BEFORE THE

UNITED STATES OF AMERICA

FEDERAL ENERGY REGULATORY COMMISSION

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In the matter of: :

STAFF TECHNICAL CONFERENCE ON GEOMAGNETIC : Docket Number

DISTURBANCES TO THE BULK-POWER SYSTEM : AD12-13-000

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Commission Meeting Room

Federal Energy Regulatory Commission

888 First Street, Northeast

Washington, D.C. 20426

Monday, April 30, 2012

The technical conference was convened, pursuant to notice, at 11:00 a.m., when were present:

ATTENDEES:

COMMISSIONER JOHN NORRIS, Commissioner, FERC

COMMISSIONER CHERYL A. LaFLEUR, Commissioner, FERC

ATTENDEES (Continued):

JOSEPH McCLELLAND, Office of Electric Reliability, Presiding

EDWARD FRANKS, Office of Electric Reliability

RICHARD WAGGEL, Office of Electric Reliability

REGIS BINDER, Office of Electric Reliability

MARTIN KIRKWOOD, Office of the General Counsel

DAVID HUFF, Office of Electric Reliability

ROBERT SNOW, Office of Policy & Innovation

PANEL ONE:

SCOTT PUGH, Interagency Programs Office
Science & Technology Directorate,
U.S. Department of Homeland Security

MARK LAUBY, Vice President and Director of
Reliability Assessment and Performance Analysis,
North American Electric Reliability Corporation

FRANK KOZA, Executive Director, Support Operations,
PJM Interconnection LLC

JOHN KAPPENMAN, Owner and Principal Consultant, Storm Analysis Consultants

DR. BEN McCONNELL, Research Scientist,
Lecturer, University of Tennessee

JOHN HOUSTON, Division Senior Vice President,
High Voltage Power Delivery & Compliance
CenterPoint Energy

PANEL TWO:

WILLIAM MURTAGH, Program Coordinator,
Space Weather Prediction Center,
National Oceanic and Atmospheric Administration

SINGH MATHARU, Senior Electrical Engineer,
Nuclear Reactor Regulation,
U.S. Nuclear Regulatory Commission

MICHAEL COUSINS, Head of Downstream Gas & Electricity Resilience,
UK Department of Energy and Climate Change

GERRY CAULEY, President and CEO,
North American Electric Reliability Corporation

DR. PETER VINCENT PRY, Executive Director,
Task Force on National and Homeland Security

MICHAEL HEYECK, Senior Vice President of Transmission
American Electric Power Company

STEVEN T. NAUMANN, Vice President, Transmission and
NERC Policy, Exelon Corporation

P R O C E E D I N G S

(11:00 a.m.)

MR. McCLELLAND: Well good morning, and welcome to today's staff-led Reliability Conference on Geomagnetic Disturbance or GMD. The Commission appreciates your interest in this subject. Thank you for attending either by person or by Webex.

My name is Joe McClelland, and I'm the Director of the Office of Electric Reliability here at FERC, and I will serve as the moderator today. A few housekeeping items before we begin. Please take time now to silence your cell phones, BlackBerrys and associated computer equipment, and whatever else I didn't mention.

Food and drinks are prohibited in the conference rooms, although water is okay. Bathrooms are located on this floor to the left and right of the elevators. Please feel free to quietly slip in and out as necessary during the event.

Lastly, although we are not taking comments or questions from the audience today, we encourage all interested parties to submit the same to the Commission under Docket No. AD-12-13. Comments will be considered if they are submitted by May 21st.

In October of 2010, Oak Ridge National Laboratory issued a voluminous report sponsored by the Commission, the

Department of Homeland Security and the Department of Energy.

The report studied the effects of geomagnetic disturbances, electromagnetic pulses and intentional electromagnetic interference devices on the power grid of the United States. This report largely agreed with other studies on the same subject.

NERC, however, issued an interim report studying the same subject matter in February of this year, particularly the geomagnetic disturbances, I should say, or limited to geomagnetic disturbances, but produced widely-differing results. The differences are mainly centered on the potential for Bulk-Power System equipment damage, and the length of time that interruptions will persist.

Today's conference will be conducted in two sessions. The first is to identify and discuss the differences between the studies. A second panel will be to discuss what can and should be done to address this issue, in particular focusing on vulnerabilities that are common to both studies.

Recognizing that the decisions rendered on this issue may have far-reaching effects for the industry, the government and for the citizens of the United States, this conference and the supplemental comments that we receive are intended to generate a sufficient record, in order that we can properly inform the Commission.

Before we begin, I'd like to recognize a few of our guests. First, I'd like to welcome Dr. Ahsha Tribble Ahsha? There she is, the Director of Critical Infrastructure Protection and Resiliency Policy on the National Security Staff at the White House.

Second, I'm not sure if I saw him here, I'd like to welcome Mr. Drew Mishiyama (ph) and Kevin Probasco from Congressman Trent Frank's office. Oh, they're there. Hi guys. Welcome.

Next, I'll turn over the floor to Commissioner Norris and Commissioner LaFleur for any opening remarks that they might have. Commissioners.

COMMISSIONER LaFLEUR: I'd also like to welcome everyone to this morning's conference. Today's topic is one that's very important to me, and I'm pleased to have such wide attendance. Having read the testimony, I think that the discussion we're about to have this morning on the reports will be very interesting.

But what I'm really focused on today and looking forward to is a discussion over the course of the day and especially this afternoon on next steps. I expect that more research and modeling should and will be done to improve our understanding of the likely effects of geomagnetic disturbances on the electric grid.

But having read the studies and testimony, I strongly believe that based on almost all the witnesses we've heard from, there's a set of no-regrets actions we can and must begin now, since they're called for by all the competing studies. Indeed, many of these actions were called for in the NERC report.

I'm particularly interested in what we do to assess the vulnerability of equipment on the grid, and the development of technical specifications and codes for new equipment on the grid. I have had personal experience with several wide-scale efforts to modernize or update experience on the electric grid.

Because of the complexity and diversity of the electric grid, these efforts are inevitably more complex than expected, and take longer than expected, because they require assessment of specific situations to balance the risk and cost. To me, the scope of the challenge argues for getting started now.

Finally, I just want to remind everyone that we as a nation, as we all know, are in the early stages of a huge investment in transmission equipment. EEI has estimated that nearly $300 billion may be spent on transmission between 2010 and 2030. We have a clear opportunity before us to assure that the next generation of equipment that we're putting in now is built to withstand the challenge we're talking about today.

So with that, I look forward to everything we're about to hear, and hope by this afternoon we'll be in the position to discuss a clear set of next steps. Thank you.

COMMISSIONER NORRIS: You covered everything I wanted to say, Cheryl. So let me just say thanks for being here. This is an important topic. There are certainly differences of opinion, so I'm hoping today we can get all of those on the table, and we can develop a record from which we may have to make decisions going down the road.

But the potential impact, what we're going to do about it and the costs associated with it are all very important to me, so I appreciate the input we're going to hear from all you today. Thank you.

MR. McCLELLAND: And now we'll move on to the first panel. First of all panelists, thank you for agreeing to be here. I appreciate each and every one of your commitments to this issue, and I understand that there are differences as far as perspective. But I expect that all that will be dumped out on the table. We'll be able to hash through these, discuss the technical differences this morning.

So I'd like you to start by introducing yourself, your organization, and then go ahead straight into your five-minute presentation. So we'll turn to each of you just down the line. We'll start with you, Mr. Pugh, and welcome.

MR. PUGH: Good morning. My name is Scott Pugh. I've worked in the Science and Technology Directorate at Homeland Security since 2007. Extreme space weather, coronal mass ejections, geomagnetic storms, obviously are not new problems. What is new though, since the last super-storm in 1921, is a continental power grid and more than 300 million Americans whose present lifestyles would be impossible without electricity.

Government, industry and academia have studied potential space weather impacts, but their conclusions are not in good agreement for two primary reasons. First, there's significant scientific uncertainty surrounding the potential magnitude of space weather events, mainly because we don't know whether the limited space weather data collected over the past few centuries accurately represents the full range of possibilities.

Second, there's technical uncertainty regarding whether a worse case geomagnetic storm would cause bulk power transmission transformers to fail in large numbers, small numbers or not at all. A 2008 National Academy study included a worse case estimate that roughly one-third of the country could lose power for several years in 1921-equivalent storm.

Even if just ten percent of this damage occurred, it would still present an unprecedented recovery challenge. A 2011 Homeland Security-funded JASON's Report argued for improved modeling and simulation capability, possibly based at the National Infrastructure and Simulation Center.

The capability for accurate grid modeling on a national scale exists today, but it would require extensive technical data belonging to more than 3,500 utilities and 700 transmission companies in the United States.

A 2012 NERC report concluded that a major storm would probably cause system voltage collapse, large blackouts, but faster than the time frame required for transformer damage. This means that once the storm ended, full recovery would be possible within a few hours or a few days.

The Defense Department verifies the reliability of the nuclear weapons stockpile by randomly selecting a few deployed warheads for destructive testing at Los Alamos every year. A testing program like this could be developed to develop data about the transformer fleet over a period of several years.

If testing showed that transformers do not fail when exposed to worse case levels of induced current, then we would know that methods to protect or replace them are not needed. On the other hand, if testing showed that failures frequently occur, even at less than worse case conditions, then we would know that proactive action is urgently needed to avoid a long duration outage.

But without this type of conclusive information it can be said, at least on this issue, that we're essentially flying blind, hoping that NERC is right and the National Academies are wrong. Homeland Security has partnered with industry to develop a recovery transformer that is smaller, lighter and more transportable than a traditional transformer.

Last month, we demonstrated that a bank of three single phase recovery transformers could be moved from ABB's manufacturing facility in St. Louis to a CenterPoint energy substation near Houston, where it was installed and energized in less than a week. Recovery transformers like these could significantly reduce recovery time, if a limited number of transformers were damaged in a geomagnetic storm.

We usually know if a CME is directed towards earth more than a day before it arrives, but NOAA cannot issue the final, most important warning until a CME reaches NASA's ACE spacecraft. Unfortunately, this does not happen until a CME has traveled about 99 percent of the distance to the earth.

Industry has developed procedures to operate in more reliable modes when warnings are issued, but a superstorm CME moves much faster than average, and can reach earth in as little as 20 minutes after passing ACE. That is not much time to issue a warning and take preemptive operator action on a multi-national scale.

When a 1989 storm caused induced currents in Canada's Hydro-Quebec grid, operating personnel had about 90 seconds to react. That was not enough time to prevent a massive blackout and significant equipment damage.

MR. BINDER: One minute, sir.

MR. PUGH: Primarily because of the short time frames associated with superstorms, many experts think that it would be prudent, at least on a prioritized basis, to install features that could protect transformers and other critical grid components against geomagnetic-induced currents. Thank you for the opportunity to represent DHS at this discussion.

MR. McCLELLAND: Thank you, Scott. Mr. Lauby.

MR. LAUBY: Thank you Joe, good morning to the Commissioners,

FERC staff and fellow panelists. My name is Mark Lauby. I'm the Vice President and Director of Reliability Assessments and Performance Analysis of the North American Electric Reliability Corporation or NERC. I sincerely appreciate the opportunity to discuss NERC's interim report on the effects of geomagnetic disturbances or GMDs on Bulk-Power System reliability.

But first a little background. In November 2009, NERC and the U.S. Department of Energy held a two-day workshop on high impact low frequency or HILF-type event risks to the North American power grid. Following the release of this assessment, the Electricity Subsector Coordinating Council or ESCC developed a strategy road map to address HILF events through an organized combination of industry-led task forces and initiatives.

NERC worked with the stakeholders to create two task forces relevant to this technical conference: Spare Equipment Database or SED and a Geomagnetic Disturbances or GMD. The remainder of my remarks will focus on geomagnetic Disturbance Task Force activities, which in a unique way brought together scientists, researchers and engineers from each of the fields of space weather characteristics, earth science, space weather forecasting, Bulk-Power System transience dynamics, transformer manufacturers and design, equipment design, as well as protection and control.

By the way, throughout this assessment, NERC had access to preeminent Canadian industry engineers and scientists who were not invited to participate in this panel. NERC was able to leverage this expertise of the Canadians, who made significant contributions to the interim report, and sharing Canada's experience on the panel sort of increased the value, I think, to all participants.

The mission of the GMD Task Force was really threefold. Validate the existing studies; identify vulnerabilities to geomagnetic-induced currents, and set an industry path forward to address identified vulnerabilities.

Based on the task force members' work, two risks were identified: Damage to bulk power assests typically associated with transformers, and insufficient reactive power, which could lead to voltage instability and system collapse. In addition, another important risk is the design of protection control systems, which need to consider GMD.

Otherwise, their improper and unexpected operation could remove reactive resources, just when they're needed. Reactive insufficiency, intensified by protection control misoperations, is what caused the 1989 Hydro-Quebec blackout.

Based on the overall work of the task force members, the effects and risks from GMD on the Bulk-Power System differ based on geology, geomagnetic latitude, transformer design and health, as well as geoelectric wave front character and peak durations.

The task force members agreed that the most likely system impact from a severe GMD is voltage instability, caused by significant loss of reactive power support simultaneous to a dramatic increase in reactive power demand from transformers.

Fast voltage collapse from severe GMD occurs on a time scale of tens of seconds, while thermal impacts can take much longer. Restoration times from system collapse due to voltage instability may be a matter of hours or days.

But industry is still taking action here. The uncontrolled collapse of the Bulk-Power System from voltage instability and the loss of a limited number of transformers is a serious reliability concern. NERC, through industry groups and the GMD Task Force, will continue to address these issues through its comprehensive plan documented in the interim report.

We're now launching activities, including system and equipment vulnerability assessment, industry's training, NERC reliability standard review, and improved equipment specifications, to name a few areas. Further NERC, through the Electric Power Research Institute, DOE and 12 industry organizations, are funding a collaborative research and development project to address these challenges.

In fact, open source software to calculate geomagnetic-induced currents was recently developed and incorporated in a commercial power flow package and available to all. In addition, publicly-available fuel electric wave front --

MR. BINDER: One minute, sir.

MR. LAUBY: Thank you. In addition, publicly-available fuel electric wave fronts have been developed by NASA, based on historical information, which can be now used and scaled, using ground impedance models that are under development by the U.S. Geological Survey. Thank you for the opportunity to speak to you today, and I look forward to the panel's discussion.

MR. BINDER: Did you get all your points in Mark, because I would have given you a little bit of a grace time on that.

MR. McCLELLAND: Well, anything he missed we can pick up from questions and answers.

MR. LAUBY: Thank you.

MR. McCLELLAND: Okay. Thanks, Mark. Mr. Koza.

MR. KOZA: Thanks, Joe, and good morning Commissioners, FERC staff, ladies and gentlemen. I'm Frank Koza, Executive Director of Operations Support of PJM. I was also the vice chairman of the NERC GMD Task Force, although my comments today are on behalf of PJM Interconnection, and not necessarily the task force as a whole.

There's no question that severe space weather has the potential to create serious problems on the Bulk-Power System. The combination of half cycle transformer saturation and increased reactive power consumption can lead to voltage collapse and blackouts if not properly managed. In addition, transformer saturation could cause a number of extra high voltage transformers to fail.

What's not well-defined and requires more work is determining the magnitude and duration of space weather events that will cause the failure of bulk power transformers and other components, and their associated failure mechanisms.

Space weather is complex, and numerous factors contribute to widely varying impacts. However, a number of preventive steps, including those I outline below, can be implemented today. Nevertheless, before any transmission asset owner can make an informed decision on deployment of mitigation measures, more analysis needs to be done.

Through our participation on a NERC GMD Task Force, we learned that substantial work is being done in this area by a number of organizations, and PJM strongly supports the continuing work that is being undertaken through the sponsorship of NERC, EPRI and a number of other organizations, to better understand the risks associated with space weather, and the specific threats to the reliability of the Bulk-Power System.

As a transmission operator, PJM will review and update its operating procedures and training, based on the work of the NERC GMD Task Force. Also, PJM will participate with other North American reliability coordinators in a dialogue with the space weather forecasting community, to enhance the dissemination of space weather forecast information to the widest possible audience.

However, PJM is not an owner of transmission assets. We operate the transmission assets of our members. The decision about mitigation strategies for specific equipment that will need to be employed will necessarily be made by our members, working in collaboration with PJM, as we analyze the overall impacts to the Bulk-Power System.

So in the near term, PJM suggests the following implementation steps, based on today's knowledge and given the attendant risks and the need for deliberate and timely action.

First is assessment of EHV transformers. Each asset owner needs to determine the overall health of its EHV transformer fleet, and develop strategies for GIC mitigation for identified vulnerable transformers, even before the more detailed analysis capability is available.

Secondly, specification of GIC withstand in new transformers. For those asset owners that are about to embark on the purchase of new transformers, they should be implementing withstand capability into their specifications, in discussion with the transformer manufacturers.

Thirdly, operating procedures. Systems in at least the northern tier of the United States and all of Canada, who do not have operating procedures to respond to GMD events, need to develop them and deploy the associated detection and measurement devices to ensure an appropriate response, given a specific level of exposure.

Lastly, we need to incorporate GMD impacts into power system analysis. GMD impacts can be modeled and assessed as part of the overall power system analysis performed by system planners and operators.

However, while these tools are not yet mature, progress is steadily being made and planners and operators need to begin to acquire this knowledge and start the process of incorporating the many complex aspects of GMD into their planning, operating procedures and processes.

At the level of today's knowledge, no one can definitively say whether the above strategy will be sufficient to protect the transformer system from a severe space weather event.

MR. BINDER: One minute, sir.

MR. KOZA: Conversely, no one can provide sufficient evidence that an immediate, large-scale investment by the asset owners or government would adequately address the risk, let alone meet an appropriate cost-benefit ratio, given the state of today's research.

In the interim, PJM suggests that the above immediate steps be taken today, while the industry and government support the ongoing work to better understand the vulnerability, develop tools to assess the vulnerability, and be prepared to act when the path forward becomes clearer. Thank you, and I look forward to your questions.

MR. McCLELLAND: Thank you, Frank. Mr. Kappenman.

MR. KAPPENMAN: Thank you. My name is John Kappenman. I've been a principal investigator on a number of the reports that have been produced on this subject area, and I feel I'll give my age away if I tell everybody that I've actually been involved in engineering and research work in this area for 35 years now.

I'd like to thank FERC for the opportunity to provide my comments today on this very important topic. In my comments, I will lay out the basis of some of the work done for the various government departments, agencies and committees of Congress, where we considered and estimated these risks on the U.S. power grid.

But I guess I can briefly summarize it up front here. The conclusions of all the studies has been the risks are serious, and let me say it is certainly not hard to reach that conclusion. There has been extensive modeling, modeling that has been validated.

But even without modeling, just using simple extrapolations from major data on the power grid from space weather environments, you can reach the same conclusion. The major data, by the way, is a very hot topic and NERC has been entirely reluctant to gather and ask for that data from the power industry.

Now think of that. How can we do a serious study lacking any real attempt to gather and investigate evidence?

In the U.S. government analysis efforts, we certainly have, as I mentioned, done an extensive analysis of the threat environments. We have experience from the March 1989 storm. A blackout did occur. Transformers were damaged. We know that the storms that we have identified from historical evidence indicate that they are going to be multiples of times more worse. Four to ten times more worse is not unrealistic of what we need to be prepared for.

We also know, if anything, as an infrastructure, electric power grids, we have been developing an antenna that is more coupled to these environments. The consequences, of course, are widespread blackouts of unprecedented scale, large spread damage to the power grid, something that could literally threaten society at large.

In the discussion, in the investigations in NERC, clearly the issues that are most contentious right now are what is the potential for damage, what does that imply for the ability to recover from these events? There are no standards that exist for rating transformers. Where there have been discussions and information provided by manufacturers in this area, they simply have not stood up to scrutiny. So there's a big level of uncertainty in these areas.

The fact that NERC is now saying that rapid collapse of the grid is going to save the system from being damaged. Well, if you look at the standards on over-excitation, they talk about damage onsets on the order of as little as ten seconds in those types of standards. So we cannot exclude that as a possibility.

NERC also totally ignores the fact that circuit breakers themselves will now be subjected to trying to interrupt large DC currents. These devices are not rated for that, and that could cause widespread catastrophic damage from that path of collapse and so forth.

So we essentially have here a situation where --

MR. BINDER: One minute, sir.

MR. KAPPAMAN: Thank you. We essentially have here a situation where a task force report was developed essentially without all of the information that should be contained in that report. It came to broad, sweeping conclusions that are not supportable by the information provided to NERC and to the task forces.

You know, and we really have a situation here where some of the information that is coming out here is ignoring risks, holding secret meetings, writing reports in secret, which essentially urge the industry to ignore available standards, operate equipment outside of their safe operating envelopes.

This is not something we really should tolerate, and we need to have more focus on that. That concludes my remarks. Thank you.

MR. McCLELLAND: Are you sure? Did you get everything in John?

MR. KAPPENMAN: I got everything in.

MR. McCLELLAND: Okay, thank you. All right. Next, we'll get at Dr. McConnell.

DR. McCONNELL: Thank you, Joe. Thanks to the Commission and staff members for allowing me to make a few words about this subject. I'm Ben McConnell. I'm a retired research scientist from Oak Ridge National Laboratory, and I've been in and around this business on and off in various projects for the last, since 1985.

So I know a little about everything, but not much about anything is the best way to put it, so I'll come down and say a few words. We recently had a discussion at Oak Ridge National Laboratory, just after I retired, looking at the Achilles heels of civilization. Those Achilles heels were things like massive volcanic eruptions, famine, disease, all those things.

But we decided to include this type of event, geomagnetic disturbances and storms, because this is a new type of event in the system. Guess what? This came out to be the most serious problem that had to be considered in the shortest time frame.

Well with that in mind, let me read a few remarks from my own note work. A large solar geomagnetic storm due to a solar superstorm could knock out major power grids, electrical equipment and factories, satellites and various communication systems. Note the word "could" and "would." Could is probabilistic; would is certainty. Watch when I use each.

The major concern is therefore not simply that electric grids would be down for a day or two, but rather that various hardware items would be badly damaged and replacement times would be a matter of months or possibly years. Estimates of constraints are needed concerning such damage, which I'm glad to hear is going on, both in the U.S. and other countries.

Areas in northern latitudes are particularly the most vulnerable, about 45 degrees. The combination of characteristics of this hazard are perhaps unique among all hazards. To wit, the recurrence interval for potential fatal scenarios is a matter of decades or a century at most, not thousands of years.

That is, this threat is very urgent, unlike so-called Achilles heels, which would result in the complete destruction of civilization as we know it, but this one could do extreme damage. Adequate and cheap means are known for protecting against the entire range of natural GMD and man-made EMPs, including nuclear weapons detonation.

However, deployment is spotty at best. What is lacking is economic incentive and political will. Only a few countries other than the United States, Switzerland being a possible major exception, have adopted protective measures. Poor countries have done nothing.

The solar geostorm of 28 August 1859, also known as the Carrington event, is classified as the most powerful in recorded history. I understand we've found some other stuff since. Issues of vulnerability, and I will reference things to that storm -- issues of vulnerability of ground-based infrastructure can be divided into severity versus frequency relationships, various intensity of storms by geomagnetic regions, including time transvariant therein, and hardware issues.

A central question is what percentage of the extra high voltage grid and generation equipment could be rendered inoperable by a major GMS. Transformers are key components and can be particularly vulnerable. But this depends strongly on design, age, operating history, location, numerous other variables, and in particular on whether the transformer is adequately grounded or grounded at all.

It is also possible in principle to protect certain equipment against geomagnetic disturbance, by installing blocking capacitors in the transformer and generator grounds. Systems for this purpose have been designed and are being tested today, but the incentives to install them is lacking.

Software and protocols for smarter operation of the grid can also pay dividends. A GMS contingency plan could prevent collapse and disconnect or monitor closely certain vulnerable components at the onset of GMS. Grid islanding is a key issue. Can we pull it off?

There is also a need to compare geomagnetic storms and electromagnetic pulses from nuclear weapons. The natural events are less intense, even in worse case scenarios. But an E-3 MHD EMP from a nuclear weapon detonation high altitude, while shorter duration is much more intense.

GMS or GMDs, on the other hand, cover a large area, while also being sufficiently intense to cause significant impacts on power grids and communications.

MR. BINDER: One minute, sir.

DR. McCONNELL: We really have very little historic data on these things. We have discovered from data that we can monitor these events recently, and we're looking at what those probabilities are. So what magnitude of severity of geomagnetic storm could be a civilization-killer, given our present dependence on electrical and electronic devices?

From the historical record of 1859, what kinds of estimates have been made of the severity of this event? Induced voltage in telegraph lines at the time, maxima, typical? How accurate are these estimates? How would these estimates indicate -- what would these estimates indicate about voltage and damage to our various electrical equipment?

How frequent are these? Once per century? Is it possible to make an estimate of severity versus frequency relationship as a mathematical function? The answer to this is possibly yes. It has been estimated that a super solar storm with an average occurrence of 1,000 years would be moderately larger, about 46 percent larger than the Carrington event, and event recurrence intervals of 10,000 years will be at least twice as large.

These recurrence intervals correspond to ten percent on the former and one percent on the latter. I ask a few more questions on my -- well, I have 11 seconds. I'll kick them in when we get into the discussion. But I have many issues, and everybody's been covering those, so I'm skipping around on my own issues here.

But I again thank the Commission for allowing me to make a few remarks, and hopefully we can get a good discussion going here.

MR. McCLELLAND: Was there anything, Ben, you wanted to cover that you didn't get an opportunity to cover? Any important points?

DR. McCONNELL: I'd like to say that I think that one of the best ways to protect the grid is simply to go into an islanding mode. But we're operating in a situation now where we operate toward economic dispatch, and that's under the deregulation that's been ongoing for now the past 10 or 20 years.

Going into a mode where we island the grid is a very serious issue, and we need to consider that, plus the ability to protect the equipment. We need to identify the equipment that we want to look at. There exists methods of measuring the internal temperatures of transformers using photonic methods, and I think those should be put into place.

I think there's a lot of technology that's here that we could make great use of that we're just starting to get in, and we need to not do research. We need to do all kinds of things to make this a reality and get something done.

MR. McCLELLAND: All right, then. Well, we'll probably get into those in the questions and answers. Thank you. All right, Mr. Houston.

MR. HOUSTON: Good morning. My name is John Houston. Thank you to the Commissioners and the Commission staff for hosting this conference today. As I said, I'm John Houston from CenterPoint Energy. For those who don't know who CenterPoint Energy is, formerly Houston Lighting and Power. Maybe that will help you identify where we are.

We supply 25 percent of the energy, electrical energy needs in Texas, which is used by the area around Houston. We operate, of course, in the southern part of the United States, and so it's easy for me to say for the last 130 years, we've not experienced a documented failure related to GMD.

However, the company and our company engaged consultants two years ago, after the HILF NERC-sponsored events, John Kappaman and Metatech at the time, to assess the CenterPoint Energy system, and to assess the system not only for GMD but for EMP risks, including the E-1 EMP risks.

So my comments today will relate to some of the observations we've made, and some of the modeling and efforts that we've had at CenterPoint, to try to understand the phenomena, not just the GMD phenomena. As my friend Mark said, the GMD Task Force concluded that voltage instability is far more likely than transformer damage.

From our work at CenterPoint, technically I'd have to agree with that. But I think it's a debatable point as to whether that is truly the end-all answer that our systems can be preserved and protected by an event such as a voltage collapse. Believe me, I don't want to go through a voltage collapse. We've spent many, many hours of effort to try to engineer our way out of such an occurrence in Houston.

So voltage collapse, while it sounds better than transformer damages that last for years, is not a good scenario for our industry, and certainly bears an amount of effort to try to resolve that and put it in the realm of, as I think Mr. Koza said, of traditional planning.

The Metatech engagement resulted in us having the models for use by CenterPoint only, and so our engineers have spent quite some time evaluating our system and working back through Metatech with some issues that enabled us to improve on those models, or enabled Metatech to improve on them.

So we're fairly confident when we say that the CenterPoint system would not experience a problem in such an event, as a GMD event, as described by Mr. Kappenman. I think that is not a conclusion, that we could stand by forever, because we are continuing to work with refinements of that, and we are continuing to understand better about the space weather effects that are the basis of this. So our conclusion could be wrong in the future on new information or better studies.

I think that's the important part about the NERC study that should be recalled. We need to emphasize what is in the rest of that study, which says we need to do a lot of things as an industry, and I think working collaboratively, as we are doing here, with NERC and EPRI and in DOE.

We certainly, my company, through our efforts in the Electric Power Research Institute, we were able to get this collaboration started with NERC. We were able to get programs put into EPRI that are being funded by a large number of electric utilities, to research and provide these tools that can be put in the hands of electric system planners.

MR. BINDER: One minute, sir.

MR. HOUSTON: It's important for such an occurrence to take place, because while we have a number of space experts and solar experts opining about the effects and how they can affect our industry, the real analysis of what the system risks are have to be calculated by those power engineers.

You have to have those well-vetted models that can be placed in their hands, and we can understand on an interconnect-wide basis what the effects are on the system.

If we find, and I want to emphasize this point for the benefit of the Commission, if we find that there are needs for additional transformers in some other part of the country than CenterPoint's, but if those prove out to be a need, there are things that we at the industry, through EEI, have already put in place.

The STEP program addresses a coordinated attack on our industry. It's in place. It has numerous companies who are participating and have signed on for the risk and for the benefit of that resilience that can be brought by sharing of transformers.

The program could, stands ready and could be made useful, I think, for any possibility of additional transformer sparing that might be needed. Of course, CenterPoint participated with DHS in a collaborative effort and EPRI, to bring the recovery transformer to fruition.

It's now operating in Houston, Texas for over two weeks. It was implemented in five days from sitting on the factory floor to being energized in a substation, a 345 substation in Houston, Texas. The factory floor was in St. Louis.

So it can be done. Two of those units are sitting on the existing transformer foundation. One of those units are just sitting on the substation gravel, because we wanted to prove the concept, that transformers can be brought in and implemented quickly, if need be.

That stands ready to be utilized in the future, if the effort continues to develop, and other voltage classes certainly can be accommodated. But thank you for the opportunity, and we look forward to your questions.

MR. McCLELLAND: Thank you, John. Appreciate it. At this point, I'd like to defer to the Commissioners, turn to the Commissioners, and see if they have any questions they'd like to leave the panel with.

COMMISSIONER LaFLEUR: I'll try to confine myself to one question, because I know that we have all the experts here.

As I hear the debates, and having read some of the 2010 and 2007 reports, and then all of the NERC report, it seems like the debate is whether the inductive power that would be potentially unleashed by a geomagnetic event will prevail over the reactive power that would cause the system to break apart.

And I mean I know it's above my pay grade to figure out that question. So I'm trying to figure out what can we do that would bear out as a good thing to do under either circumstance, while we continue to debate the power question.

I'm struck by Dr. McConnell's comment that things would be better, which I'm sure is true on this point, if we would island the grid more and kind of go back to more local geographic operation, because there wouldn't be as much interdependency.

But of course, that's the exact opposite of the whole direction the electric industry has gone in for the last 20 years, and a lot of what we do with this Commission is to try to get people to think bigger and think across regions and do more transmission.

So I'd like to ask the experts, with all this money going into transmission, are there things we should be doing on our grid now, to build the new part of the system better, as we build out, you know, more regional transmission lines, even lines between regions, beyond just analyzing the likely performance of the existing grid?

Should we be doing something different on what we're building for the future? Are we ready to set standards and move forward? I'm interested in your thoughts.

MR. KOZA: I'll make a first comment to that, I guess. I think we've got the grid that we have, and that's because we were trying to extract the maximum economic benefit out and keep the product affordable. Anything that would suboptimize that, we're talking about increased cost to the customer. So I think we've got the grid we have just to maximize economic benefit.

Regarding the issue of what I'll call reactive versus inductive, if we need to get a better answer to the issue of transformer failure, I believe we're going to have to do more testing. We do have some preliminary test results of people who have injected currents into transformers.

It's certainly not enough. It's kind of included in the report. We may have to get to the point where we do destructive testing of transformers, to solve that issue one way or the other. So more needs to be done, I think, to establish that.

On the reactive side, I think those of us in the industry that are involved in operations, we understand that issue pretty clearly. Generation of harmonics and that kind of thing are going to cause a lot of problems on the grid system.

The issue there is we need to put the modeling and the tools in place to analyze that, and figure out what to do to fix that problem. So I think those are the things we need to be looking at at a high level, Commissioner.

COMMISSIONER LaFLEUR: Standards and codes on the new transformers that would bear out. I mean because it's obviously much cheaper to build something in on the front end than go try to retrofit it later, and I know you had transformer manufacturers on your task force.

MR. KOZA: We did, and IEEE is pretty heavily engaged in that with the Transformers Subcommittee, to put the standards in place that are probably going to be necessary for what I'll call the next generation of transformers, that will include GIC withstand capability and other features.

MR. KAPPENMAN: There is one problem with even standards for transformers. I mean there have been new transformers that are being purchased with some sort of specified GIC withstand. The problem with that is, again, they're lacking standards in the design area that make it open, transparent and certifiable.

Even in some of the transformers that are being purchased right now, the manufacturers themselves are not able to test, actually test those transformers up to the standard levels. They rather depend upon providing the customer a simulation model of that transformer.

There is a problem in those simulation models. There's been no simulation model that has been provided by anybody I know of, that captures all of the behaviors of the transformer and damage modes that the transformer exhibits. They're not even able to benchmark the existing tests that happen at much lower levels of GIC.

We also have data from industry itself. There is one U.S. electric utility company that reported information publicly from the March 1989 storm. In that storm, they reported harmful impacts to 36 percent of their transformers from that March 1989 storm.

We are now looking at a scenario, like I said, that could be four to ten times larger. We also know we have age and condition issues with the existing transformers out there, that are essentially the withstand decays with age. It's a lot like a public policy of letting flood dykes erode with age, you know, something that would not be tolerated at all from a public policy standpoint.

So I really think at some point we're going to have to come to grips with a design code that actually prevents GIC from coming into the power grid. Essentially, we have engineered a power grid that is tied to ground. Most of the time, that is a safe thing to do. But during a geomagnetic storm, ground becomes a danger to the power grid itself.

And we can certainly look at other examples like seismic codes and so forth. We know we can't, we don't function in society without seismic codes where it's appropriate in those areas, even though most of the time ground is not shaking there either.

COMMISSIONER LaFLEUR: So are we years away from -- I mean are we able to do something sensible now? Are we five years away?

MR. KAPPENMAN: I honestly think that codes of higher GIC withstand for transformers is not nearly enough, you know. You're still going to allow GIC into the grid. That GIC is still going to drive those transformers into saturation. That withstand is going to decay with age.

You still have the possibility of breakers being damaged by the GIC. We don't know the answers to those questions. So you know, these ideas that buying a transformer with a bit more GIC withstand, that is not going to be a workable solution to all the problems.

The best solution is to prevent the environment from entering the grid in the first place, and that's where I would recommend that policy pursue those sort of objectives.

DR. McCONNELL: One of the issues, I tend to agree with both remarks in some way. One of the issues in design of transformers, you have to have a very good finite element model. What we've got in this particular situation is a non-linear relationship that is stochastic in nature. What you just spelled out was a chaotic situation.

In chaos, you don't know what the heck is going to happen. You really don't know where the hot spot went. You know where you designed it to be, but in the event of a geomagnetic storm, even the smallest amount, you don't know where that hot spot jumped to, and just measuring top oil temperature doesn't give you anything. You need inside that transformer good measurements of where the temperatures are at.

Furthermore, chemical sampling of the oil doesn't tell you a lot. That's a homogeneous measurement of something that looking at the whole oil mixture, after a period of time, it tells you yes, my oil looks like this. But I don't know what the hot spot did, and I don't know where the hot spot is at.

I would strongly recommend that we do look at some kind of standards. But by the same token, to back up the issue of whether or not we've islanded the grid, I know we're operating economically. I've done work in this area for my entire career. That's the whole point. That's the reason we're going to the long lines.

But we just made one heck of a big antenna, and the case is now we're absorbing energy like crazy in this thing. So I don't personally think it would take more than a half day's work to figure out how to island the system. It might not be economic, and we might all pay 100 percent more per kilowatt hour during that two or three days.

But to heck with it. That's the way it ought to go. Save that system, because if we go down even a third of the grid with that, even a tenth of the transformers and the base load structure went down, we would be in a world of hurt. I strongly recommend that's one approach that needs to be implemented.

MR. HOUSTON: I guess my comment would be that I guess I'm not as pessimistic as John. I believe that the industry standard could be set for transformer withstand, if the manufacturers and some additional tools could be developed to enable this temperature monitoring.

It could be that I'm wrong, that that can't be done. But I think that until we've looked closely at that, I think we should pursue that, because there's opportunities that could be presented if going forward we could specify a withstand and manufacturers could actually meet and prove that they met that not, as John said, with some actual -- with actual tests as opposed to with some hypothetical test of it.

I agree with Dr. McConnell, that the temperatures will not be in the places predicted for normal loading of transformers. That's what makes this problem much more challenging for us to solve.

MR. LAUBY: Thank you for your question, Commissioner LaFleur. I think there are two areas to be looking at.

One, I think you mentioned the specifications. There are a number of organizations, in Europe for example, Sweden specifies certain kind of GIC withhold, withstand capability, and I know the IEEE Transformer Committee is looking at this as well.

Another is reviewing the spare capability that we have. As I mentioned, the Spare Equipment Database Task Force completed activities recommending the creation of a database for long lead time equipment, and there's an emphasis there on high voltage transformers.

So data collected there is going to be -- really, we're going to start gathering that at the beginning, well at the end of this quarter, and I think that will also help us then to assess what our policy is there. I think these are things that can be going on in parallel, while we develop some of the detailed models to validate some of the things we're mentioning here today.

One of the things that I wanted to mention was that when you do study work like this, you really kind of look at the two time frames, and one, you look at voltage collapse and you say well, what kind of volts per kilometer am I looking at? This is kind of a way to measure the geomagnetic-induced currents and what the transformers are going to see.

You then calculate the absorption of reactive power and just simply look at what you've got available on your system. The other is to look at a little bit more of a slower time frame, looking at different dimensions and direction. Then you look at the wave fronts and like I mentioned before, NASA has developed a few. You could scale them, and then you could look at the thermal issues.

Now with a certain kind of engineering judgment, you can look at worse case scenarios, and from that then, you identify those that perhaps have the most worry, and then you do your finite element analysis on those transformers that you're really concerned about out of the whole set.

COMMISSIONER LaFLEUR: Thank you. I just want to clarify. My earlier comment on islanding, I didn't mean to dismiss the concept that Dr. McConnell said, of operating protocols to island the system in an emergency. I was talking more about the direction of its normal operation. Thank you, Joe.

MR. McCLELLAND: Okay. So we have a little time to dig through these issues. Whoops, I'm sorry. Commissioner Norris.

COMMISSIONER NORRIS: No, I just want to make --

MR. McCLELLAND: I'll leave now.

COMMISSIONER NORRIS: I was just going to interject parochial interest here, and that was being a Midwesterner, I was hoping you were going to say we've got that transformer discussion, the high performance characteristic of sway-based transformers would solve this problem. I sense from your comments that alone will not do it.

But I think the performance of transformers is going to be critical, and the new transformers that we'll be developing, we've got to find ways to make these help solve the problem.

MR. KAPPAMAN: You know, I would also like to add, you know, transformers is one of the most important and vulnerable of assets that could be damaged. We also know of problems with large generators as well. We also suspect there's going to be problems of over-current of capacitor banks, SVCs, even with proper relay protection and so forth.

Those become big issues, and again, other apparatus. We also know that there's some unknown unknowns out there. You know, I would like to point to some tests that perhaps may be beginning to reveal some things that are being considered at Idaho National Lab and so forth. We have concerns about data centers being at risk.

You know, into the electric customer area, there are critical functions out there that could be harmed by these disturbance areas as well. Just last week, I was contacted by an electric utility company that happened to have widespread number of surge arresters that failed during a storm April 24-25.

We had seen that before in other storm events. We don't know exactly what's going on there either. We know of long duration, low level storm activity that is also very harmful to transformers, because you can kill a transformer by a brief high intensity surge, but we also have concerns that long duration events like what caused the large number of transformer failures in South Africa, could come into play here as well.

So again, withstand on equipment is -- I'm not sure it's going to be able to yield the proper protection that we need to be considering for the power grid in the long run.

DR. McCONNELL: Let me throw one thing in on withstand. Even on withstand to high voltage electric strikes, we have certain anomalous failures that occur because we don't test to that specific wave front. Faster wave fronts of even shorter duration caused delayed installation failures.

I've seen issues in this particular phenomena that, sort of referring to what John just said, that seem to imply we've had anomalous failures that may or may not have been involved with this particular area. It's a delayed failure, but so we can delay something six months and we still lose half the transformers, that's a tenth of the transformers in the base load.

That's still a big issue, because even though we've got, going to have five new plants on line or four new plants on line to produce transformers, that's still a massive load, and I agree with the concept of, I think you call it, where you have a backed packages of single phase transformers you can put out there.

It's not a bad concept, but not every transformer can fit that situation. So I'd strongly take a good look at trying to instrument transformers better, and instrument the ones we're testing, because testing to failure will test you one and only one design. It does not tell you about -- transformers are really tricky to analyze the hydraulic flow in, because it's a convective flow.

The minute you get something that is not the normal temperature distribution, at best you're going to get a good approximation. But you really can't quite tell what's going to happen. A wall of the transformer tank gets red hot, cuts off, gets red hot, cuts off, gets red hot, cuts off.

What happened to the oil? Where do the disturbed installation processes go? How did the thing work, and six months later, bang, the things blows sky high. So what is the issue? That's a tough problem, and I think we've got to think about it and get going on it.

It's an issue that I'm ready to retire, but I'll keep fooling around with it a little bit. Thanks.

MR. McCLELLAND: Commissioners? Okay. Just make certain this time. So I've asked staff to sort of pull me back when I ask too many questions. We've all got questions here, but I'm really not sure where to start. I think I'll start with Dr. McConnell.

The question I have for you is the 1921 storm has been termed a 1 in 100 year event. Do we have any sort of statistical information to validate that claims? What is 1 in 100 year event?

One of the things that staff wrestles with, and I'll put some cards on the table, because I think this session ought to be about putting cards on the table, all right? One of the things that staff wrestles with is if the industry moves forward or the Commission moves forward to consider a standard, what standard would you consider?

If you put dampening devices in, to what level do you dampen? Do you dampen to a 1 in 20 year level, a 1 in 50 year, a 1 in 100 year, a 1 in 500 year? What do you block? If you block, I think one of the panelists for this afternoon talked about unintended consequences.

So you sort of push that GIC around. Now granted you're pushing it theoretically to higher impedance systems, so you are per se dampening it. But it's got to be a systematic approach. One thing that's clear is there has to be a systematic approach. It doesn't look like this problem can be solved technically in isolation by the entities. It looks as if it's got to be systematic.

So the first question is what is -- is the 1921 event, is that 1 in 100 year event doctor?

DR. McCONNELL: From what I've been able to tell, and initially, when I started preparing my remarks for this, I had asked the question what kind of relationship exists, mathematical relationships and the data exists.

I wasn't sure there was a marker, and I got to discussing this with my colleagues at Oak Ridge that had worked on what we called Achilles heel stuff, and they started looking at nitrous oxides and ice.

They had looked at some results of some studies, that that's one good measurement of what might be happening, and they were able to get among that and some other data and actually to come up with something.

The Carrington event, which was the 1859 event, was something like 46 percent better, greater than or was about 20 percent, I think, better, worse than the possible event. This is just off the top of my head, than the 1989 storm.

But we could potentially see a once in a 100 year event. We might actually see 20 to 30 percent greater than the 1989 event. 40 percent to twice as big would be a one percent chance, 40 percent and ten percent in a 1,000 years, ten percent chance -- one percent chance in 1,000 years would be about 20 percent greater.

But we certainly -- this event is much shorter time duration than the other catastrophic events, and it's something we, as a society, have the ability to look at, coordinate, tie together not only the operational aspects on what we see in the operation of the grid and do something about it.

Of course, that 20 minute approach a minute ago with a fast coronal mass ejection was a little scary. But we have other things that happened just as fast in many areas, and I'd like to throw in at this time. I thought to mention the fact that, you know, our nuke plants, if we lose the grid, and we're trying to operate on offsite power, I've done about four studies that have to do with loss of offsite power in nuclear plants, and they are really risky.

If you -- you can just ask the boys at Fukushima about that one. It's happened before, and you just have to be very alert. Just having the ability to pump oil and everything around the system, you lose five or six percent of it.

You've got ten percent. You've got difficulty pumping, operating large equipment and it's not easy to do. I hope I answered your question, Joe. I'm hoping that I can give you a report that will help amplify that a little bit.

MR. McCLELLAND: Well, I appreciate that, and you know, I can ask for also comments or answers from the other panelists. John, Mark, any additional comments?

MR. KAPPENMAN: You know, certainly I've looked at important storm events. We know in the case of the March 1989 event, the important thing to look at is the rate of change of the geomagnetic field. It's the Faraday effect that produces the voltages and the induced currents that flow in the power grid.

So if you know the rate of change, you can appropriately scale the intensity of the storm. In the case of the March 1989 storm, the Quebec grid collapsed at a local intensity there of about 500 nanoteslas per minute. Most of the impacts across the U.S., including the damaged transformer in New Jersey, were at levels in the 300 to 500 nanoteslas per minute range.

When I've looked at historically important storms, and even with the high quality data of modern storms, we can see events that even in the modern data have exceed 2,000 nanoteslas per minute, at latitudes of concern for the U.S.

Now they didn't happen to fall on the U.S., but this is a very random process. They have equal probability of occurring in the U.S. So when we look at that category of storm, the data there suggests it's somewhere in the neighborhood of about a 1 in 30 year probability for at least that level.

Going into the 1921 storm, we have very good data there that allows us to estimate. That probably approached about 5,000 nanoteslas per minute, ten times larger than the March 1989 storm. That being said, there are a lot of other storms that data probably could be gathered from, that would tell us that.

You know, there's been a lot of attention on the 1859 storm. Unfortunately, no data that I'm aware of that allows us to tell the intensity of that in nanoteslas per minute, although we think it was probably an important storms. But there's other storms. 1870's there were several storms; early 1900's into the 1940's.

Scientifically, no one has bothered to go and look at that data, to extract whether we're looking at maybe a 1 in 50 year, 1 in 100 year, 1 in 150 year. You know, there's a bit of uncertainty in those levels, as far as frequency.

MR. LAUBY: It's a very interesting question, because what we're finding, based on what's documented in NERC's report, that 1 in 100 year changes and is different based on your geomagnetic latitude, and its potential impacts will be, of course, affected by the geology.

So you know, my view is that, but again, in NERC's report, is to get this to the point where we have an understanding of, you know, if I am in Boston, here is my 1 in 100 year storm, what it looks like. If I'm in Atlanta, here's my 1 in 100 year. It really gets beyond the nanoteslas per second. It really gets down to volts per kilometer, because that's what's driving it, you know, and the duration.

I mean you can have a very short duration of nanoteslas per second, it's a slope, or you can have a very long one. So it's not a good, complete measure. So we need to understand the duration and peaks, and again, those wave fronts we are developing with work from NASA.

But also there's some calculations using extreme value theory, which determined, you know, based on let's say if you're in British Columbia or Quebec, we documented them in NERC's report, and we're working now with the USGS and NASA to kind of deepen that knowledge and understand, you know, depending on where you are, what a 100 year looks like.

MR. McCLELLAND: So a couple of questions on that then, follow-up questions. Are we making the grid more vulnerable, unintentionally so? But are we making it more vulnerable as we build long lines out, say, to remote renewable resource areas, higher voltage lines? Are we making a better path for the ground of these currents?

If we are, how do we account for the changing system conditions, especially to someone's earlier point about purchasing transformers? So we'd be looking at this, moving forward as we modernize the grid, as we update the grid. So we'd be looking at that particular aspect.

Then the second question, Frank, I'm going to look at you on this one, is that, you know, I've heard the nanoteslas per minute, you know, metric. But particularly the GIC metric. Where should the GIC monitors be located, and at what levels does say PJM take action? It is 10 amps, 20 amps, 50 amps, 100 amps? What do you look for as far as levels of amperage, and what are the particular actions you should take?

And John, I'd ask you the same question. What do you do when these things occur? So let's start with the first, I think the easier question. Is the grid becoming more vulnerable as we move along? Then the second question, particularly to the system folks, what are the levels of GIC that you're concerned with, and what are your particular actions on those levels?

MR. KOZA: Well Joe, regarding your first question, first of all, I think you understand, there's pretty substantial difference between the eastern grid and the western grid, the western grid being characterized by long transmission lines, the eastern grid being characterized by short, densely packed.

So I'm not convinced we're making it worse, other than we have many more EHV facilities out there. That would be my answer to the first question.

Second question, PJM does have an operational procedure. It does require us to take action when we get 10 amps of ground-induced current at the monitoring stations we have in PJM. Is that the right value?

I don't know. Based on the work that we've done at the GMD Task Force, I've kind of gone back to the technical people at PJM and asked is ten the right value?

Maybe it should be higher; maybe it's too conservative. It did come out of the 1989 event and the damage to the Salem transformer. Whether that's still valid or not, I don't know, and certainly we're going to review that as part of the work we're going to do in the future here.

MR. McCLELLAND: John, do you want to comment on this please?

MR. HOUSTON: Well, I think they're -- Joe, you bring up the point if we're making the system more vulnerable. I think it's just like we've modernized since 1921 it's become more vulnerable. I mean I think we can't stop the progress of electrification or people's use of power.

Clearly, though, the higher -- you've heard the parameters and you know them just as well as I do. The higher the voltage, the more the concern. The geology is important. So the geology of the west versus the east is important. The latitude is important, which is the geography.

I think the connections or the mesh or the design of the system and how it's connected is important. So all of those boil down to if we understand, if we have the models that Mark is talking and EPRI is talking about and John may already have, we need to have applied to our system and usable by the planners.

I think we can move forward responsibly. I think we can take this as just another risk associated with building out the system, and address it. But we are adding more antenna, so you have to do something about that.

MR. LAUBY: I'd like to also suggest some comments on that. NERC's report, of course, talks about monitoring and the need for monitoring, because that's how we can validate the models that we develop over time. We can validate the GIC flows, geomagnetic-induced currents or GIC flows based on certain storm parameters, and then compare that to models that we have.

So obviously having an optimal selection of monitors that's being gathered and shared, so that we can go ahead and publicly validate the models that we would be developing.

Of course, these models are, you know, not only the ground impedance, but also the reactive absorption models that we're developing, and kind of a simpler input-output model for thermal as, like I said, as a baseline, a worse case, so then we can just identify transformers that have a real need.

When it comes to the longer lines, of course I'm assuming we're talking about less than 200 miles, because after that, then we start talking about maybe series comp, and then the problem goes away. So series comps, of course, eliminates the geomagnetic-induced currents.

You know, clearly any time that you are increasing the volts per kilometer, it's something we need to be studying carefully. That's, you know, kind of documented in the report. So with having the tools that we're talking about for the planners, like I say we developed an open source code with EPRI, and that's been released now.

But of course, validating some of the models through monitoring the system, and then of course through some key thermal tests of transformers, I think we'll be in better shape than we are today.

MR. McCLELLAND: I'd like to start one other series of questions, sort of an issue, and then I'm going to turn to staff to ask some questions. They've been more than generous with me, as I've sat here.

But one thing that we've seen, I think one of the major differences with the NERC report is that there is the premise or the basis that reactive power would be in short supply or would be necessary, so that there would be voltage problems and the collapse of the grid itself, thereby protecting the transformers, because the grid would be taken offline.

Something you said, John, that struck me, and I sort of had the same thought process, is that that may be so. But it certainly doesn't seem as if it's acceptable solution, you know. It may be an intermediate finding, and I've got plenty of questions about how that might work, especially one other part Mark, and thank you for your testimony.

You pointed out that under harmonics, you know, the relays and controls don't work the way you think they're going to work. So you have that sort of issue, and then you have the other issue that some of the panelists alluded to, is that you know, there's sort of thermal inertia, the transformer itself, and then there's hot spot, you know, and then there's saturation, right.

And so as you look at the different aspects of the Transformers themselves, when you talk about saturation or over-saturation, hot spots, you may get a problem area of that transformer to occur very quickly. So if you're looking at -- and one other issue too.

In Quebec, when the grid collapsed on reactive power, there were two transformers that were lost St. James Bay. So somebody mentioned that. I think it was you, John, that mentioned that in your testimony. So there's also an issue of sudden collapse of the grid that can cause equipment damage.

So you sort of throw all those into the mix, and then there's just one more thing that I'll -- if you'll indulge me, I'd like to read this to you. This is from the 2003 blackout report.

"The blackout began a few minutes after 4:00 p.m. Eastern Daylight Time, and power was not restored for four days in some parts of the United States. Parts of Ontario suffered rolling blackouts for more than a week before full power was restored.

"Estimates in the total cost in the United States ranged between 4 billion and 10 billion US dollars. In Canada, gross domestic product was down 0.7 percent in August. There was a net loss of 18.9 million work hours and manufacturing shipments in Ontario were down 2.3 billion Canadian dollars."

So if we all think it's an inevitability that we're going to have a solar magnetic disturbance, and I think I heard that, at least some level of solar magnetic disturbance, perhaps a very severe storm, in the end, there's uncertainty associated with what it would do, except that it may cause a reactive power loss.

Certainly, and I think in your submitted comments, Mark, you talked about, you know, sort of equivalent to the 2003 blackout. That was relatively limited compared to what you could see from a large system collapse, and yet the cost was four to ten billion. How much mitigation could you buy for that?

Again, I appreciate the comments from one of the other panelists, that said hey look, you've got to be careful about pushing GIC around. I understand that. But how much mitigation could you buy by starting to or by identifying those vulnerable transformers and putting some solutions into place?

It seems to me for $100,000 a transformer or whatever that number might be, you can buy a lot of mitigation for less than four to ten billion dollars. So I'm going to throw all those issues on the table. Speak to whichever you like, and then I think staff at this point is about ready to take the microphone.

MR. HOUSTON: Joe, if I could speak to a couple of those. One is the effect, what I call a "whack-a-mole" effect, because if someone fixes their problem by blocking, then someone else's system, because it's interconnected, has just gotten a lot more GIC.

So it's got to be an interconnect-wide, a study of the system has to be done. You can't allow the whack-a-mole and just people with their assets, I'm protecting mine, I don't care what happens to yours. That can't work, and we know that can't work in Texas either.

So we're going to have to address that. That's why the tools are important for people to plan. It can't be a single company planning. I think that the Eastern Interconnect, and I'm not in the Eastern Interconnect, but they have to study their individual situation.

Because the situation in Texas may be fine for CenterPoint and we're comfortable where we are as far as GMD. We're not comfortable where we are because I don't know what an EMP event looks like yet, in terms of what I need to withstand.

But the people in the Eastern Interconnect for this particular need to think about what their particular situation is, what their transformers are, and I'm giving advice as though -- you're paying me for it. But you know, it's clear that we're trying to develop those tools, because asset owners are going to do this.

Asset owners have the risk. Asset owners have to invest in either the mitigation or the clean-up after the fact. The clean-up after the fact means that consumers have been harmed. You just pointed that out.

MR. McCLELLAND: Yeah, we have to talk about it.

MR. HOUSTON: I think that's the unacceptability.

MR. McCLELLAND: That's right.

MR. HOUSTON: So I think it's not just modeling of transformers, but we have to understand the effects on relays and whether we can do something different in terms of system protection, and we're willing to do that to resolve the issue.

These effects of the harmonics can be significant, and I'm not sure their well studied yet.

MR. McCLELLAND: Thanks, John. Others?

MR. KOZA: I guess I would add to John's comments, Joe, that it would be nice to be able to tell you there's a one-size-fits-all solution to this, and the process that John described is exactly it. This is going to take detailed analysis by planners and operators, and would require specific solutions based on location, design, a whole bunch of factors. So this is not going to be an easy answer.

MR. LAUBY: The only thing I would point out is in our report, we did talk about the reactive insufficiency inefficiency. As I mentioned in my testimony, you know, this is still a very serious issue, certainly to NERC. Uncontrolled cascading of the bulk power system is like one of the tenets that we were formed, to study and working with industry, to develop standards to address.

So we take it quite seriously, and that's why we put together a detailed plan of action. In that plan, we talk about some of the things you chatted about earlier, which is, you know, monitoring sites for validation, etcetera, so that we can start developing the right solutions.

Some of the solutions may involved, you know, blocking geomagnetic-induced currents from coming on the system. Some may be, you know, sorting out your relaying.

In some places, I know for example in Canada, as they monitor the voltage potential, they start making decisions, operational decisions on what they're going to do with load that they're going to serve, and transformers that they're going to protect, as they start working their way up to six volts per kilometer or ten volts per kilometer.

So they start making those kind of decisions, and we'll be putting those systems in place from an operational perspective in the fall. So you know, having the right tools so we can make the right judgments, I think. But that being said, the industry takes reliability very seriously, and our report, I think, documents the way forward.

MR. McCLELLAND: And it sounds like from the answers, I don't mean to cut you off, John. Please, if you have a comment, jump right in. But it sounds like so far what I'm hearing is consensus at least in the fact that it's just going to take a coordinated response.

To the whack-a-mole comment, if somebody does GIC blocking in isolation, and someone else decides to accept the risk as it's presented, they may not realize that the landscape just changed, because their neighbor is doing GIC blocking, and now has shifted the GIC over to them.

So it sounds to me as if this is going to take a coordinated sort of interconnection-wide response, in order to properly solve the problem. Would everyone agree with that?

MR. LAUBY: I agree, and one of the elements we call for in NERC's report is to look at our NERC standards, and to see what the enhancements are needed there, because that, of course that will then, working with industry, call for that coordinated action.

MR. McCLELLAND: Is there -- and I don't want to put you on the spot, Mark. If you don't know, that's fine. We'll get it for the record later. But is there a standard now that talks about the GIC or geomagnetic disturbance?

MR. LAUBY: The only standard I'm aware of, and I could be corrected, is the IRO standard, which calls for information to be shared about alarms coming from the space weather prediction center, etcetera.

MR. McCLELLAND: Okay. So it is specifically mentioned in the standards, at least from that aspect?

MR. LAUBY: I believe so. But we're looking at planning standards, you know, and operational standards down the road, once we have the right information in front of us, so we can work with industry to put the right things in place.

MR. McCLELLAND: Okay, and John you want -- you looked like you wanted to say something earlier.

MR. KAPPENMAN: Well, I would, you know, I would just emphasize again the points that it needs to be coordinated. The best way to achieve coordination is through standards and requirements that don't leave it up to be voluntary, ad hoc, you know, deciding, the one company deciding this is a risk, while others decide it's perhaps not a risk.

Standards underpinned are underpinned by force of law, you know. If you look at, you know, building codes, essentially they are underpinned bay force of law. Environmental emission standards are underpinned by force of law, seismic codes and everything else. So we really need to have a public policy underpinning here, that needs to be understood, developed and articulated to serve as a guiding reference for any of the standards that industry will be considering going forward.

MR. McCLELLAND: Does anyone disagree with the standards comment? Speak now or forever hold your peace.

MR. HOUSTON: Well, I guess my concern is that we don't want to develop a standard that, for example, said today, well, let's just require everyone to block every transformer in the system.

Such a standard would be detrimental to the reliability of the CenterPoint system, and would have no positive effect, at least with my current knowledge, on its withstanding GIC or other events.

So a standard that's not well thought-through and isn't based on the scientific knowledge could be harmful to our reliability and our industry. So I just want us to be careful with that.

MR. KOZA: The point I would make is that when you say "voltage collapse" and "blackouts" to a utility audience, you don't have to say anything else. None of us ever want to see that happen, and you don't necessarily need standards to tell us that. When this report came out and it talked about voltage collapse and blackout, everybody got the message.

DR. McCONNELL: One little comment here is basic coordination among people, coordination of the relaying structure has to be redone after you block, and that's got to be very -- included in the whole thing, and it will have to be worked together.

The other day, I was teaching a course in synchronous generators, and I hadn't really thought about this issue. I opened my mouth and said "you know, the status of this thing is we grounded it." I said "wait a minute." In the back my mind, I said "uh-oh. There's one I haven't thought of."

I don't know what happens to the generator. It doesn't have oil circulating in there. It's cooled by a different method. Now where do the hot spots move in that thing?

MR. McCLELLAND: And very tight tolerances too.

DR. McCONNELL: Yes, yes. I have no idea on that one. I hadn't thought about that, but that hit my mind just as I said those words. I told a couple of students later, you know, I just came up with another problem I hadn't thought about.

MR. McCLELLAND: Any further comments on those subjects?

(No response.)

MR. McCLELLAND: All right, thanks folks. I'm going to turn it to staff, Ted and others.

MR. FRANKS: Mark, you mentioned that NERC put out an alert for GMD. Is there, going back to Commissioner LaFleur's request that, you know, is there something to be done now. Is there enough support maybe from the alert that that can be turned into a standard sooner rather than later, waiting for all the studies to be performed?

MR. LAUBY: Well, the alert was really a set of operating procedures, as well as long-term planning procedures and of course, now that we're making tools available, it certainly could be a basis that one could look at, to say "well, here's a piece that maybe belongs in a planning study or planning standard. Here's a piece that might belong in the operating area."

What we are doing, though, based on the results of our study, is considering, you know, reviewing that alert one more time and updating it, based on the results and also looking at the category of alert right now. Thank you.

MR. WAGGEL: I guess my question surrounds the transformer damage and the collapse of the grid, and the collapse of the grid concerns me, like it does everyone. I'm not really sure which is the worse case, whether the grid collapse is worse or whether the transformer damage is worse.

But I got to thinking and wondering, we talk about the most severe case, the most severe GMD case. Is it possible that we could have GMDs of a somewhat lesser value than the severest case, and possibly not be -- possibly be able to compensate for the VAr requirements on the system and have that GIC actually -- in essence, I don't want to exactly say "cook the transformers," but in essence that's what happens.

And also, I think Joe alluded to this, as well as John. Joe had mentioned about our protection systems and John had mentioned about the inability, or possible inability of breakers to interrupt DC currents.

It was actually pointed out at the task force standard

about possible misoperations or non-operations of the protection systems is that when you combine the possibility of the protection systems not operating, and the breakers maybe not being able to interrupt, is it really conceivable to rely on a system collapse in that case?

Because you could possibly have elements not actually coming out the circuit when you're relying on that. Under those situations, it is what actually happens.

MR. KAPPENMAN: I'd like to just provide a few comments on some of these areas that you've raised. Certainly, there is a concern about the lower-level, longer-duration storm that can occur. These are also, you know, somewhat well-documented and in the environment and so forth.

We have really not gotten much in the way of answers or really honest answers from the transformer experts on this area though. We know that if you look at the over-excitation standards, for a brief period of time you can stand a 40 percent over-excitation. But when you get out to longer duration events, they talk about you cannot tolerate even ten percent over-excitation, even when the transformer is unloaded.

The space weather environment can cause either of these scenarios to unfold. If we talk about a very low-level, long duration event, we will not have a system collapse. We'll probably be able to manage the operation of the system to prevent this sort of scenario. But it could inflict significant damage on the transformers.

We think that is what unfolded in the case of South Africa, and there is nothing unique about the U.S. grid that precludes that from occurring here for that sort of scenario as well.

We also have concerns with the rapid collapse for a big event. We have a tremendous amount of unknown unknowns as we talk about it in relay operation, the sequence of the collapse, and even if we look at the over-excitation standards, again 40 percent over-excitation, which will be caused by a large GIC, the standards now allow only a ten second duration. They're very specific on those time limits.

So if your collapse scenario evolves over tens of seconds, you arguably could have sufficient time there to cause sufficient damage to a large number of exposed transformers.

Then you start worrying about the physics of all the other things that are going on. You know, circuit breakers. No one has an idea how they're going to behave, whether there will be catastrophic damage.

I have seen circuit breakers that have blown themselves apart. In the process of blowing themselves apart, they become a bomb that sends shrapnel everywhere else around the substation yard and damages other equipment in the process.

So again, we have some potential for some very ugly scenarios to develop, and we should not try and sugarcoat to assume the rosiest scenario, in saying that all of these events would only lead to a few hours of duration of blackout and recovery. I think that would be a public misstatement.

MR. LAUBY: That's a very good question, Rick, and that's why we advocate that when you do studies for, you know, the impacts of geomagnetic-induced currents, you look at the different volts per kilometer and different directionality. You really do it in two phases, because there's two time constants you're dealing with here.

One where, you know, the voltage itself, you know, volts per kilometer, and that's going to drive your voltage stability, and it will happen within a certain amount of seconds after you experience that voltage. The other is looking at the wave fronts and looking at directionality of those wave fronts.

That, of course, is much more of a time series issue, and that's where you'd like to look at the thermal performance of transformers. From there, then you can determine which ones you have the most to worry about, and do a detailed finite element analysis just on those transformers that seem to be seeing most of the geomagnetic-induced currents.

In the report, we did talk about breakers, and we talked to an expert from one of the manufacturers, who indicated what would happen, you know. These are breakers that handle thousands of amps all the time.

Then the DC would perhaps shift the zero crossing, but in fact it would find a crossing. If it's lightly loaded, though, that's where there may be a bit of a concern on breakers. And then on the South Africa, we also talked about that in the report, and we found that that there were a lot of corrosive oils in the transformers.

So those transformers, of course then over time, of course with the geomagnetic-induced currents, resulted in dark spots on them and had to be taken out of service.

MR. KOZA: The only comment I want to make, Rick, is that we can manage reactive within certain limits. I mean that can be managed. I mean I feel pretty confident within PJM that we can deal with K-7, K-8, K-9, some of the minimal impact.

But to put this in perspective, the Oak Ridge report is talking about magnitude ten times greater than anything we've ever measured at PJM, in terms of ground-induced current, over the 20-something years we've been measuring it. So I don't -- I don't think anybody knows what we can do in that kind of a scenario.

MR. McCLELLAND: I thought I saw some chatter there on the breaker and the DC. You know, if you've got something to contribute, throw it right on the table there guys. I'm sure Mark's feelings won't be hurt. An issue with the breakers, of course, is that with the DC breaker you don't have zero crossing, and therefore you have to ride the entire current out.

DR. McCLELLAND: The other issue about the whole storm thing comes down to short duration, high intensity storm, longer duration, repeated levels, lower down. You may not have the instability that breaks the grid down with the reactive. You may well have nothing but slow, direct heating that you don't see, and maybe that's what happened in the South African unit. Who knows.

There's all kinds of reasons why you can get crud in the oil. I mean overloading the transformer, improper maintenance all kinds of things. But when you get the crud in there, sooner or later something's going to give. So that's just a couple of comments you can make on your own side.

MR. KAPPENMAN: And actually there was no evidence that I'm aware of that was provided to draw the conclusions about corrosive oils. The owners themselves addressed that issue. The transformer expert that we found to have serious credibility problems made those claims. if there is some independent evidence that would verify that, I am not aware of it.

MR. McCLELLAND: Do you know how many amps per phase were involved with the South African incident?

From what I can see, the information on that incident's been very limited. It's been very difficult for us as staff to receive any of that.

MR. KAPPAMAN: Well, I think they've made some estimates. We're talking, you know, in the few amps per phase, you know, just a few amps per phase is levels that they may have been experiencing in those transformers.

We know that from observations in the U.S. as well. We've had some incidents of episodic failures of transformers, all associated with long duration, low level storm activity. Now these failures are not required to be reported. There's no independent experts that ever have the ability to examine the utility data, and that, I think, is a failing of the current system that we have.

You know, I mean it's a lot like the FAA or National Transportation Safety Board being prohibited from looking at black box data. Only in this case, there are not even any requirements of the power grid to install black boxes to begin with, and there's certainly no requirements ever put on the industry, you know, to provide data.

The only data that has become available to us is stuff that has been volunteered, and we know there's lots of other data that does exist. NERC has refused, actually, to ask for that data, to collect that data.

It is evidence. You know, if this is an investigation, we need to have access to the evidence, to determine the findings of this investigation. This is being prevented here by NERC.

MR. McCLELLAND: I'm going to give Mark a chance to respond to that if he likes, and then I want to drill down more to the technical levels, you know John. So what I'd like to do just focus on the technical aspects of these failures. Mark.

MR. LAUBY: Well NERC, through its investigation of these different events, had industry experts that were on our task force, and this included folks from various utilities that have experienced these events. We asked them to provide us their information and they did, and we documented what they provided us.

As far as detailed data, I didn't see a particular need, because we had the industry experts there to provide it to us, and we've then suggested that the folks contact the utility directly.

So I wouldn't say that we're preventing; rather, we were digging deep into each individual organization and asking what happened and give us your perspective. So they had all the reports there and they could summarize them for us.

MR. McCLELLAND: And maybe as a result of this conference too, we can better identify what categories of information would be of interest to the industry, to the experts. We can protect it properly with CEII, and find some ways to release that information to full review by folks that need to see it.

Again, back to the South African incident. I would be especially interested in, you know, any objective data that we can find regarding that event. But let me rewind this, because that -- sort of that exchange reminded me of something in the Oak Ridge report that I think was particularly important.

There was a correlation, John, and then I'll ask everyone to comment on it. One of the points I think you make, Mark, in your written testimony was that the duration, magnitude all have, you know, an impact.

In South Africa was low amperage. The GIC was low. That's one I'm particularly interested in. If it was low, but it was long in duration or repeated, you know, during some period of time, repeated often during some period of time, that could have had an effect.

You know, and it could have snuck under the stability screen, right, because it wouldn't have caused system instability, high reactive consumption, power consumption and no resulting voltage loss. But it could have, in fact, damaged the transformers, which looks like the case.

One of the interesting aspects of the Oak Ridge report that seems to correlate is that you found, John or I'm not sure Ben. I guess it was you, John, that found that there was a sort of a cluster failure associated with GMD events, or could be associated. I mean associated is probably too strong, but it's like a year or two delay, and you saw these cluster failures across system transformers.

Now if you've been in the industry any period of time, you know that those types of cluster failures are very unusual, out of the blue. There might be some incident that occurs that causes the failures to happen, but when you see those clusters, you should really look at them. So do you have any comments on this John, or anybody else, about why that correlates or doesn't correlate?

MR. KAPPENMAN: Well, you are correct. We did do some statistical analysis of failures when they occurred. We looked at what may be the environmental drivers.

We looked at things like U.S. temperature trends. We looked at, of course, space weather as well, and we found the greatest correlation of increases and decreases of transformer failures happen to track geomagnetic storm activity.

In many cases, we can see aging or insults in heating to insulation occur from a geomagnetic storm. It does not cause immediate failure, especially if it's a low level sort of heating event.

But every heating event takes life out of the insulation, and then that accelerates the possibility of failure, or may work in combination with other stresses that happen to initiate the failure in that weakened piece of insulation, in that transformer, and actually the cause gets fully attributed to that other event, even though the geomagnetic storm was a significant contributing factor to that cause.

So we have those sort of problems with, you know, virtually no access to that data to make independent assessments. Now Mark has talked about experts. Well, his definition of experts is not my definition of experts, and in fact we have had significant problems with some of the information provided by their experts in these areas, where we have found them to contradict their own previous statements, where we have found that their claims do not stand up to scrutiny, or that their claims are essentially unsubstantiable in various ways.

You know, I fear that sort of bias is in the process here.

MR. McCLELLAND: Any other comments, particularly on that cluster failure aspect?

MR. HOUSTON: Well, I think that the problem of the cluster failure and trying to go back and figure out when that happened or what drove it, it's clear that people like us at CenterPoint ten years ago were -- we were in Texas, and we weren't worrying about GMD. We weren't worrying about solar storms affecting us.

So if we had a transformer failure, we wouldn't have even attributed that to be a possible cause. So we wouldn't have today, if I look back at the failures over the last, my career at this company, 40 years, I couldn't identify one that was GMD, nor do I even think there are any.

But if there had been, I don't think I would have identified it as such, because that would have seemed bizarre to me.

MR. McCLELLAND: Are you folks immune from GMD, John?

MR. HOUSTON: No, but we're far south, and we thought we were immune until the reports came out.

MR. McCLELLAND: So you're also looking at this now too?

MR. HOUSTON: Oh yes, yes. As I said earlier, we're looking at it extensively.

MR. KAPPENMAN: You know, I would have to comment that there are equatorial processes that can drive very large GICs as well. I tried to identify that for NERC in one of the reports that I filed with them, this phenomena of a sudden storm commencement. This can actually produce large GICs at low latitudes, as a big electro-jet driven disturbance can produce at high latitudes.

We know even less about that phenomena, and NASA and so forth are not even aware of that phenomena in the sort of estimates that Mark is talking about, that are being assembled by that group.

MR. McCLELLAND: Can you point at any incidents where that occurred, John? Can you point out and say "hey, this is historical evidence"?

MR. KAPPENMAN: Yes. There's a number of them. In fact, you know, like I said, it's documented in papers that I've written, reports that I've filed with NERC. You know, New Zealand lost a transformer during a sudden commencement on November 6, 2001, and that's documented as well.

DR. McCONNELL: I just wanted to caution everybody about cluster studies, because you've got many, many variables, and you have to look at the one that seems to be the best most likely cause of this thing. But if you eliminated a lot of others and you do a cluster study and you've got something you can explain, I used to think it was probably severe lightening strike or indirect lightening strike with a steep front.

But it's just as likely to be a long, slow GMD effect of some sort. You just need some way to correlate it, and it's a tricky area, very tricky.

MR. HOUSTON: But I do think that goes to the efforts that are underway, collaborative effort between EPRI and NERC and the industry, to put more GIC monitors out there, to do more documentation of what's happening with transformers, to gather data and correlate it with the Sunburst Program and understand, so that we can correlate the phenomenon all the way to the transformer.

I think we need more sites. We're putting one in at CenterPoint. There's others in the country going in, to try to gather more data.

MR. KAPPENMAN: And I agree with the value of the data gathering. I think that is a very important thing. The part that we're very concerned about is will that data be made publicly available. Will it be made available to independent experts, or will it only be like it is right now, closely held and unavailable or only available to the asset owners.

MR. McCLELLAND: If staff doesn't have a question -- oh, go ahead Rege, because I've got some more.

MR. BINDER: Okay. This isn't about clusters, but I just wanted to get a clarification, Mr. Houston. Whenever you're talking about the modeling efforts at CenterPoint, do you know if CenterPoint modeled all of ERCOT, or just part way into ERCOT?

MR. HOUSTON: No. We only modeled our portion of ERCOT, and part way into ERCOT, to enable us to have the topography. Yes, if we were to model all of ERCOT, we would probably clear up some more of the anomalies that we have with the current data. But we didn't have that luxury at the time. We engaged Metatech to look at our system only, from that perspective. So yes, there's still things to be learned.

MR. BINDER: Okay, thank you.

MR. McCLELLAND: Scott, I have a question for you. In your testimony, you talked about the 20 minute, as little as 20 minute warning. What does that mean, and what type of warning is provided within that 20 minute time frame?

MR. PUGH: Well, I know we'll hear from some NOAA people this afternoon, but of course NASA has a spacecraft called ACE that has been at this point where there's no net gravity between the sun and the earth, about a million miles from the earth, and it's been there since 1997.

So when a CME is launched from the sun, we detect that by a variety of means, and we -- I think even in the Carrington event, it took 18 hours for that wave front of that CME to reach earth. So we get many hours heads-up that a CME is coming, but we don't know -- it's like hurricanes. We don't know if it's a weak one or a strong one until we get more data, and typically the most important data that we get is when the CME actually reaches ACE, and we get information about the magnetic polarity, the density, the speed and all that sort of information to help us determine whether this is likely to be a very strong of just an average event.

And because the bigger CMEs, the superstorm CMEs are moving fast, just by time and distance, it means we have less time than normally. I mean typically we get 45 minutes of reaction to ACE. But for a superstorm like Carrington or 1921, it could be as little as 20 minutes or so.

So we talked about islanding the grid, options like that, unloading long distance transmission lines that act as the best antennas. But that's operator action, and to think that NOAA could issue a warning at 3:00 a.m. on an average night and everybody's going to see that in time, react to it perfectly, not only in the United States, but in Canada, Mexico and other countries around the world, where they could also be affected, I think that's sort of hard to imagine that going off perfectly, since we don't rehearse that very often.

And again, that's why I think a lot of people think that we ought to be also looking at ways to protect the grid, rather than just think that operators are going to be able to do the right thing, given that time frame.

MR. McCLELLAND: And is a KP warning? Is it sort of just validation of what the KP level is for the operators? I mean how does that correlate to the GICs, because what I heard Frank say a little earlier, and I think John was there too, is that look, we're looking at GIC levels, you know, ground-induced current levels. We're looking at amps.

How does the KP correlate to the amps for the operator, because really on a KP index, I mean there have been lots of hey, there's going to be a KP-7, 8, maybe even a 9, and the event hits, and the GIC level is relatively low.

So you know, I think it's a matter of people are maybe conditioned that when this occurs, it might not be so bad. So what is the specific metric that the ACE satellite provides with that 20 minute warning?

MR. PUGH: Well again, I think maybe Bill Murtagh or somebody this afternoon could be more specific, but what it gives us is the magnetic polarity. You know, it's opposed polarity to earth, it's worse case. If it's -- fast is worse than slow; very dense is worse than less dense.

So we get that type of information. NOAA has their scales for, RS&G scales that I'm sure we'll hear about. But so the G scale that goes 1 through 5, just like for hurricanes for geomagnetic storms has a problem, you know, in that in every 11 year solar cycle, we typically see four or five G-5 warnings.

Well that's worse case, and yet all of us have lived through decades of those and never seen a major superstorm. So I think NOAA is struggling a little bit with how to not get into the "he cried wolf" syndrome, you know. How do we get to where we can issue warnings that no kidding, this is a storm for which you better take action in the next 20 minutes, because it's unlike anything we've ever seen, and we don't really have that.

MR. LAUBY: I would add to that too. I think, you know, there is a real need for improving our granularity and ability to forecast, because I know that industry does take action every time certain levels are hit. Of course, Frank can talk to you about that.

But what I -- when I was asked what I want, I told them I want granularity, volts per kilometer, you know, right down to a linear mile if I could get it. The idea of having a global KP index, which is the best we can do, and remember we're not just talking about our infrastructure here. It's also communications, it's GPS, and so it just seems that there is a real need, and we talk about this a little bit in the report, for improved forecasting, not only methods, but also more, you know, infrastructure into the sky.

DR. McCONNELL: This is kind of a classic situation. We have a good warning as the coronal mass ejection curves. It hits ACE. We might have a short of 20 minutes. We get on the ground. We need GIC. The more data we need, the closer we get to the problem.

So and by the way, I think that the more GIC data we could get, the better off we'd be, and even for that matter, just to have some kind of measurements in the individual transformer legs. It's a difficult measurement, by the way, but still something that wouldn't hurt.

There are some E field sensors, I understand, that could be souped up to possibly complement the dv/dt. So there are some issues we've got to look at here, and yeah, 20 minutes is kind of short, but we scram nuke plants in far less than that. So we've got to think about that. Thanks.

MR. McCLELLAND: And it's also not just a matter of level too, because again low level GIC is a problem. So it's, you know again, I'll just point back to Mark. In his written remarks, he talked about duration. So isn't it also -- you know, we could have low levels, but it's a matter of sort of the cumulative effect. How do you address that, Frank?

MR. KOZA: I'm not -- I don't have an answer for that, Joe. I don't know how you address that necessarily.

MR. LAUBY: I would suggest that we need again, the models as John indicated, and we've documented in the report, and gathering the information. We need the infrastructure for the geomagnetic-induced currents, perhaps in a centralized location across the interconnection, so that we can do forensic analysis.

We can start looking at, of course, transformer failures going forward. I've seen information on a time period from '68 to 1993, I think, or '91, something of that nature. We need to kind of update that information, you know. The infrastructure has been going through an upgrade, as Commissioner LaFleur indicated.

So we need to kind of take a look at those. It is a major effort, but I think it's something that could bear fruit in the long term.

MR. McCLELLAND: And it looks like it has to be, you know, at least from what I heard, you know, back to the immunity comments. It looks like it has to be interconnection-wide. Everybody's got to be involved with this.

We've got to look at what the levels are, sort of what the standard of action might be, you know, what levels, with what duration might precipitate, which largely we don't know in some cases, because there are many different types of transformers out there, many different issues associated with the transformers, how gassy they are, what the moisture content is, whether they're end of life, you know, the criticality of the transformer itself and what your neighbors are doing.

So you have sort of all these issues on the table, and they're interconnection-wide issues.

MR. KAPPENMAN: Well in some cases, as I pointed out to NERC, we've been making transformers more efficient as well. That works to increase the vulnerability of those transformers. Now instead of taking a couple of amps of GIC per phase to drive that transformer into saturation, ten times lower GIC will cause those transformers to be driven into saturation.

So those are the sort of evolutionary things that we've been doing, that made sense from an engineering standpoint, but without realizing that there's a vulnerability creeping into the system from this environment that we have never had any standards for, never had any regard for.

MR. McCLELLAND: How about this side of the table? Any questions?

MR. HUFF: I just wanted to ask a couple of questions, to try to discern between the studies of transformers and the impact of GIC to the transformers, the hot spot and so forth in the study, in what I understand is a different type of study studying the electric grid for reactive support. What would happen to the grid during a GIC event?

Frank you mentioned in response to Commissioner LaFleur's, one of her questions, that we have the tools now to, and correct me if I don't have the words exact.

MR. KAPPAMAN: Careful Dave.

MR. HUFF: We have the tools now to study reactive support of the grid. Maybe they're power flow tools, and John, you mentioned earlier about getting the tools in the power engineer's hands to do this analysis.

What's being done right now with the capabilities that we have, for analyzing the grid under reactive support, and if keeping the grid stable? What tools are in place, and how are those being coordinated right now?

MR. KOZA: I would say that those tools just starting to become into place, and we're just on the cusp of trying to apply them to analysis of the system. I mean some people, the early adopters are already out there doing that. They're to be congratulated for that.

Widespread use of those kind of tools in the system I don't think is there yet, but I would expect that will occur within the next year, as progress gets made on creating the tools, getting them out in the industry and getting them into use.

I think your point is well-taken, in that that's a whole different type of analysis, and what is needed to simulate GIC in a transformer. A totally different kind of problem, a totally different kind of analysis.

Those tools kind of exist today, but that's done by the equipment manufacturers for the most part, not the power system planners and operators.

MR. KAPPENMAN: You know, I would also add a word of caution of yes, you know, this is a proper thing to do, to go into a system evaluation of the megavars, and there are some people that are starting to do that. I did that, you know, 30-some years ago, wrote the first paper on that subject.

But we also know that harmonics need to be understood as well. You know, harmonics play a role in whether your compensating device might be there, in the case of switched capacitor banks and so forth. Whether your relay system will have some other upsets that change the dynamics of your system, in a way to negate your ability to confidently study these sort of scenarios. So it becomes an enormously complicated set of problems when you look at it in those facets as well.

MR. LAUBY: I think that you make a very good point, you know. Where are we now and, you know, where do we need to be? As Frank indicated, you know, we have developed an open source code in working with EPRI and 12 other industry organizations. There was a training course recently held at NERC, to show people how to use the tool, and it's now open source and we'll have some follow-on work as well.

Part of that will be, of course, identifying what is the geomagnetic-induced currents that you may see in a transformer. Now, of course, the validation around absorption models, reactive absorption models, we of course fairly well understood. It's documented in a number of reports. Of course, we talk about it in NERC's report.

And then of course harmonic evaluation is fairly well understood too. Once you know what the geomagnetic-induced currents are, and then you know then, of course, you know, you can model some of these perhaps in a simplified way or even more sophisticated with advanced tools.

But the key thing was getting those tools in the planners and operators, I call them operators, operational planners' hands, so that they can do a day-ahead, put the operating procedures in place, as well as start designing systems to meet certain levels.

So I think we're just, you know, launching that piece. We've been at this for well over a year now. So you know, I think that we've got the industry's attention, and we have a very extensive plan that we're going to be pursuing going forward.

MR. KAPPENMAN: On the issue of the open source software, you know, software is one thing. There's been open source versions of this software that have been out there for a long time. What is really the key, though, is the data to put into the software.

Is that going to be open source? Is it going to be transparent? Will it allow for validation and independent testing and analysis and so forth? I think that's an important public policy issue that should not be overlooked.

MR. McCLELLAND: I mean I could just comment on that briefly. I've heard both sides, and I think as far as the concerns for proprietary software, and whether or not they're open and transparent, I think if NERC is able to duplicate the results with its open source software, then I think we validate each other.

If there's a discrepancy or difference, I think we want to -- staff wants to know about that, you know, the open source software that you're using to really determine the same results. The results should be equivalent. If they're not, I think we've got a problem. If they are, they're not such a problem to me.

Regarding the data, I certainly see NERC's concern. The objective of today's conference and moving forward is not to telegraph weaknesses or vulnerabilities in the Bulk-Power System. But I certainly see the other side too as far as peer review, and the best work that we do as engineers and scientists is to subject it to peer review.

So there may be a way to accommodate peer review in a closed, sort of a closed circle, pursuant to some releases of CEII information. So it's just a thought. I mean when I read through the differing testimonies, I didn't see that much of a difference in that area.

It seemed to me that perhaps, you know, parties at the table determined to conduct these type of reviews and reach consensus, should be able to get past these issues. So that's just a thought, folks.

Any other questions? I think what we'd like to do is probably wrap up in the next ten or so minutes. We'll wrap up a little early to let folks scoot down to the cafeteria and get a soda and some quick sandwich or something like that.

MR. SNOW: Just for the record, I'd like to make sure I understand. Many of you in your testimony have used similar concepts but many different words. We talked about over-excitation, GIC current inductions, over-voltages, a whole bunch of different terms.

Could you kind of knit them all together, so that when I chat with my policy and innovation people, who are mostly economists and lawyers, we can say take some idea of what are we really talking about? Because to a large extent, the main theme I've seen so far is "it depends."

If you're in the Houston area, and you see currents of three or five[amps], and John, you can comment on how much current you felt was at no risk, and how much current you might have thought would be at risk for your units.

We know from Frank talking about he has the value of ten amps. I think that's Missouri Avenue, if I remember right Frank? You can tell me where Missouri Avenue is and what the hell that means.

MR. KOZA: Atlantic City.

MR. SNOW: And what that means relative to the rest of the world, because I think it's a 26 kV station that you're measuring currents at. And then how does it all knit together? You know, Ben talked about islanding, as going back to the 1920 system, and bluntly, Mark upped you one by saying well, we have islanding today. It's called series compensation, because it islands the system, as far as GIC is concerned.

It's also a great way to increase transmission capability, which might be something one would look at in Order 1000 implementation, for inter-regional. But knit this together for me.

MR. KOZA: All right. I'll take the first crack. I would say look at the Hydro-Quebec scenario. What happened there was generation of harmonic currents; protection system failure led to tripping of SVCs and a blackout. That's the thing that I can -- we are most concerned about relative to this.

What kind of magnitudes of currents of GIC? That's the thing I don't think we know yet, but the failures mechanisms, I think you look at the Hydro-Quebec incident, that's the one that I think we're most concerned about.

MR. KAPPENMAN: Well, I would offer, in addition to the Hydro-Quebec incident, the failure event also of note during that storm was the permanent damage to the Salem transformer as well. That had to have had occurred within about a one minute interval of time, a very short duration of time, and sufficient heat was entrained in that transformer, to actually not only burn insulation away, but actually melt phase conductors as well.

We know that there are storms that are going to produce multiples of that intensity as well. Even if you want to define it in terms of nanoteslas per minute or volts per kilometer, if you have something that's increased by a factor of four, Faraday's law is pretty specific. It will tell us that the volts per kilometer will go up by a factor of four or a factor of ten as well.

So and these sort of heating events can be very rapid onset. I don't think the models that are portraying these heat events are at all dependable and reliable. They certainly have not been validated.

MR. LAUBY: It's a good question because you know, sometimes people say that I talk in two tongues, engineering and then regular, and sometimes I get tied into the engineering part, and even I don't understand myself sometimes.

Specifically, with what we see happening on the grid and, you know, why we have kind of taken this kind of engineering approach to look at the system first and foremost, to see well, what is the reactive requirements? How quickly does that onset happen, and then of course then you can play your what ifs on SVCs, etcetera, not being available.

Then not ending there, not stopping there. Also then go to the next time frame. Look at the wave fronts. Look at what's possible. Play with those wave fronts. Do your sensitivity analysis. Look at the different ground impedances and how you might want to amplify that. Look for worse case on your system, because we can then look at the resiliency.

So look at both of these elements, because they do tie together, and of course validating the information is going to be very important, and we take that seriously. That's why we're pressing to get some additional tests done on transformers.

My colleague, Frank, talked maybe to fail or whatever. Of course, it will depend on the kind. There are a handful of different types of transformers, and I wouldn't even try to lecture you on what happened at Salem, because you studied it ad nauseam.

But you know, we learned something from that design, and presumably we can learn things from other designs, and that will continue to improve the specifications going forward.

DR. McCONNELL: I would make one comment. You were talking about basically excitation of a transformer. What happens is we've got better steels. In fact, they're very low loss. As John pointed out, we've worked our way right into a hole.

It turns out that those steels have a very sharp knee, and we try to operate as high in the steel as we can operate, to get the most bang for the buck. About 1.8 teslas is pushing the limit, but that's about where we're at.

All you've got to have is a little bit of DC on the other side and the curve turns the corner and it's extremely non-linear out from that point. Just a few amps into that neutral will push one side of the operating envelope into a saturated event, and it's super-saturated at that point.

I mean the core will heat up extremely fast, and then that becomes -- that couples back to a heat transfer problem that is not simple to calculate here. The invective flow model is not blown completely away. So you've really got to play around with this calculation.

It's tricky, and knowing what the geomagnetic injection is conjection is, and knowing the transformer design, whether it's shell form, core form, single phase, a three phase, five leg, three legs, you know, even four legs. You've got all these kind of things that are going on that are difficult to calculate.

I'm all for testing. I've done my share of it. I've tried to wreck a few transformers, and I've managed almost to do it until somebody decided to blow the fuse and get me out of the building. But nevertheless, I think we've got a tough problem. But we do need data. We need to share the data. We need not try to hold it close to our vest because we've got something we think is proprietary.

This kind of data is going to help everybody. If we lose one part of the grid, the rest is going to have to suck wind and fall soon to come up with it. So it's all tied together. You've got to do that kind of thing, and the modeling is not simple by any stretch of the imagination.

MR. HOUSTON: I'm not sure that we've knitted together all of the acronyms in the discussion this morning. But you asked about the why are we somewhat confident in Texas at the moment. Well, it's based on models that we've secured from Metatech, and we've used our internal engineers to evaluate the specifics of our system.

We've gone back to Metatech and clarified the results, and in some cases made some changes. But it's a theoretical GIC, based on the situation that we are in in Texas. We are installing GIC monitoring, but we don't have long history of data on that. The Sunburst system, we're members of that.

So we don't have a correlation to actual GIC in Houston, Texas in transformer damage. That's why I couldn't answer Joe's question earlier, how come you don't know if there were GIC failures?

But I think there's some -- Mark talks quickly about studies and things. I think the harmonics piece of this is going to be one of the more challenging aspects, because that's not just pure power flow. You really have to have your relay engineers involved to understand which relays are subject to harmonic distortions and which ones are withstanding it.

That's a whole system design as it sits out there today. Then lo and behold, you find that that's not going to be functional. Now you've got to figure out what you're going to engineer to change that. I don't think Mark, with those kind of studies, are going to be something we can do on a NERC basis.

MR. LAUBY: Well, you wouldn't -- harmonics are more of a localized phenomena. And so, you know, we know how to study short circuits, harmonics. Those tools are available to folks. It's a matter of now germinating well, what does that wave front look like?

We had that. In part of a study, we had, you know, a major relay manufacturer engage with us, and they've looked at how you would filter these things out and say that the mechanisms are there.

But you're right. You need to be able to set these right up and do the studies. Set them right, so that you're not tripping early like what happened in Hydro-Quebec, where you hit over ten amps, I believe, or something of that nature, and were tripping out static V Ar compensators when they shouldn't have been, you know, when they needed them, you know.

MR. SNOW: See if I got this right. We've got some GIC currents --

MR. McCLELLAND: Bob, I'm going to give you a little caution. We'd like to wrap up probably in the next five minutes. But please, finish your question, please. Just hurry, Bob.

MR. SNOW: So we've got the GIC currents that cause saturation. The saturation is very similar to over-excitation that we see in the existing standards. That causes fluxes to move in areas that weren't designed to move in. So you get connections and other things that cause failure.

John identified the, I think the two transformer failures at Salem, Salem I and Salem II respectively, where the windings, part of the windings and part of the leads, at least the open source information identified melted those windings, melted the metal in the windings, charred the insulation. So that's one type of failure. You can get a bunch of other different types of failures.

The system impact of all of this is that when you're saturated, then you start to absorb lots of reactive, and you produce lots of different harmonics that you hadn't seen before, some of which look like negative sequence and hit your generator end windings and retaining rings and cause, just as they did at Hope Creek, the negative sequence alarms to go off in those units.

So kind of, I think, your response to what if this happened to a generator, I think we know what happens to a generator with negative sequence, and it's not good. So this is kind of how you put the dots together.

So but it all depends on the geology, where are you and I think John you put together some identification, that not all transformers are equally susceptible, and in your report, I believe you indicated you agreed with John Houston that Texas, his area, probably has very little, in terms of 90 amps or greater, transformers.

But the areas where I'll call it in Frank's backyard or front yard, as the case may be, and New England, Michigan, those are all front and center in your things. Did I kind of knit all that together right?

VOICES: You did. You did a good job.

MR. SNOW: Thank you.

MR. McCLELLAND: Yeah, you did.

MR. SNOW: Is that quick enough, Joe?

MR. McCLELLAND: But it wasn't a question, Bob.

(Laughter.)

MR. McCLELLAND: No, it wasn't a question.

MR. SNOW: Did I get it right? It was a question.

MR. McCLELLAND: Yes, you did. Martin, a question.

MR. KIRKWOOD: Thank you, Joe, and my question actually starts leading into the next panel, but while I have Mr. Koza here, I just wanted to ask him about something he mentioned in his prepared statement.

That is that you provide four suggestions, and in one of them, and maybe others, you suggest can occur even before more detailed analysis capability is available.

One of those suggestions is that each asset owner needs to determine the overall health of its EHV transformer fleet, and develop strategies for GIC mitigation, for identified vulnerable transformers. What strategies do you see coming out of that type of analysis?

MR. KOZA: Well, let me talk about the process first. We all abuse transformers in their life, and I'm hesitant to go to medical analogies here. But I mean the transformer has a history, just like our personal health does, and we need to understand that. We need to understand what it's been through, that kind of thing.

It's from that point that we should look at where are I'll call the weakest links, given the relative transformer health on the system. Let's look at the transformers that are the weakest ones, and develop strategies to take care of it.

It could be blocking. It could be to consider replacement. It could be additional protection systems. It could be a number of different things, based on the factors that are involved.

MR. KIRKWOOD: And would those activities, I understand that the suggestion is that each asset owner would take that on. Is that happening today?

MR. KOZA: I can't speak for the asset owners. You'll probably have some of them on the panel this afternoon.

MR. HOUSTON: I can speak. It's happening for some asset owners like ourselves, and there's others that I am aware of in the industry, yes.

MR. KIRKWOOD: Okay. All right, thank you.

MR. McCLELLAND: Well, unless we have any other burning questions from staff, Commissioner. You could ask any question, not just a burning question.

(Laughter.)

COMMISSIONER LaFLEUR: I have burning questions for this afternoon.

MR. McCLELLAND: Okay, great. Well, I appreciate each and every panelist that was here. Thank you so much. It can be difficult. I know we had some differing perspectives, but I appreciate the candor and the professionalism that each of you showed, and also the willingness to come in here to the Commission today.

So thank you. We're going to convene this technical conference until quarter to two. Quarter to one. Quarter to two. I was right the first time.

(Whereupon, at 1:18 p.m., a luncheon recess was taken.)

A F T E R N O O N S E S S I O N

(1:49 p.m.)

MR. McCLELLAND: Okay. If we could find our seats, we can reconvene this afternoon's panel. Well welcome back, everyone that chose to come back for the second session. I think we had a good, productive first session. I'm looking forward to hearing from everybody on this second panel.

It's entitled "Moving Forward on GMD." The first panel was more about the technical issues. The second panel will be more about policy. What should we do, sort of any commonalities that we found that we could address together.

So I appreciate it. I want to thank each and every panelist that came today. I appreciate you spending the time to prepare testimony and for taking time from your schedule to be here. So I look forward to hearing from everyone. In order to facilitate that, well I think we'll just jump right in.

So I would ask each of the panelists to introduce yourselves, name the organization you're from, and then continue right into your five minute comments. So with that, we'll start with Mr. Murtagh. Welcome.

MR. MURTAGH: Thanks, Joe. Good afternoon, everyone. I'm Bill Murtagh, the program coordinator at the NOAA Space Weather Prediction Center. The Space Weather

Prediction Center is the nation's official source for space weather, alerts, watches and warnings. We monitor the solar images for the development of sun spots.

Sun spots are to us much like an area of low pressure is to a meteorologist. That is, it's an area where we're going to see weather, but of course for us it's space weather. Sun spots represent a localized, complex magnetic field, where solar eruptions can occur.

When a large eruption occurs, it usually consists of both the solar flare and the coronal mass ejection. Coronal mass ejection, otherwise known as a CME, is a massive cloud of billions of tons of plasma gas in magnetic fields. CMEs occur almost daily during active periods in the sun, mostly during the solar maximum, which we're approaching now. The next maximum is expected in 2013.

They are ejected out into space and are on occasion earth-directed. They can take anywhere from 17 to 96 hours to make the 93 million mile journey from the sun to the earth. So quite a range there.

For the forecasting process, the four critical steps in geomagnetic storm forecasting is one, we have to observe to see if there was a coronal mass ejection, first of all; determine then is it earth-directed, because these things pop out from the sun going in every direction; determine how fast it's moving; and then of course the biggie, predict the magnitude when it impacts here on earth.

If it's determined that it will impact earth, the NOAA forecasters will issue a geomagnetic storm watch. So this is a hurricane 48 hours offshore. We'll give a watch to people on the shoreline, something's coming; we know it's going to be fairly big; we don't know the details just yet. But we will advise customers that a geomagnetic storm is likely. We will say when it's going to occur, when we expect it to occur and how strong it will be.

Many hours or days later, after traveling most of the 93 million miles from the sun to the earth, the coronal mass ejection will impact the NASA Advanced Composition Explorer, that ACE spacecraft at what we call the LaGrange orbit.

Forecasters now have a much better understanding of just how strong the geomagnetic storm is likely to be. So we're still in predictive mode, and a warning will be issued, indicating that the geomagnetic storm is imminent. Some 20 to 60 minutes later, the coronal mass ejection will impact earth's magnetic field, and then the alerts are issued that the storm is now in progress.

A worse case scenario would unfold if we had a series of these coronal mass ejections. Something that hasn't been really touched on yet, but there are certain situations when we can have a couple of big sun spot clusters in the sun, producing these coronal mass ejections, and if we should see that situation where we get one, two or three coronal mass ejections over a two to three day period, it would be pretty significant.

I did want to mention, and we can elaborate this perhaps in our discussion, that in 2003, on October the 28th, we were looking at an 1859 Carrington scenario. If in the next coming weeks, months or years, and I see the sun like I did on the end of October 2003, I will be on the phone to a lot of people in this room. Everything was there except for the last piece, that we should talk a little bit more about in our discussion.

The dissemination of this information. Watches, warnings and alerts in the NOAA SWPC are sent to the Midwest ISO St. Paul, Minnesota office and the Western Electric Coordinating Council reliability coordinators in both Loveland and in Vancouver in Washington. They've been designated to receive and disseminate these notifications of potentially severe storms, and they redistribute it to the reliability coordinators, balancing authorities and transmission operators around the country.

So that process is a very important process that's in place right now, and just recently, we did a little bit more work, to make sure that when we had a kind of extreme situation, that we could get this information out, and that we set up a process to establish, to essentially coordinate with all 16 reliability coordinators on a teleconference.

MR. BINDER: One minute, sir.

MR. MURTAGH: I just wanted to mention one or two things about the limitations, the forecasting limitations that were discussed already, and one is on the K scale and K alerts and warnings. They're not very useful in specifying GIC. They have their use, because our customer base is a lot more than just the power grid.

So they're useful in other areas, but certainly limitations in support of the power grid, and they are global. It's a global warning. It's not specifying regionally where this GIC might occur. There's a saturation point that's a big problem. I could have a G-5 condition that would be, we measure it in nanoteslas deviation that would be 500 nanoteslas, and if I have a deviation of 5,000, it's still a K-9 or G-5 storm. That is a problem. We're missing that big picture.

So just to conclude, in our response to that problem, efforts are well underway, working with NASA, NOAA and the Community Coordinated Modeling Center at Goodard, to provide regional specification of geomagnetic storming, using more appropriate indices, dv/dt, and to map out where and how strongly geomagnetically-induced currents may impact earth.

So we recognize the limitations. We're trying to do something about it. Thank you.

MR. McCLELLAND: Is there anything, Bill, that you didn't get to include, that you'd like to sort of name right now? Because I know we hurried you along there.

MR. MURTAGH: Say again?

MR. McCLELLAND: Was there anything that you didn't get in your presentation?

MR. MURTAGH: Well, one other thing, it will probably come up in discussion to, is the importance of some of the satellites that we're relying on. That ACE satellite I talked about, that sits out there at a million miles out, it's 15 years old. We really need that for warnings.

If it goes tomorrow, so does our warnings, our imminent warnings. Now fortunately, we've had some success, thanks to some people in this room indeed, to make this issue very high visibility on the Hill and in the White House, and we do have a solution in place, the Discover spacecraft.

We're hoping to launch it in summer of 2014. It's a tri-agency effort with the DoD and with NASA. It's a NASA spacecraft. DoD is going to provide the launch vehicle. NOAA will fly the mission do the refurbishment. So that's a very important piece of good news to share with the folks in this room.

MR. McCLELLAND: Thank you, Bill. Singh, welcome.

MR. MATHARU: Good afternoon Commissioners, audience, FERC staff. My name is Singh Matharu and I work at the Nuclear Regulatory Commission. I'll give you a brief background to our regulations and where we are today.

The discussion that I'm going to provide below is strictly the view of the staff, and not necessarily a view of the agency. The NRC role, as you know, the overall responsibility is to license and regulate the nation's civilian use of nuclear materials, in order to ensure the adequate protection of public health and safety.

Commercial nuclear power plants rely on electric power transmission network to export power and to regulate safety on the plant when required. For this reason, the NRC regulations assume high reliability for transmission network in the vicinity of the plants, to ensure long-term safe shutdown capability of the plants, and continued cooling of the onsite spent fuel.

Onsite power systems, such as the batteries and emergency diesel generators are available in the event of loss of power from the transmission system, and have the capability to provide power up to seven days, depending on the location, depending on the circumstances.

The NRC staff does not have direct regulatory authority over the electrical transmission systems. However, the staff does collaborate closely with FERC and NERC, because grid reliability is important to us.

The current regulations. The regulatory requirements for the design and operation of nuclear plants are delineated in Title 10, Part 50 of the Code of Federal Regulations, and there's an Appendix A specifically titled "General Design Criteria," that provides specific guidelines that U.S. plants are required to comply with.

I'll give the two specific ones that are applicable here. One is GDC-17, that relates to electric power systems, which requires that nuclear plants have onsite and offsite electric power systems to permit the functioning of systems, structures and components that are part of the safety.

We also have GDC-2, that talks about design basis for protection against natural phenomena. It requires structures, systems and components bound to safety to be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, etcetera, without the loss of systems ready to perform safety functions.

We also have 10 C.F.R. 50.63, which is power station blackout, which talks about complete loss of AC power. As we know, the existing nuclear plants were designed prior to the indepth understanding of geomagnetic storms and their impact on electrical equipment.

Hence, the GDC-2 that I talked about, natural phenomena, was not really applicable when the original plants were licensed, and it's not in the design basis of most plants. The NRC is aware of the potential significance to EMP to the critical missions, critical infrastructure.

We've done studies. In '83, there was a Sandia Lab report that the NRC commissioned, that looked at the EMP and results, and it concluded that the safety-related functions would not be deteriorated as a result of EMP.

In 1989, when the storm in Canada did some damage to the equipment, NRC issued Information Order 90-42, which was titled "Failure of Electrical Power Equipment Due to Solar Magnetic Disturbances."

The intent of the IN or the Information Notice, was to alert the nuclear plant owners about possible failure modes of electrical power equipment in nuclear plants, and the connected transmission systems due to solar magnetic disturbances.

The information order details all the things that happened at Salem, Hope Creek and a couple of other plants.

MR. BINDER: One minute, sir.

MR. MATHARU: Geomagnetic Task Force, we are participating in the agencies that are evaluating the effects of the GMDs, and we'll look at the recommendations that NERC and FERC give us on that. As far as the impact of geomagnetic disturbance on nuclear power plant, we realize the offsite power is vulnerable, because we do have connections to the switchyard here on the grid.

The connections involve transformers and breakers, and we know there's a vulnerability there. As far as the plant transformers, a typical single unit nuclear plant has maybe a step up transformer or a GSU. It has got two auxiliary transformers, and two start-up transformers.

The start-up transformers are the ones that are important to us, because they are the ones we need to safely shut the plant down. They are the GDC-17 source of power. These transformers have ground neutrals, are connected to the HV system, but they are not loaded. Typically, they're not loaded. They are in standby condition.

So we suspect or we expect these transformers to be reliable in the event of a storm. The onsite emergency diesel generators are in typically standby mode, and are not expected to be affected by solar storms. So the current practices that we have, we expect the NERC mandatory requirements that the transmission system operators have reliable offsite source.

We realize that in the event of loss of offsite power in the vicinity of nuclear plant, existing agreements between nuclear plant operators and grid operators require a high priority for restoration of power to the plants, and we also know that some plants have procedures to reduce power output in the event of a solar storm.

So in conclusion, I would conclude we expect the transformers that are required for offsite source to be available if the grid is available. We are monitoring the activities that NERC and FERC is continuing on, as far as the protection of the infrastructure. We are enrolled in the ongoing activities.

The near term actions being taken in response to the Fukushima Daiichi event, we are looking at restoring or at least securing fuel for our onsite power supplies. That concludes my presentation.

MR. McCLELLAND: Thank you, Singh. Direct from the UK, Mr. Michael Cousins. Mike.

MR. COUSINS: Thank you. My name is Michael Cousins. I'm the head of -- I'm sorry, thank you. My name is Michael Cousins. I'm the head of Gas and Electricity Resilience at the UK Department of Energy and Climate Change.

So thank you for the opportunity for the UK government to participate in your GMD conference. The risk of GMD to power grids is fully recognized by the UK government. Our government departments have worked extensively with space weather scientists and engineers, industry, private sector, asset owners and regulators, to gain the best available constant assessment of the risk to UK infrastructure.

Depending on the magnitude of the event, the current assessment is that severe space weather would be expected to have moderate to significant effects on the UK infrastructure. In the energy sector, the UK government is working closely with industry, through the Energy Emergencies Executive Committee, commonly referred to at E3C, to clarify the potential impacts on GMD on electricity assets.

This will inform continuously planning mitigation, that is appropriate and proportionate. The E3C has representation from industry, trade associations, Ofgem the independent economic regulator, the HSE, the independent safety regulator, consumer groups and government.

The UK government believes that the effects of GMD are more fully understood by extending and continuously improving on models developed through that forum. So moving forward, I'll describe using the following headlines: modeling, monitoring and mitigation, the 3 M's.

So first, the modeling. Currently in play, the generating community in the UK have submitted new information to the prior TSO, at my department's request. This was initiated in October last year, and all data have now been received. The information requested was for details on generators, transformer design, location and connection configuration.

This information is now being used by the primary TSO, in association with the British Geological Survey, to expand an impact assessment model that previously considered the transmission network only, to now consider generator transformers also. The findings of this work is to be reported to E3C in the coming months.

Secondly, monitoring. A new European Union project to forecast space weather began in 2011, and will run until 2014, led by researchers at the British Antarctic Survey. The Spacecast Framework Protocol 7 project will provide web-based forecasts primarily for satellite operators.

But the UK is also involved in the European Risk from GIC Project, another FP-7 project, through the BGS. The same to produce the first European-wide real time prototype forecast service of GIC and power systems. And of course, there is the ongoing collaboration between the Met Office and NOAA, Colorado, to improve forecasting techniques and to share knowledge and skills on space and terrestrial models. The METOP is providing Ensemble, which is their model for forecasting.

The UK government believes it is important that the UK has sufficient access to up to date monitoring information, both to inform any response to a significant space weather event, and to support routine business continuity.

Importantly, our primary TSO has recently contracted BGS to provide data for the monitoring and assessment of GIC to MAGIC (ph), to calculate the current state of GIC flow in the transmission network. This uses data from three magnetometers in the UK, to provide a nowcast of the electric field, and interleads this with the TSO's network model.

It's a model GIC. The TSO is also installing new equipment for the direct monitoring of GIC and transformer-neutral connections at a number of substations.

MR. BINDER: One minute, sir.

MR. COUSINS: Thirdly, mitigation. There are, of course, two main methods of dealing with the risk posed by GMD, operational and hardening. Take hardening. The primary TSO has adopted design standards on transformers which are better able to withstand GIC, and it has increased its spare holdings of transformers.

Consideration is being given to the installation of series capacitors on certain transmission lines, albeit the series capacitors are primarily being considered for reasons of load control, to overcome future operational challenges, of operating large amounts of renewable generation.

There's also a watchful eye on the development of neutral current blocking devices, but it is recognized that there are both risks and benefits associated with hardening equipment. Cost is, of course, a factor when dealing with risk in a proportionate way, and hardening one part of our system may simply transfer the vulnerability to another.

This is especially relevant to the UK, where its transmission network is heavily interconnected, and undergoes frequent, continual reconfiguration. Preventive operational mitigations are linked closely to the performance of integrated forecast and monitoring chores, and the UK describes an all-in strategy consisting of returning circuits from maintenance, coupling substations as much as possible, and reducing large power transfers across systems, increasing megavar reserves and synchronizing more generators to provide margin for fallback across the network, and therefore lightening the load on generator transformers.

Lastly, industry has well-exercised blackstart procedures. In such an emergency, government and industry have significant roles to play, and E3C maintains and updates contingency plans for managing energy emergency. Only last month, we exercised our rotor disconnection procedures. Thank you.

MR. McCLELLAND: Thank you, Mike. Did you get everything in?

MR. COUSINS: I did. Thank you.

MR. McCLELLAND: Long drive to get everything in, so we've got to make certain.

MR. COUSINS: You're welcome.

MR. McCLELLAND: Mr. Cauley.

MR. CAULEY: Thank you, Joe and thanks to the FERC staff for sponsoring this conference, and the Commissioners for their attention to the issue. I think it's clear from everything we've heard today, we have a very difficult task ahead of us.

We look at risk to the Bulk-Power System in an all-hazards perspective. There are things we deal with every day, from storms and equipment failure, and the challenge is really to understand the risks, and really be able to characterize them in a way that we can envision solutions, and many of these are mature issues that we understand well and some are not. I think we're on one of those today.

The NERC Task Force report points out two key risks, one for system disturbance and voltage collapse, and the other for potential equipment damage. I think there were some things said earlier in the first panel about NERC's theory being that voltage collapse will save the day. I don't recall seeing that. I don't think that was intended to be the implication of the NERC study.

I think what we're saying is there are dueling concerns. The magnitude of a voltage collapse can be significant, as we saw in Hydro-Quebec. We also know that there's evidence of equipment damage. But we need to put each in perspective, in terms of what the information tells us, and the magnitudes of those individual risks, supported by data as well as historical information.

One thing's clear today, is that we're dealing with a great deal of uncertainty. This is not a well-known science. I heard one of the first panelists even mention chaos theory, and in some respects, this is a natural phenomena that sort of emulates chaos theory to some extent.

So it's very difficult to think about structuring forecasting tools and analytical tools around something that really is a free form type of major event.

This is also a risk that we share with other industries, satellites, communications, air transportation and so on. I think the NERC report and its intend was really to put 20 recommendations on the table, and I view that as basically a starting point, a road map. It's not the end of the road, and I think we've heard some ideas today that I think add, flesh out some of those suggestions.

But the challenge really is in policymaking, and how do you make policy in such a great -- with great uncertainty and lack of clarity in terms of the technical underpinnings of this. I think we have to do that carefully.

I'm going to suggest some things I think are good next steps. I think they're very consistent with Commissioner LaFleur's remark regarding no regrets, yet significant progress forward.

First off, I think one of the keys is analytics modeling, and analytics in the data to support that. I would envision a mature science around geomagnetic disturbances as being something akin to our understanding of fault currents, planning tools that we have, harmonics that we study regularly and we include in our design and planning requirements. I think that would be a mature vision.

I think we have a lot of work to do to share the models. I think some of the joint work we've done with EPRI to share that information has made some progress. I think we can also work with the vendors to get some of the detailed modeling of the transformer characteristics as well.

As a complement to the modeling aspect, I think one thing we heard today, this morning that I agree with is the need for more data. So I would be an advocate of data devices that can monitor the currents themselves located in key locations, as well as the performance and response of system equipment to those events.

MR. BINDER: One minute, sir.

MR. CAULEY: Yes, thank you. Another key aspect would be the work on the historical basis of the magnitude of events, and what are critical scenarios.

I think we heard today that it's difficult to frame it around 100 year or a particular magnitude. But what are the key attributes of events, and how do we benchmark against historical events that we're seeing, to get a better picture of what the appropriate benchmarks would be?

I think we have an opportunity to work with vendors. I think we've seen a lot of progress from vendors to date, following the '89 event in Quebec, where we saw some technical studies and some advancements in equipment design. I also have talked to some utilities who have made modifications to some of their equipment already.

The question of vulnerability assessment, I think Commissioner LaFleur, I spoke with her, and we're looking for some kind of near-term assessment of the vulnerability.

I would advocate that we gather information from industry on transformers and equipment that might be more susceptible, might be in the near-term more vulnerable, and see if we can understand better the nature of that, in terms of the number and the nature of those susceptibilities.

I think we should begin the task of monitoring forensics on transformers, not just normal maintenance and performance, but looking at failed transformers and other historical performance, to see if we can gather data that would help us piece together the puzzle here.

I apologize for going over, but I had one more remark, at least. The spare equipment, I think, is a key aspect as well. I know EEI's STEP program has made a concerted effort to identify spare equipment for catastrophic failures, and I think we need to look at expanding that program, and make sure that it's available and not just to EEI members, but also to the entirety of industry, as well as potentially generator step-up transformers or GSUs.

I applaud the effort in the modular transformer research. I think we need to continue that. We also encourage further investment in the forecasting and alert process. With that, I'll end. I'm encouraged by the industry's response and the seriousness with which they're taking the issue, and I think this discussion today will help progress for the future. Thank you.

MR. McCLELLAND: Did you get all your points in today?

MR. CAULEY: Yes, I did. Thanks.

MR. McCLELLAND: Thanks. Okay, Mr. Peter Pry.

DR. PRY: Thank you so much for the FERC giving me an opportunity to testify today. Thank you for having me here. I'm Dr. Peter Vincent Pry, Executive Director of the Task Force on National and Homeland Security, that is newly-established to advise Congress on natural and man-made EMP and other threats.

I've spent most of my professional life working on security issues and electromagnetic pulse effects, first with the CIA and then on the House Armed Services Committee, and nearly a decade on the Congressional EMP Commission. NERC recently released a report asserting that even a worse case geomagnetic superstorm, like the 1859 Carrington event, would likely not damage most power grid transformers, and result in a blackout lasting only hours or days, but not months or years.

NERC's assertions are not supported by any of the official studies performed by the U.S. Congress or the U.S. government. Reports by the Congressional EMP Commission, the National Academy of Sciences, the Department of Energy and NERC itself, the Federal Energy Regulatory Commission and most recently the Defense Committee of the British Parliament, all independently arrive at the scientific consensus that a great geomagnetic storm could cause widespread damage to power grid transformers, result in a protracted blackout lasting months or years, with catastrophic consequences for society.

My task force recently produced a report comparing the scientific methodology used in the industry-sponsored NERC report with that used in one of the U.S. government studies, the 2010 FERC report. Our analysis finds that the FERC report used a far more rigorous scientific methodology, and arrived at better-substantiated and more credible conclusions.

Therefore, the U.S. government-sponsored FERC report is recommended over the industry-sponsored NERC report as a basis for making public policy. Our and other critiques of the NERC report are appended to my testimony.

The NERC report is not serious science. It is junk science, political science intended to derail legislation now before Congress to protect the national electric grid from geostorms and other threats. We hope the NERC report will be retracted or ignored.

We urge the NERC report's authors to recognize that their report, unique among all others in its optimistic assertions, could contribute to a possible failure to harden the U.S. grid against a severe geomagnetic storm.

The electric grid alone is not at risk. Everything in our modern society depends, directly or indirectly, upon electricity, including all the other critical infrastructures, communications, transportation, banking and finance, food and water, that sustain modern civilization and the lives of 300 million Americans.

What is to be done to increase our understanding of the threat to the electric grid, and to advance protection of the electric grid on an accelerated basis, given the already-known severity and proximity of the threat?

Continued study of the natural EMP threat from geomagnetic storms and a solution to protect the grid should not be led by NERC. Instead of NERC, a truly objective and trustworthy actor is needed, to lead continued study of threats to the electric grid and solutions.

On my short list of nominees for this leadership role are FERC, Oak Ridge National Laboratory, NASA and the National Academy of Sciences, NORTHCOM, the Defense Science Board Task Force on EMP, or my own task force.

Continued study should not become an excuse for doing nothing. We already understand geomagnetic storms and other threats well enough, and already know that the danger to society is great enough to warrant taking immediate action to begin protecting the electric grid now.

Passage of the Shield Act is necessary to put in place the legal authorities and financial mechanisms necessary to start grid protection now. Pilot projects should be launched to protect the electric power grid from geomagnetic storms, nuclear EMP, cyberattack and all hazards in one or more states.

From pilot projects, we can learn what works best, what is most cost effective. A pilot project could be launched in Alaska. Alaska passed a resolution calling on Washington to help protect Alaska's electric grid from natural and nuclear EMP. This resolution from the state and people of Alaska, calling upon Washington for help, is appended in my testimony.

New York state is another possible candidate for a pilot program to protect their electric grid. New York is among the most vulnerable of the lower 48 states to natural EMP because of its latitude, and to nuclear EMP because of New York City.

Over 1,000 mayors passed a resolution petitioning the White House to protect the New York state electric grid from natural and nuclear EMP.

MR. BINDER: One minute, sir.

DR. PRY: This petition from the people of New York state is appended to my testimony. Texas and other states have shown interest in moving forward to protect their grids, without waiting for Washington. I only wish the wisdom and enthusiasm of these states for protecting their electric grids and their people from an EMP catastrophe could be matched by the Washington elites, who are supposed to be protecting them.

As FERC Commissioner Cheryl LaFleur declared last year at the International EMP Summit, we have done enough studies; it is time to act. Thank you for hearing my views, the views of my task force, and this concludes my statement.

MR. McCLELLAND: Thank you, Dr. Pry. Mr. Heyeck.

MR. HEYECK: Good afternoon. I want to thank the Commissioners and staff for the opportunity today to speak on behalf of American Electric Power. I just wanted to say that the agenda says that I'm president of Electric Transmission America, which is correct; but I'm not president of Mid-American Energy Holdings Company, nor am I president of AEP. I'll speak on behalf of American Electric Power.

MR. McCLELLAND: We did our best, Mike.

MR. HEYECK: AEP owns approximately 39,000 miles of transmission, including over 2,000 miles of 765 kV, and we go from the Mexican border in Texas, north to Michigan and eastward to Virginia, encompassing PJM, Southwest Power Pool and ERCOT.

My written testimony deals with things that are already covered. So I wanted to go over a few points of what I think could be done today, and I think some of these agree with prior panelists.

Let's take advantage of the current cycle to get data. Let us centrally monitor numerous sites collectively and consistently across North America. We have at AEP, we do have a number of sites that we're monitoring today.

There's EPRI Sunburst. There's a lot of anecdotal monitoring I suggest that we centrally monitor and bring together in real time, as well as for forensics. In real time, I think an RTO would be a great place to collect the data. Again, AEP has several monitors already. So let's take advantage of the current solar cycle to learn from it.

Number two is to work with manufacturers, IEEE, IEC, to develop more robust GIC standards and testing procedures. We do order transformers today with higher GIC withstand ability. The issue is it is hard to test to those abilities. So we get the transformers, but they haven't been tested fully to those GIC withstand capabilities.

Number three is identify vulnerable transformers and vulnerable protection of large reactive power devices to monitor and mitigate issues. AEP is a large company. We tend to know what is vulnerable, and we're acting on it.

But there are thousands of players in the North American grid, thousands, one which may only have 1 GSU in a critical plant in a critical location. Munis and coops, they don't know whether to do something or not.

Number four is to develop a North American database of spare transformers in a vulnerable class, as NERC is suggesting.

Number five is to keep the best of the old as spares when replacing large transformers. This is an AEP transmission practice. We have very much -- we're the only player in the United States significantly of 765 kV transformers. So when we spare these transformers, we put in three single phase units, and we have a fourth come in brand new.

Well that means we have four others. So of the four others, we're going to keep the best of the old, and that's our practice. 345 kV transformers, we do have high sparing as well, and we also subscribe to the STEP program in that. So let's keep the best of the old, if we got it wrong with respect to solar cycles.

Last but not least, let's employ a risk-based approach to ensure our customers are not paying more than they should. We've got to recognize that someone out there is paying for all this.

I wanted to give you analogy, because I'm a pretty practical person, okay. I am not a geologist. I don't know anything about hydraulics engineering. But I do recognize in my house that I have a sump pump that's very active, and when does a sump pump stop? When a storm's around.

So what did I do? I got a battery. I didn't do any studies. I just got a battery to back it up. I figured if that battery runs out in four hours, I've got a few other batteries in my cars to do it.

The point is we could do something right now to take a good approach as to what spare equipment we have, what equipment is vulnerable, and what more spares we ought to go over.

MR. BINDER: One minute, sir.

MR. HEYECK: And then let's act on that. But I remind you that AEP is a very large company, and I appreciate being here. But there are thousands of other entities out there in North America that really need the help and guidance of what we come out with. Thank you.

MR. McCLELLAND: Thank you, Mike. Did you get all your points in, because we had the one minute warning there? Did you get it?

MR. HEYECK: Yes.

MR. McCLELLAND: All right. Next, is Mr. Steve Naumann. Welcome, Steve.

MR. NAUMANN: Good afternoon. I'm Steve Naumann from Exelon, and I'm appearing today on behalf of the Edison Electric Institute, of which Exelon is a member. Thank you for inviting me to speak at this conference.

Now that NERC has issued its interim report, we need to implement the action steps on an expedited basis. The analysis phase needs to be performed, to provide input for further analysis of the potential vulnerability of the transformers, any system changes, including possible mitigation, and information used in the specification of transformers.

Performing system analysis to determine potential broad system effects and impacts on both the electric grid and transformers is necessary before NERC or anyone else can recommend what if any mitigation strategies should be used to ameliorate the impacts of severe GMD events.

This analysis and the underlying models must be open for review by experts from all parts of the industry. If the industry is to make recommendations, possibly including proposed standards, we must all have confidence in the modeling, the data and the analysis, and that confidence is best achieved by means of an open process subject to peer review.

To accomplish this goal, EEI recommends that the analytical work take place under the direction of the NERC

Planning Committee as a special assessment. The technical expertise and diversity of the NERC PC and members of any special analysis group would be invaluable for defining the assumptions and parameters of such analysis, including specifications of any additional data that might be needed to conduct the analysis, such as the more detailed information on transformers that you normally find.

Subject to appropriate protection of CEII information, these planning committee meetings and any analysis group meetings, as all NERC meetings, would be open. We anticipate that the work will analyze in more detail the response of the North American Bulk-Power System following severe GMD events.

The analysis would determine whether and at what GMD levels any potential voltage collapse might occur, and if so, how broad an area would be affected. The analysis also would determine the magnitude and length of time of the geomagnetic-induced currents at different GMD levels, which in turn would be used by asset owners to determine impacts on their transformers.

EEI also shares concerns regarding the potential vulnerability of transformers of a certain age and design to severe GMD events. As stated above, after the PC completes its analysis, asset owners will conduct detailed technical analyses of transformers, especially those that have the greatest vulnerability to GMD events, using a number of technical experts: the North American Transmission Forum, the STEP program, transformer manufacturers and others.

Under the direction of the PC, the asset owners will develop project plan and communicate this plan to NERC and the Commission. Now that's the order that I would like to see. Having said that, as a practical matter, if you're looking for some early indication, another option would be in parallel, to perform the transformer analysis.

You would start out with a postulated different GIC levels, and then go on and perform the analysis. By doing this, you could see at a parametric study, given different GIC levels in these transformers, how would they react? But one has to be realistic. These would be postulated numbers, and they may or may not reflect reality of the system after you did the study, but it would be a way to move things up.

MR. BINDER: One minute, sir.

MR. NAUMANN: While analysis is an important part, in the shorter term, it's important to realize that there have been a number of communications and mitigation procedures. I think Frank Koza described a lot of them.

Also, as Mike said, and I think this is important, companies have installed or are installing GIC monitoring, and it's important to get the information from these devices, so that you get real world information. I thank you very much, and I look forward to answering your questions.

MR. McCLELLAND: Thank you, Steve. At this point, I'll turn to the Commissioners, to see if they have questions for the panelists.

COMMISSIONER LaFLEUR: Well thank you very much. I think I opened this morning by saying that this was a very complex problem, because of the need, any time we do anything on the electric grid, to look at the risks and costs of different locations and different equipment, and if anything, everything that's been said serves to prove how complex it is, especially everything we heard this morning.

Because you've done such a good job outlining action steps, I'm going to up the ante and ask two somewhat harder questions, I think, to pull on that information. A number of you have outlined really potential next steps along the whole spectrum that Mr. Cousins put forth, of modeling and monitoring mitigation, both hardening of the existing system and new standards, and operating practices.

And I'm interested in any of the panelists giving any indication of how quickly you think we can put some time frames around these things, and proceed in parallel, as has been suggested. When can we start on potentially assessing the vulnerability of the existing inventory on a systematic basis?

Because at the risk of sounding like an alarmist, we may or may not have this solar cycle to -- we might have a long time before we need this information; we might have a short time. I'm interested in any teeth we can put around what you propose.

My second question, I'll preface it with a comment. Much of this just sounds to me like it cries out for national standards. Just as we have seismic standards and other things, it doesn't seem to lend itself to -- although the situations are all different, but we have numerous reliability standards on tree trimming or relays or so forth that respect different situations in different geography, but still sets some sort of national baseline that has to be met.

I'm interested in people's thinking about which of these things lend themselves to standards, so we can get started on that also. Thank you.

MR. CAULEY: Commissioner, I'll try to answer both your questions at once.

COMMISSIONER LaFLEUR: Yeah, so that you wouldn't have to all go twice.

MR. CAULEY: I think at this point, I'm really trying to understand, you know, how do we collectively get our arms around a very difficult set of risks that are technically challenging, and I think it's very difficult to frame a standard at this point, where I can put out an answer that is the correct answer that will address this risk.

Ideally, what I would like a standard to do at some point, which I think will be achievable, is to set some kind of performance expectations, some kind of planning and design criteria, to which we would expect the system to perform, similar to some of the TPL standards that we now have covering various aspects of risk and failure.

So it would very difficult, I think, for me to envision a standard that would say "just get it done. Fix the problem." That said, you know, one of the things we're trying to do at NERC, understanding the complexity of our role, really is to avoid catastrophic failures, avoid bad things.

The way we're looking at it is if you understand the problem enough, can you set out a series of steps, to get us back to an acceptable risk level. I think what I'm hearing of the, depending on how you count them, 8 or 10 or 12 activities that could work in parallel at different time frames, if we had a detailed road map with some anticipated time lines, I think it would give the Commission a sense of accountability of these tracks doing what they're supposed to do.

It's not a perfect world, so I'd envision some of them will move along well, and some of them might be more difficult than initially envisioned. But that would be my suggestion, really to get where I think you're trying to get to, is how do we take a really serious set of risks, and how do we set a path towards progress, but do so in a way that's accountable to the public.

I think that would be the way that would come to me, is to set out not just the NERC report and some recommendations, but a road map with time lines based around some of these activities and manage to that, report to the Commission our progress, and at some point, I don't know when, but at some point standards. When we know what this all means and how it works, standards will make sense.

DR. PRY: We certainly don't know everything we need to know about geomagnetic storms and the threat, but we know enough already, that they do destroy transformers. We know that's been documented. We know what field strengths occur. We know enough so that we can set standards now, and then as we do more research, improve upon those standards in the future.

As I said in my opening remarks, additional study and analysis shouldn't become an excuse for doing nothing. The truth is you can take almost any catastrophic phenomenology like earthquakes. Do we know enough about earthquakes to absolutely know, you know, everything we need to know? They didn't at Fukushima.

Or volcanoes, you know, or hurricanes, in terms of the dykes being large enough and strong enough, you know. You're never going to have perfect knowledge. Is our knowledge good enough at this point to actually take steps forward? You know, the Congressional EMP Commission that looked at both geomagnetic storms and nuclear EMP thought so, and made such recommendations to Congress in 2008.

That's almost half a decade ago. You know, the Commission's estimate was that if we had spent, I think it was five to ten billion dollars over three to five years, not only would we have the electric grid protected by now, to a standard that was considered adequate by the Commission, but all the critical infrastructures could have been protected for that kind of an investment in three to five years.

Now we've been -- somehow that time has just disappeared, you know, because the primary problem has not been technological, and it hasn't been one of money, but it's been political and institutional, you know. Who has the authority? Nobody seems to have the authority, and that is what has cost us so much time.

So there are things that we can do, at least on a pilot basis, where we can start doing some experiments, and that would be an excellent feedback loop. You know, what we learned, for example, if we were working in Alaska or trying to harden say a node, an important node like the hydroelectric facility in Niagara Falls, which is very important, take some of those nodes, could be an important feedback loop of additional research and planning that we want to do, you know.

So you kind of take the principle of Federalism, but apply it to this problem, where you have a number of laboratory experiments going on around the country, to find a way forward. But we need to actually start making some progress installing equipment, doing something in a physical way.

Otherwise, I fear and I know the EMP Commissioners feared, that nothing will actually ever get done, and this is going to become a cottage industry for generating paper studies that end up gathering dust, and then some day there will be a catastrophe, and then we'll act. But by then, it will be too late.

MR. NAUMANN: First of all, Mike had a very nice list of things. But let me add some of which will be overlapping. On operations and communications, I think there's probably a little more work that NERC can do, reviewing the existing operations and communications, and maybe step that up with the information they've gained.

That's probably the easiest.

On monitoring, I think both Mike and I have mentioned the installation of monitoring equipment. You know, exactly who determines where it should go. As members of PJM, we would work with PJM on what they thought were good sites.

PECO has already installed monitoring equipment on all its 500 kV substations. Com Ed is in the process of installing equipment, and by the end of the year, Baltimore Gas and Electric, our newest operating company of Exelon, will have installed equipment. That's probably a low cost thing to do. You can learn from that.

I think we should do the analysis, because it's a -- you have complex interactions here between the power system and the equipment. The third thing, and here's the hardest one, okay. We're going to be installing equipment. We're installing a new substation. We're going to install transformers.

To what level? 100 amps for 30 minutes; 50 amps for 15 minutes; 300 amps for an hour? You know, someone, that can be ordered from the manufacturer. You can go there and you can say I want a GIC withstand of X number of amps for X amount of time.

It's a trade-off, and it's clear how we get to a point of saying what should that be if the Commission, and I want to be very careful, if the Canadian regulatory authorities, who have a stake in ths game too, decide that we need to take those actions?

So that's a hard question, as to who decides that, and then I do need to say that. Those costs need to be recovered, and some of the people who will be installing transformers don't have a method of recovery. So if you're going to do something like that, it should be like an extra NERC charge.

Sorry Gerry, but you know, I mean people need to recover the money if they're going to do an extraordinary thing for national security, and as Mike said, it's going to be paid for by customers, one way or another. I'm sorry if I put words in your mouth.

COMMISSIONER LaFLEUR: I mean I appreciate your speaking up, and I hate to put you on the spot. There's places in the NERC report that say "transformers put in recently have enough thermocoupling. They're not that vulnerable. It's mostly the old ones we're worried about," which sort of suggests well then we maybe should just be worrying about the old ones, because the new ones, it's kind of taken care of itself.

I've also heard Canada is putting in and the UK different transformers than we are here. You know, I take that on faith. I've read that, and now heard it. I mean but then whenever it gets to the dicey question of what we should put in here, it seems too complex.

So how do we get our arms around this? Is even just giving guidance that people should spec for GMD as they see reasonable in their system of above a certain voltage in order? Or are we already putting in transformers that are pretty resistant? You guys are the engineers.

MR. NAUMANN: We have, Exelon has a spec for Com Ed, for PECO, for Exelon Generation. I know AEP has a spec, a number of others have a spec, and they're all different, and we're all I mean physically situated different, operate at different voltages throughout the country.

One way may be to use the good offices of the Transmission Forum to push this on a short-term basis, and give a recommendation, and say we're going to -- you know, it's not going to be right, our answer. I guarantee you whatever the answer is won't be right, but it will be something and the country's willing to take a risk on this, because of the problem.

But again, as I said and I have to reemphasize it, the people who put that money out on this, we're not sure what, really do need to see a way to recovery, and some of those are generators.

MR. CAULEY: The difficulty is not just one thing to do. I would view this as a progression, and I would argue that all these things are not more studies and more analysis. They're actually doing things.

So one thing I think we could do, we know enough anecdotally or historical evidence of what kinds of transformers might be the most vulnerable, and I think we could go through the process of finding those and identifying them, how many are there, what's their situation, and ask the companies that have those to take some extra look at the risks of failure, whether they might think about accelerating a replacement schedule or closer monitoring of that equipment. So I think that's one piece of it.

I think we could also early try to understand the best practices in specifying what do mean the withstand capability, and what are the practices that people are doing now? But both of those tracks, I think, would progress if we have both the earth monitors and system monitors sort of working in parallel, and coming together with data that we can analyze, to figure out well, what's the real impacts? What should the number be?

Then I think we can fine-tune and progress both the specifications and also our understanding of the risk of the existing fleet. But you can't get to those end points right away. We have to start from basic, you know, back of the envelope type estimations and progress over time.

MR. COUSINS: Perhaps I could just -- sorry. Did I interrupt?

MR. NAUMANN: That's quite okay.

MR. COUSINS: Okay. You asked two questions there. One was where are we now and what are we doing, you know, immediately, and the other one was on standards. So on the where are we now, the UK sees this as a very long-term continual improvement-type process, that there won't be an end stop to this. There's a need to continue to improve, say for example, the report that we're expecting industry to provide.

We would fully expect there would be more to be done once we have that, in the spirit of continuing improvement, and I'm sure there would be questions as well as answers that come out of that.

But in terms of urgency, we do see this not necessarily related to the solar cycle. Whilst that does get everyone's attention, you know, the worst events in history haven't necessarily occurred. In March 2013, you could have another solar peak, and also with the solar cycle activity being quite low, that also potentially gives us the chance of a greater CME type of event.

So we see this as really quite urgent. So the pace of work that's going on here, the UK government is encouraging action from industry every moment we can.

On the question of standards, the UK does things slightly different to here. I'm not going to get into the debate as to which is right and which is wrong, because the situations are quite different, and within the UK, given the tightness of the geographical space and the single operator, if you like, for GB and the fewer numbers of transmission owners, we tend to put standards and push standards down to be set by industry themselves.

But then even that goes down further into equipment level standards, as to what industry does in terms of its persuasion and its discussions with industry, to in the spirit of customer need, as to what suppliers and manufacturers actually produce.

But whatever the case, what they are asking those manufacturers to produce, the knowledge and intelligence of what they're asking, that work still has to be done, and I don't think that the UK, the international community are in a position yet to know exactly what that standard is.

There's still more work to be done, that as you quite rightly said, it's a hugely complicated problem that goes across geological data, electrical data, operational philosophies. Once they are more refined, notwithstanding the fact that I see this as urgent, once they're more refined, I think there's that standard's evolution on how that comes out. It should fly.

DR. PRY: There were a couple of questions that you had asked that I didn't really hear being answered, but at least I'll give my answer to them. You know, one of them was is it just the older transformers that are vulnerable, and the newer transformers we don't have to worry about, because I do think there's a misconception.

There's an impression that's been created that the new transformers are invulnerable, and all we have to worry about is the old ones. That 's not true. We haven't had standards for that. We don't know if these new transformers are less vulnerable.

John, who's a bigger expert on these transformers than I am, John Kappaman, you know, has pointed out it's conceivable under some circumstances these could even be more vulnerable. I think he made illusion to that in his testimony during the first panel.

So we're not safe in terms of the new transformers either, you know. The old transformers, we know those are likely vulnerable. New ones might be too. The other issue you had asked earlier about how long would it take to do a study, and I don't want to give the impression here that I'm against doing studies.

I absolutely think that the kinds of analysis that have been proposed here need to go forward. It's indispensable, especially basic fact-finding like the size and age of the transformer fleet and all of that, trying to do the best modeling that we can. I just don't want that to become an excuse for not actually physically doing something to the grid, to do what we can, since it is an emergency, you know.

It is a crisis, and not just from geomagnetic storms. We haven't been talking about, you know, one of our criticisms of the NERC report was that it focused just on geomagnetic storms, and didn't look at an all-hazards approach like the nuclear EMP threat. I mean Iran is very close to the bomb. North Korea has already got it.

You know, we need to be looking at all of these threats and taking an all-hazards. So we need to urgently -- we don't have time to just endlessly study the problem. You know, based on the knowledge that we have now, and our task force believes and the Commission believed that back in 2008, we had enough knowledge at that point, you know, to be able to start actually taking steps forward to protecting the grid and protecting other critical infrastructures, and to prove to our task force doesn't have anything to study.

We're doing a study ourselves, that we're trying to do on an accelerated basis, you know, because one of the objections, we know, is well how much is this going to cost? Is this going to be so costly that it's going to be unaffordable? We're doing a study that we hope to complete in less than a year, you know, on an accelerated basis, that would look at -- that would do a cost estimate, you know.

Here's our best cut at what we would do to protect the national grid, and this is what we would cost, you know. We're going to take a robust plan, a minimal plan and then what if you're doing an individual state, and Washington still doesn't have its act together, but you're the governor of North Carolina, let's say, and you've decided you want to protect your state.

What could you do to protect that state and how much would it cost? So we also believe in studies and support doing them, but we also believe in actually starting to put the -- to actually take concrete actions, in terms of protecting the grid now.

MR. HEYECK: Commissioner, you might find it uncharacteristic for me to not jumping in initially. But I just wanted to think about what it is we could do right now, and what it is we are doing right now.

I think there might be a misnomer that the industry is not doing anything. We are sparing transformers. We do that with the STEP program, and we are taking it active at AEP with 765 kV.

Are we doing it just for GMD? No. We're doing it for normal acts. In fact, when 765 kV was initially introduced in the 60's and 70's, there were a rash of failures because they were first of a kind of transformers.

We survived those events and tried to get a better design and better design with the manufacturers, and we do have a better design today. However, again I mentioned we're AEP. We're big. We can do these things.

Another example of what we're doing is typically, when you refurbish a substation, the control house is a very complicated animal. So we came up with a drop in control house concept, and that drop in control house actually comes in on a flat bed.

It's dropped in on a crane right next to the old one, and we're thinking about -- we're actually trying to come with a Faraday's cage approach, to deal with the high altitude EMP, and we're actually shielding the wires into the controls, again to try to deal with the high altitude EMP.

We have no results. We just have intuition, based on what we've seen to date. We don't have any studies or results, but there are things we can do, and I think Gerry and Steve have hit on a couple of them.

First, let's find out what sparing we do today. Second, what's the age of these transformers and what types, and we could probably get them at the shell and core and things like that, five legs, three legs.

We could do all those things probably within a few months. That's not hard to do, and then identify which are risky and which are not. Prior to the EPA regulations, RTOs didn't know what units were going to retire. So what did they do? They looked at the age and the size of the units.

So there's a way, I think, to bifurcate the at-risk or the more at-risk versus the lower risk units. Those are the types of things I think we can do this year. But I can't over-emphasize. We've got to get the monitors in. We have the monitors in, but we're collecting it anecdotally.

There's no synchronous way of collecting this data, until all of us get together, probably under the auspices of a NERC, to have an RTO collect this data, to at least capture what we know today, while we're inventorying transformers and the age of transformers. I hope that helps.

COMMISSIONER LaFLEUR: Thank you. That's very helpful. I think I'll cede the mic. I just want to acknowledge the cost point, both the cost-benefit of looking at specific situations. Obviously, any time you have a fleet of resources, some are close to end of life and you're not going to do anything to them. Others are maybe worth retrofitting. Some you do an operational solution.

I mean there's always a cost analysis, as well as Steve's point on cost recovery. I don't think that's been the big issue that's held this up, but I do think -- message received. Thank you.

MR. McCLELLAND: Commissioner Norris?

COMMISSIONER NORRIS: No questions, thank you.

MR. McCLELLAND: I didn't want to make that mistake twice. So I have a question. Regarding the NERC study, you know, there was a listing of say these are critical vulnerable transformers that are end of life, older, gassy, high moisture, those type of transformers.

Considering Mike's point, and I'm the same way, Mike. If I see sort of a critical system in the house, with us it's cars. We have three kids that drive, my wife and I. So I have an old pick up truck. I mean it's old, you know, from the 70's right.

But it's an extra pickup truck, and when something happens and I'm down here at work, we don't worry about it. The kids grab the truck and away they go, right, and life goes on. So the question would be is it a good place to start? I mean we do know what to do in some regards, right?

You know, Steve had it in his written remarks, and it's a point well taken. If you put blockers in place, you're going to push the problem around. But maybe there are places where it's worth putting some blockers in place. Maybe it's just not the vulnerable transformers. Maybe it's

Singh's transformers, your SATs, for instance. They're not loaded. That's a point well-taken.

But I think there have been transformer failures on unloaded transformers, and considering what these transformers service, perhaps it's worth putting blockers or series capacitance on the nuclear power plant lines, and by the way, series capacitance is another solution. What would be the paycheck time associated with that?

But perhaps we identify, can sit down and identify critical systems. But we simply can't tolerate a failure. Maybe it's service to large urban areas, or maybe it's critical to military functions at specific bases.

Maybe we ought to identify those facilities first and so, you know, as an industry, on an interconnection-wide basis, let's put some mitigation there first, and then let's figure out the results as we move along. Let's protect what might be the most critical elements or the most vulnerable places. So I'll throw that out for discussion. Gerry.

MR. CAULEY: Thanks, Joe. I think, you know, I'm not opposed to blockers or the capacitors, and I think they're reasonable solutions. But for the 30 years I've been looking at the power system, we don't ever do anything unless we've studied the impacts of that.

So I couldn't say well, let's take the vulnerable ten percent and the solution is let's put blockers in all the neutrals and that will fix the ten percent. We don't change a wave trap, we don't change a switch, we don't do anything unless we study the impacts and consequences from the local physical equipment and system.

One of the approaches we took on a very hard problem, which was the right-of-way maintenances and clearances issue, I think we did try to set some priorities. We put our thoughts on which were the most important rights-of-way. That happened to be based on voltage, and we asked the industry to go after and fix that problem.

That would be the approach I would do here. In the early stage, when we feel like there's a problem but we don't know exactly how big or the nature of it, and we don't know exactly fix A or B will exactly solve that, I would say let's, through NERC, work with industry and identify, based on a certain set of criteria, the most vulnerable equipment that we think is a concern, and say these are on a watch, and we expect some kind of mitigation plan or remediation plan for those.

What the individual companies would come up with, I think, would be based on their assessment of the options, their analysis of that part of the system and, you know, the age of the equipment and all kinds of things. But give them a chance to come back with a solution to mitigate that problem.

MR. McCLELLAND: Would you also add most critical -- I mean you said "most vulnerable."

MR. CAULEY: I think criticality and risk, yes.

MR. McCLELLAND: Others? Yes, Peter. Dr. Pry.

DR. PRY: I understood your question to mean that of course you would study, you know, the possible impacts of putting in blocking devices on these when you asked the question.

So I think that goes without saying, and I think it's an excellent suggestion, that if one took a look at that and decided well, you know, the risks that might be entailed in terms of protecting these key assets, versus the risk of doing nothing to protect them, you know, that one could make a --

I think that's an excellent suggestion. I think it's an example of something that should be followed. It's the kind of thing that we could do in the immediate future.

I'm concerned that in the NERC report, you know, the focus in terms of what we can do in the near term is almost entirely on like operational procedures, and creates the impression that we would be able to deal with an 1859 Carrington event if it happens next year during the solar maximum, by operational procedures.

Yes the ACE satellite, upon which is the hinge point for these operational procedures, because it provides the early warning that everybody -- it's so old, that it's giving false warnings. It's really not reliable enough to support a serious strategy of protecting the grid.

Moreover, it was mentioned. You know, we've never practiced shutting down or shifting the loads across on a national level against something like this.

To me, that seems like a much more -- if we're serious about implementing it, that seems to me a much more risky kind of a strategy and one that's not likely to work, given that we can't even protect ourselves adequately against ice storms and hurricanes and the normal kinds of weather phenomena that happen, to put people into blackouts for protracted periods, you know, let alone an unprecedented phenomena.

And the Discovery satellite, which we all have high hopes for, you know, if we're fortunate and Congress goes forward with it, won't even be in place until 2014, which is after the solar maximum.

MR. McCLELLAND: Steve.

MR. NAUMANN: Just a quick comment, and I think everyone agrees. You've really got to study this. It's been a long time since I've looked at this, Joe. But I do recall when I was a young engineer, which probably in the time of the Carrington event, you know, there was a generator down at Mojave, and one day the shaft broke and everybody said "gee, that's weird. Must have been a bad shaft."

They finally found out that series capacitor caused sub-synchronous resonance. So I would be very careful about, before I put some series capacitors right on lines into a nuclear station, given the number of connections on the shaft. It would have to be studied, you know, really, really well. Just a caution.

MR. McCLELLAND: Mike.

MR. HEYECK: Yes, okay same point. So I guess the point was get the subset first, right. Identify the subset, but look at mitigation actions. So study the mitigation actions, yes. Study the mitigation actions before you take any action, yes.

But maybe list those locations as your priority locations. I mean Singh, I noticed in your testimony or in your written statement, that you discussed Sandia had conducted some analysis, as far as whether or not the nuclear power plants could survive a GMD or even EMP, and the answer happily came back "yes."

But I ask that that analysis consider the loss of offsite power. You heard the first panel that talked about the reactive power failure, voltage collapse and then grid collapse, system collapse. The restoration could be extremely complex, and although the nuclear power plants would be given first priority, it's not necessarily clear to me how long it would be until those plants were restored. It depends on the outage and sort of everything else that they're dealing with.

So did Sandia consider voltage collapse or grid collapse as part of the GMD or EMP, or were they specifically only studying the nuclear power plants?

MR. MATHARU: The answer to your question is no, Sandia did not study the impact on the prolonged blackout conditions in the vicinity of a plant. The intent in those days was to figure out if you would degrade the performance capabilities of the onsite systems, specifically your controls and instrumentation that you need to monitor the facility and shut the plant down.

We always rely on our onsite power source as the last source. Even though the offsite source is the preferred source, it's a much stronger source, we want to use that. But when your back's against the wall, we rely on our emergency generators, and the Sandia report looked at the nuclear power plant, not the external connections.

MR. McCLELLAND: Any other comments to the issue?

MR. COUSINS: Just a couple of points actually. On the question of criticality and vulnerability, I think we can easily identify the critical places, because just the network configuration is the vulnerability that's really quite uncertain right now, and that's, that's certainly our focus, so that we can see, you know, which sites are actually vulnerable.

But against that, it's really important not to discount, on the basis that hardening of some of these places is so costly that they shouldn't be considered at all. So it's quite important not to get into the mind set that those things are just not on the table, because they're --

But having said that, you know, and as I've mentioned, the UK's approach is to approach risk in a proportionate way, that we need to be actually sure that we've ticked off all the other possible mitigations that are around. When I mentioned the 3 M's, in terms of modeling, mitigation and monitoring, they do combine together quite a lot.

So when it comes down to, for example, space weather forecasting, the models that are used, and then that integrates into operational planning and day-ahead studies and all that sort of thing, and good visualization of the actual situation, then that in itself provides, for example, low level long duration events.

That in itself provides a mitigation, because there are operational reconfigurations that can be done to actually dissipate that particular problem. So in the round, we should not discount that hardening. We should look against everything else. But also, and I think it was the point, you know, Peter made just now, that holistic approach of looking at all hazards.

So not just GMD, but you know, other hazards, for example, flooding and volcanic activity and all those sort of things, that together a particular course of action might, you might have a vulnerable side that's not just vulnerable to GMD; it's vulnerable to many other things that a particular mitigation, hardening mitigation, its case is strengthened.

MR. McCLELLAND: Thanks, Mike. I think that's very helpful to me. I should retrace just a bit, say that the vulnerability subset that I've identified. I'm not certain that there's consensus on that, as far as that's the only subset. My only suggestion was I think everyone can agree that that's at least a subset we all recognize.

That subset, I think, can be quite large, because end of life transformers, older transformers, high moisture, gassy, that's a large subset. If you add to it the critical transformers and then sort of take a tiered approach to how mitigation might occur, keeping in mind that new investments.

You know, the prior panel talked about actually the lower loss transformers can saturate much easier, and they may indeed be more susceptible to GMD that the current transformers. So is that sort of the approach that the UK has taken? How have you identified which transformers, or is your system just sort of an all, approach it all at once type system?

MR. COUSINS: Well, the UK approach is that firstly, it's identifying information that wasn't readily to hand before, in terms of the construction design of these transformers.

So integrate that, integrate visibility of what that all looks like, and many of the newer transformers are three core type or three-legged transformers, which inherently have got lower risk to this particular situation, and they're also quite large, because of the premises of our system.

But what's really key is having the associated support of the British Geological Survey, for example, and those earth conductance models and other things. So arriving at that what is vulnerable isn't just a case of -- well, they're all important, but it is a case of actually knowing what the reasonable worse case scenario is that you're looking for and defining what that is.

But it's not just the electrical parameters and the construction design of the transformers that's important. Again, they're important, but that's not the whole story. It's having that other model of what you're -- what rock these transformers and what location they're actually built upon.

So that work, I think, you know, once that's, as I mentioned, this is a continual process, a continual improvement. Once we have that, we're in a better position to understand those vulnerabilities. But it's, you know, it's absolutely spot on that we agree is definitely a subset.

A vulnerability subset is something to get clarity on. But of course, once you know that, that then supports a case of what you do about it, and then you have to look at that, we believe, looking at all hazards together.

MR. McCLELLAND: Thank you, Mike. Hang on, Gerry. I saw Mike's hand up just a second before yours. Go ahead, Frank.

MR. HEYECK: I'd just like to link a couple of things here. Commissioner LaFleur in the morning said that we're going to be replacing this grid in the next 10, 20, 30 years. We're actually going to be replacing it. Probably two-thirds of it will be replaced probably in 30 years.

So instead of looking at the vulnerabilities of the existing grid, it's what can we do as we replace, and there's a couple of directions. One is the Department of

Energy has a wealth of science and math experience within the labs, in order to take some transformers and actually test them to failure.

We do have the monitors, we've mentioned many times, to get the geological issues modeled. But what about using more fiber instead of wire for protection and controls and communications between substations?

Those are the types of things that the industry can learn from, and I think the only way to get it is to have somebody test it. Now if we rely on the manufacturers, there needs to be a commercial bent to it.

So I think the Department of Energy may be able to help with the manufacturers. Take some transformers, the five or seven different kinds, and test them to failure, and age them or whatever they need to do to get some indication of what we need to do as we replace.

So those are the types of things I'd like to do, I'd like us to do. Not just look at the vulnerabilities of the existing grid, but what can we do to build it in in the first place.

MR. McCLELLAND: Thanks, Mike. Gerry.

MR. CAULEY: Yes. I just want to go back to I think where you were getting about looking in the near-term at the most vulnerable transformers and the most important. I wanted to suggest maybe those are both good activities, but maybe decoupling them from some respect.

If you take a look at the most vulnerable transformers, I think we could put a different standard, so to speak, on expected mitigations if we really, truly thought they were more vulnerable.

But if I look at the more important, the most critical transformers, I wouldn't have the same confidence level about, you know, dictating specific remedial actions or corrections, because at this point, I don't think we know enough about, you know, the cause-effect or the unintended consequences of well-designed, well-installed, it's running perfectly and now we're going to do something to it because it's critical.

So I just -- I'm not saying not do that. I just think we need to think of them as -- I would put more immediate urgency on the actions, on the vulnerabilities, and maybe think carefully about the critical ones, and just see what kind of situation are we in, and will we know more, as we do the modeling and the analytics and the data collection, to really study and come up with sharper answers. Then I'd be more confident about that. I just wanted to separate those two.

MR. McCLELLAND: Any other comments to this? Okay. I'll turn it over to my colleagues. I'm sorry, Singh. Please.

MR. MATHARU: Just to reinforce what I just heard Gerry say, I think it's important to look at the critical transformers also. I understand what you are talking about, the nuclear power plants and the SATs, and we need to focus on those. But the SATs are no good if the critical transformer in the system has failed, and we're unable to get the power supplies to the SATs.

I know there's a couple of nuclear power plants where you do the N minus 1, and it's getting close to where it may not be an acceptable situation on the grid. So we need to look at the whole picture, rather than just focus on the narrow ones, or just into the plants.

MR. McCLELLAND: Right, and hang on one second, Steve. Maybe the SATs are, you know, maybe that's a good example of an isolated type transformer that may have minimal impact on the grid, but it may be a good system to at least look at for specific applications, in addition to the MTs. I understand, Singh. Okay Steve, please.

MR. NAUMANN: At the risk of either confusing things or saying something that is problematic, if you're going to identify critical transformers, I would hope we do not get -- would have a process that does not emulate the critical assets of CIP, where we've gone through a multi-year process of saying you haven't designated the right assets or you have, or we don't know what they are, and then we just drew a bright line.

So you know, when you start talking about critical in a huge network, you know, where you have systems that are designed under stress, for example, in PJM under certain conditions, N minus 1 minus 1, and in a real, real, real emergency, you know, you may not be operating at full load for a short time, before you start saying we'll identify critical transformers, we need a very, very clear definition of what that is, or we're going to be in the same thing we've been in for four years, which was not fun, and I'm not sure it got us a whole lot of place.

MR. McCLELLAND: Go ahead, Dr. Pry.

DR. PRY: I just wanted to comment again on the issue of further study on the threat before you take steps to protect the transformers, and again, I'm not against doing all the analysis that has been proposed here. But I'm just against the notion that we are so ignorant about the threat at this point that we don't know enough to go forward. That's just not true.

I think it has to be understood that I want to draw a black line under the point, you know, that our knowledge is never going to be perfect about the threat from geomagnetic storms. It's never going to be perfect.

In fact, if I had to make a rough estimate, I'd say we probably know about 75 percent of the universe of what is discoverable, in terms of the knowledge about the geomagnetic storms, and that we can invest a lot more time and a lot more money studying them, and it will not result in a dramatic and great increase in our knowledge, so that we'll finally come up with a number, you know, for hardening a transformer that's going to satisfy some of the people at this table, you know.

There's always going to be uncertainty, and it is simply because of the fact that we've only been collecting data for about 70 years, and the sun is 4-1/2 billion years old, you know. We don't know what's coming down the pike. We know about some of the things that have come at us, and that's going to have to be good enough.

MR. McCLELLAND: Okay, thank you. Turn to my left. Staff, questions?

MR. WAGGEL: Yeah, thank you Joe. I have a question. As we touched on the urgency here and one we need to accomplish and do things and the upcoming solar max, and it seems that what we want to do is wait for lessons learned, to go on and be prepared for the next solar max.

I just have a question, and I think this is primarily for Bill, is did the periods of high GIC that we're going to be looking at or GMDs, do they coincide or do we have anything to worry about beyond next year? Should we be looking forward further than that?

MR. MURTAGH: Yeah, absolutely, and one of the confusing issues with the solar cycle is we get this maximum, and people sometimes associate the high activity with a year or two right around that maximum. Whereas the reality is some of the bigger events, we've seen; in fact, I think if I looked at the AP scale, for example, the biggest storm that occurred on the record since 1930 occurred four years after the solar maximum.

We see that quite often. Even 2003 events that we talk about those Halloween storms and the impacts. We know they had some, not as much in the United States but they did bring the grid down for a short period of time in [CITY]
Sweden. That was October 2003, also four years after the sun spot maximum.

So by no means do we let our guard down with the passage of 2012 and '13 and the Mayan calendar. But certainly years after that, we have to recognize that that threat is still there.

One other thing I just wanted to mention is that some questions came up too about the size of the solar cycle and it's anticipated to be smaller than average or smaller than we've seen anything in the last 80 or 90 years, which is the case. That is our prediction.

But the question, of course, should be so what, and the reality is the 1859 and the 1921 storms that are garnering so much attention here did occur with sun spot cycles that were smaller than average. So we may see less number of storms, but we could get the one storm that causes the big problem. So recognize that.

MR. WAGGEL: Since I have you on the hook here, it's something that you had said earlier that I need clarification on, about your watches, warnings and alerts, and when they're actually given. I take it the warning is given whenever the event hits the ACE satellite?

MR. MURTAGH: Right.

MR. WAGGEL: And then the alert would actually be into the event on earth. It's something that we would be seeing. Do you happen to know when utilities would take action, how their action response to that, and also since the warning is at the ACE satellite, is what time frames are we talking about?

MR. MURTAGH: Yeah. The ACE satellite, it could be, you know, it's 20 or 30 minutes on the real fast ones before it impacts the magnetic field. So we don't get much warning or lead time. It was mentioned earlier that the geomagnetic response, the strongest part of that storm could sometimes be in the onset.

But statistically mostly, it's several hours into the storm before we get the significant impacts. So while we might only get 20 minutes lead time for the onset of the storm, often and most often, the actual GIC that's going to cause problems will be a couple of hours, but again, not all the time.

The whole sequence of alerts and warnings, when we see the eruption from the sun and we issue that watch, and with Frank Koza and others here in the task force that I worked with, we talked about the procedures.

Of course, I have some of the standard operating procedures from the various groups, whether it's the New England ISO or PJM or Bonneville, Dominion Power, and they all have different procedures in response to the activities, the activity levels that we're predicting.

But just simply for the watches, I always like to give the example that some of the folks, the Bonneville folks shared with me. If they have some of the lines out for maintenance, big 500 kV lines on the west coast out for maintenance, and we see something like we saw on the 28th of October in 2003, if we can give them that 12 or 24 hour heads-up, that they, this looks like it's going to be something big.

So at least with that early watch, they can do some, implement some procedures to put them in a more robust state, to be prepared for when that thing actually comes. The big, big question mark is how the magnetic field of the cloud is oriented. We don't know until it hits that ACE spacecraft, and that is the one big variable.

I talked about 2003 being a Carrington-like storm, it was. From the space weather forecaster perspective, we were looking at the sun. We saw the sun spot grow bigger than Carrington. The coronal mass ejection was just as fast as the eruption Carrington saw. The last piece was how it coupled with the earth's magnetic field, that Z component we call it.

If we could know that, we'd provide you guys a great service. But we just don't know that. We know something big's going to come, but how big. That's the last piece of the puzzle that's missing.

MR. HEYECK: Richard, I'd just like to add to that. It's hard to do something continent-wide to reduce power or do things like that, but to get facilities back in service, that would be the case. That's why I think we really need some coordinated monitoring across North America, to identify where the pockets are showing up, in order to localize the operating procedures.

MR. FRANKS: I was just going to ask a question about the STEP program. I'll try to be careful with my would and could, Dr. McConnell. So from what I'm hearing from the different studies, there could be a geomagnetic storm that could result in minimal damage, or it could result in damage up to maybe 300 transformers.

I just want to ask a question. How robust is the STEP program, when we're talking about spare transformers, and Mr. Cauley, I think you said -- I apologize if you didn't say this -- and should it include generation step-up transformers?

MR. NAUMANN: Well, it doesn't include -- it does not include generator step-ups. I believe it does --

MR. FRANKS: I asked should it.

MR. NAUMANN: You know, it's a lot on a practical matter. I think it was a lot easier, as difficult as it was, to get the agreements between for T to T transformers. For one thing, the voltages are the same. For another, the sizes are roughly the same. I think the 765s are not included, but there are only a couple of worthy 765s, and those are single phase transformers.

My understanding is they're not spares for 300 at one time. Now, you know, again, you'd have -- if you postulate 300, that's really an awful lot of spares you're going to have to carry. You know, how many of those are going to pop immediately and how many of those are going to degrade life is important. You have time, you know.

Remember, we're operating on an N minus 1. It doesn't mean you're going to have the lights go out, you know. But STEP was never -- STEP was postulated after 9/11. It was put together after 9/11, for a postulated by the industry terrorist attack, and not for the simultaneous loss of 300 transformers, including GSUs. So that --

MR. FRANKS: Is there somewhere in between? Would you guesstimate between 0 and 300 where it would, you know, where it could be enacted?

MR. NAUMANN: We could get the information. I can get the information, and we'll file it afterwards.

MR. FRANKS: Okay, thank you.

MR. HEYECK: I just wanted to add to Steve's comments. GSUs tend to be right next to the generating plants, and a generating plants are a little more secure than substations out in the wilderness, one of the things.

The numbers of transformers that we have would be in the single digit percent in sparing, which is, in 765, would be double-digit percent, because we're the entire space of 765 or most of the space of 765. But from a 345 kV transformer, I wouldn't say they're ubiquitous across the system, but there are a large number of standard units out there, and to add to that, the 345 transformers, that is the modular one that CenterPoint installed.

DR. PRY: I just wanted to comment on the step-up transformer program, which I think is a good program. I'm glad it's being done, and I think it can make an important contribution to making the country safer. It's an example of something that's actually being done, and it's not just a paper study.

But I've seen in the press, and I don't want to give people false hope that this is the answer to the problem. That isn't going to be the answer to the problem, you know. The power of those generators, you know, is not sufficient to replace, and we certainly don't have the numbers, and it was never conceived as something to deal with, a nuclear EMP or a geomagnetic storm that would give you a continental-wide catastrophe.

The Department of Homeland Security doesn't even have that in one of the national emergency planning scenarios. They're all localized scenarios that presume that the rest of the critical infrastructures nationwide are intact. In order for this thing to work, for example, you know, the transportation system has to work.

There has to be fuel available, communications and all the rest, you know, none of which would be the case in a worse case kind of a scenario that we're talking about. So it's more for localized terrorist type activities, you know, but not for a national catastrophe.

But I also just wanted to throw out an idea. I mean here's an idea, that it's an action that could be taken. You know, it was mentioned earlier, you know, that eventually we're going to be replacing about two-thirds of the grid. Most of the transformers are old, are getting old.

Here's one potential way, a thing that could be done, and I think it would actually save industry money, is when we retire, you know, these EHV transformers, they're not run into the ground. So that there's usually some life left on them, okay. You know, let's not destroy them and scrap them. Leave them onsite or move them off to the side or something, or just leave them onsite.

Then when you bring in a new transformer to replace them, you know, you've got a spare that's already paid for. It's already there, it's on location, and it costs a lot of money to destroy one of these transformers consistently with the EPA regulations, because of the way they're designed and they're loaded with fuel and the rest.

You might find that if you follow that policy, you could actually save money and make the system safer, a lot safer, because you're over time giving yourself a reserve of EHV transformers. Thank you.

MR. HEYECK: And that is our practice today.

MR. McCLELLAND: Yeah, and you know, just along those lines, GSUs are very specific, very individual to the generators themselves, and yet at the Commission, at least our staff has been, you know, we've been getting an increasing number of announcements of power plant closures.

So I guess the question would be is there any opportunity to review those closures, rather than let those GSUs be scrapped? Is there any opportunity to look at those power plant closures and perhaps reserve appropriate GSUs?

So it's a thought. You don't have to address it, and in fact you probably better not, because I'd like to leave some time for my colleagues on the right-hand side. So colleagues, questions?

MR. HUFF: Michael, earlier in your discussion you stated about the 3 M's, the monitoring, modeling and mitigation. I think you said that you're about three months away from completing the study. Can you provide what you're anticipating, what that means as far as results and maybe next steps beyond that?

MR. COUSINS: Yeah, thank you. Well actually we're looking at, here in the findings in the study in May, so it's more eminent than three months away. I think I said in the coming months. But that's just my bit about making sure about this and fattening what I say, I think.

In terms of what it will say, I don't know. I think one of the important points that we haven't touched on is that certainly in the UK, we operate with regulated, but we've got different layers of industry, regulated monopolies in transmission and distribution. But we have strong competition in generation and supply.

Of course, the sensitivities of announcements of a particular transformer on a generator is more vulnerable to space weather. That kind of message has to be handled carefully, because we also have a media that sees space forecasts as quick as in the same time frame as everyone else does, and interprets those forecasts in their own way.

So there's -- the process that we go through is that this project that's being completed by a primary TSO, because it's done that work so far. It's doing it under the auspices of our Energy Emergencies Executive Committee, which is a coming together of all the players within the industry, the regulators, safety and economic, trade associations, the industry themselves and government.

It's within that forum that the findings of that will be discussed. So it's probably unwise -- you know, I have to say, I have got early sights and understanding of what the kind of rounds of what that outcome would be. But it's unwise for me to talk about that, because (a), it's not complete and (b), it may change by the end of May, as these things can do.

But also I think there's several outcomes that can come from those findings. One is that it might say that actually because of the location of the UK, in terms of magnetic latitude and the actual physical location of the generators, and the physical design of those transformers, it may say that actually the number of transformers that are high at risk is actually quite low.

And in that particular scenario, then, the focus will be discussed about possibly, in line with the earlier point about vulnerabilities as to with this modern mitigation on specific sites, depending on the magnitude of the risk, or whether there's a general operational mitigation stance.

But if that study was to say, and you know, in an extreme there are many generators that have high vulnerability because of their location and where they are, etcetera. Then there's a discussion to be had on actually how we handle.

When we get, you know, 48 hours' notice that there's a large CME coming, we don't know how big it is and all that sort of thing, what the actual reaction might be from that generator community, and whether there's market arrangements that have to be modified, to allow for specific actions, and that discussion has to happen.

So you know, to answer your question, actually it's imminent. It's close. There's in terms of actually those findings becoming transparent and more widely spread, that probably is something like three to four months away, because there's that discussion to be had with the generator community first.

MR. HUFF: Thank you.

MR. SNOW: Singh, I understand that in nuclear, you speak for yourself, not your agency, and I understand that position, so this is a question for you as an engineer.

I know if there's a hurricane predicted, that the plants that are in the path of the hurricane typically shut down and are in cold shutdown mode prior to the event occurring. Hurricanes can go in all different directions, you know, may not. But certainly the grid wasn't designed to handle a full hurricane force.

So you, in your general design criteria 17, you'd be in compliance with that. Since you've now heard or the interim report talks about we expect the system to collapse in a large storm, what would you expect the plants to be doing?

MR. MATHARU: If you are postulating the loss of offsite power event in the vicinity of a nuclear power plant.

MR. SNOW: Loss of the grid, including offsite power.

MR. MATHARU: I understand, I understand. Let's start from just at the plant itself, and again the expectation would be for the plant to bring to a total shutdown, and be in a safe condition, so it can be on the diesel generators if needed.

If you are postulating then if you stretch yourself to the collapse of the grid, then the obvious answer is yes, you would expect all the plants to be shut down.

MR. SNOW: But Michael has kind of told you or Bill told you that it's going to take 20 minutes. No plant's going to shut down, or at least be in a cold shutdown mode in that time frame. So what would you expect them to do ahead of time, use the 18 hours?

MR. MATHARU: Given the warning from NOAA that a storm was due in 18 hours, and the prediction was that the whole grid is going to collapse, I think they expect --

MR. SNOW: Whichever. I'm basically trying to understand, what would you be expecting from them?

MR. MATHARU: Again, the safe position for the nuclear plant is the shutdown condition. So you would trip the plants, if that dire situation was predicted. Now you started off by discussing what happens in the hurricane situation.

If the procedures that we have right now, and we are postulating a station blackout, to avoid that, what we expect the plant to do is if the hurricane is four hours away from hitting the site, the plant should be a cold shutdown at that point.

So to extend that to what you're asking, we would actually expect the plant to be in some kind of shutdown.

MR. NAUMANN: At the risk of getting outside my area of expertise, I think you've postulated a question for a situation that at this point will not take place. You're not going to get a warning that is going to say the grid is going to collapse, and so it's very hard, at this point in isolation, to say every nuclear plant where should go into cold shutdown.

Now you know, I think you got a theoretical answer. I don't know that it's a practical answer, because that kind of warning is simply, with any likelihood, not available.

That would have to be, I would venture to guess, through some sort of NRC rule, that says when you get a warning of a K-9, which we've already said has a broad range, certain actions have to occur. I don't think any nuclear plant, on hearing there's a K-9, every nuclear plant across the country is going to shut down.

MR. MATHARU: And I think the answer to that is correct, because you don't want the grid to collapse, just because we shut down a couple of nuclear power plants as base loads.

MR. SNOW: Again Mike, my question was trying to understand what is your design criteria. It's been too long since I've played in that ballpark to remember half the stuff, and one reading of that things, just as in -- we have predictions that give us terrestrial weather, hurricanes; we have predictions that give us space weather, in a little larger ballpark.

And when we know if something's coming in our direction, as far as a hurricane, the plants do shut down. I'm trying to understand what would one, since -- what would one need to be in the same safe mode? The policy mode is, I think as Singh identified, and if I misquote you, please correct me, that you want to keep the nuclear steam supply system safe, that the safety of the public is the key value.

That's the policy discussion. How do you do that? We know how we do that in hurricanes. I'm trying to understand how do we do that with a space weather event, and what needs to be encouraged to implement that policy is yet -- is not in front of us. We just want to understand what's the policy?

MR. NAUMANN: I think that's a policy for the Nuclear Regulatory Commission.

MR. MATHARU: I think we were clear on that. It will be the -- the answer that I gave wasn't the NRC position. It was a personal question to me, and what safety aspects are involved if you lose the grid, and right now, the requirement is that if you do not have adequate offsite power sources, you will shut the plant down.

MR. SNOW: When you shut a plant down from full power, and assume at the same time you lose offsite power, what are the critical or what are the key nuclear activities you need to worry about?

Cooling the core; certainly collecting any radioactive waste or byproducts. So when, at what point in time after you bring the core down from, the reactor down from full power do you need offsite power to run larger pumps or other things, to handle nuclear waste issues?

MR. MATHARU: Can I go on that on a personal level?

MR. SNOW: Whatever level you want.

MR. MATHARU: If we have -- I was on a team involved in the post-Katrina restoration for a nuclear power plant, and the issue was to restore the grid and start the plant up. We needed the grid to be stable. For the grid to be stable, we needed a load in the vicinity of the Katrina region.

There was no load, no industrial load for three or four days, five days, and generation hadn't come up yet. All the transmission network had not been put together yet. The plant itself, the nuclear plant itself was generating a lot of waste water, and you do need to dilute that waste water or you need to treat it.

For that, you need some large pumps, which you need the offsite source for. So we survived for about two weeks holding the water in our tanks and treating it. Beyond that, you needed -- you're bottling yourself up. You need some external power to take care of your waste systems. Did that answer your question?

MR. SNOW: Yes, it does. Thank you.

MR. McCLELLAND: Did the -- Commissioner LaFleur, any further questions?

COMMISSIONER LaFLEUR: No. Just a closing.

MR. McCLELLAND: I would say, please.

COMMISSIONER LaFLEUR: Well, I just wanted to thank all of the panelists earlier, and these panelists, first of all, for your remarks today, but also all the work you've done on this issue leading up to this in the years past, which has really informed where we are right now.

I appreciate your suggestions for action steps, and your all answering my question on standards. We will still be taking comments from anyone up until May 21, and I think then it will be incumbent on us to figure out what are the next steps here, working with the Canadian authorities and NERC and so forth.

I do think, you know, this isn't an issue I ever expected to get as involved in as I have been, but I don't think I'm going to turn back now. I do think it's well within our reach to start -- I don't want to say start tackling it, because I know a lot of things are being done, but start doing it in a more concerted and accountable way, and I thank you for your contribution to that.

MR. McCLELLAND: All right. Well, I would like to issue an apology to Mr. Ken Friedman. I see Ken there from the Department of Energy. Ken, I should have recognized you at the onset of the conference.

DOE has been a great friend and very active in this research and this analysis, and in fact, had it not been for their national labs, the Commission would not have been able to issue the report, and also the part sponsorship of the Oak Ridge report. So thank you Ken. My apologies.

I want to thank each of the panelists for being here. I think we had a very productive discussion. Combine this panel with the first panel, and I think we've come a long way. So I appreciate all your perspectives. I'm glad you took the opportunity to travel here.

The docket is -- Mary Agnes. It's AD12-13?

MS. NIMIS: Correct.

MR. McCLELLAND: And anyone, including anyone on the Webex, can issue comments to that docket. The Commission staff will consider it. We do take the matter very seriously, and we think this is an important issue. We think it has very serious ramifications.

So staff will be collecting those comments and summarizing them, to better inform the Commissioners. So again, thank you to each and every person. We encourage everyone who is interested to file those comments, so that staff can develop the record. Thank you folks, and bye.

(Whereupon, at 3:49 p.m., the meeting was concluded.)