EXERCISE REPORT AND SUMMARY OF FINDINGS – On October 4-5, 2011, leading figures from industry, state and federal agencies, the Armed Forces, and other relevant organizations met at National Defense University's Institute for National Strategic Studies in Washington, D.C. to conduct and participate in a crisis simulation of severe solar weather effects on the nation's power grid. Their purpose was to explore issues pertaining to how private and governmental agencies would react to widespread damage to the grid, how they might cooperate during such a crisis, and to explore what steps could be taken to mitigate the effects of severe events.

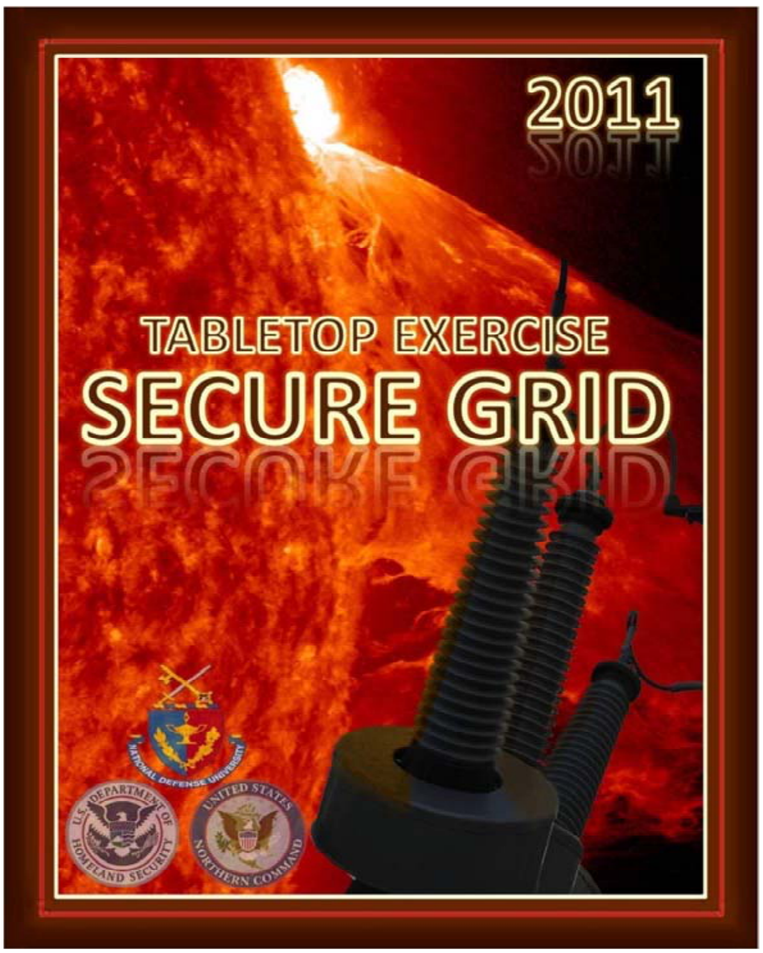
SECURE GRID '11

ELECTRICAL GRID CRISIS TABLETOP EXERCISE

Institute for National Strategic Studies

National Defense University

October 4-5, 2011



The views contained in this report are those expressed during the tabletop exercise by participants and do not reflect the official policy or position of National Defense University, the Department of Defense, or the U.S. Government.

Sponsoring and Hosting Organizations

Department of Homeland Security

United States Northern Command

National Defense University

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“While a severe storm is a low-frequency occurrence event, it has the potential for long duration catastrophic impacts to the power grid and its affected users. The impacts could persist for multiple years with potential for significant societal impacts and with economic costs that could be measurable in the several Trillion Dollars per year range.”

An Overview of the National Academy of Sciences Report on Severe Space Weather and the Vulnerability of the US Electrical Power Grid
Metatech Corporation

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Secure Grid ’11 Overview

Secure Grid ’11 is the third in an ongoing series of exercises that National Defense University’s Institute for National Strategic Studies (INSS) has conducted in conjunction with the Department of Homeland Security and U.S. Northern Command on the vulnerability of the North American Electric Grid. Previous exercises examined the ability of public and private institutions to work together to prevent and mitigate cyber and physical attacks on the grid. This year’s game examined the threat posed to the grid by extreme solar weather. This type of event is considered a low-probability high-impact event, that is, while the probability of an event is low in any given year, the potential harm it could do to the United States and other countries is high.

The exercise scenario was based on a space weather event with impacts similar in nature but less severe than those described by the National Academies of Science (NAS) 2009 Report Extended Summary “Severe Space Weather Events – Understanding Societal and Economic Impacts.” The NAS report described a possible geomagnetic disturbance (GMD) similar to a superstorm which occurred in 1921. This GMD produced a magnetic field change rate of 4800 nanoTeslas per minute (nT/min) at 50 degrees geomagnetic latitude. The NAS report explains that such an event occurring today could result in widespread power outages lasting for several years. By comparison, this exercise postulated a less severe event producing fewer long term power outages but still occurring at an unprecedented scale and duration. Additional scenario background is provided in the appendix to this document.

Secure Grid ’11 was held on October 4-5, 2011 at National Defense University in Washington D.C. and attended by leading figures from industry, state and federal agencies, and the scientific community. The exercise entailed a crisis simulation with the goal of exploring how private and government agencies would respond to a solar storm causing widespread damage to the grid, how they might cooperate during such a crisis, and to explore what steps could be taken to mitigate such severe events. The scenarios in the exercise were designed by a team of experts from industry, the Department of Homeland Security, U.S. Northern Command, and the National Oceanic and Atmospheric Administration.

The tabletop exercise was conducted in three modules using a guided seminar structure to explore relevant questions and issues. After opening comments on the morning of October 4th, participants were assigned to four separate breakout groups containing a diverse mix of representatives. Each group was instructed to address a specific set of broad questions in each stage, which consisted of an early warning stage, an event occurrence stage, and a post-event damage assessment/consequence management and mitigation stage. Groups were given two hours to address each stage over the course of the first day. The second day, October 5th, consisted of post-exercise analysis, which brought each team into plenary session to debrief the entire group on their findings, insights, and recommendations.

On the second day of the event, all participants were able to hear and discuss the findings of the individual groups. The afternoon outbrief session provided a forum to present the game's results to senior officials.

Although the details of the lessons learned and recommendations that resulted from each group's participation and immersion in the experience are discussed in detail below, the most important findings are summarized here.

The broadest consensus reached by the participants was that in an event as severe as the one posited by the exercise, prevention is preferable to response and recovery. Improvements in early warning, especially the replacement of the Advanced Composition Explorer (ACE) satellite, hardening of critical equipment, stockpiling of replacement transformers, and improved resilience in the grid were identified as crucial components of any effort to minimize the probability of long term grid outages resulting from a GMD.

The biggest unresolved question concerns the type of damage such an event might cause to critical grid components, especially large extremely high voltage (EHV) transmission transformers. Although the effects of ground induced current (GIC) on transformers have been studied, significant technical uncertainty surrounds questions regarding whether typical in service transformers would catastrophically fail in GMD conditions. This factor complicates efforts to accurately estimate the possible extent of equipment damage and related grid failure that might occur. EHV transformers are very large, extremely heavy, and highly difficult to transport to the remote sites where they are typically installed. The numbers of existing spares are not sufficient to recover from a GMD that damages a significant fraction of the national or international fleet. Global supply chains would be unable to produce replacement EHV transformers at a rate needed to meet demand if large numbers were suddenly required to recover from a GMD affecting several industrialized countries.

Extensive stockpiling of replacement transformers is a highly expensive proposition, both in terms of manufacture and storage. Further, given a catastrophic event, the just-in-time production systems currently in place would be vulnerable to the cascading effects of a broad, long-term power outage, making it difficult to obtain replacements post-event. These two factors create a conundrum in which stockpiling prior to an event is expensive and problematic, while replacement post-event would also be highly problematic and extremely time consuming when time is of the essence. Thus, neither option is palatable for industry to address, particularly given the low-probability of such an event occurring. Therefore, it was the consensus of the exercise participants that industry especially requires a more developed understanding of exactly how likely such an event is, as well as how much damage is likely to occur from a severe GMD.

Participating Organizations

One-hundred and twenty-eight individuals participated in *Secure Grid '11* and were drawn from a wide variety of private and public organizations. Participants were selected to represent organizations responsible for operating, regulating, and protecting the grid. These organizations include:

American Public Power Association

Analytical Services Inc. (ANSER)

Atmospheric & Space Technology Research Associates (ASTRA), LLC

BCS Incorporated

Booz Allen Hamilton

City of Chicago Police Department

Defense R&D Canada – Centre for Security Science

Department of Defense

> Office of Assistant Secretary of Defense for Homeland Defense and America Security Affairs (OASD HD&ASA)
>
> Office of the Assistant Secretary of Defense for Operational Energy Plans and Programs (OASD OEPP)
>
> Office of the Secretary of Defense for Installations and Environment (I&E)

Department of Energy

> Infrastructure Security and Energy Restoration Directorate

Department of Homeland Security

> Office of Infrastructure Protection
>
> Science & Technology Directorate

Edison Electric Institute

Electric Infrastructure Security Council

Embassy of Sweden

Emprimus

Exelon Generation, LLC

Federal Emergency Management Agency (FEMA)

Federal Energy Regulatory Commission (FERC)

FriiPwr, Ltd.

GeoStrategic Analysis

Headquarters, U.S. Army Corps of Engineers (HQ USACE)

Hoover Institution, Stanford University

ICS/SCADA Threat Focus Cell Team Leaders

Idaho National Laboratory

Interagency Coordination Directorate

ISO New England

NARUC Staff Subcommittee on Critical Infrastructure

National Aeronautics and Space Administration (NASA)

National Association of State Energy Officials (NASEO)

National Communications System

National Defense University

National Oceanic and Atmospheric Administration (NOAA)

National Weather Service

Naval Sea Systems Command Dahlgren – Mission Assurance Division

NAVFAC Mobile Utilities Support Equipment

Navy, OPNAV N00X (Naval Warfare Integration Group, and QDR)

North American Aerospace Defense Command (NORAD) and United States Northern Command (USNORTHCOM)

NORAD and US NORTHCOM Interagency Coordination (IC)

NORAD and US NORTHCOM J7 – Joint Training and Exercises

US NORTHCOM J34 (Assessments and CIP Branch)

North American Electric Reliability Corporation (NERC)

Geomagnetic Disturbances Task Force (GMDTF)

PHI Service Company

PJM Corporation

Potomac Electric Power Company

Progress Energy

PSEG Services Corp.

Reliability First Corp.

Secured Sciences Group

Space Plasma Laboratory

SSG, LLC

Storm Analysis Consultants

The National Association of Regulatory Utility Commissioners (NARUC)

The Praemittias Group, Inc.

Transtector Systems, Inc.

United States Air Force/Air Force Weather Agency (AFWA)

United States Nuclear Regulatory Commission (NRC)

White House

National Security Staff

Office of Science and Technology Policy (OSTP)

Objectives

Identify and understand the potential impact of a major geomagnetic storm on the North American Power Grid.

Explore and socialize ways to minimize the impact of a major geomagnetic storm on US critical infrastructure.

Examine and assess processes and procedures for recovering from a catastrophic geomagnetic storm.

Clarify and deconflict roles and responsibilities between public and private agencies.

Background

The sun is subject to periods of increasing and decreasing sunspot activity approximately every 11 years in what is known as the solar cycle. Sunspot activity has been correlated to the occurrence of solar flares and coronal mass ejections (CMEs), which can cause geomagnetic disturbances (GMD) on Earth. Although CMEs occur more often during the “solar maximum” when the incidence of sunspots is greatest, they can still occur at any time during a solar cycle. Most CMEs are harmlessly directed into interplanetary space but some travel directly towards Earth. When a CME moving through space at millions of miles per hour interacts with Earth’s magnetic field, the normal field is quickly disturbed and can continue to change for many hours until the effects of the storm have passed and the field returns to an undisturbed state. As the Earth’s magnetic field changes, DC electric currents are induced in long distance high voltage transmission lines. These transmission lines are connected to grounded EHV transformers designed to operate only with 60 cycle AC power. Geomagnetically-induced DC current causes AC power transformers to operate abnormally and can result in rapid overhearing and failure if conditions are unfavorable. Most geomagnetic storms have relatively limited and temporary effects, however, stronger storms can adversely affect critical infrastructure, both in space and on Earth. In addition to the geomagnetic effects already discussed, solar storms can temporarily distort the Earth’s ionosphere adversely affecting radio communications and Global Positioning System (GPS) service. Surface charges can build up on satellites, causing unhardened electronic systems to malfunction or permanently fail.

In 1989 a strong geomagnetic storm caused a blackout in Quebec just 90 seconds after the CME reached Earth. Since NASA’s ACE spacecraft was not launched until 1997, there was less effective early warning available to grid operators in this event. It took nine hours to restore the 18,000 MW network after repairing or replacing destroyed equipment. A geomagnetic storm in 2003 took down the Federal Aviation Administration’s (FAA) GPS-based navigation system for 30 hours and damaged electrical systems from Scandinavia to South Africa. These and other recent storms were small compared to known superstorms in 1859 (Carrington event) and 1921. The 1859 superstorm featured two consecutive CMEs first observed by British astronomer Richard Carrington. When the first CME slammed into Earth about 18 hours later, there was no power grid that could be damaged but many telegraph systems failed or caught fire across Europe and North America.

Modern storms can cause much more damage and disruption than earlier events because infrastructures around the world are more ubiquitous, complex, and interconnected. If a Carrington-level event where to occur today, it could cause enormously more damage, potentially knocking out large portions of the world’s electric infrastructure and creating massive blackouts across the globe. If such blackouts were long lasting they could affect physical infrastructure including water distribution, perishable foods and medications, heating/air conditioning, sewage disposal, telecommunications, and fuel supplies. According to the 2009 NAS report the damage inflicted by a major CME could cost the US

$1-2 trillion in its first year. Although the 1859 storm was a rare event, storms with around half its intensity occur much more frequently. The 1921 superstorm is the most recent example.

Concerns about the susceptibility of US electrical infrastructure to GMD effects are significant compared to other similarly industrialized countries for several reasons:

- Much of the US is located in relative proximity to Earth's magnetic north pole where GMD effects are stronger.
- Because of geography, the US has a large number of long distance east-west oriented high voltage transmission lines which act as good "antennas" for best case coupling with GMD-produced electromagnetic fields.
- The US has added increasing amounts of higher voltage transmission infrastructure in every year since the last GMD superstorm in 1921. High voltage lines tend to be longer in length and therefore act as better antennas for coupling GIC into the grid and potentially damaging EHV transformers.

If catastrophic grid failure should occur as a result of a solar storm, effective response and efficient recovery will depend on the highly effective cooperation and coordination between public and private entities.

Tabletop Exercise Part 1: Prevent (T0 + 7 hrs)

0945, October 4, 2011 – Brief to Players

NOAA's Space Weather Prediction center in Boulder, CO, reports that an intense eruption on the sun associated with a large sunspot cluster on the sun has been observed. They report that this flare has already registered an R5 level on the NOAA Space Weather Radio Blackout Scale, one of the biggest flares seen in the last forty years. A radiation storm, approaching the S4 to S5 level on the NOAA Space Weather Radiation Scale, is expected to accompany this event in the next several hours. The CME is extremely large and both NOAA and NASA computer models show that it is heading towards Earth. Some Earth-orbiting satellites are already being affected.

A very large geomagnetic storm is expected at the G5 level, NOAA's space weather equivalent of a Category 5 hurricane although about 4 events of G5 strength occur in a typical 11 year solar cycle. Higher latitudes are typically more vulnerable to the storm, particularly in proximity to large bodies of salt water, which acts as a conduit for ground-induced currents. The effects of the strongest storms can actually be greater at mid-latitudes and leave extreme northern or southern latitudes less impacted.

Impact Estimate

Up to 130M Americans initially w/o electricity for several hours
Up to 2 months to fully restore normal power
Secondary impacts:

- Energy
- Communications
- Water/Sanitation
- Banking & Finance
- Transportation
- Emergency Services
- Government Services

Summary of Team Discussions

The teams were given two hours to discuss the ramifications of the impact estimate and to discover where weaknesses in preparation capacity may reside. As representatives from various organizations spoke, it became clear that issues of coordination were less of a concern than those of physical capacity to respond. Given such a disaster, government agencies explained that only industry had the appropriate resources to respond.

Timeframe of warning – The primary issues repeated across each team was the timeline of warnings and the resultant capacity of industry to make meaningful decisions within that timeframe. From the time the ACE satellite provides final information about the anticipated severity of an event, industry typically has about 45 minutes to make decisions on how to protect and preserve the grid. This timeframe is marginally sufficient for system operators to work through mechanisms to identify and analyze information about the event as it is passed down. Important actions can be completed or initiated in this timeframe but there is essentially no room for even the slightest delays or mistakes. Actions of this type can include unloading or even securing some long distance transmission lines through a variety of possible measures in order to reduce the GIC that will enter the grid, and starting "peaking plants" to establish a situation where regional loads and generation are more balanced.

- Advanced warning can come as early as two days prior to an event, but these warnings have significant margins of error, thus making them difficult to act upon.
- Advanced warnings on measured ground surges come more rapidly out of Canada than from US agencies.
- Certain operating steps can be taken within twenty hours of notification to reduce vulnerability of the system and the procedures for these steps are already in place.

Immediate Steps – Given the warning timeframes, the discussion turned to what steps could actually be taken to mitigate impending damage to the grid. An industry-wide conference call would occur, similar to the calls conducted before hurricanes. All eight NERC regions would be brought in, with their respective coordinators, to challenge them to prepare for whatever type of space weather might be approaching and analyze what the impact could be.

Load shedding and the possibility of a temporary grid shutdown were discussed as likely candidates for immediate action. Load shedding included such concepts as islanding or establishing micro-grids within the system to isolate potential problem areas and reduce the need for long distance transmission. The most contentious issue was the idea of simply shutting off the grid for some period of time to protect it from extensive damage. It was agreed that the decision to take such a drastic measure resided entirely with the utilities, but it was clear that the potential liability issues associated with a false alarm scenario were too great for a grid shutdown to be a reasonable option. Complicating issues include:

- Maintaining service and keeping the grid operating is a long-standing deeply ingrained top priority from industry's point of view.
- In-place procedures are based on getting ready once an alert is received, but the rest of the procedures are not implemented until the grid is actually overloaded, thus in-place procedures are reactive, not proactive.
- From the perspective of participants that were not part of a utility, difficulty existed in understanding the procedures that utilities already have in place to deal with crises.

- The grid is dynamic; it can have highly stable voltage at one moment and poor voltage stability a few minutes later, etc., and as a result, any mitigation strategy will change daily or faster.

- The basic strategy of commercial power companies is to maintain reliable service and avoid a shutdown at nearly all costs. Under normal conditions this approach ensures the availability of power to utility customers but under severe GMD conditions this approach increases the probability that some amount of damage to operating equipment will occur.

- Much of the burden for rapidly responding to early warning falls upon the utility companies who are bound by a set of standards that prohibit them from dropping customers under most conditions. If forecasts are incorrect about the event, the utility will have to answer to regulatory agencies. There is no certainty about what damage will be caused and utilities, operators, engineers, and others do not agree on how much damage may occur. Because there is no legal protection, utilities have little incentive to take strong preventative steps.

- Seasonality is a critical factor as well. Two to three months without electricity would have different impacts in a hot summer as compared to a harsh winter. This scenario assumed that the weather was mild, but should a similar outage occur in sub-freezing conditions, the reactions, procedures, and outcomes would be vastly more challenging.

There was a consensus among exercise participants that a more accurate assessment of the severity and timing of GMD conditions is required. Better modeling and simulation capabilities could help in this regard. Additionally, a better technical understanding of the effects the storm will have on extremely high voltage (EHV) transformers themselves is imperative since this is the most critical factor affecting the duration of a blackout and recovery.

Transformers – The primary piece of the electric grid to be affected by an event of the magnitude posited by the exercise are the roughly 2000 EHV power transformers in the bulk transmission grid. Excessive direct current (DC) flowing through a large alternating current (AC) transformer ground connection may cause overheating and failure. While the true number of transformers that could be damaged by a severe GMD is unknown, losing a significant portion of the fleet would result in widespread long term power outages. The damage susceptibility of an individual EHV transformer is influenced by its age and "health," but also by the local ground conductance and geology of the transformer substation location and connected transmission line length and orientation. Factors such as these can combine in ways that can make some older transformers less vulnerable than some newer ones.

Significant points:

- Most large EHV transformers are manufactured outside of the United States. If there was an event that impacted the U.S. and other countries, and if key pieces of equipment were damaged and required replacement, it would take a long time to replace them, possibly months or years, and the U.S. might not be the first priority of the manufacturing countries.

- Another complicating factor is replacement EHV transformer transportation to the remote locations where they would be needed. Many large EHV transformer locations are not easily accessible and these very large and heavy transformers require special transportation equipment that has limited availability. If there is a large magnitude event, little capability exists to rapidly replace transformers.

- There is the STEP program (Spare Transformer Equipment Program) which involves sharing spare transformers between utilities that are voluntary signatories to this agreement. This program was designed to handle short notice requirements for small numbers of replacement transformers following an event such as an isolated terrorist attack on a few substations. The question regarding an adequate number of spares for larger scale events such as a severe GMD is more difficult to answer and there is currently no industry position on this subject. Furthermore, the lead time can be as longs as 1-2 years for procuring major transformers, many of which are uniquely designed for a specific grid location in terms of voltage and power ratings.

- In the 1921-level scenario described by the NAS report, hundreds of large transformers might need to be replaced in the U.S. and it would take an extremely long time, as only a small fraction of the voltage classes and types needed are currently produced domestically.

- If a GMD superstorm does produce a blackout, service can be restored to many locations using lower voltage systems to effectively bypass damaged parts of the high voltage grid. Generation is well-connected at lower voltage levels.

The Military – According to USNORTHCOM, its bases at the installation level are not normally provided real time advance warning of an impending GMD. Certain missions directly impacted by space weather do currently receive forecasts and warnings. However, notice to installations to ensure readiness of the support infrastructure may be necessary as well. It is essential that bases hosting critical missions have sufficient electrical power to sustain independent continuous operations even if the surrounding commercial power grid is lost. Though many installations possess diesel-powered electrical generators, they have limited diesel fuel storage. In the event of a widespread grid outage, fuel supplies could dwindle rapidly, thereby impacting the ability of installations to conduct primary missions.

Tabletop Exercise Part 2: Protect (T0 + 20 hrs)

1300, October 4, 2011 – Brief to Players

NOAA's Space Weather Prediction Center in Boulder has issued a G5, extreme geomagnetic storm warning. The coronal mass ejection that left the sun less than twenty hours ago has reached the ACE (Advanced Composition Explorer) spacecraft and is an extremely intense coronal mass ejection that has the worst case magnetic polarity and will begin to affect Earth's magnetic field in the next twenty to thirty minutes.

The consequences of this event on the power grid certainly could be significant. The most significantly impacted areas will likely be in the Northeast including the Northeastern Canadian provinces, through New England into the Mid-Atlantic States, the central Great Lakes region, and also in the Pacific Northwest.

Impact Estimate

Widespread power outages possibly lasting for longer than in any previous large blackout.

Summary of Team Discussions

The discussions for the second module primarily centered upon two main topics: communications and authority. Given a significant outage after a severe space weather event, issues discussed included how communications would take place, and, in particular, how local authorities would communicate with the public to prevent panic and maintain levels of order and public safety. The authority issue centered on who had authority to authorize widespread protective measures for the grid, such as a shutdown.

Communications – Cascading effects were of some concern regarding the problem of communications during a massive power outage. Questions regarding how communication in that situation would occur were asked amid concerns over public panic given a long-term outage of power.

- Landlines and cell phone service will very likely be overburdened or down. It was questioned how communications would occur in this case. Some utilities have dedicated communications lines, but the majority have migrated to commercially-provided services. This is particularly important between private and public sectors. The nuclear industry has dedicated lines with the NRC.

- Public behavior and reactions can produce dangerous situations even in normal weather events. It is not known how the public would react to warnings about happenings in outer space. It is unknown what range of response to expect from the public (they could panic or could disregard warnings), and those responses will vary from place to place.

- Given the nominal thirty minute to one hour final warning provided to utilities, there is a question regarding whether there should also be provisions for warning the public beyond the NOAA web-based notification process. It is not clear what the public could do in response to a warning except to wait and see where power is lost then take appropriate action where possible. Space weather is not a well-known threat among the public. It is hard to gauge how seriously such warnings would be taken, particularly since NOAA typically issues four to five G5 worst case GMD alerts in a typical 11 year solar cycle.

- Ensuring that clean water supplies and sanitation are a first priority needs to be communicated to all players, especially the public. Attention must be given to health and security if outages are potentially long-term.

- Local authorities need to be given timely information, particularly in case of a long-term event, to minimize the possibility of civil disorder.

- Before and during Hurricane Katrina, the electric utilities made preparations, to include conference calls, alerts, warnings, actions, procedures. Loss of communications expected to accompany widespread power outages would make recovery coordination very challenging, and a significant problem given the potentially short timeframe between final warning and the possible loss of power.

- Defense Support to Civil Authorities (DSCA) may be especially important if a long term power outage occurs. Although DOD activities have robust backup and redundant communications equipment, that does not necessarily mean the local authorities do as well. Coordinated effort must be made to ensure communication channels are open during an event.

- Industry needs to keep government informed about with the status of the grid and any major difficulties pertaining to communications. However, there was significant disagreement about the ability of communications systems to remain functional in a power outage.

- Better understanding of the timeframe for a possible “window of panic” is needed so that authorities can get in front of the problem and prepare accordingly.

- FEMA has emergency broadcast responsibility and there are backup systems to that as well. Radios and other basic equipment might be used to provide information to the public, as internet and television will eventually be lost at most locations in an extended power outage. If FEMA needs to provide radios then they will do that but obviously this can only be done in limited numbers.

There was also some discussion about the possibility of establishing a national coordination center. Industry participants were critical of that idea, claiming that the federal government already has too many operation centers. A better alternative would be a process rather than an ops center. “There is already a good deal of monitoring going on, we just need better communications.”

Authority and Role of Government – On each of the four exercise teams the question was pointedly asked, “What can government do to help utilities during this kind of emergency?” The response was a unanimous “not much.” It was quickly established that government has little to no authority to dictate to industry how it is to handle these situations. Many of the procedures needed, such as prioritization of critical infrastructure, are already in place: water, sanitation, and hospitals top that list. The principal questions, then, were whether there needs to be a governmental authority to order utilities to shut down or reduce loading on the grid in order to protect it, whether instead what is needed is protection from liability should utilities choose to do so themselves, and, given that most of the regulatory responsibility rests with the states, just what is the role of Federal agencies in this situation?

- What are DOE and DHS doing? At this stage of the emergency, DHS and DOE will be closely engaged, but will probably not take any direct action affecting privately owned utilities. At the time NOAA issues the alert, DHS and DOE will be following the situation but do not have authority to require any action.

- What are the states doing? In many cases state emergency management offices will probably not even be aware of the threat of a GMD alert before it could start to affect the grid. Those that are will be spinning up Emergency Operations Centers in preparation.

- For FEMA the first priority is to protect lives and property. FEMA’s National Response Coordination Center would be initiating response plans at this point. Communication between the Federal government and the states would begin as well. FEMA already communicates with the NOAA Space Weather Prediction Center in Boulder. VTC at 20 hours with all partners, with multiple levels of activation. For example, Level 1 brings 15 disparate organizations and activates dialogue channels. Level 2 brings ESF2 and ESF12 into the dialogue. FEMA will not be telling them what to do, but using them as the main points of contact for the rest of government. ESF3, public works support, will provide generators if needed and will begin preparations to move them to where they think the most affected areas will be. FEMA will not be directly involved in telling industry how to correct problems, but they will reach back to find out what problems need to be solved first. FEMA does have a desk which includes private sector personnel to determine what services industry and the private sector are able to provide.

- Industry’s major coordination role during this type of crisis is to evaluate the scale and extent of an event and to communicate with governmental agencies.

- A Stafford Act declaration might be needed.

- Secondary concerns need to be analyzed. What fuel supplies do hospitals and other essential services have? Are airports still operational?

- The primary major issue requiring mitigation is potential public panic. Public panic may lead to a run on resources, social unrest, eruption of violence, and denigrate the ability of local government to restore order. Emergency services are likely to be strained to capacity and lifesaving services delayed. Local government officials will be responsible to effectively communicate unfolding events to the public and to maintain public order. It is imperative these officials are provided with the pertinent information to fully understand the events and empowered to communicate that information to the public.

- The question was raised by one participant, "Should we shut everything down for 24 hours in order to protect the grid? Furthermore, does anyone have the ability to make that call in regulation?" The unanimous answer was, no. The grid interconnection authorities could tell power plants to shut down but there is no established authority to direct this action. The President has the ability to protect utilities from liabilities but should authority be given to the President to be able to direct the shutdown of the power grid? Industry representatives stated that plant owners are best equipped to make these decisions.

Other Items:

- An obvious step that government could do to help utilities would be to provide a replacement for the ACE spacecraft that provides the most important early warnings. It is already several years beyond its design lifetime. A replacement spacecraft is scheduled for launch in 2014.

- Are we prepared to activate emergency centers based on space weather alerts? Are utilities prepared to tell the public that they may lose power due to what is going on in outer space?

- Power loss means different things in different regions. Better understanding of this issue is needed. Rural communities tend to be better prepared for power loss than urban areas.

- Federalize the risk rather than the grid. This approach allows regional operators to continue to make timely decisions to protect the integrity of the grid and minimizes the probability of extended blackouts.

- Some liability concerns may be misunderstood or inflated, as hospitals and other mission critical industries typically have backup generators available for emergencies.

Tabletop Exercise Part 3: Respond (T0 + 20 hrs)

1500, October 4, 2011 – Brief to Players

FEMA and its federal partners are responding to the worst geomagnetic storm in decades. This global event has produced widespread impacts throughout the United States, Canada, and several other countries in Asia and northern Europe. NOAA is reporting that the storm is essentially over now, but a variety of critical infrastructures were heavily damaged during the storm though the most problematic impacts are associated with the power grid.

There are large power outages in the Northeast and Mid-Atlantic States, as well as across the northern border where most of the Canadian power grid is interconnected to the U.S. Many cities, towns, military bases, and industrial centers are currently without normal power supplies. Similar electrical outages have been reported in northern Russia, Japan, Sweden, Norway, and the UK. Major disruptions to GPS service and some telecommunications occurred, but those effects are expected to be temporary and these services should return to normal over the next several hours as the final effects of the storm fade away.

The global nature of this event also presents problems since, in some cases, the components to replace damaged equipment will be needed in many countries at the same time. That can place a severe strain on the worldwide supply system. The scope of this problem will require federal, state, and private partners to provide assistance in many parts of the country.

Damage Estimate

40M Americans w/o electricity

- About 65% expect to be restored in 8 hours
- About 25% not expected to be restored in less than 2 weeks
- Final 10% not likely to be restored in less than 2 months using normal supplies

Summary of Team Discussions

The bulk of the discussion for the third module centered on backup generation capabilities, system restoration, and coordination. It was during this session that ways government can help industry were better identified and expressed. Given the unprecedented loss of dozens of US transformers, a gap discussed during the first module was how to get replacement transformers to locations where they are needed given the difficulty in transporting them. Government can aid considerably in overcoming this problem. Further, government can play a significant role in finding and deploying temporary power generation options for isolated critical infrastructure.

Backup Generation – given an event of this magnitude, some areas may become isolated from the grid. In those instances, local generation for some temporary period is needed to keep critical infrastructures running until the grid can be repaired to a state where it can provide consistent power again. There are a number of FEMA-owned two megawatt electrical power sources kept available for hurricanes and other disasters. Capacity exists to move these and quite a few customers could be restored with those power sources. This is an opportunity for the government to assist by identifying needs and supplying electrical power generation capabilities in a timely manner to mitigate loss of life and property damage.

Discussion findings were identified as follows:

- There are portable generators that come in containers. FEMA owns many of these containerized generators.

- In the commercial market, there are rental generators, but they move with the global market, so those may not be available unless the US pays some kind of retainer to keep some portion in the country.

- There are some generators in the US to which industry has exclusive rights. A premium is paid so that industry has first rights to them. 80 percent of the mobile market is a lower voltage than the grid uses and would typically need a step-up transformer to get to the proper voltage.

- An effective response will also require close coordination at the highest levels of DOD.

- It is unknown how much backup generation refineries and other large customers have. Although many companies have hardened their systems to varying levels in recent years, this practice has not been widespread. Many have purchased or leased generators for use in emergencies. Hospitals have backup generation but only a few days of fuel. The fuel re-supply problem would apply across the board for such backup generation.

- A primary problem is that there is only enough fuel to run backups for a few days. Here is another place where government can help by prioritizing fuel supply to generation systems in place temporarily. For instance, in the Vancouver Olympics, the government aggregated key players' needs for fuel (diesel) generation and found that not only was there not enough fuel in this area of Canada to refuel the supply but also not enough transportation capability to get fuel in place. The UK experienced a similar problem in 2007 when there were major floods and difficult decisions had to be made about prioritizing distribution sites.

- Florida has mandated that all gas stations along evacuation routes have backup emergency generation capabilities. This step may be a good idea to help mitigate the fuel problem posed by any long term power outage.

System Restoration – Ultimately the power system has to come back online. Government assistance would be needed to help facilitate the restoration process and some potential solutions are outlined below:

- Easing of regulations during catastrophic events. One way that government could help is through the issuance of waivers to existing regulations, especially interstate waivers of vital commodities, such as fuel. The Federal government could assist with allowing a cheaper fuel to be used to facilitate faster restoration. Permitting could also be utilized to ease the routes. Each state would have to approve these waivers unless the federal government mandated it. The movement of large heavy transformers would be very resource-constrained; they need to move incredibly slowly and there are very few capabilities to facilitate movement of equipment this size and weight.

- Planned rolling blackouts. During power restoration, rolling blackouts are a potential method to ration power so that there are fewer locations with no power at all. Service can be provided to some customers, but not everyone at once. The goal would be to provide the best available service to normal customers after the most critical services are restored.

- Prioritizing power restoration. There may be severe economic damage in steel mills and industries such as electronics fabrication facilities that normally require continuous power to maintain sterile manufacturing conditions. During the restoration period there will be power, but it will be limited. Not everyone will have power all of the time.

Coordination – Issues of coordination were a significant point of discussion among all the groups, but the consensus was the primary coordinating body would be FEMA, under DHS. DOE would coordinate the energy industry recovery, while DHS would deal with the overall federal response. It was made clear again, however, that industry is not controlled by government, and that utilities were largely free to respond as they see fit. In an organizational sense, responding to a long term power outage would be the responsibility of the state with the Federal government making resources available.

- In terms of authority, the greatest uncertainties are prior to the event, not post-event. Once an event has occurred, communication processes are well-established, though significant doubt exists that these processes would function smoothly in a large power outage. States and utilities that have managed many real disasters will be better at dealing with them than states that have less real experience even though the same mechanisms are in place for all types of disasters.

- Under emergency situations some generation priorities may be fungible. If Ohio is able to supply all of its normal power requirements but its neighbor state Indiana is 75% blacked out then should Ohio deny power to some of its own territory in order to assist Indiana? There is no clearly established process for making this type of trade off decision under crisis conditions. Today these decision processes rest with utilities. State governments work with utilities to keep some public assets running, such as hospitals, but the utilities own their power grid and can make determinations themselves. There are plans filed with each state regarding priorities for water, fire stations, people on life support, etc. During emergencies it is made known according to those plans which sources are the most critical. In 90 percent of restorations, utilities make the decision about what goes back online first, based on instructions and what they can physically do. Utilities frequently have interruptible power supply agreements with large customers and the conditions of these existing contracts can determine the order in which power is restored to users. There is not a list that is provided by the Federal government. In general, however, mandates exist for hospitals and other critical facilities.

- A major potential gap involves understanding how long the power could be lost. Many coordination issues can move forward properly and confidently if that information is known early.

Military – The military has a critical facilities list that will be used as the military manages outages affecting its bases. A considerable number of critical assets on military installations have generators or other backup power supplies. Many installations can provide back-up electrical power to sustain continuous operations for mission critical facilities such as communications centers, although the long-term sustainability of these assets depends on the availability of fuel supplies.

- Some bases may have some excess power that could feed back into the grid, but only temporarily. In past disasters, base commanders have coordinated these decisions with utilities.

- Defense case studies are being conducted to discover the actual duration that bases can sustain themselves. There is some debate over how long a typical base can sustain itself. Some say a week would be a very optimistic estimate. Mission critical functions are often covered but day to day assets are not. Others claimed that the military has a fairly robust program to provide fuel and has a robust backup system for critical facilities. Some claimed that the military bases could run their generators for several months if need be, but others doubted the capacity to get the fuel in place needed to do that. An obvious exception to this limitation would exist at many military bases where there can be millions of gallons of aviation or shipboard fuel stored on base. Generators that could run on this type of plentiful fuel instead of diesel would have more than enough supply to provide power to a base for many weeks or months.

Recommendations

On Wednesday, October 5th, the four teams gathered to discuss the exercise and summarize the results from the previous day's efforts. The following summarizes these discussions.

- **Replacement of the ACE Satellite:** The ACE spacecraft is currently living on borrowed time, having well exceeded its design service life. A replacement needs to be scheduled as quickly as possible. NASA and NOAA are working to launch the Deep Space Climate Observatory (DSCOVR) spacecraft on a DOD vehicle in 2014. DSCOVR will provide the indications and warnings that ACE has provided in the past.

- **Hardening the grid is the preferred solution:** Prevention is preferable to response and recovery. Appropriate methods to provide effective hardening to protect transformers and other critical grid infrastructure in a GMD superstorm need to be examined, studied, developed, assessed, tested, and deployed. A national strategy is needed to determine how the costs of hardening the grid against space weather events should be funded. There are promising signs that many of the most critical grid systems could be hardened for less than $1B total cost.

- **Improvements in forecasting accuracy and timeliness are necessary:** Although early warnings are typically provided by NOAA 24 to 36 hours before a CME can reach Earth and produce a GMD, the final most important information is generated by the ACE spacecraft only about 45 minutes before GIC can occur in the grid. This timeframe is short for taking effective action at more than 3000 independent utilities and transmission companies in the US alone. Additionally other countries depend on this same short warning time.

- **Grid shutdown is seen by industry as an unrealistic option:** There is no national authority to direct a grid shutdown to protect critical infrastructure against GMD impacts. If estimates cited in the 2008 National Academies of Science report are accurate, the costs of not shutting down the grid could easily exceed the cost of a temporary shutdown. If the authority to implement a shutdown is left to industry, legal protection against liability claims would almost certainly be necessary.

- **Until the grid is hardened to prevent transformer failures in large numbers, the capacity to replace transformers in large numbers over short timeframes needs major improvement:** The United States has limited capability to manufacture the numbers and types of EHV transformers that could be needed following a GMD superstorm; therefore there is dependency upon foreign suppliers for replacements. Whether a transformer is produced domestically is not directly relevant to its usefulness but following a GMD superstorm foreign manufacturers would likely be responding to orders from many international customers and the US might not be seen as highest priority. This limitation could be addressed through a combination of expanded domestic manufacturing capacity or increases in stockpile replacement spares. In both cases there is no business case for such action from industry's perspective. Government would need to identify a national security risk requiring such action by industry and find a reasonable way to fund these measures. This would be similar to what happened after 9/11 when another national security risk was identified. Although the airlines and airports were privately owned the government required changes including major airport security enhancements, hardened airline cockpit doors, Federal Air Marshalls, changes to critical airspace restrictions, etc.

- **Efforts must be made to better educate state and local emergency management officials:** Space weather remains a poorly understood topic to most emergency planners and managers. Although it is considered a low-probability high-consequence event, there have been two superstorms in the past 150 years but in both cases the world was far less dependent on electricity supplies to provide adequate living conditions to billions of people. The public does not need to understand the details of CMEs, GMDs, GICs, and spacecraft warnings but it does need to be better prepared for long term power outages whether they are caused by space weather, other natural disasters, deliberate attacks or simple equipment failure associated with aging infrastructure and growing demand.

- **A more comprehensive study looking at cascading effects is needed:** The impact on the economy of a widespread and long-term grid shutdown due to a space weather event is highly complex and poorly understood. The potential effects on society are even less well known. A better understanding of this subject is needed at a national and international level.

- **Federal, state, and local emergency management officials need access to an accurate database of portable generation equipment:** Should a significant event occur, it is likely that some sections of the grid would remain operational in an islanded mode. In order to keep crucial infrastructure in these regions online, especially water and sanitation, it would be helpful to know where all portable generation assets are, and to have someone with authority be responsible for prioritizing their deployment across state lines and between utility service areas when necessary.

- **Provide timely information to local governments and municipalities:** The burden of maintaining public safety and communication with the public will largely fall upon the shoulders of local authorities. Industry and Federal agencies need to establish effective emergency backup communication capabilities that can keep enough of the public informed even though normal power supplies may be unavailable.

- **Revisit the transformer sharing plan:** Few of the participants had confidence that the current plan would hold up to an emergency of this magnitude. Additional cooperation and agreements should be put in place. The existing industry STEP program for transformer sharing is voluntary and was developed to handle emergent needs for small numbers of replacements such as might be needed after an isolated terrorist attack on no more than a few substations.

Appendix – Secure Grid '11 Scenario Background

The SG'11 scenario was designed to examine problems similar to those highlighted in the 2009 National Academies of Science Extended Summary Report "Severe Space Weather – Understanding Societal and Economic Impacts." This figure taken from that report shows one scenario examined by the NAS based on an event similar to an actual 1921 superstorm.

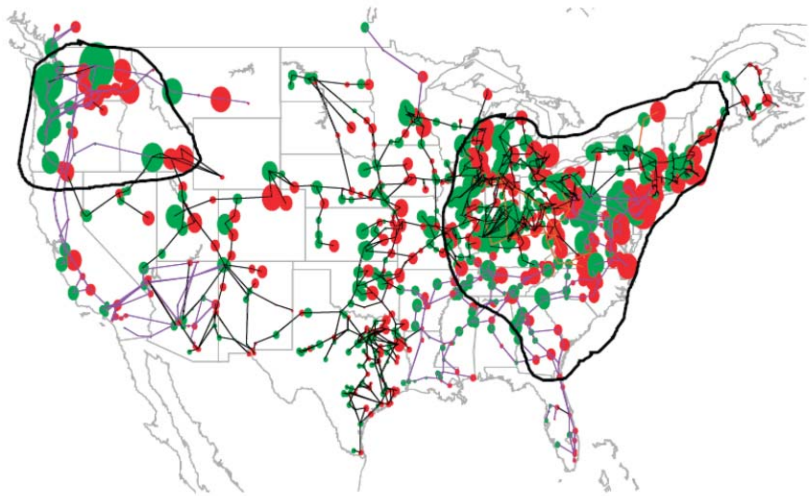

Figure 5. Regions susceptible to power grid collapse during a 4800 nT/min geomagnetic field disturbance at 50° geomagnetic latitude, where the densest part of the U.S. power grid lies. The affected regions are outlined in black. Analysis of such an event indicates that widespread blackouts could occur, involving more 130 million people. A disturbance of such magnitude, although rare, is not unprecedented: analysis of the May 1921 storm shows that disturbance levels of ~5000 nT/min were reached during that storm. (Image courtesy of John Kappenman, Metatech Corporation.)

For SG'11 the following assumptions were selectively made in order to provide an extremely challenging but more manageable scenario:

- The exercise geomagnetic disturbance (GMD) produces geomagnetic induced currents (GIC) which quickly causes power blackouts within the two outlined areas shown above.
- About 65% of the electrical loads and generation in these areas can be restored within 8 hours.
- About 25% of the electrical loads and generation in these areas cannot be restored by normal means in less than 2 weeks.
- The final 10% of electrical loads and generation in these areas cannot be restored by normal means in less than 2 months.