cause a radio blackout. However, FM (frequency modulated) radio waves are not as affected because they do not go as high into the atmosphere as AM (amplitude modulation) radio waves.

Effects on the Biosphere

The Sun's very-high-energy particles can affect living organisms in space. The effects from these particles are not unlike the effects of low-energy radiation that emanates from nuclear explosions. Both are capable of causing radiation poisoning, and both can produce chromosomal damage and even cancer and other troublesome conditions in humans and other life forms. Large doses are immediately fatal to a living organism.

In October 1989 the Sun produced enough high-energy particles to expose space-suited astronauts out on a space walk or on the Moon with what probably would have been fatal doses.

Other studies reveal the magnetic field's effects on the navigational abilities of homing pigeons during geomagnetic storms. Migratory animals such as dolphins and whales, and migratory birds like geese and ducks, have internal biological compasses composed of the mineral *magnetite* wrapped in a bundle of nerves.

So, how can humans protect themselves from exposure to the particles of a sudden, extreme geomagnetic storm? How can we be forwarned to stay protected during such periods?

A Short History of Geomagnetic Storms

Probably the earliest recorded geomagnetic storm occurred in the 19th Century, on December 21, 1806, when a German scientist, Alexander von Humbolt, first observed the storm's effects on his compass and, a little later, when Auroras filled the night sky.

Half a century later, during the first two days of September 1859, the largest recorded geomagnetic event—believed to have been a G5 category storm—occurred during solar cycle 10, when the world was barely moving into technology. It came to be referred to as the Carrington Event, named after Richard Carrington, one of England's most revered solar astronomers.

> *"…during…September 1859…a G5 category storm…so brilliant that newspapers could be read at night as if it were daylight…nearly wiped out the world's telegraph system…"*

Just before dawn on the following day, he reported seeing the skies erupting in green and purple auroras so brilliant that newspapers could be read at night as if it were daylight.

The only existing electric infrastructure at the time was a nascient telegraph system. Practically no one depended on that early technology, so the GIC that coursed through telegraph networks that year—and nearly wiped out the world's telegraph system—hardly caused a social hiccup.

The next most significant geomagnetic storm in recorded history occurred on May 13, 1921 and lasted two days. The storm crippled the entire signal and switching system of the New York Central Railroad, burned out a telephone station in Sweden and interfered with telephone, telegraph and cable traffic over most of Europe and the aurora was visible even in California.

A less notable but more recent event was the Northeast Blackout of 1965 that affected the New York City area and parts of the Northeast and Canada, when there were still few computers, no Internet, and none of the public services that depend so much on this technology. It is easy to imagine how much more we would be impacted today.

The Northeast Blackout left over 30 million people and 80,000 square miles without electricity for up to 12 hours. The cause was human error, not a geomagnetic storm, but it portrays well the string of malfunctions that just one point of failure can produce. Maintenance personnel incorrectly set a protective relay too low on one of the transmission lines between generating stations in Ontario, Canada and State of New York. The safety was supposed to trip if the current exceeded the capacity of the transmission line but it did not. As power lines began to fail, it created a massive overload in the grid system and plant after plant experienced load imbalances and automatically shut down.

Then, on March 13, 1989, a severe (not extreme) geomagnetic storm caused the collapse of the Hydro-Quebec power grid in a matter of seconds as equipment protective relays tripped in a cascading sequence. As a result, six million people were left without power for nine hours and the affected area suffered significant economic losses.

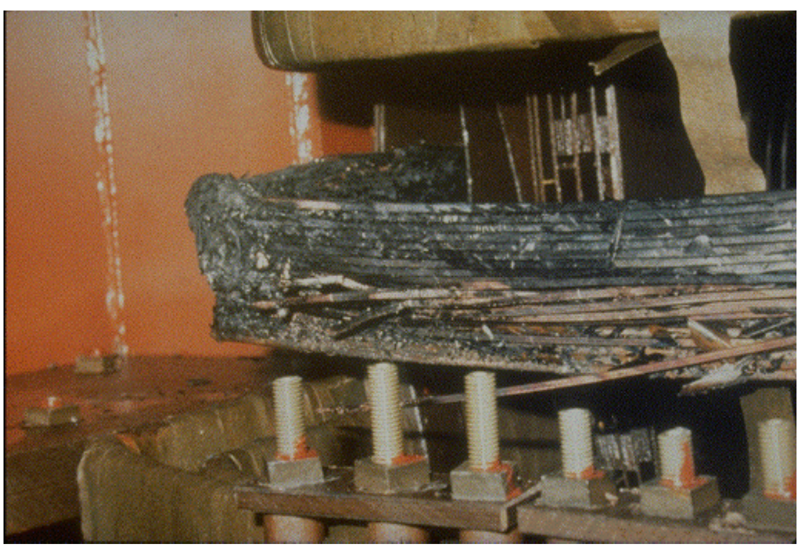

Figure 3: March '89 GIC damage to the Salem Nuclear Plant (New Jersey) that also caused the Quebec blackout

While we have focused much of our media attention on the effects that geomagnetic storms can have on our infrastructure, geomagnetic storms can also have sinister effects that we are beginning to recognize only now. What would happen to birds, whales, fish, turtles, and the thousands of species whose navigational abilities will be impacted by an extreme geomagnetic storm?

So, how would we fare today in the face of a geomagnetic storm as intense as the 1859 event?

Leading experts agree that without proper warnings or system backups and effective emergency procedures, the losses would be in the billions of dollars and would cause chaos in the nation. A massive solar storm as intense as those that occurred in 1859 and 1921 could leave millions of people around the world without electricity, running water, or phone service and the more technologically advanced the country, the more susceptible it is to geomagnetic storm damage due to its growng dependence on satellites and electronic devices.

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The World Then and Now

When the Carrington Event occurred in the 19th Century, the electric infrastructure was extremely simple. The world of the 21st Century is starkly different: the systems are now complex, pervasive and highly sensitive to geomagnetic induced current variations that can cause interruptions in our electric transmission grids and corrode pipelines.

Nearly everything today runs and depends on computers, the Internet and email, satellite and telephone communications, GPS devices, and electric transmission systems and modes of transportation. Our modern world is completely dependent on electricity and radio waves to operate the services we require.

We have come a very long way in a very short time. Advanced technologies have made our lives luxurious and comfortable—but they have also set up modern societies for a potentially hard fall.

Energy's Vulnerability

Our modern electric power transmission systems consist of multiple generating plants inter-connected by electrical circuits that operate at fixed transmission voltages controlled and directed by substations. In recent years, there has been a tendency to produce higher voltages and lower line resistances to reduce the loss of transmission over longer pathways.

While Europe favors short pathways, the U.S. favors long pathways due to the huge distances that need to be covered in the North American continent. Unfortunately, long lines have low-resistance and low-resistance lines are more susceptible to the flow of

GIC. In addition, power transformers have a magnetic circuit within them that can be disrupted by GIC. This, in turn, causes inefficient power transmissions and higher power demands that can lead to the reduction of protective measures. Today, new transformers must show GIC tolerance levels. But the majority of older models still in operation do not.

The United States is clearly vulnerable to GIC damage resulting from an extreme geomagnetic event. It is imperative that our telecommunications systems, electric generating systems, and all other sectors of our society soon work together to reduce vulnerabilities to our nation's infrastructure.

An Unaware Public and Emergency Management Workforce

Anecdotal accounts and our own initial surveys of the business community in South Florida point to a disquieting fact: that the vast majority of those questioned are unfamiliar with geomagnetic storms, their potentially destructive effects on our infrastructure and electronics, or how to mitigate the threat. (See the survey box in the next page.) And *there is no reason to think that this is localized to South Florida*.

While the nation faces high unemployment, budget deficits, economic woes, and struggling families who have lost their homes and jobs, there are other issues that we must also be concerned about. The media is preoccupied with what happens today or with the economy in the near future. Concerns with what could or may happen in the next years are far from the public's radar or the media's attention.

Still, we must take preemptive action to avert a catastrophe in the event of expected or unexpected threats that may come our way no matter how far in the future they may be. The occurrence of a geomagnetic storm is not a question of *if* it happens but *when*.

We tend to address potential conflicts that are immediately before us. But emergency management personnel must prepare for what may happen on all levels. They cannot wait until signs of the crisis are present for that would be too late to protect the public domain.

While government agencies need to invest in preparing, training, and providing the resources to meet the challenge whenever it presents itself, the media must also be ready to alert the public in a timely and objective manner.

Our Current Preparedness (We're Not)

It is very difficult to say with any accuracy how ready we are to deal with an event that could cost billions of dollars and affect entire continents and world economies. How prepared is our nation? This question we can address partially. What we know, based on our

GEOMAGNETIC STORM AWARENESS SURVEY

In October 2011 the Inquesta Corporation surveyed a random sampling of business representatives in the County of Miami-Dade, Florida about their awareness of geomagnetic storms. The sample was comprised of 159 attendees (who were other than emergency managers) to two different meetings of two different chambers of commerce on consecutive days. No attendee participated in both meetings. Small-, medium- and large-businesses make up the two chambers of commerce. Among the attendees polled were employees of energy and telecommunications companies. Following an introduction to the topic of geomagnetic storms, the attendees were polled for “yes” or “no” responses to the following questions:

1. Do you know what a geomagnetic storm is?
2. Do you know that a geomagnetic storm can potentially disrupt or damage your company’s electrical infrastructure, computers, cellular phone communications, GPS devices, satellite communications, pipelines, and/or radio systems?

Of the 159 South Florida business representatives polled:

- **Only five (3%) knew what a geomagnetic storm is,** and, of those,
- **Only three (less than 2%) knew that a storm can potentially damage or disrupt businesses**.

preliminary assessment, is that we are not fully prepared and we have a long way to go to achieve adequate protection.

The good news is that there have been some efforts to confront the threat and act accordingly. Here are some of the steps being taken:

1. The federal government has allocated hundreds of millions of dollars to provide grants to the states to assist them in developing their readiness. However, these funds are likely to be insufficient to meet the real cost of fully preparing states and provide coordination at a national level with experts and sentinels at every corner of the country.
2. Our nation’s premier “guards” in space—NASA and the National Oceanic and Atmospheric Administration (NOAA)—are alert for signs of a solar storm that could be aimed in our direction. They continually monitor and disseminate data obtained from satellites and monitors far in space and around our planet’s inner orbit. On the other hand, severe cuts that have been made to these agencies’ budgets will be detrimental to their ability to detect and communicate potential dangers to stakeholders on the ground with sufficient efficacy and urgency.
3. The U.S. Department of Energy is committed to better protect our infrastructure by investing funds in research and the development of new materials and resources. While this is true, not enough private-public programs are in place to provide

significant developments to protect the nation's infrastructure from a severe geomagnetic event.

4. The private sector with a vested interest and essential resources is revamping its systems to make them more redundant and resistant to GICs and their effects. But they have been poor at informing the public on what has been done and what still needs to be done, to provide the "concerned citizens and scientists" a measure of confidence and comfort in our preparedness for a geomagnetic storm.
5. Some states have utilized federal funds, as has Florida, to develop exercises and drills that will provide clues to our vulnerabilities and ability to respond effectively. The flip side to this is that there are no known efforts to establish cooperative exercises amongst states that share grids and/or infrastructure that could result in sequential damage if certain areas in one state affect neighboring states.
6. The State of Florida in particular has begun the process of preparedness at a regional level by developing a series of exercises to meet this particular challenge, both regionally (locally) and statewide. As a forerunner in this effort, the State of Florida is committed to set an energy assurance planning benchmark that can serve as a model for other states.
7. Scientists throughout the U.S. and the world have provided well-grounded conclusions via publications, scientific data reports, *etc.* on the potential for damage and critical breakdowns in our systems, but few have done so as a consortium. Doing so could help define the urgency, and our awareness and readiness. While there are articles and videos on the internet, there have been very few alerts or recommendations on how to secure our systems in the public sector as noted in our recent survey of public officials, media outlets, and public institutions.

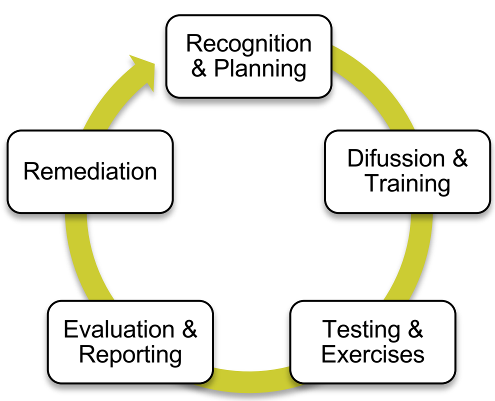

Figure 4: Emergency Management Cycle

Federal agencies have been working to raise awareness of the geomagnetic threat through national "regional" events, and federal grants are being awarded to states to begin the process of mitigation. But most states have yet to progress past the "recognition phase," if they are there at all (Fig. 4). Florida is among the few states that have come to recognize and plan for a geomagnetic event and it is now in the process of accomplishing the second step, "dissemination," and is working to get through the first cycle of "testing" and "evaluations" by mid-2012.

A Decentralized Early Warning System

In the U.S., the Space Weather Prediction Center (SWPC) is part of the National Weather Service (NWS) and is one of the nine National Centers for Environmental Prediction. It is the nation's official source of space weather alerts, watches and warnings.

Contributing to space weather intelligence are 13 regional warning centers distributed around the globe in China, Russia, India, Canada, Czech Republic, Japan, Australia, Sweden, Belgium, Poland, South Africa, Brazil and the United States. The U.S. center is located in Boulder, Colorado as part of the NOAA.

A close ally in this endeavor is the Canadian Space Weather Forecast Center in Ottawa, Canada. It is operated by Natural Resources of Canada with support from the Canadian Space Agency. It is a regional warning center of the International Space Environmental Service (ISES).

ISES' global network monitors a variety of parameters that help to characterize the conditions of the Sun, and space between the Sun and Earth. Data collected is used by the ISES regional warning centers and others to develop space weather warnings and alerts.

This is a relatively decentralized matrix of many players. There are no assurances that critical, time-sensitive information will flow among them and out to the EM community and first responders in time.

Today, this is probably true even in North America. In most cases channels of communication between the intelligence (event detection) centers and the EM community and first responders are not well-defined. Critical information that should be disseminated to first responders within hours, if not minutes, of an impending geomagnetic storm (and any accompanying destructive GIC) is more likely to be heard in a passing newscast in the days following the flareup, too late to trigger effective protective procedures if such procedures even exist in the first place.

A Viable Response

One sure way to avoid imminent risks is to develop full-scale and tabletop exercises that can effectively measure readiness and our ability to respond to a crisis of this magnitude. If this is accomplished, we will be able to gauge our readiness posture and identify what we need to invest in to avoid a catastrophe that could severely impact our economy and our way of life.

One investment could be in the development of geophysical models that measure the time-varying source field[2] in the atmosphere as they relate to a conductivity model on the Earth. There are many challenges to making this model possible, but the U.S., U.K. and Northern Europe have done it to some degree. It is essential that we analyze major storms and their consequences so that vulnerabilities can be identified in the transmission system with hypothetical event scenarios.

"Critical information that should be disseminated to first responders within hours, if not minutes, of an impending geomagnetic storm…[today] is more likely to be heard in a passing newscast in the days following the flareup, too late to trigger effective protective procedures…"

It is time for the scientific community to work with emergency managers in local, county, and state agencies to develop policies and procedures that can be carried out by the public and private sectors to minimize the effects of this threat.

Both public and private sectors must come to terms with this potential crisis. Already the State of Florida has used funds to take the initiative in identifying and assessing needs and prevention steps to reduce losses and services to our population.

Meeting the Threat

Like any other response to a potential threat, there are actions we can or must take to counter or at least mitigate geomagnetic storms:

1. **Acknowledge** the threat;
2. **Activate** a state-level agency ("regionals" within the nation) to make the connections and lead the way;
3. **Identify critical subject matter experts** to provide advice and technical expertise in creating assessments and exercises;
4. **Produce a plan** that includes a thorough assessment of needs;
5. **Test the plan** through a series of exercises (tabletop or full-scale) to determine states of readiness and vulnerabilities;
6. **Identify needed resources** including the private sector's most critical components (power companies, telecom, cell phone, and other service providers) who would be most affected, to offer protection techniques and viable solutions;

[2] An electric field can be produced, not only by a static charge, but also by a changing magnetic field. This is calculated in a formula of Faraday's law of induction that results in "magnetic flux density" and "magnetic vector potential" measurements that may help predict the potential for geomagnetic storm damage.

7. **Produce an assessment** that incorporates lessons learned, deficiencies, recommendations and action steps to be carried out prior to the threat's arrival;
8. **Identify funds** from federal, state or private sources that may be applied to meet the corrections and/or protection necessary to contain damages and/or losses;
9. **Devise new or revise existing facility plans** in business continuity/continuity of operations plans (COOP) in the event of a catastrophic failure;
10. **Develop policies and procedures** that will provide redundancy when required and a safety net when needed;
11. **Incorporate the media** into the EM network to communicate preparedness and response capabilities in the event of a threat[3]; and,
12. **Centralize the space weather intelligence system** so that each state's emergency operations center (EOC) is the focal collection point and the direct, flash dissemination of SWPC early warnings to pre-identified emergency managers and first responders.

"The public sector's political power … should be harnessed to promote an energy assurance agenda that will prevail..."

Armed with intelligence about the threat, we must convey it to as many responders as possible. The public must also be made aware of the potential cost of a failure to prevent such as catastrophe.

Our best champion for the prevention of an energy catastrophe may well be the public sector, but not just the emergency management community. The public sector's political power at all three levels of government should be harnessed to promote an energy assurance agenda that will prevail and meet the challenge when the inevitable energy meltdown occurs.

Conceptual Preparations to Avert Disaster

The science of magnetic events and engineering solutions are both evolving, and much still needs to be studied, tested and implemented to reduce our vulnerability to these storms. But there are some strategies and engineering solutions, covered superficially here, that specific industries may employ now to mitigate the effects of a magnetic storm.

Power companies will be the most immediately affected by an extreme geomagnetic storm. So, how can power companies protect their hardware and equipment? Although our scientists are at work to identify a better set of strategies and solutions, we already know some:

[3] The media's role should begin immediately, during the assessments, exercises and remediation/fortification of vulnerable systems; and it should also participate in the training and exercises for first responders and those who provide support services.

- Turning off some systems before the time of highest activity may provide protection to the grid and its components. While electric power may be reduced or eliminated the equipment will survive the attack and be able to respond as needed once operations return to normal.
- Grid managers can increase excess capacity on lines to withstand spikes in current.
- High-density power lines can be replaced with low-density lines that are more favorable to GIC.
- Cathode protection is a technique often used to control corrosion of a metal surface by making it the cathode of an electrochemical cell. Attaching another more easily corroded metal to act as the anode of the cell does this. This process is often used on pipelines, storage tanks, oil platforms, oil wells, etc. and could be applied to long lines.

Airlines have achieved cost savings by creating pathways over the North Pole to cut the time and distance when traveling from one side of the world to the other. Geomagnetic storms can be particularly damaging to polar flights as they stand to lose their navigation systems and communication with traffic controllers. And they can expose unsuspecting commercial travelers to unhealthy doses of radiation. To reduce the risk of equipment failure, airlines can divert proposed paths to a lower latitude, or a lower altitude for radiation mitigation, even if flights are prolonged and fuel consumption is increased.

Communications systems are also highly vulnerable to geomagnetic storms. Operators of satellites, radars and radios also need to institute preventive measures:

- As is true for emergency management in general, a good understanding of the nature of the threat leads to effective and tested (exercised) *standard procedures* that cut reaction time and confusion and, when followed in a timely manner, may reduce the risk of damage.
- Turning off communications devices during a severe storm may prevent damage to internal components caused by static or GIC.
- Providing shields may offer some protection, especially to satellites in space.

There are many other industries we could address here with suggested strategies particular to them. These are only meant to show that there are actions we can take now to mitigate the threat to some degree. A good *continuity of operations plan* (COOP) or *business continuity plan* (BCP) will contain more than a few bullet points. We are not necessarily at the complete mercy of nature until we more fully study the threat and engineer better solutions.

The Challenge in a Nutshell

It's not enough to know how to avert an energy catastrophe. Our larger task is to find ways to implement these strategies and solutions to:

- **Educate** the EM community, the greater public sector, and the general public;
- **Engineer** protective measures and motivate the organizational changes that will empower responders; and,
- **Centralize** geomagnetic event space weather intelligence and operate an effective early warning system.

Once the EM community and first responders are sensitized and trained, and the managers of infrastructures have taken protective measures for their systems, *space weather intelligence* will be key to the succesful mitigation of geomagnetic events.

Thus, the formation of a central early warning center with the mission of collecting, analyzing and producing space weather intelligence is essential. Once organized, the center's primary focus should be to (1) identify the vast network of emergency managers and first responders; and, (2) build and maintain direct channels of communication with this network to alert them of a potential or a detected geomagnetic event in near real-time.

Accronyms

AM amplitude modulation

BCP business continuity plan

COOP continuity of operations plan

EM emergency management

EOC emergency operations center

FM frequency modulated

GIC geomagnetic induced current

GMS geomagnetic storm

GPS Global Positioning System

ISES International Space Environmental Service

NASA National Aeronautics and Space Administration

NOAA National Oceanic and Atmospheric Administration

NWS National Weather Service

SWPC Space Weather Prediction Center

U.K. United Kingdom

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Joseph R. Piñon, chief operations officer for the Inquesta Corporation, has been involved in emergency management and training for over 25 years in a number of senior level capacities: as a City of Miami Beach, Florida assistant manager responsible for emergency operations and departments; lead coordinator and emergency management director in 1992 during the Hurricane Andrew catastrophe; director of Homeland Security for Miami Dade County; and as a U.S. State Department provincial reconstruction governance advisor for two years in the Middle and Near East. As a private consultant, Mr. Pinon has reviewed, revised and developed many emergency operations plans in several counties and states and has been lead controller in major exercises in Florida and South Carolina. He also has been serving as chairman of the Miami River Port Security Committee and is an active member of the Area Maritime Security Committee.

Jacques R. Island, president of the Inquesta Corporation, has been a crisis manager since 1977 when he began service with the U.S. State Department protecting U.S. missions, diplomatic personnel and U.S. citizens abroad from terrorism, civil wars, and natural disasters. He wrote numerous emergency contingency plans and executed several in response to the forceful take-over of a U.S. embassy by a mob, and the evacuation of another embassy in the midst of a civil war. He transferred to the Federal Bureau of Investigation in 1982 where he performed collateral duties as a crisis negotiator and manager, dealing with prison uprisings, hostage takers, and terrorist incidents. He retired from the F.B.I. in 2002 to provide risk management services to corporations in the U.S. and abroad. He is the author of *Your Plan is Your Parachute: A Simplified Guide to Business Continuity and Crisis Management* (review copies are available pending publication).

Both authors are currently cooperating with energy assurance professionals and companies to heighten geomagnetic storm awareness among emergency managers in government and with energy and communications companies, and to provide solutions to protect the nation's energy infrastructure.

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