# Session 3: Space Weather Services, Science, and Supporting Infrastructure

**Speakers**

- **Dr. Thomas Zurbuchen**, Associate Administrator for the Science Mission Directorate, National Aeronautics and Space Administration
- **Dr. William Easterling**, Assistant Director Geosciences, National Science Foundation
- **Dr. Louis Uccellini**, NOAA Assistant Administrator for Weather Services and Director, National Weather Service
- **Dr. Conrad Lautenbacher**, Chief Executive Officer, GeoOptics Incorporated and American Commercial Space Weather Association
- Moderator: **Mr. Martin Frederick**, Northrop Grumman Civil Space Programs

**Marty Frederick**: All right, everybody, we're going to go ahead and get settled in. We've got all of our panelists here today, and quite a panel it is. Start by introducing myself, I am obviously Matt Jones. Actually, no. I'm Marty Frederick, I'm filling in for Matt Jones. In case you confused the two of us, I'm the shorter one, and I don't dance or play an instrument, as Matt does.

If you'll see in your program, Matt is quite an accomplished guy, and we miss having him here today. He had a family emergency, and we're happy to step in. I'm here with Northrop Grumman, and also the Space Enterprise Council. We're happy to bring this activity to you today.

We're in session three, "Space Weather Services, Science, and Supporting Infrastructure." We've got quite an excellent panel. Dr. Thomas Zurbuchen is here to my left. Dr. Bill Easterling, to his left. Dr. Louis Uccellini and of course Conrad Lautenbacher are here.

Very quickly I'll introduce each one of the speakers and give them an opportunity to have some words to say to you and then we'll go to Q&A.

Let's start with...to my immediate left Doctor Thomas Zurbuchen. He's the relatively new associate administrator for the Science Mission Directorate at NASA headquarters having joined NASA in October of last year. He was a professor of space science and aerospace engineering at the University of Michigan in Ann Arbor.

He also was at the university's founding director for the Center of Entrepreneurship and College of Engineering. Thomas' experience includes research in solar and heliophysics, very appropriate for today, as well as experimental space research, space systems, innovation and entrepreneurship.

He's got quite a very extensive biography that I will not go through here today unless there's something that you would like me, Thomas, to point out.

**Dr. Thomas Zurbuchen**: We're good.

**Marty**: OK. Why don't we go with you and then we'll pass it to Bill after that?

**Dr. Zurbuchen**: Very happy to be here today and be part of this panel, and talk about the space weather activities that we have in a Science Mission Directorate.

What you saw of course at the front page, the slide that I just moved from is the Parker Solar Probe mission that's getting ready to be launched and kind of encounter our star, kind of upfront and personal and really make observations that hopefully will teach a science that currently eludes us from answers because of the fact that we don't have constraining data in some of these environments.

I'm projecting now, of course, the title pages of the space weather action plan and this has a really simple purpose. The purpose is to say that were committed to the collaboration that is outlined there.

At NASA, we have important roles and I'm going to talk about them. The roles interface and come together into that framework that is outlined in a space weather action plan to really provide both the fundamental science but also the translation to operational weather forecasting, which other agencies, of course, are participating in at various stage during that continuum.

Basically, we've been actively engaged. Some of the people on these committees sit right in this room, Steve, I'll say add others, actively engaged in these discussions are going forward and are committed to staying engaged.

Here is the fleet that is in basically focused on solar and space physics or heliophysics as we refer to it. You have of course some of the missions in extended ops, those are the blue ones that are out there.

Some of them I know really, really well, because as a grad student or postdoc, I worked on some of them early on, for example, Ace. That tells you, if you look at me, that they're aged.

They're of course two important science still and are really part of that kind of broad view, kind of a system view that emerged as the essential part of that science especially when it comes to the geophysics data that they're investigating.

There are also, of course missions, that are basically in...There's one mission there, NASA Primary Operations. I'm going to talk about that, just because it's another example, just like the Parker Solar Probe, that is really focused on fundamental science.

A role that we hold on to together with our partners from the National Science Foundation. We really do focus on fundamental science especially the ones that, the constraints can only be gained as we're flying through the plasmas and so forth.

Other missions, they're focused both on the sun at the geospace at a variety of levels, including some of them looking at the very interface of the upper atmosphere that you see GOLD and ICON are really getting ready also to be launched.

That interface, of course, where a number of important physical processes happen that have tremendous societal impact, but we're also there, some of the scientific knowledge the processes at work have eluded us so far.

The three things that I'm going to talk about are really fundamental research that I've already talked about. It's something that's really core to the NASA program, but also I'm going to talk about innovative architecture. The recognition that the way we thought about space weather twenty years ago may not be the way we want to build an architecture in the future.

Something of course that we want to focus on with research in mind, but we are already talking to our friends at NOAA and elsewhere, focused on translating some of the knowledge into future solutions that are operational in nature.

I also want to talk about models. Models are absolutely essential to bring together the distributed observational points that are there into a coherent set of knowledge, especially in the context of forecasting.

Really in a way that just like multiple weather stations are integrated in our weather model, integrated models are also here. Important to assimilate data and really include the science that we are learning from fundamental research through these innovative architectures. These are the three topics I'm going to focus on.

Again, fundamental research, MMS. Sometimes I say it's one of the underreported missions, just because the data are so exciting to those of us who are used to looking at plasma data, the leap that this mission has made from what we knew before in terms of timer solutions, spatial resolution, to where we are not only looking at these data also with the MHD glasses but also on the kinetic side.

That leap is just enormous. It's in some cases 100x, some cases 50x in key parameters. It is really an example of where we think at NASA we can play a role.

The connection, as you know, is important not only in the geospace environment but also when it comes to heating the solar atmosphere, we think releasing in CME's and so forth, and therefore it's absolutely critical to understand the process as such as a physical process.

By the way, if we understand that, there's other domains in science that benefit from that also, especially astrophysics when it comes to x-ray and other emissions in the universe.

This is kind of the mission portfolio as we look forward and it's a reflection on the Decadal that's already set that besides the small explorer and medium-sized explorers. One of them is in the middle of its decision process. The other one is bound to come out. Basically, IMAP is kind of an image you're looking at the boundary region of the heliosphere and really looking at the neutrals.

In addition to that imaging function, there's in-situ measurements of interstellar gases and pick-up binds that are provided there. We have, of course announced that NEO will come out shortly. You've seen a draft process. But behind that, you saw the GDC dynamic in Medici. All of the other missions besides that imager that's really driving the size, largely speaking, of that IMAP missions.

Besides that, the three others, are multi-point measurements, and I'm going to start harping on that. The multi-point measurement nature of heliophysics, and especially understanding our geospace, are going to be really crucial. I was part of that Decadal, and I assume Dan Baker's here, but I haven't seen him yet.

Basically, what I remember really clearly is that the paradigm that we're using to do a small explorer or medium-sized explorer does not translate into a multi-point mission in a simple fashion.

In other words, to do one spacecraft is not the same to do 10. 10 spacecrafts is not 10 times 1. You really want to come up with a different paradigm because you can't afford 10 times kind of a small explore or 10 times a medium-sized explorer.

It's that paradigm that the community has been working on many of you have been working on. Also, it's really starting to bear fruit and that the paradigm is...I'm going to show two images.

The first one is the MinXSS CubeSat observation from the University of Colorado. I've really focused on that because what's exciting about this mission is it's a CubeSat, first of all.

Of the CubeSats that I've seen, there are others, but this is one that has really proven to provide tremendously valuable data. In this case, x-ray irradiance and observations that are out there.

Needless to say, we all recognize that CubeSats were really pioneered in the National Science Foundation, because we really approached their programs so that we're doing, and I'm going to talk about that at NASA as well, just because we think the platform has been advanced enough.

The National Science Foundation should take a lot of credit for the work they did. We won't forget. Basically, the overall x-ray irradiance increases that are shown from these events are measured with a vehicle that usually takes many times the mass and the power of this. We can talk about it along.

The second one is a not in this realm, but it's in the weather realm, and this is Cygnus, which is a constellation of eight spacecraft that's flying right now, looking at GPS signals reflecting off the surface of water and, therefore, making predictions of measurements of strength of hurricanes or cyclones around the tropical zone.

Basically, what you see are data down there. It's a little bit fuzzy at this point. They're also really early released data. They are data that showed the strength in a cyclone that's getting onto a shore in India.

This is a place where we normally don't really have a lot of observations. We don't have our hundred airplanes. Being able to do these measurements or steps would be critical.

What's on the left is text that you've looked at. That says that we are at NASA, as part of our 2018 budget, proposing to do a small sat, CubeSat initiative that is focused on the science that we can do, especially having in mind that there is a opportunity to take some of this multipoint measurements that are so critical for our future observations of the geospace environment, and also in the heliospheric environment for that matter.

Really learn how to that, and to do so in an interdisciplinary approach, multidisciplinary approach so we learn from each other better than if we do this independently.

We've come out of the exploratory phase of that technology developed in place that we're ready to exploit, that technology that's there and really have every intention to use that.

This is the architecture that was envisioned early on. By the way, this is the possible new future of such architecture that is out there. You see some of the new players there in blue. NOAA assets are colored.

Some of the things that were...they're extended missions are no longer there. We recognize that even though missions have been good to us, they won't do as so forever. But what will the architecture be in the future?

For us, this is the original WS architecture. I would like to submit to you that with the advent of these smaller assets, if we start developing it and really learn how to do these multipoint measurements, a newer architecture will be space redistributed contemporary measurements, provide contemporary measurements and evolutionary.

We learn. We can build the constellations as we go forward and really make the measurements that it takes, the number and types of measurements that it takes to move forward. I'm getting towards the end, but focused on one really critical piece, which is the integrated models.

The Community Coordinated Modeling Center is something that was developed by the initiative of a few. I think it's really a model for how developments, and theory, and extended models can be used for a broader community. It's going in the direction that we actually need the models to go if they want to be forecasting models in the end.

The first one is you're the only one using the models then your colleagues are using it. You learn how to make the models robust. Eventually, you learn how to move these models out. The Community Coordinated Modeling Center is one way for us to really talk about the models. Of course, it's the models that are going in that give it the value and there's many of them.

It's also over 80 that are being made accessible. It's really our intent to continue to focus on that and moving the models towards utility and towards the forecasting type of function that are so dear to the heart of this community.

Bottom line, again, I already said it. Fundamental research will be critical. There's a lot of science we don't know, and we will focus on getting the science resolved. The innovative architectures are, I think, have a lot of promise. But we need to materialize that promise.

The promise, by itself, is not enough. We need to learn whether we can actually do these architectures that we think are out there. Based on what we learned, our optimism grows over time and the models will bring it all together.

We have to and will invest in the theoretical and model type of areas, just to make sure that the models evolve together with the other two. Thank you so much.

[applause]

**Marty**:  Thank you, Thomas. Next up is Dr. Bill Easterling. Dr. Easterling was appointed assistant director of geosciences at the Nation Science Foundation on June 1st, 2017. Welcome aboard.

Previously, he was dean of the College of Earth and Mineral Science at Penn State. As dean, he focused on strengthening the college's position as a world leader in earth material, energy sciences, and engineering.

Before his appointment as dean, he served as director of Penn State Institutes of Energy and the Environment. The central coordinating structure for energy and environmental initiatives and research at Penn State.

In addition to numerous other awards and accolades, point out that Bill is AAAS fellow. We are very glad to have him here today. Thank you very much.

**Dr. William Easterling**:  Thank you. It is very good to be with you. I am reflecting back on my past 10 years as dean of that college at Penn State. How I have watched the rise of the importance of space weather, certainly, among our atmospheric sciences and Geosciences colleagues and never dreamed that I would be sitting in front of this audience and my first public talk talking about space weather.

I have learned quite a lot through the years. It's hard not to absorb the importance of this research area and the tremendous opportunities to make significant progress in bringing really truly usable knowledge to serve the public interest.

Just listening to Tom, you're going to hear a lot of reciprocating information which is a good thing because it shows that there already is inter agency cooperation. Significant inter agency cooperation.

NSF is committed to this area, and I will also point out that this area for NSF, and I think most of you in the audience know this, is really an opportunity to direct what the agency does best and that is to orchestrate and support fundamental research in the area of space weather.

To start out, let me just state what I think we probably all know to be the obvious, but it's a good starting place and that is, that space weather impacts really don't respect political boundaries. It is a global phenomenon and it affects people wherever they live.

The image that you see on this slide, which is from the NASA TIMED platform, is ionospheric anomalies shown stretching pretty much across from Africa to South America. This gives you the sense of scale.

Then to follow this up, society is highly vulnerable and becoming more vulnerable by the minute in its evolution of technologies that are especially vulnerable to the impacts of space weather.

I suspect everybody knows these examples, but they bare mentioned power grids, pipeline systems, communications systems, satellites, all of these now that we are so dependent on in commerce, security, and so on are vulnerable to space weather.

The nation, it should follow needs to be space weather ready. I would submit...and I think our colleagues at NSF would support this, we're not there yet.

Looking back in history and we've already seen the national space weather action plan courtesy of Tom, NSF was the first agency to consciously support space weather research dating back to the early 1990s. The agency also is highly supportive of four of the six goals that are outlined in the NST C's national space weather action plan.

NSF's main contribution and this is going to sound like a refrain is to support fundamental research across several of its directorates, but we especially focus on it in the Geosciences Directorate.

I want to give you a heads up that we are requesting community input on information that can be used to establish space weather benchmarks and to continue to refine our research priorities.

It's useful to point out that our benchmarks for just general use are usually defined as one in a hundred year events, and what are those? What are those events and how do you define them?

We're putting out a request for input and series of workshops and I do want to encourage the broader community, those of you who have vested interests in this science to be active, to participate in these workshops when the opportunity arises and when the request comes in your email.

Let's talk about inter agency collaborations. Tom did a good job of kind of laying the groundwork for me because there is a substantial amount of interaction and collaboration between particularly NASA and NSF in this area.

A lot of it focuses around what we share as a high priority, a high need for there being a strong suite of community models of various kinds that are available to the research community.

I point out to NASA and its collaboration with NSF on the development of the community coordinated modeling center, it's a defined entity and it is the flagship for space weather model of development and testing.

We're in conversations with NOAA as well which we hope will lead to efforts to operationalize some of these models as they become ready for prime time. I also want to point out that this is the last year FY17 for the support from NSF on the NSF, NASA space weather modeling strategic capability.

We work with DOE and have done so for more than 20 years in the area of space of basic plasma physics. Now, to no great surprise to anyone in the room, in a period of budgetary uncertainty, NSF is facing a number of difficult decisions and the same applies to the space weather area.

We've got a menu of what we consider high priority challenges or choices really that are coming up. I'll just list a few of them here, the joint NSCI pilot program jointly with NASA that's expected for fiscal year 18, the Heliophysics Science Center's also with NASA. In an area that we see a great deal of promise operations to research with both NASA and NOAA.

NSF is very much in the space weather observation business and we have observing capabilities that truly span the entire geospace system.

Let's look at the individual components. At the sun itself, we have the Mauna Loa's Solar Observatory, Inouye, solar telescope that's about to come online has great potential.

In the magnetosphere, there's the ampere program, the ionosphere super darns and back to CubeSats that Tom just mentioned. I'll elaborate that in the following slide but that could be a disruptive technology, and I think Tom kind of hinted that. It didn't say it outright and also the magneto-telluric survey.

Let me go to the NSF CubeSat program. CubeSats, and I'm just kind of stating this a little bit differently from Tom, are a class of research spacecraft called nanosatellites.

I would imagine everyone in the room probably knew that but I'm banking that there might have been one or two who did not. These are cube shaped and they're about four inches on a side and they weigh less than three pounds, just to give you a sense of scale.

They can be deployed in many combinations and that's part of the excitement. We see those from NSF as a key to advancing space weather research. We're seeing it also as a major training tool for both undergraduate and graduate students pulling them into the space weather area.

I want to give you another heads-up that there will be a new CubeSat solicitation planned for FY18. I have just a couple of concluding slides. This is really just boiling down to summarizing what we do best again at NSF. We fund basic research and in particular, we're aiming that research at improved prediction modeling ultimately to predict the complete sun to earth system.

Many of the models that have some kind of origin with NSF funding are now operational at NOAA and the connection to operations, the so-called research to operations to research, is a major focal point for us in the future going forward. This we think is important to the entire community.

To wrap up, space weather is a global round-the-clock challenge. NSF recognizes that research to operations to research is important to advance the field worldwide.

To say it again, it's crucial for improving our predictive capabilities and just our basic understanding of the sun to earth system. We remain committed to supporting curiosity-driven science. Don't ever forget that we don't forget that that is our primary mission.

We hope that will lead to innovations that propel the space weather ready nation forward. Thank you.

[applause]

**Marty**: Thank you, Bill. Next up is Dr. Uccellini who is NOAA's assist administrator for weather services and director of the National Weather Service. In this role is responsible for day-to-day civilian weather operations for the United States, its territories, adjacent waters and ocean areas.

Prior to this position, he served as the director of the National Center for Environmental Prediction, NCEP, for 13 years.

Other previous positions included being director of the National Weather Services Office of Meteorology and chief of The National Weather Service's meteorological operations division amongst many many things in his long and distinguished career. Dr. Uccellini was elected AMS fellow in 1987, and served as AMS President from 2012 to 2013. Dr.Uccellini thank you for being with us.

**Dr. Louis Uccellini**: Thank you. You should also know I was in NASA for 11 years. I remind Steve of that opportunity.

[crosstalk]

[laughter]

**Dr. Uccellini**: Actually, I'm delighted to be here this morning. What I plan on going over some several items that you've probably now have heard, maybe you think you've heard enough of it this morning, but the space weather operations research in mitigation and space weather action plans are historic.

We just know how they are not only driving the research, but the research operations and the operation development itself. I was a co-chair of that group, but I want to note that Tammy Dickinson is sitting in the fifth row and she was the chair OSTP and it really was a remarkable effort.

I know that there a lot of people that didn't think we'd make it, but we not only got the strategic plan out but the action plan as well. It's becoming a driver for NOAA space weather services. There are others I'll just note those. We also used to suffrage sustain and operationalize some of the research observations that were out there.

Not just the space aspect as we heard about the DSCOVR but the GONG network itself. We were able to get resources for that. Then this was certainly improving our operational situational awareness but it was also using these observations for our models.

One important point, if I leave you with nothing else is that, unlike the terrestrial weather community where models were originally developed in the operational world first, and then the research community came on board and NCAR was a very important part of that history.

In the space weather community, one of the things we recognize when Admiral Lautenbacher operationalize, that was fun, we operationalized the space environment center into what we now know as SWPC, is that all the numerical models have been developed in the research community. One way or the other.

We recognized early that we needed to capitalize on that incredible investment to be able to spin up the modeling activities.

These are the plans. I should also note here that Bill Murtaugh, who is sitting next to Tammy was, and everybody knows Bill, but he was a driving force for this happening in many ways, but it was charted under the White House Office of Science Technology. It was co-chaired of OSTP National Weather Service and Department of Homeland Security.

You'll see the structure of this plan. How that partnership really paid dividends. We'll outline the goals for operations research mitigation in response. We'll also focus on extreme events, but as we're seeing now that we've operationalized space weather that there are day to day products and services as well.

We just got to show these goals. The important point here is the order in which you see them on this sheet. Just became the outline for the strategic plan and then the action plan. This wasn't what we went in with. Everybody wanted to do research first, and then observations and then services and then...OK. How are you going to mitigate?

We realized that the different groups and a number of agencies that were involved in this were just still just circling around each other. It wasn't until we put the target up front. The benchmarks the mitigation steps, the agencies that would actually be out there responding to the event. What do you need?

What do you need in terms of prediction? What do you need in terms of observations? How does the research community fit into that? Because like we said, we're on the front end of this modeling enterprise and this prediction enterprise. It didn't take long for that thread to develop and for this plan to gel when we made that change.

What I'm going to be focusing on is the goal 5. It is the improve space weather services through advancing understanding and forecasting that will focus on it.

The Action Plan itself came out of that. First of all, I didn't even know I was going to get involved in this when I volunteered Bill. I was the player that got named later, but I also thought that this would end with the strategic plan and it didn't.

That's another important aspect of this whole activity. We went into an action plan and involves all the agencies that were involved in the strategic plan itself. One of the aspects that came out of this was the recognition with OMB was at the table, that we would have to focus on sustaining and transitioning appropriate capabilities from research to operations and operations to research.

The reason that I was excited about this, I've been preaching this for years and the terrestrial weather community. We're working it better today, but we still have issues. To have this just basically put right down on paper right from the beginning was new for me.

The reason we have this operations to research is that if we can get the research community to not just throw new models over the transom and tell us, "Hey operationalize." Once they become operational are you going to continue doing research with that infrastructure?

The reason that's important is that if we can get the research community to work with us like that, we can accelerate the improvements into operations.

That's one of the key aspects of this plan. It's not just doing the R2O but accelerating it as we move forward. As part of that there was actually, as part of the orders that came in and what was listed in the action plan in the executive order and in the Senate version of the bill that just got approved, was basically laying out all this activity now in law.

Which is quite remarkable. One of the next steps was the MOU to be signed by NOAA NASA to get to CCMC and the SWPC folks working more effectively together not only authorizing it, but sort of cementing it into the relationship. That was signed in May of this year and the first SWPC-CCMC meeting will be this Thursday.

Steve, the two individuals that helped work this, Steve Clark and Bill Lapenta are sitting there in the second row. We are now working towards a more formal relationship. Building on the success that we've already had. I've mentioned that there are other drivers. We have the strategy and action plan. The executive order, the first reliability standard, the Senate bill.

That's passed, the House is considering it. We do prediction in NOAA, but we're not quite sure when exactly they'll take it on. Then we've had this international activity. The UK Met, worked very closely with SWPC to spin up their operational capabilities. We now have a collaborative forecast process with them. They actually are a backup our international backup.

All this is being done within the world meteorological organization as an umbrella. We do have this international component and that was one of the chapters in our strategic plan was to build on that operational activity. Now you saw this diagram in Steve Volz's talk. What I want to know is the start point of the blue, which is in 2005 which is when we've operationalized the SWPC.

We're really at the front end of this entire effort from an operational perspective. We've been operational in terrestrial weather indications since 1870. We're new at this. What also fascinates me about this chart is the continued growth even during the minimum. You could say that the growth was in anticipation of the Max in the 2013-'14 Time Frame, but it continues to grow.

This is a reflection of the needs. Even in Relative Minimum and the growing demand for this. One of the other points I would like to make for you is as in a terrestrial weather environment, the government agency know we can't do this alone. We're already working in a public-private sector relationship in this space for the community like we have in the terrestrial weather community.

Right now, we have a $9 billion private enterprise in terrestrial weather. I believe there's a lot of opportunities here across the entire enterprise. We also heard about the weather ready nation aspect of the weather service and NOAA has promoted this weather ready nation as a strategic outcome that's actually driving the weather service for communities to be ready, responsive, and resilient.

You see these types of things we have to do, better forecast and warning. Consistent products and services, actionable environment intelligence. Connecting forecast to decisions. We do envision the same for the space weather community.

You already heard this from Bill in his talk, and it clearly provides a framework to bring together the observations to new modeling capabilities. To provide better information connected to key stakeholders for better decisions as mapped out in the SWAM and the SWOP plans.

Again, the emphasis here is the partnerships. It's going to involve the entire US space weather enterprise working together to make this happen. Just like the terrestrial weather community has been working especially since the turn of the century.

The government and the way we help make this work is we provide a basis of information, for not only the private sector but NCOs, the academic community, and others to work with.

We mentioned the observations of...Steve gave a great talk on DSCOVR and GOES-16. I'll mention the GONG network. This was one of the items that came out of the SWAP and it does provide the operational support. We now are sustaining the ground based imaging. We work with the Air Force on this.

This was an NSF research observation system that's now been operationalized. You see some of the future plans that we have for the replacement for DSCOVR and then the Cosmic 2, which is planned for a 2018 launch.

Putting this together, we have a series of models that have come out of the CCMC. The Enlil model, the geospace model. Enlil from the George Mason University, University of Michigan, geospace model. We've been working with CIRES on this whole atmospheric model. We do an E-field model from an operational perspective that's come out of the work with the USTs.

The idea here is that on the left-hand side you would start on a longer lead times. We do have lead times up to three days not just 15 minutes on some of these events. The idea is that would help support the watch.

The geospace model, a shorter time frame would help support a warning capability. When you get into the right-hand side you are in an nowcast model. It's the same kind of structure that we're looking at that will work within the terrestrial mode.

I should just note here. These are just some of the fields that have come out of the geospace model. It's already operationalized. There's an improvement scheduled now in September of this year. The right-hand side you see some of the predictive magnetic disturbances. We have the velocity density and pressure fields that the model also provides.

These will become more recognizable within the space weather communities, obviously some training that needs to be done in that.

With respect to the whole atmospheric model, basically, we're taking a terrestrial model of what we call the Global Forecast System all the way on the left, and adding layers all the way up to 600 kilometers to account for the thermosphere and exosphere and then have this ionospheric model embedded with it.

It turns out in some of the initial experiments with this, we're seeing just as much influence on the terrestrial space as we're seeing the potential of the radiating waves up in the into the thermosphere and ionosphere. This could be a big win for us across the whole spectrum of prediction models.

I should note in the E-field model we're, I'll just say here we're working towards an operational item by the end of this calendar year, but we also need the magnetometer data from the USGS. This is one of the observations that are at risk in the budget.

Think of a river forecast. We make river forecasts. USGS provides river gauges to help calibrate those models and give us the outcast. That's the same thing we need but with the magnetometer. In conclusion, we're obviously excited. We are new in terms of the operationalizing the research. The tremendous research investments that have been made over the last 20 years.

We're very interested in working with the research community moving out forward. I think as we start developing this operational infrastructure will actually provide a basis for research that can be done. Certainly, will be serving a larger community and supporting our users and partners.

In that word, "partners," we do include the private sector. Folks who are also growing within this enterprise. Thank you very much.

[applause]

**Marty**: Thank you, Lou. I appreciate that. Speaking of the private sector, let's move on to Admiral Lautenbacher. Retired US Navy Vice Admiral Conrad C. Lautenbacher Jr.

He is the CEO of GeoOptics, Inc. and serves on several boards including the boards of AccuWeather and Sakura. Formerly he was vice president of Scientific Support for the CSC Corporation.

As undersecretary of commerce for oceans and atmosphere and administrator of NOAA, Lautenbacher spearheaded the first international Earth Observation Summit in Washington in July 2003, it seems like only yesterday.

The subsequent activity to establish the group on Earth observations and sustained Global Earth Observation of Systems, GEOS, probably from that. Before joining NOAA, he served as the President and CEO of a consortium for an oceanographic research and education, that's the core program.

As Navy flight officer, he served as commander US 3rd fleet, director of force structure resources and assessment, J8, on the joint staff of the commander of US Naval Forces. He is a graduate of the US Naval Academy holds both MS and PhD, blah, blah, blah [laughs] Thank you very much, Admiral.

**Admiral Conrad Lautenbacher**: Thank you. Thank you. It's a fine introduction.

[laughter]

**Admiral Lautenbacher**: Anyway, it's a great pleasure to be here with you and to be with this distinguished group at the dais here. I'm happy to see this many pieces of wonderful turnout, so congratulations to everybody here. I want to go a little bit further. I'm only going to bore you with one slide from the SWORM but we want to get further.

There's an old saying, "If you're standing still, you're actually falling backwards." You got to be keep it moving forward all the time. You've got to be thinking in next steps and you've got to go forward. Let's talk about how we really get the partnership going. How do we get the private sector into it, and all the talent is there.

It's important. What's happened is very important and what I want to go through and talk about the whole enterprise the pieces of it. How you work together. These are things that scientists don't like to mess around with. They want to be in their laboratory and they want the results. I understand that completely, but sometimes you have to organize things so it all works.

You can actually make progress. Let's go through. Let's see. There's my one slot from the SWORM which is a great achievement. I echo everything that's been said up here in terms of getting the government to work together is a hard thing to do. I can assure you after spending 47 of my last 56 years working for the government on the planet, it's hard.

These are these are some words that show you that it's supposed to be a real team effort. A collaborative environment, government, industry, American people. Leverage existing public and private network of expertise and capabilities. That's what the United States is good at.

It's not good cause it has a great government. It's good because it has a great combination of the way we work together with free enterprise, and bring the talents together to make it a whole inclusive activity. Let's take a look at, as Louis mentioned, the analogy with the weather enterprise.

We are talking about a total range from basic research up through products and services that are needed for it the run. We're not just talking about how good our models are. We're talking about how they're going to be used and how we're going to protect the public.

The world needs protection. We all know. I think we've come a long way in educating the public and Congress and other leaders on space weather this is important. Anyway, if we used the analogy for the weather enterprise. We want to maximize value. We've got a three-legged stool again.

I think it's a reasonable way to break it up. You've got academia, you've got government, and you've got commercial. It's got to all work together. Each of them has their talents and their skills and their place in the wheel house here, because it's to control the everything. Academia, science, and research, you got to have that. That's the place where it gets done.

Government, we got to have it. Public safety is important. National defense is important. Regulation is really important. We'll talk about that in a minute. Commercial, this is where you actually get two people, and work with the creativity of the American population. Services, efficiency, competition, a robust economy, communication among people, you get the pieces that actually make this effective.

It's good to think of it that way. We've been thinking about that way and weather enterprise for a long while. It works fairly well.

We debate now and then about who does what and how it should be set up but I think if you see the value of the commercial weather enterprise, you will see that there's a lot of work goes on that helps build the safety and the efficiency of our public and commercial businesses.

Let's look at that a different way. Going to put the three things back up there, government, academia, and commercial. I've changed a little bit there. Let's look at how we connect.

The first thing is, we all connect with money. Money goes back and forth from these various pieces. We all have to think about that, because without money none of us function very well in government or in commercial world. There's money involved here. OK?

It's not just, "What am I going to do in my laboratory?" it's, "How am I going to pay for it?" and "How am I going to make it work?" and, "Who's going to do what?"

Now, academia is really good for the basic research. Let's face it, a lot of grants that go out from NASA and from NOAA and the Defense Department. My PhD thesis came from a grant from ONR. It's done in academia. This is one of the major parts of this stool here.

Commercial, it's where we reach the econ-, where we reach the general public, how we put creativity, competition in there.

The government exists to create a bigger government. I can tell you that from 47 years of working in the government. There's nothing wrong with that. We want good government, but you have to have some kind of a balance and understand how things work together.

Commercial helps us make that balance. There's a few things that can help us in the Space Weather. There's CRADA agreements, I put down there, the cooperative R&D agreements, if you look between these arrows, you go back and forth, the small business technology transfer program which you bring in academia and commercial and government.

It's a very nice partnership idea. Small business innovation research, CRADAs don't have to have any money attached to them by the way, but the others do have money attached to them and of course, you would like money coming in from the commercial system too.

You don't want this to circulate the government money in here. You want to bring in other money if you're going to grow this enterprise and create the kind of safety net that we should have for the world, at least for the United States to start with.

Regulation. That went dark. I must've hit the wrong thing. We'll go backwards. OK. Regulation. There is something that the government has that we don't look at very often as a way to deal with you harnessing the commercial sector for government use.

How do we get power in the United States? We get it from private companies. How are they managed? Through regulation. The government sets up the rules on how they do it, provide the services and we can do the same thing. You can do this in this part of the world too.

There are ways to set this up so that everybody has their share and it works. If you do it collaboratively, it's not a bad idea. If you are going to have a partnership, which I suggest that we have because we are far too small, I say we as the space weather community, we are so small we don't even show up as a decimal point in the federal budget. The amount of money and the number of people involved in this.

We need to build a partnership among all the people who care about this and as I say I'm happy to see even more in this room than there were five years ago. That's good.

These are the rules that are at the end of one of my pitches for partnership but you got to start with harmonized policies. We got to have policies that are compatible, you got to level the playing field so everybody feels like they're involved and are willing to take chances. Stick their neck out, get together.

You have to have frequent consultation between these groups. You can't all go back into your laboratories and hide or in wherever you are. You've got to come out and talk. You have to define the roles. What are we going to do among ourselves? How are we going to treat that? You go back and you go up to the top there.

Active engagement and support for one another. We have to work together and win-win psychologies really work. When it's win-lose, I can tell you the loser always goes home. It's not a good idea and in the end, you've got to have public understanding and support.

We have to reach the public, which requires getting through this whole chain that I'm talking about and that gives us that budget resources through the systems to meet our needs. That's a wonderful theory, but now you get to do something about it.

Let's talk about the structure, the construction of this. You've got a federal budget which is very small and you've got space weather with a really not much of a spin, not much of a budget.

Let's face it. It's not a big budget, all right? We have promulgated national needs with circulars. We're going to lose our whole electric system if we don't do something about this.

Almost everything today if you have electromagnetic problems, you're going to lose it. You're going to lose the Internet, you're going to lose everything. You're going to lose navigation, you're going to lose your power. It all goes. This is a big deal.

What's the best way to think about filling that and you've got to make use of the three commercial, the agencies, academia? It's all got to work together and you've got to have these lines going back and forth.

You have to figure out how you're going to let use the commercial sector to draw more money into this system because it isn't going to come in by us sitting in government and academia trying to get grants back and forth.

We have to figure out what the products and services are, who's going to do them and how it all runs, how it can run. That's going to require collaboration and work.

This is swim lanes problem. What systems architecture is the most efficient do you think? You like the one that is on your on your right, we're all just...we jump in now.

I grew up in a middle of Philadelphia. A little row house and that was my swimming pool. I didn't learn how to swim till I was 13 years old because you're in the jump in those pools you jump on top of each other. People grow up in the city but that's it.

I wasn't introduced to this kind of swim though, a swim lanes thing is really a good idea. You get really chance to learn how to swim, you got a teacher, you got some rules, and by golly, you can really do well.

Are we going to have a free-for-all? Are we going to talk about swim lanes ways to figure out how to channel our activity so we're in the right swim line? this is what our PhD science pays for. That's my swimming pool.

[laughs] You're going to have a hard time with this. You've got two things to worry about. You got to develop what it is and we have a lot of research to do. Space weather is in an area we don't really know what goes on in the Sun all the time, do we? We're working at it.

RDT&E, let's face it. It's government funding. Most companies, there's some others out there that fund it, but most of this stuff comes from government. We have to press government to do the R&D, and we have very good agencies that can do that.

There will be some government money. That's kind of one pool and there's going to be some people racing and they get out at the other end. Some of them aren't going to make it, but they have to go over to the products and services.

At that point, there's some lanes there that are total government lanes. They have to be government. The government's got to provide for the health and the safety of various enterprises, etc.

This government goes all the way out. They make the products, they do the services just like the weather service does. There are other places where the government starts it and you can start to pass this off as you get companies that can do this, who will then go to the public, and you get the public response which is, "Gee, we'd really like this."

We have an efficiency and the money comes back into the system from the front end. On the top, you take care of national security safety, on the bottom you worry about efficiency robust economy. That makes everything work and the public has that we have to get to the public.

This is what we have now for the commercial space weather association. I've saturated you with the logo in every slide. If you don't know what this logo looks like, I go back and look at my slides.

It's a group. It was only five members in 2010. It's now 19 members. Those are all the initials. These are real people. They're on the executive committee.

This can grow and will grow if we work together and collaborate and try it because this is the only way that I know how to work from the government to the private sector efficiently. That has to be industry associations because you can't go out and work with every particular company very well, but you can work with industry associations.

That's got to be thought about so excellent. All right, now the value chain is important. If you notice a logo it's there again, America's first Commercial Space Weather Association. There are things in every one of these upstream midstream downstream.

There are companies that are involved in every one of these. Probably it's different for I'm over and a red our camera going to quit. OK. There is a lot more research in the commercial weather industry than there is in the tropospheric or atmospheric weather. That's mostly towards products and services, and that's odd. It's spread evenly so we've got to think about having all of that.

I'm just going to flash through four slides and then we quit. That' the company that I work for. I'm trying; I'm doing the CubeSat small satellites. I think that's the next big revolution. We're going to be able to give you a much better ionospheric data in the space world. That's what that says.

This is CPI. They do space hazardous monitoring and they produce GIC hazard analysis for power utility research planning and operations. They ought to be doing that and the power utility people ought to be paying them to do that. That's what ought to happen. Space hazards monitoring making the instruments to do that.

GIC Hazards, computational physics, sensors, data products, models, models. A lot of modeling goes on in the private sector that has been used in the government and needs to be considered to try to jumpstart and keep things going. This is the space environment technology. I'm not showing everybody, but it talks about how do we take care of every aviation radiation exposure.

Where it comes from, the instruments to do it, how do we manage it? Here is the instruments that they make. Here's another set of solar indices from "Space Environment Technologies." You could see the things we do.

Low orbit or neutral densities. There's lots of things that can be done and you can bring...and then at the end of this all these people will go to Congress and say, "We need more money for space weather."

That's a lot stronger than a government official going in and saying that. I give you my experience of doing that. That's it. Thank you.

[applause]

**Marty**: We have about eight minutes before its lunch time. I see a couple of microphones. Please, if you have a question approach the mic, and we get our first question over here. Please, stage question and who it's to on the panel.

**Ben Davidson**: Absolutely. My name is Ben Davidson with "Space Weather News." This question is actually open for anyone but I'm mainly speaking to the director there, Dr. Uccellini. I suppose to you as well. The concept of the public's version of private enterprise and space weather.

For example, I run a Space Weather News program at 6:00 a.m. every single day. You can learn everything that happened on the sun. Everything that's happening geo-electrically, geomagnetically. There's 300,000 people subscribed to the service and there's 90 million views for these daily videos every single day on YouTube and on other social media sites.

The question is, is there a place for the generally interested individual? The citizen of the populace. For example, the way that the weather channel is good at disseminating information and the way that it is good at informing people. Is there room for that general public outreach for the general populace?

Given the fact that the allure of space weather and just how exciting it is has very much proven its popularity among the general population.

**Dr. Uccellini**: Like all the products and services that we provide, we make it available to not only specific users but to the general population. We work with the media and the media now is becoming a broader range of people like yourself and not just a few outlets, but we work with the media to distribute the information as well.

We cannot, because we're not a regulatory agency and I'm not, I hardly ever disagree with Admiral Lautenbacher, but I certainly would want to stay out of the regulatory aspect of it. Provide the information for those folks who disseminate. They tailor the information. They have specific customers, specific angles they want to emphasize.

That's up to the people who are actually disseminating the information, but we provide a unified basis to start that process from. That's true in the terrestrial weather community as well. We make everything available. It traces back to the Paperwork Reduction Act in the late '90s. It's written into law that we have to do that.

**Dr. Easterling**: I'd say the same thing in NSF. It has become quite clear to us at NSF that we can't just be satisfied to do fundamental research and just let the chips fall where they may in the peer reviewed literature. Through the years, we have made a very concerted effort to become a disseminator of what I'll call usable knowledge.

That's taking basic research findings that may or may not be intelligible to the public and turning it into useful information for the public to know. Now, I have colleagues here who have a great deal more experience with the space weather dimension of that and I'm going to turn to them if they want to make a further comment.

**Dr. Zurbuchen**: Thank you. When Troy Smith fumbled with two seconds left and we beat Ohio State, this half of my face was blue. This half of my face was white and I was in the front row.

**Marty**: Thank you for that.

**Irfan Azeem**: Irfan Azeem, I'm from NSF, I'm the program director for Space Weather Analogies. I'll make a quick comment to follow up on Bill's response that we certainly have recognized that we need to engage the community, the public at large in the fundamental research.

We are also, as part of that we are engaging the broader community via Citizen Science. We're actually asking citizens to provide us the data so that we can begin to use with that they're getting more engaged with space weather and now I'll give an example.

We all know there's a solar eclipse event coming up in later this summer. NSF has organized several events and we're encouraging the public to participate in those events provide the scientist with data so they can actually execute some of the research. That's one of the ways that NSF is trying to engage the public in fundamental research.

**Admiral Lautenbacher**: Let me ask, what's your business model? Are you getting money from subscription, or ads, or media service? What do you do?

**Ben Davidson**: [off mic]

**Admiral Lautenbacher**: You're a business man. You've got a business. Join ACSWA and start it. This is how weather got started. [laughs] There will be public interest in this, and we get people who specialize in it, like you, who know what you're doing and are connecting with people, and this is ambassadors, weather ambassadors for the Weather Service. This is how we part of how we grow the thing. That's great. Thank you.

**Marty**: All right, with one minute left, I'll exercise moderator privilege and ask a question to each of you. If 100 percent is fully operational, how close are we to having in the United States, a fully operational space weather utility? [laughs] You can decide who's going to answer first.

[laughter]

**Dr. Uccellini**: I would say from an operational perspective we're at about the 1960 level of terrestrial weather with regard to the implementation of models and use of observations. We're just at the front end. I'd say less than five percent, from an operational perspective.

**Marty**: Admiral? Want to take a guess?

**Admiral Lautenbacher**: Yeah, that's it. [laughs] I'm definitely below the 50 percent level, so I don't know if it's low as five percent we do have networks, but if we had a big disaster we'd be in big trouble. It depends on what kind of disaster you're talking about. I'd maybe give it 20 percent.

**Marty**: Bill? You've been three weeks on the job, so you should have a good number.

**Dr. Easterling**: Sometimes out of the mouth of babes, but, I was thinking to myself, my research area is climate change and food security and I'm thinking now how does space weather factor into this.

Just about every tractor in the Midwest is outfitted with a GPS, and it could be a real disaster if we had a really poorly fertilized field because of some sort of anomaly but then, thinking where would I get that information? I need to avoid that sort of risk. I don't know.

On the basis of someone who is just coming into the space weather sciences, I would think it's just at the embryonic stage. Is it five percent? Is it 20 percent? It's low.

**Marty**: I know NASA's not an operational agency but Thomas? You want to?

**Dr. Zurbuchen**: No. I'll listen to the operator when you ask an operator.

**Marty**: Yeah, there you go.

**Dr. Zurbuchen**: For me the one thing I'd like to say though is point to the positive gradient. I was part of the Decadal. I was the vice chair there and when we looked at the models that were translated at that point, we could count one, because one was in the middle of being translated. Look at the list that you put up there, right now, Louis, just earlier. [inaudible 73:22] entirely different world.

Some of the missions that are out there, in research mode, are already ingested, in some kind of demonstration mode, it's like, "Yes, we're low." Leadership is about gradients. The question is, are we going to manage to drive it up there.

The beauty of this panel, what I took away is, "Hey, we're all committed." For me, we're locked on to where the target is, we're learning how to dance, and no, we're not there. Nobody says we're there. I certainly don't, but to me, my optimism is based on where we've come from in the last handful of years.

**Dr. Uccellini**: Let me just emphasize here, about being on the front end and comparing it with terrestrial weather. I might be making an analogy. Back in 1960, we didn't predict more than four inches of snow. We didn't predict an East Coast storm until it was actually developing, secondary development.

There were researchers who claimed that we would never be able to model that. Now we do it seven, eight days in advance. We do a lot of extreme weather events with a long enough lead time that FEMA can actually start pre-positioning assets five to six days in advance.

We are not there with space weather. We react to events. Tom Bogdan still talks to me occasionally and says, "Well, you've got to be able to look into the sun and be able to predict a solar flare days before it happens. You want people to pre-position adequately? That's what you've got to do." We're not there yet.

Now, research community, NASA operational satellites? Knock yourself out. We need that information and we need to get it into models and remember, we don't develop the models. We implement what comes out of the research community. I think five percent is a pretty good number.

**Marty**:  Thank you very much. Let's have a round of applause for everybody.

[applause]

Transcription by CastingWords