INTERVIEW OF

DR. JOHN KAPPENMAN

October 11, 2013

Conducted by Troy Cline
MR. CLINE: Well, thanks so much for your time. This is really going to be great. I don't know how much Carolyn told you about the project that we're doing.

DR. KAPPENMAN: Well, a little bit. I understand you're talking to various people that are involved in looking at this issue of space weather and how it can all impact us and trying to look at it over its history and timeline.

MR. CLINE: That's it, and it's going to be built into an online tool that -- like a timeline, so people are going to be able to go through, and we'll split up these interviews into segments and parts and quotes, along with stories and images and pictures.

DR. KAPPENMAN: Sure.

MR. CLINE: And then the user's going to be able to go through and just select any thread that they'd like to follow through space weather. I think that's --

DR. KAPPENMAN: Right.

MR. CLINE: -- the overall vision, so it
should be pretty cool.

DR. KAPPENMAN: Okay.

MR. CLINE: Well, in this type of interview that -- what I like to do is -- eventually, we edit my voice out as much as possible so it's all the person being interviewed, and so what I'll often do is we'll get things started. I'll ask one of these general questions. And then I won't say much until, you know, you've completed the thought or you've gone through what you'd like to say.

And sometimes, if there is a conversation that starts up or if a question just pops up, I'll throw it in there, and if they decide to edit me out later, they can; if not, they'll keep me in.


MR. CLINE: And do you have any questions, though, before I start?

DR. KAPPENMAN: No. No, I'm --

MR. CLINE: Okay.

DR. KAPPENMAN: -- ready to go.

MR. CLINE: Awesome. Well, thanks again.

DR. KAPPENMAN: Sure.
MR. CLINE: Let's start by you just telling us who you are and what you're doing right now, and then we'll get into the actual questions.

DR. KAPPENMAN: All right. My name is John Kappenman. I'm with Storm Analysis Consultants. I've been working on this problem of space weather and how it impacts electric power grids for about 37 years now. The work that I'm involved in now continues to be focused on what is the vulnerability of electric power grids, especially the U.S. electric power grid, and also what things we can do to solve the problem that space weather causes to the electric power grid.

MR. CLINE: Okay. That sounds -- that sounds perfect, then. And our first question, I think you've actually already answered, pretty much, your -- about what is your primary research interest and --

DR. KAPPENMAN: Sure.

MR. CLINE: -- what you're doing right now. Do you have more to add to that, or do you think you answered what you want to ...

DR. KAPPENMAN: Well, you know, I certainly can talk about some of the specifics of what has
occurred in this area; for example, you know, I started work on this problem in 1977. At that time, we knew about the problem that these storms could cause to electric power grids. We still largely felt at that time that these were nuisance-level problems as far as how they could impact electric power grid operations.

The company that I worked with was a power company in northern Minnesota. We were building a long, high-voltage interconnection to Canada, so we felt we had to do a little bit of research at that time to try and understand the problems more fully. Me being the new guy in the Engineering Department, I ended up getting stuck doing that research, and here I am 37 years later, still trying to research this problem.

Over that period of time, we have learned through studies as well as through painful experience that these severe geomagnetic storms could perhaps be the largest natural disaster that electric power grids could face, and by extension, perhaps the largest natural disaster that the country could face.
So it has taken on a much more focused role, a much more important role in trying to understand these vulnerabilities, and, actually, the role has evolved to try and engineer solutions to reverse some of these vulnerabilities or engineer out some of the vulnerability that we have in the present-day electric power grid.

MR. CLINE: Can you describe a little bit further of what you mean by this being one of the largest natural disasters? What types of things would happen if we had a significant solar storm direct impact, an impact on the ground?

DR. KAPPENMAN: Sure. Well, we have had some experience with modern-day storms that give us a hint as to what could happen for a more severe storm. For example, there was an important storm back in March of 1989, March 13th and 14th of 1989. At that time, it had only been theoretically proposed by me and other research collaborators that such storms could cause a blackout of the power grid. And this March 1989 storm did, in fact, cause a blackout to a major portion of the North
American power grid, the entire province of Quebec. And it came very close to precipitating a blackout that literally could have extended from the Mid-Atlantic Region of the U.S. all the way across to the Pacific Northwest.

In addition, we learned for the first time during that March 1989 storm that large and difficult-to-replace electric equipment, like transformers, could be permanently damaged by the induced currents that these storms closed to flow in the electric grid.

Since that March 1989 storm, we've done work to try and estimate more extreme storm scenarios. We had misestimated for many years, even following the March 1989 storm, how much more severe storms could be. And we now have a scientific understanding that tells us that in many -- in some of the most important aspects, that we could see storms that could have intensities ten times larger than the March 1989 storm.

Now, we already know the March 1989 storms caused some historic impacts to the electric grid. The things that we're concerned about with the
reoccurrence of a very large storm would be that it would not only cause blackouts to major electric grids, like the U.S. power grid, perhaps other economic developed countries around the world, but could also destroy enough equipment on those grids to perhaps greatly extend the blackout beyond just a matter of a few hours or a few days, perhaps into a blackout that could extend into months and perhaps years, across very wide regions that these storms would occur over.

In the case of the U.S. -- the analysis that I've done for the U.S., this could have enormous impacts across society. You know, when you think about how electricity is used in our society, it is vital for things like being able to deliver potable water. You know, we would lose supplies of potable water within a matter of a few hours after a blackout occurred. The ability to treat and pump sewage. Perishable foods would be lost after about 12 hours; perishable medications as well.

If you think about perishable medications, in the U.S. alone, there's a million patients that
need daily supplies of insulin to stay alive. So loss of that over a wide region could cause enormous risk and loss of life in this country from these sort of scenarios.

When you look at everything else that society is dependent upon as far as electricity, within a short period of time, you lose the ability to maintain transportation systems. The ability to pump fuels via pipelines and things like that is lost. Within a short period of time, perhaps a couple of days, the ability to maintain communication systems, telephones and so forth, will also be lost, as they have backup battery and generation supply, but then they become logistically bounded because of loss of electricity and inability to refuel. So it becomes a situation that could place many millions of lives at risk in modern-day society.

MR. CLINE: What -- based on what you were just saying, what types of preventative measures over the course of time that -- since people like you have been studying space weather and research and solar storms and the impacts -- what types of preventative
measures can you tell us about that have increased over time to try to protect us from these things?

DR. KAPPENMAN: Well, actually, we don't know of any preventative measures that have increased over time. The story in electric power grid vulnerability has actually been the opposite. We've grown more vulnerable over time, remarkably more vulnerable.

You know, for example, when we had the large storm called the Carrington Event in 1859, the only electric technology we had at that time was telegraph systems. The same is largely true for the major storm that occurred in May 1921. We were still very much at the state of infancy as far as electric power grids, communication systems, and that other sort of infrastructure that can couple with these disturbances in the magnetic field that are caused by these storms.

Since the late 1950s to today, we have developed a high-voltage network of transmission lines that span continents all over the world. These types of infrastructures are enormously well-coupled to disturbances in the Earth's magnetic field, but we
have been completely unaware that this was a threat environment that we needed to be concerned about.

We have had no design code that has ever taken this sort of environmental threat into consideration in the design of electric power grids. And it's only been just this year that the Federal Energy Regulatory Commission finally issued rules or regulations to the electric power industry to tell them to begin developing standards and design codes that take this threat into consideration.

So we've got many decades of increased vulnerability that we have to now try and figure out how to undo as we've greatly expanded this modern-day infrastructure.

MR. CLINE: That's incredible to think about, especially the impact, and, as you mentioned, the increased vulnerability with the addition of communication satellites and all of the different things that we rely on here on Earth. So I do know and I'm aware that warnings go out from space weather researchers and scientists to just alert various industries that, you know, a potential threat is
underway?

DR. KAPPENMAN: Yes.

MR. CLINE: Can you tell us what that is?

DR. KAPPENMAN: Well, the NOAA and the Space Weather Prediction Center do issue notices, alerts, and warnings for geomagnetic storm activity, space weather activity, and so forth. This information is distributed to the electric power industry. And, as I mentioned before, it's information that's passed along to the industry, but there has been very little done with that information, other than to try and just, you know, heighten awareness, situational awareness that a storm is occurring and it may explain some of the variations and disturbances that occur in the electric power grid.

We now have regulations that will require U.S. electric utilities to develop operating standards that take these conditions into consideration. So they will be working to develop more formal operating procedures that they can adopt when these storms occur.

The concern that I have, however, is that
these operating procedures may not be at all adequate, especially adequate for the very largest storms that are likely to occur. We know these large storms have occurred before. You know, the physics of the Sun, the physics of the Earth's magnetosphere has not changed. The physics of the electric power grid has changed in a very adverse way, and as a result, we know these large storms have the potential to create enormous widespread damage to the power grids.

We really can't -- cannot do anything to prevent storms from occurring or prevent these storms from having these impacts on the power grid, unless we take additional steps to reengineer the power grid and try and block these flows of induced currents into the power grid that create all the problems. And that's a large part of the work that I'm continuing to focus on is methods and devices that we'll be able to use to block these geomagnetically induced currents.

MR. CLINE: That's an -- that's an incredible answer to that, because I don't think -- you know, I've heard quite a few stories and interviews and talked with people over the years, but
I didn't realize until talking with you today that we are as vulnerable as we really -- as we are. You know, I've heard people talking about how, you know, power grids can be shut down or different components of satellites -- certain things can happen to where they'll try to reduce the amount of static discharge and all of the different things that they try to do. But it sounds like we're still at the infancy of being able to protect ourselves.

DR. KAPPENMAN: Well, that's true. You know, in fact, we've raised these questions with the White House taskforce looking at geomagnetic storms and pointed out to them that, you know, if we knew that a very large storm were to occur, like, next week, what is it that we could reasonably do to safeguard the country?

You know, one of the scenarios would be to have the president issue an order to shut down the electric power grid. Well, that's not something we want to take lightly either, because even the shutdown of the electric power grid is a disaster for the country. You know, if you'll look at the blackout
that occurred in August of 2003, that affected 60
million people in the country. That cost the economy
about $10 billion in lost gross domestic product.
Fortunately, we recovered from that in a
matter of a couple of days. Shutting down the entire
U.S. electric power grid would probably take, you
know, longer to recover from, perhaps a week or so,
but at least we would have a power grid that we could
bring back into service.
If we allow the storm to occur and it causes
the widespread damage that we think is possible, we
know we do not have any of this equipment as spares
that could be readily replaced. It could be as much
as a decade to try and recover from that sort of
scenario. And then, of course, you become concerned
about the issues of what impact would that have to
society, you know, a widespread loss of water, foods,
medications, you know, ability to keep people warm and
sheltered, transport, emergency provisions, things
like that?
You know, we predicate all of our disaster
recovery methods on being able to provide assistance
from nearby unaffected regions. In the case of these space weather events, these are things that can have literally a continental laydown, a planetary laydown. We may not have nearby unaffected regions for some of the worst-case scenarios that one could face.

MR. CLINE: So even on the -- this may be a very simple question, but it does -- the daytime side of Earth, or the side that's impacted most directly by a storm, is that actually -- which side of the Earth is facing the Sun, does that actually have an impact on how people are affected on Earth, if there is an incredible storm like that?

DR. KAPPENMAN: Well, actually, for the processes that we're concerned about, these are geomagnetic storm processes, and they usually tend to be more severe on the side away from the Sun, the nighttime side of the Earth, although we have seen some of these magnetic storm processes produce large, impulsive disturbances into the day side regions as well.

Typically, for a storm of the class that we're concerned about, this is something that's
probably going to last a day or more, is going to have
a large number of intense sub-storm events that will
occur over the course of that several-day period, and
it therefore has the potential to sweep across to most
of the planet and produce impulsive disturbances that
could be quite regionally intense for many, many areas
of the country over the course of that storm.

MR. CLINE: And over the course of space
weather research, and, really, pretty much the more
intense study has been, what, the last 50, 60 years?

DR. KAPPENMAN: Well, yes, right.

MR. CLINE: And so based on that, I would
assume at the beginning and for the first probably
several decades we didn't have much warning time. We
knew a storm was happening back then. But now how
much warning time would we have for a significant
event like that?

DR. KAPPENMAN: Well, you know, I was one of
the people that helped to champion the current space
weather warning satellite that we use, the ACE
satellite. And with that satellite, it's positioned
out at the L1 position in space, so it sees the
incoming coronal mass ejection before it encounters the Earth's magnetic field. And, you know, for the fastest-moving events, it could probably give us at least a ten-minute warning before the CME first encountered the Earth's magnetic field.

And then, of course, it would continue to provide status data on that CME over the course of its entire transit to Earth. And, you know, it becomes an important input to, you know, simulation models that we have a capability to run to try and tell us what that CME means as far as the potential for storm severity.

MR. CLINE: So even in that worst-case scenario, with something moving that quickly, that's hardly enough time, I would think, to really shut down a power grid system across the country.

DR. KAPPENMAN: No, that's right. We'll certainly see, typically a day in advance, something big that has happened on the surface of the Sun, be able to see that it is something that looks like it's very well-directed towards the Earth. But, you know, that's still, you know, not the same resolution of
clarity of data as we would get from actually measuring the CME itself as it passes by the ACE satellite.

MR. CLINE: Now, in some of the questions that we have, one of the questions we'd like to ask -- and I believe you've actually already touched on this somewhat through this interview -- that are what are some of the key events or turning points in your space weather research?

DR. KAPPENMAN: Yeah. Okay. Well, you know, like I said, we originally started this work in 1977, thinking it would be a rather small and simple problem to solve. Once we started getting into the research, though, we -- you know, it continued to be an ever-mushrooming set of problems that these storms presented.

For example, I published a paper back in 1980 where we made the very meek, one-sentence statement in that paper that we think there's a non-zero probability of future geomagnetic storms causing blackouts to power grids. Well, that did become a reality in the March 1989 storm, when the Quebec grid
blacked out. We also didn't realize or didn't expect that large transformers could be damaged by this. So we were enormously surprised by the large power transformer that was damaged also during that March 1989 storm.

So we continue to have a situation, even in modern storms, where we often get greatly and unpleasantly surprised about how geomagnetic storms can impact electric power grids; you know, for example, we didn't realize that these storms could produce that same sort of damage, even at very low-latitude locations. The October 2003 storm ended up destroying 15 large transformers in the South Africa grid there at very low latitudesgeomagnetically.

So it revealed to us that these sort of storms, especially if they were very large-sized, could truly have planet-wide impacts to modern-day power grids and, therefore, modern-day society.

MR. CLINE: And my understanding of the storm that you just described from October, that actually was -- it just sort of glanced us. Instead of a full impact, that could have been absolutely
devastating.

DR. KAPPENMAN: Well, that's right. You know, we -- I think we've gotten -- we've been blessed to have some wake-up calls provided to us without having to experience firsthand the full consequences of one of these really large storms. And that's what I -- that's the message I try to carry to people in my industry, in that, you know, we cannot afford to learn our lessons firsthand on this type of disaster, because its consequences could be so large that we may not, as a society, be able to easily recover from it.

You know, we learn, unfortunately, from natural disasters that occur in one region. You know, for example, most recent event I can think of or point to would be Hurricane Katrina. And then we work harder to prevent that sort of disaster from occurring in many other regions.

This sort of disaster literally could cause unacceptable consequences over very, very large regions of our planet, and, you know, as a result, we -- you know, we wouldn't have the ability to understand the full potential of these consequences.
without suffering all of the consequences themselves
or the full potential of these storms without
suffering the consequences firsthand.

MR. CLINE: That's amazing. That is
amazing, and it really brings home the importance of
not only understanding space weather, as we have
started to do in just the past five or six decades
intensely, as you've been describing, but into the
near future, especially with the growing
vulnerabilities that you've described.

DR. KAPPENMAN: Well, that's right, and we
know that, you know, these storms have occurred
before. They are certain to occur again. The only
ting we don't know is exactly when they will occur.

MR. CLINE: Do you have any other types of
impact stories or personal stories or anything else
you would like to add to the interview?

DR. KAPPENMAN: No, I think we've pretty
much covered ...

MR. CLINE: We really have. This has --

DR. KAPPENMAN: Yeah.

MR. CLINE: -- been an incredible interview.
1 DR. KAPPENMAN: Well, good.
2 MR. CLINE: I'm like, "Wow."
3 DR. KAPPENMAN: I'm glad it was worth your while.
4 MR. CLINE: It really was. I mean, you're the first one, I think, we've interviewed who's talked about direct impacts to that extent because of, of course, what you do.
5 DR. KAPPENMAN: Right.
6 MR. CLINE: And I think it's going to be a real great addition to this. This is the one that the people are going to listen to and be like, "Oh, wow. We need to listen to that more. That's really important. It's not as abstract."
7 DR. KAPPENMAN: No, that's right.
8 MR. CLINE: But thank you so much --
9 DR. KAPPENMAN: Yeah.
10 MR. CLINE: -- for your time. And our next --
11 DR. KAPPENMAN: You know, and if you think about electricity --
12 MR. CLINE: Uh-huh.
DR. KAPPENMAN: -- let me give you a little statistic. You know, we've expended an enormous amount of geopolitical capital to preserve the security of oil supplies to the country and to the world. Electricity in the U.S. is about 40 percent of all of the energy that we use. It's more than double the amount of energy we use due to oil. So it's more than twice as important as oil in terms of the type of energy that we use.

MR. CLINE: That's amazing.

DR. KAPPENMAN: Yeah.

MR. CLINE: Wow.

DR. KAPPENMAN: And we've been very fortunate that -- you know, up until now, you know, our electric supply has not been threatened. It's been incredibly reliable, stable, not subject to political hostilities and things like that. But, you know, the Sun could change that equation in an instant.

MR. CLINE: In just a flash, I mean, literally.

DR. KAPPENMAN: Yeah. It really ...
MR. CLINE: You know, what we'll do with the -- everything that we've just talked about is Carolyn will have this translated.

DR. KAPPENMAN: Yeah.

MR. CLINE: Or -- and then --

DR. KAPPENMAN: Transcribed, yeah.

MR. CLINE: Not -- transcribed, excuse me -- yeah, into English. She'll have it transcribed for us. And then what she'll do is go through, do some minor edits, and then send you a copy that you can go through and actually read through the entire interview and add to, strike, move anything around you'd like.

DR. KAPPENMAN: Yeah. Very good.

MR. CLINE: And then we'll send that off to the audio engineer to come up with the actual final copy of what we do.

DR. KAPPENMAN: Very good.

MR. CLINE: So -- all right?

DR. KAPPENMAN: All right. Thank you.

MR. CLINE: Thanks so much for your time.

Again, it was --

DR. KAPPENMAN: Yeah.
MR. CLINE: -- just great.

DR. KAPPENMAN: Have a good day.


(Whereupon, the interview of Dr. John Kappenman was concluded.)
CERTIFICATE OF TRANSCRIPTION

I, MARY E. YOUNG, hereby certify that I am not the Court Reporter who reported the following proceeding and that I have typed the transcript of this proceeding using the Court Reporter's notes and recordings. The foregoing/attached transcript is a true, correct, and complete transcription of said proceeding.

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Date                      Mary E. Young

Transcriptionist