



## Welcome and Opening Address

### Speakers

- **Mr. Ralph Stoffler**, Director of Weather, Deputy Chief of Staff for Operations, Headquarters, US Air Force
- **Major General Scott Vander Hamm**, Assistant Deputy Chief of Staff for Operations, Headquarters, US Air Force
- **Dr. Stephen Volz**, Acting Assistant Secretary for Environmental Observation and Prediction, National Oceanic and Atmospheric Administration

**Ralph Stoffler:** Good morning. Great to be here. I think what we're seeing in this room is already impacts of space weather. Without a doubt, a lot of our partners are experiencing GPS scintillation and having difficulties finding this place. The crowd is not quite as full as it should be but I'm sure as time progresses on, everybody will find their way.

Admittedly, even for myself, an experienced traveler, between the construction and everything else, I was looking for the cold and we are here.

I really take this as a great meeting, a great forum, for us to partake and exchange information and continue to work our cooperative efforts.

I think all of us know that as budgets become tight as we continue to work, we need to really leverage one another and work together to achieve ultimate success because space weather is an operational thing that impacts us each and every day.

We, under the Department of Defense, in particular in the Air Force, feel those impacts everyday as we continue on with combat operations throughout the globe.

Space weather is a big deal.

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This is a team sport. We're not alone. We're all working together. I think that cooperation is getting better and better all the time. Not only do we have government agencies, we work with academia and we're increasingly cooperating with the commercial sector.

We know that both NOAA and the DoD have commercial programs in place. The commercial sector will play a greater role. Of course, there's nonprofits out there as well that we're working hand-in-hand with to improve the capabilities and really deal with space weather effects as we continue to go on.

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Objectives are pretty clear. We want to increase the exchange of information, increase cooperation. Even though these things are being worked by us all the time, one thing which I really want to emphasize, we need to get to the point where we do like we've done on the tropospheric side of our operations.

We need to start creating a unified framework that facilitates the exchange of information and allows us to go down the plug-and-play world.

It's a lot of effort when somebody builds a capability and we have to spend a lot of time to reinvent that so it works in somebody else's model applications. That to me, personally, is a big focus area because if we can start leveraging other people's capabilities and bring them into operations, that will make us light years ahead -- quicker, faster, cheaper and more efficiently.

I think we're on the right track to do that. We're cooperating on the big picture policy, the exchange of data and every agency is finding its swim lanes and leveraging everybody else to get the job done.

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Here's the agenda. You're seeing the opening even as you speak and this morning we're going to talk about which is very important to us from an Air Force DoD perspective and that's the impact on ops.

How do we deal with that? How do we prepare? What are the mitigation strategies that we can employ because space weather does hinder operations?

The commercial sector will feel that more and more. We've already seen as commercial airliners spend more time flying over the globe as more ships transit at the Arctic and Antarctic regions, there will be greater impacts of space weather across the board.

That's a big deal this morning and then this afternoon, we'll talk more about the partnerships the inter-agency which is happening at the SWORM level in the White House.

I think great structure, we just need to continue to follow through and get it going. Next slide, please.

We've got some key folks here. I really appreciate the opportunity. Dr. Volz is here. He's going to talk to us on governmental perspectives and particularly from a civilian point of view and how NOAA is interacting and helping this area out. I really appreciate you're here, sir. You have great contributions to make.

Next slide.

Now, of course, let me talk about General Vander Hamm. I've been in this business for 36 years but a lot of times, we see it in graphs, in meteorgrams and theory.

We talk about operations but frankly, a lot of us may not fully understand what operation is.

I have the lead operator of the United States Air Force here today to talk to you about that and what space weather really means when you're flying in a B-52 or a B-1 or a B-2 bomber across the globe to hit a target in enemy territory.

General Vander Hamm has done that. He's got over 4,500 hours of flying time in these weapons systems which are critical of the Air Force and really do the force projection that we have. He's lived it. He's got the T-shirt. He can really talk to you about what operations in space weather really means.

Vander Hamm?

[applause]

**Major General Scott Vander Hamm:** Well, thanks for the introduction, Ralph. Thank you, ladies and gentlemen, for being here and the invitation to represent, of course, the air force and an operator at this year's forum. It's also great to be in an audience or with a group of people who are being smart as cool.

Probably more PhDs and Masters degrees are present in this audience than I'd see probably in weeks at the Pentagon. I appreciate what you all do day-in and day-out.

This year's theme, I'll talk a little bit about ops and tell a few vignettes. Ralph did say I have a long-range strike background, so B-2s, B-1s and B-52s. When you've flown sorties like I have been in excess of 38 hours airborne nonstop from the continental United States to strike targets in the Middle East and to fly all the way home, you experience all kinds of weather impacts.

Space weather, particularly, impacts the long-range strike portfolio because of our ability to use either long-haul comms through space or digital HF or HF and you don't know how many times, I struggled just to find a good frequency from which to do my recording, doing the over water operations. This is near and dear to my heart and hopefully it will resonate with you.

I think that this year's theme of implementing National Space Weather Partnership is relevant. It's fitting particularly because of where I sit right now. We, the operators, implement and execute every day.

I have found in my experience in the national capital region, for those of you that are from here with me, that work in this bubble environment policy tends to be, at least from my seat, easy, execution and the implementation are hard.

Anything involving space, I think, both policy and execution is hard. Today, I'd like to talk a little bit about weather, on our Air Force and joint force, how we operate and how critical it is to both the air fight and the joint force fighter. I've spent over 30 years doing this, in both conventional and nuclear capable aircraft, working from non-kinetic to kinetic, nonlethal to lethal in the full spectrum of operations.

Weather to include space weather, because this is often left out when we get our weather brief, it does play a huge role in our successes and our ability to bring effects to objectives.

In full-spectrum, no-fail missions like the nuclear mission and missions of homeland defense, space weather is vital to our Initial Threat Warning and Assessment or what we call ITWA and then the Nuclear Command, Control and Communications.

Beyond those two areas, ITWA and NC3, space weather is at a critical nexus to decreasing ambiguity, I believe, for senior leaders and our national security.

Strategic miscalculations could have and may in the future be made because of not a good understanding of what is going on in the weather, and in particular in space weather.

Operational decisions and tactical execution, they all rely, to some degree, on timely and accurate space weather data. You all know, it can degrade GPS signals. Ralph alluded to that today, and in fact to how some people are going to filter in today.

I don't think it's because of the GPS but it can, if you have been in a place where you're using your Waze application and you go through a tunnel.

I didn't realize how much I was relying on Waze until I was in a one-mile long tunnel. I'm still asking my wife. "Is that the action I am supposed to take? Was it the capital or was it with Third Street?" Which one was it? It's wandering. We become reliant on these.

As operators, we do the same thing. I have flown both B-52s, like I said, B-1s and B-2s. When we go into degraded navigation operations when GPS signals are lost or we lose a few satellites in the constellation and it's not as accurate, the Kalman filter algorithms, they begin to cause INs to drift because they even become reliant on GPS.

I've found myself in very precarious situations and in uncomfortable situations in international airspace because I didn't have that fix that I needed. It also impacts the employment of other technologies like stealth technologies, both in the ground and on the air.

Our United States Navy because of where they operate, they are heavily reliant on different wave forms and primarily in the HF spectrum.

Those can also suffer as we know from space weather. The list goes on and on, but I'm going to give you a few illustrations to drive the point home. The first is a vignette. Let me take you back about 40 years. Some of you are less than 40 years old, but some of you are not and you may remember May 23rd, 1967.

Almost 50 years ago, 45 or so. Actually just add 50 years and there was a short time after the Cuban Missile Crisis. On that day, May 23rd, NORAD or the North American Aerospace Defense Command witnessed a degradation in their warning capabilities.

They thought that the Russians were jamming our missile, not our missiles but they were jamming our warning capabilities. In those early warning radars, we thought that to be an act of war. NORAD basically elevated the defense condition, the DEFCON.

Subsequently then strategic air command followed by elevating our force posture and to put those bombers into a ready launch status. That was the time when we were still at the tail end of what was called Chrome Dome Missions, where we were flying airborne alert at West and North and on East Coast Chrome Dome Missions.

Those were bomber missions flown by B-52 D models and G models where we had nuclear weapons on board the airplanes. That was a very aggressive force posture, but the rest of the bomber force was on nuclear alert.

To increase that posture means that you take aircrews, you put them in the cockpit or you pre-positioned airplanes to the hold line. Should something go wrong, then they're in a better posture to launch if missiles are in bound.

They were put in that posture loaded with weapons and those crews were fully trained to complete their mission. When we were nearing again the end of this Chrome Dome thing, so were in a very interesting situation.

Fortunately for us and for the research and development community, the science and technology community, this was about the time when we started monitoring the sun's activity.

NORAD had solar forecasting center and was able to determine convincingly and convincingly articulate that the sun was negatively affecting our radars, not the Russians, despite those false radar returns that appeared to imitate bombers from Russia coming over the poles. I've been that bomber aircrew on alert before sitting both nuclear alert in the B-52 and the B-1.

I know what would have happened had we launched. It would have significantly altered history of the world as we know it today. In other vignette, fast forward to 2015. In November of 2015, Swedish radar stations were not relaying correct data to air traffic control.

That prompted controllers to switch basically how they were managing aircraft in and around their country, and restrict the number of airplanes allowed into their airspace. This disruption wasn't long. It was only about 90 minutes.

Experts, even though that was more than two years ago, are still debating today as to whether this disruption was caused by a cyber-attack or space weather.

Either way, either type of event could affect how we conduct our mission sets. Highlighting the criticality of understanding space weather and the picture that it creates to quickly and accurately attribute cause to any kind of an alarm event.

Another vignette, and this one, some or most should be familiar with because it deals with an operation in Afghanistan during Enduring Freedom. In March of 2002, we lost seven Special Forces troops, six SEALs and one Air Force airman TSgt Chapman was the Air Force airman.

They were injured in the mountains of Afghanistan during an engagement known as Roberts Ridge during Operation Anaconda.

Anaconda was supposed to last three days. It lasted 17 days. Now, it's been hypothesized that during that rescue attempt in Operation Anaconda that ionospheric disturbances were causing UHF satellite communications outages. That would limit our troop's ability to, one, call for help or two, let those coming for help know that they were landing in a hot zone.

Now there were a lot of things that went wrong in Roberts Ridge. There were a lot of things that could have made a rescue more effective and more efficient. We may or may not have lost lives. This isn't armchair quarterbacking.

That this is just a plea to let you know that had operations really understood and was better to predict that they may have comm outages of some sort. They may have acted different and we may not have lost those.

You've seen the heart of those combat search and rescue warriors. They want to go in and get the guys on the ground. I've been there. I have orbited in Afghanistan in a B-1 like a bird of prey if you've watched "Star Trek." You're a visible deterrent to forces on the ground that would come after friendly forces.

I've been on the radio listening to troops on the ground in contact. You hear the gunfire every time they key the mike. You hear them under fire and you feel like, "Well, if I could do anything, I'm going to swoop down and kick some ass." You're limited by your ability to do that as accurately as you need to within the rules of engagement of that particular fight.

If you put yourself in the place of the operator, we want to arm them with every piece of information we can. That includes the ability to understand comm outages that could be affected by weather or space weather.

Even though that cause of radio outage is still not determined. It illustrates that we need that help and you are here to talk about, not to bring that help to us.

The reason this one is particularly close to me is because I'm a father-in-law of a Navy SEAL. I have a first cousin who just retired as a Navy SEAL.

Every six months, he's deployed, my son-in-law. I have my daughter and three grandchildren. They come stay with us for a period of time. My prayers are constantly for those warriors downrange.

As a general officer who sends men and women into harm's way, we have a vested interest. We have skin in the game. I want you to feel that just like the war fighter and father and me feels.

I think we as a group, there's an imperative that we need to help get that sensor to operator path perfect, whatever the sensor is so that we can operate more efficiently and effectively.

Space weather is important. It's important to you. Many of you are researchers, many you are writers, some of you are operators.

Ralph is my interlocutor, as the A3W, the operator for the Air Force. Ralph, as he stated, has not been in harm's way necessarily, and shot at, missiles shot at, or otherwise.

We need the collaboration and it's important. I think you understand that today. Now, we don't need to rest on our laurels and our current capabilities, as advanced as they are.

We need to articulate space weather impacts to decision makers on the national stage because it'll impact national security, and our operations day-in and day-out, if not now, even more importantly than it was back in the '60s.

Space is becoming, as you know, more congested, more contested, of course more commercial, and we will need the ability to articulate accurately those impacts that the space environment has in support of the air, land, and the sea domains.

Not only must we advance those abilities and capabilities, we must effectively integrate space weather impacts in regional and national level exercises.

When a combatant command has an exercise, or an agency has an exercise, like GridX, which is where the power is brought down in the nation, I think it's imperative that we, due to mission assurance,

understand where the space weather impacts. It needs to be played in those exercises, so we can learn to fight through it.

We need to fight through effects that space weather would cause, like power failure, or commanding control failure. How do you work when you're separated from the mother ship?

Navigation errors, that I've already mentioned, and the insidious drift that inertial navigation systems have now, because they're not as robust as they used to be because they rely on the Global Positioning System.

Finally, precision guided munitions and dropping those. I've been in environments where weapons were going between precise and less precise, GPS-guided versus inertial navigation systems guided. There was a rule of engagement, an ROE, for each of those scenarios.

If you're having space weather effects in the middle of a run, like I've been over Kosovo, over Iraq and Afghanistan, dropping weapons in harm's way, the operator in me wants to put it as close to the target as possible for collateral damage. Actually, you want to decrease that. Hit the military target and nothing else.

Space weather can have an impact even employing day-to-day on precision-guided munitions we drop around the world. When we get our arms around those types of questions, "What is the risk to mission?" and "What is the risk to force?" "How will this change the way our decision makers execute at a strategic operational and tactical levels of war?"

Today, in kicking off, setting the context, Ralph wanted you to hear from an operator. It's not as relevant or as cool as some of the scientists and the R&D folks who're going to talk later, but it's just really nice to be around this group of people.

I wanted you to know, as an operator from the Air Force perspective, that we certainly appreciate the work you're doing, and look forward to the continued collaboration and the betterment of us to do our job, whether that effect is kinetic or non-kinetic because sometimes you don't have to schwack something to take out the capability.

Thanks for listening. Ralph, thanks for inviting me to partake in this forum. I'll pass on to the next speaker.

[applause]

**Stephen Volz:** Thank you. I understand General Vander Hamm has to go, his schedule is tight. I hope he gets there on time and on the right location.

Good morning, everyone. I want to thank you for the opportunity to speak here, and thank you, Mike Bonadonna, for setting this up. I'm going to talk a little different.

My task is part of this overall Space Weather Enterprise discussion day, is talk about the overall Government perspective, but leaning a little bit towards the civilian side.

You've heard a little bit of the particular aspect of it from the military side, but looking at it from a civilian perspective, and more specifically from what the National Oceanic and Atmospheric Administration or NOAA has, which is where my work right now.

I know many of you having worked as the Assistant Administrator for the NOAA Satellite and Information Services, or NESDIS, and I've had the opportunity of the last few months to work acting in the role as Assistant Secretary for Environmental Observation and Prediction during the transition to the new Government, so I've met many more of you.

Part of that role as the ASEOP, as we call it, is to get a broader view of all of the different aspects of what we do within NOAA, and of the national efforts as well.

You just heard a very compelling discussion from General Vander Hamm about his customers -- his customers being his pilots, his crew, his family, his grandchildren -- in terms of his operational nature in a very specific and detailed way.

From a NOAA perspective, the customers are just equally clear, but much broader, in a sense that's everybody. It's everybody in this room, it's everybody in the nation, actually everybody in the world because the services that we provide, both with NOAA and all the different weather and space weather observations, really touch everybody on a day-to-day basis, even though the vast majority of them are not aware of it about the services that we provide.

From the NOAA perspective, I'll lead off a little bit. You can describe what we do in three words -- observe, understand, and protect. We observe our environment from the surface of the Sun to the bottom of the ocean, with the various different observing systems.

We work through science, analysis, and modeling to understand what those observations mean. We provide protection or information services by providing actual information to help Americans and others prepare for and respond to consequential and day-to-day environmental events.

You heard a little bit about the specific, the very accurate, and the deviations on the millimeter of the meter scale from the previous speaker. We'll talk a little bit more in our talk about the consequential events of major events that occur, significant solar storms and the impacts they can have.

What's remarkable that you see, humans are not actually prepared to deal with low probability high impact events. It's not part of our DNA or part of our nature to do that. Some of the most consequential events in our culture are of low probability of occurrence.

These pose a challenge both in the...It may not be immediately collected or understood by the collective imagination. How do you prepare for an emergency event? How do you really prepare for those low probability high impact events? The challenge that we have is we know these will happen at some point.

We have to prepare for those on a regular basis. How do we prepare? What exercises do we do? How do we tip the scale from being aware to actually being prepared?

We think we're there, but we may not be there. From the NOAA perspective...to use an example of Earth weather, terrestrial weather versus as a comparison to space weather.

Up until 2005, it may have been difficult for us to conceive that an entire major US city would be under water. We know about storm surges, we know about local floods. They're transient, they happen. We watched on the "Evening News." The next day, everybody said, "Wow, wasn't that a mess?" Some people were hurt, but we move on.



The thought of an entire city being submerged in water for days at a time was really not conceived. The people of New Orleans knew they were vulnerable to flooding. They knew the major hurricanes come on irregular basis. In particular along that section of the coast, they were vulnerable to dam breaks and the like.

Actually, the year before Katrina, we ran an exercise called Hurricane Pam. Almost simulating exactly what you might think to be ready for. You might say there was a feeling of complacency. Not really, we knew it was possible, we thought we were prepared. Low probability, high impact, and it happened.

We thought we had an advance, but we weren't able to connect all the dots where the secondary and tertiary effects which lead to a catastrophic impact of Hurricane Katrina. We're still doing after action understanding and reports to figure out how we can anticipate those.

The connectivities between different disciplines, different organizations, which aren't revealed in the very deep and accurate assessments we do, and by a discipline basis. We've learned from that, if nothing else, that we need to be...We're not as smart as we thought we are, and we need to be prepared against complacency.

I bring this up for these two reasons. One is just as we're susceptible to terrestrial weather, we are vulnerable, susceptible to space weather impacts in the way you've just heard. In another way, we'll talk about in a little bit. The second is, we all know that at some point, we will see a significant geomagnetic storm.

We will see that happen, and it'll hit us. It's our challenge. It's our burden, responsibility to understand it and to prepare for it. We all know it, because we've seen it happen in the past. Everybody here knows the Carrington Event Storm of 1859.

Imagine you're sitting on the Caribbean and you're seeing over the warm breeze over the water, and you have Northern Lights in the sky above you. It's not something anybody can expect or would have expected. That was seen as low as...

The 1859 events saw Carrington Events as far South as Venezuela, reported by people at the time.

The impact in 1859 was small. We don't have video to show it, but we know it was observed, but not impactful. Nowadays, it would be much more significant, clearly. 2013 Lloyd's of London Report indicated that a similar event happening in the US alone could take out power to major regions for as long as months.

Could have an impact in the economy of more than \$1 trillion, dwarfing, of course, what we saw with Hurricane Katrina. The observation, mitigation, and preparation for a space weather event are different than what we do with observing terrestrial weather, whether it's the satellites and the ground systems we have.

In many ways, the preparations we have to take, undertake and prepare for are very similar, because they're social, they're organizational, they're political, as well as being observational and science-based. Just as it's been difficult to consider a city under water for a week or two weeks, imagine the nation without power for several months.

You can imagine with that impact of such a storm, our society would not be ready to continue as without impact, and we have to be ready to do that. This awareness of this impact has been growing

over the past years. Many of you are the ones who brought that forward and made that clear to all of us.

The Administration and the Nation have focused on this on the last several years, with an Administration effort to prepare ourselves, and that was through the Space Weather Operations, Research and Mitigation effort, the Task Force established from the OSTP, and with many of you on board as a part of it.

The output of that was to understand comprehensively what we need to do as a nation through the Space Weather Action Plan, which followed soon after that. What was clear from this whole activity was, it wasn't just an observation, it wasn't NASA research needed to do more, NOAA observation systems needed to do more.

It was clear that it was an all administration, all nation event and response that was required to do this. It's a challenge we face together. It's a challenge we are moving forward with.

It has to be done in an integrative way so that we can connect those dots between impact of a storm and the loss of a power grid, or the loss of traffic monitoring and the like.

Things that are second or third order effect can be surprisingly impactful when they do occur. The SWORM Task Force provides the form for this collaboration across the different nations, like agencies. Over a dozen federal agencies were involved in being a part of this activity, and continue to be part of it.

They're working through the implementations of the activities laid out. We define the Space Weather Action Plan. Came up with a series of different goals and activities for each to address. This was a national administration approach.

It was represented by agencies. Each of those agencies was expected and followed through to reach out to their individual organizations, their communities, their users, the commercial sector they work with to represent them as best we could within that.

In the Space Weather Action Plan, we brought all that intelligence and communication together and identified a series of goals, which you'll hear more about in the different panel sessions this morning.

One of the key pieces of going through with this was it wasn't just each of these agencies coming forward and saying, "This is what I need to improve my mission, do my part."

It was looking at the problem holistically starting at the user, starting at, "Where will the impact be felt? How do we, that user need to prepare for it?" If you look at the goals one through six, first was to establish, "What is a space weather event?" so they can all have all common language.

Under enhancing the response and the recovery capabilities, "Who are those impacted by an event?" The power grid system, transportation system, let these folks, these organizations say, "What do I need to do to be able to respond?" There's no point in having a research measurement which is interesting to scientists but not useful to a user.

There's point for there's interests for science. It's useful there. I don't mean to say science is bad. From an operations perspective, its application, its usability by the user community that is the driving force.

If you walk through these six activities, it was with that in mind. You needed to have the user community to find what their sensitivities were. You needed to have the infrastructure managers to understand how they respond to those and what they need for information and precisions.

You needed the operationals, the goal three and four, to understand, "What do we need to improve our events? What observations are critical? What model inputs are needed so that we can know the measurements are driven by the models, and the models then inform what measurements we need?"

Each of these was dependent upon the other in a way that was very thoughtful and put forward coming from the observations, from the user need at the beginning, and resulting then in the list of objectives and responsibilities that each of the agencies were expected to take forward.

We ended up with a number of actions. This is self-imposed actions we placed on ourselves across the different agencies within the administration. This is some numerology. I won't go through it in detail here, but it indicates the breadth with which each of the different administrator organizations was a piece of it.

Each of these, you can reach out and think, "What are their communities?" Their science. Their research. They're commercial communities that are also impacted.

This doesn't imply that each of these have those....There was a lead, secondary, and supporting agency, a support for each of these as well. I'm sure you all read this.

Many of these were coupled. NOAA may be the lead on one, NASA and the Air Force secondary. Another one, it's the other way around. These are made to be complementary so that we can watch and keep track of all of these.

As of earlier this month, approximately 80 percent of the action items within the SWAP were listed as either on track, submitted, or completed. We continue to make, I would say, slow but steady progress against many of these goals.

That's part of the theme of what we'll hear about in terms of the progress side, is that they are driven by available resources. They're driven by prioritizations within each individual agency.

The constant, the awareness of, and the sponsoring of the advocacy for the importance of this mission is key as we talk to all of our stakeholders. Completion of these goals will be an important and critical first step in better preparing the nation for space weather events.

However, it's not the end of the journey. We don't know everything we need to know about what will be our response to preparation for significant space weather events. The plan allows for modifications, improvements, and corrections based on what we find in the interim process.

As we go through step-by-step, we find there are sensitivities that we didn't anticipate that changes our observing systems structure. It may change the way we do modeling. We have multiple models as we talk about, I mean, "What's the best way to do the mitigation and the modeling forecasting?"

We need to continue the space weather environment and research activities so that we can improve our understanding of the underlying phenomena, which will drive a different response potentially in our observing systems or our user communities. Part of this, too, is to reach out to our inter-agency international partners to see how they are responding and are prepared to work with us.

The SWORM and SWAP are a start and an initial step, a key initial step in bringing all of the agencies and all of the communities together to see an objective, a common coordinated objective, but they're just a start.

Now I'm going to pivot a little bit to the observational infrastructure that we provide and we as different organizations provide to do this. If you look at the example of, and I'll often hear this, space weather is like your weather. It's terrestrial weather, space weather -- how they similar they are.

They're similar in we have the user community, but they're different in many ways as well.

If you look at the global observing system that we now have in space and this is just a piece of the number of observing operational satellites we're using in space for terrestrial weather.

There are number of agencies at multiple governments and administrations around the world providing critical observations. It's a very mature and very capable system. It's developed over the last 50 years.

We are now in a data rich regime for Earth weather. We have more data than we can process on a regular basis. We struggle to try and keep up with our models in our data assimilation integration to understand what is impactful, what is useful and what is cool.

That's the template, the hallmark of what we think we would want to be able to do for space weather in a sense.

We'll add also the NOAA perspective -- from NOAA's portion of this -- this is just a piece of that. If you look at these two, you see that we benefit from an international collaboration and contributions from multiple agencies.

That's a feature that will be true in space weather as well. This didn't include many of the research satellites as well but that's another feature of what we'll see going forward.

What I would also add then, if you look then at what our space weather observing system looks like right now, first note how sparsely populated this is. It doesn't include all of the missions but most of the missions we have in space weather. It is not that many. It's not we are years behind where we were on terrestrial weather side. We are not in a data rich regime but more in a day to starved one.

It is key that we understand as we go forward, is what are the critical measurements we need to provide that are most important and the most impactful.

With respect to these different observing systems, you can look in this particular picture. We go back to here, most of our observations are lower Earth orbit geostationary, and that's fine for earth weather. For space weather, we are now understanding we have a much broader context of where we need to make our observations.

We have the geostationary orbiting in the lower Earth orbiting a few In-Situ. We also now have location points at L1 and a number of some research satellites moving around and a broader one.

We've broadened our capacity and our observing requirements to a bigger picture to planetary or solar system based space weather observation system.

Looking at the two platform locations here -- from the geostationary side -- geostationary satellites have been providing forecasters with key observations, for critical observations for many decades. The GOES satellites in particular have provided solar physics, solar observations from about 40 years at various levels, from the geostationary perspective above the earth.

Just recently, in November of last year, we launched the first of the next generation of GOES satellites, which is now GOES-16, which continues that 40-year trend.

It is now going to be operational over the East Coast and will be followed soon by the GOES-17 and beyond. The primary news and information on GOES has been about its Earth observing advance baseline imager measurement but there are more space weather instruments on GOES than there are earth observing.

We have series of as many as four different observing systems on GOES which are monitoring the sun and the environment. The space weather instruments contribute and deliver not just the beauty but also information, for example, the solar ultraviolet imager's telescope monitoring the sun and extreme ultraviolet wavelengths, a number of different wavelengths.

You can see right here, this is from the early January imagery coming from GOES from the SUVI instrument with many more in NOAA, in an operational cadence.

SUVI provides observations at multiple spectral wavelengths, which provide different levels of information. These spectral bands provide the different levels of information that will go into the modeling and go into the physical understanding.

These observations will be supporting critical...these are baseline observations you'll be seeing on an operational basis. These will be supporting research operations for years to come as well, as you can count on this particular measurement, this particular quality from two different platforms operating in GEOS for decades.

This is baseline operation which allows the research then to expand beyond that to take the next step, knowing this information will prevail on a regular basis.

For example, SUVI can help monitor solar flares and you'll see an example in a moment in the upper left-hand corner here of a flare occurring on April 18th of this year.

The benefit of an operational platform such as GOES, going back decades and going forward decades further is that this is a baseline that anybody can assume and can count on for regular delivery of service of information to support those other operational research and development missions that may come forward.

The second platform location we use is the Deep Space One from the L1 platform. Until recently, except for GOES, many of our missions have been based research operations from NASA and other research agencies, and have gone from Deep Space in addition to the GOES geostationary.

The research focus has helped develop and understand the fundamental physics that we rely on to develop our modeling in our operations. I think that's another example which is going to go forward into the future that the research arm, the research aspect in contribution for space weather is not going to diminish.

It's going to be enhanced as we know more and will be wanting to understand more, and the research contribution will be critical.

Our Deep Space Weather Satellite Observations from L1 have been key as a part of that and all pioneered by the NASA and ESA, SOHO mission and by the NASA Advanced Composites Explorer mission, ACE, which demonstrated the value of an L1 mission.

ACE is another example of a good operational research partnership because prior to the launch, NOAA contributed a small amount to NASA mission to provide that data on near real-time basis so that we could use the data operationally, as we have for the last 20 years.

The success of ACE and the success of SOHO have led us to the definition of what are an example of an operational transition.

The DSCOVR program which was meant to follow the success and the need for the ACE observation was deployed to the L1 location in 2015. The Deep Space, as now called the Deep Space Climate Observatory, DSCOVR, was launched then primarily to measure the solar magnetic storms, and solar wind data, providing forecasters with those measurements that we need to give advance warnings of 15 to 60 minutes of CME critical events.

It was pressed into labor, into force by this, it was not meant to be an operational mission. It was not developed that way but it was recognized as we became more aware of it that this is a critical need that we needed to fill.

NOAA has defined and understood that that measurement from L1 is going to be critical in the long-term and is a piece of our long-term program, with our space weather for the observatory to continue those measurements into the future.

Those are just two of several platforms. You could see in this picture what we're seeing now as we understand better the other locations of a true planetary weather system such as L5 and L4. L5 in particular trailing in orbit in the Lagrange point is another key observational location that we are discussing and working with our partners, with the NASA, also with the international partners.

That's a likely place for critical space weather observations, both clearly from a research benefit but also from an operational benefit as well. It's the system that counts. It's not just the observation.

From the system side, it is important as we found with the ACE not just to get the observations they get them down soon and quickly. NOAA working with our partners understands that this requires a robust ground system and robust ground stations to get the data down on a regular basis.

Again, a place where international inter-agency partnerships are key. NOAA maintains several ground stations and with our international partnerships developed and agreed to over many years provides a global network of ground stations for rapid development of delivery of data from the L1 and remote points so that we have the low latency we need for space weather observations.

Once we have the data, we have the observations, the next step is to do something with those and to turn them into actionable information in forecasting.

The Space Weather Prediction Center out of NOAA's National Weather Service is operating at Boulder Colorado and uses these specialized forecasters working with researchers, working with operational

assets and an understanding to develop, continually monitoring the weather in the forecasting, providing out alerts and warnings for the nations as the official civilian source for weather watchers warnings and alerts forecast.

SWPC also works very closely with the Department of Defense counterpart, the US Air Force 557th Space Weather Wing, to ensure these forecasts are coordinated with the same kind of information which you heard earlier from General Vander Hamm.

As we see, each individual agency may have their own specialized tools and products they put together, it's important again to have the baseline of observation systems that we provide.

SWPC also works with our research partners both at NASA and with academia to continuously improve and update our products and services and models. It is key as a piece of that to understand how much we are in a research and operational scenario right now, not just research to operations.

We require both work in parallel and it's the underpinning research that is really driving the capabilities that we're able to deploy in an operational cadence.

The customer base for space weather is growing. If you look at the curve here, the straight line is the solar cycle and the blue shows the number of customers who are regularly tapping in to this SWPC products and services out at the Space Weather Prediction Center.

It continues to grow even as the solar events have been relatively quiet as the information becomes more richer and more quantitative, and the model outputs and forecasts become more useful and the sensitivity community becomes greater as well.

The customer base increases on the order of 200 new subscribers every month to our services through the SWPC space.

Some of the common users within SWPC products include emergency responders. Major airlines are regular daily users, drilling and oil exploration companies, satellite companies, transportation sectors, and anybody who is using and that means almost everybody GPS in some form or another.

With all examples, I gave about how these are affecting on a day-to-day basis in a way that was not envisioned decades ago.

Aircraft communication systems are clearly affected potentially by space weather events. We just heard the examples in the military side but on the civilian side, it's very key as well.

A continuous two-way communications, between flight crew and their traffic controllers, is essential in crowded airspaces but also in long overhaul flights over the North Pole or the like.

Sometimes, warnings from NOAA can actually be essential in terms of preparing for or not having to worry about events that may occur. In May of 2012, for example, a passenger airliner route to Tokyo went silent for more than 30 minutes and there was a concern. Emergency responders were preparing at the traffic centers, along the lines were trying figure out what was going on.

SWPC provided a prompt and accurate assessment of ongoing space weather event which allowed the air traffic controllers to assess that, this may have been driven by space weather and not by some problem with the aircraft itself, which is what the event actually was.

It does mean that it couldn't have been something but allowed a plausible reason for why this was occurring and allowed them to prepare for the visual uptake and communication when it did come a few days or few minutes later.

Another example, just more recently in January of 2014, Orbital Sciences delayed a launch to the space station based on a space weather warning about a flare which would have been in the monitoring the radiation measurements that were coming from the GOES satellites allowing them to delay the launch and prepare to prevent the loss potentially of a launch vehicle going supplies-ship to the spacecraft, to the ISS.

On research and operational satellites in general, we constantly watch for proton events and major flare events to determine if we go into safe mode or shutdown instrumentation on satellites to protect them.

On the GPS sector, you heard earlier clear examples of GPS sensitivities. Across the board, as we become more sensitive to location services, the GPS are key.

Farmers use them for precision farming and thanks to NOAA alerts, these equipments on storm and events, these equipment are prepared for delay activities and work around the upcoming events to avoid inaccurate development and delivery of fertilizer or other services.

Construction companies use these observing as much as six inch deviations from true elevations during geomagnetic storms. That can be significant obviously when you're building and maintaining roads and highways and the like. Some of these construction companies subscribe on a regular basis to SWPC to use them for planning and their day-to-day activities.

I should say that NOAA, NASA, the NOAA/USAF and NSPO mission COSMIC-2 which we're launching in the near-term is a constellation of six GPS RO satellites will significantly contribute to improvements and understanding the ionosphere from high precision GPS measurements of the transects of the atmosphere.

These examples just scratch the surface of actionable information that NOAA and its partners provide through their prediction center and are critical to the national infrastructure.

What does the future hold? How do we, as an organization, as communities prepare for what's to come next? I talked about research and operations and research to operations.

It really is key that the research that we have developed over the decades, in the past years, is incorporated into our operational cadence as best we can. There are many ways in which research and operations can work together.

There are different examples. There's no one-size-fits-all. Here is three, I'd give examples of for...It could be in instruments, it could be in missions, it could be in modeling.

In the instrument side, the demonstration from SOHO, of the LASCO instrument is shown, the critical value of a CME or Coronal Mass Ejection measurements, from a coronagraph. It's an old and venerable instrument that will not be there forever.

The NOAA has very clearly, and the community has really clearly identified that is the leading unmet need in terms of long-term sustainable measurements.



We've been developing a compact coronagraph to deliver essentially the same science, the same observations but in a smaller form, fit and function and it's one of our key identified deliverables. This is our next mission. It's an example of a research from a NASA and ESA mission to a NOAA operational.

From a mission side, ACE to DSCOVR is an example of research measurement that led to an operational need and an operational platform that we built, we deployed for DSCOVR and are planning to deploy as well with our space weather follow-on.

It may actually be an example of a research to Operations to Research and operations again, because some of these scenarios we look at may include co-flying of research and operation assets on the same bird on the same launch vehicle.

To take advantage of the synergy of both the data that we get from those, and to mitigate the cost of getting these space for this complex systems.

Currently, the modeling that we use within the National Weather Service and the NOAA, we use about two percent of our total modeling on timeline to your cost in our computer systems on space weather with a 98 percent being earth weather.

It's not an indication necessarily of the importance of one versus the other, but the maturity of one model and one output versus the other. We expect that to improve it particularly as we focus on the research and operations on the model and upgrades that are planned within the next year alone.

We have a number of different models that are shown here that we're exercising and advancing.

There's the WSA Enlil model which is used to determine the impacts of coronal mass injections on the earth. We have geospace models providing better regional space specificity to where the storms would be the most severe and the most impactful.

There's a real-time ionospheric model that NOAA has the WAM-IPE and there are others as well.

There's a bunch of individual models and one of the objectives, the goals in the long-term is to see which are the most important and how can these be merged into global models which are more comprehensive and allow for greater common use across all the platforms and all the users.

Effective O2R, Operations to Research, and R2O processes are really key as we go forward to improve this toolkit for forecasters and to make the operational data usable in immediate basis by the research users and vice versa. We don't have the time or the resource to go independent. We have to work together.

From the operational perspective, NOAA has, in our platform, in our program, a significant investment over the coming years. We have three additional GOES-R satellites poised in development to be launched in the coming decades.

The GOES-S is scheduled for launch next March with T and U to follow as needed to maintain the three satellite constellation in space.

These will be providing data through the late 2030s and beyond. Those measurements we are used to, we can count on. We can leverage off of those. Cosmic-2A, the cosmic constellation, will be launching next spring bringing a much better view as I've mentioned in the ionosphere.

The space weather forward observatory mission NOAA's SWPC mission, not on this chart, is in planning and is developed. Although it's been delayed by the most recent budget proposals going from the president this year, will be delayed some with a start but scheduled now for FY'19.

I leave us with a final thought and to prepare for the rest of the day. As we look to the future, it's our task to ask ourselves, will we be ready for the storm when it comes? How will we anticipate and prepare ourselves and our nation for that?

Low probability, high consequence events may be rare but we know they occur and we know they will occur.

It may not be tomorrow, maybe decades from now, but the impact is not going to be lessened by its delay. Eventually, we will have another storm of significant proportions. We need to make sure we're ready for it. NOAA's providing a platform of the long-term operational missions.

NOAA and NASA and the other agencies on research from the operational side, observation side are working together to understand and to present those observations.

Our participation across all the agencies through the SWORM and SWAP activities allow for the user to define the needs for us as the operational observers to provide the input and the models that are most beneficial and most useful for those.

It will take an effort from all of us as I said. That is why this event is really key to bring the stakeholders together and also to remember that we need to make sure our sponsors are aware of the importance of and the value that we bring.

It's not just scaring that things will happen and we have to be ready, but, alerting that things will happen and we know how to get ready. We know what steps are taken today, next month and next year. It's to prepare us for a much better and a more prepared nation when these events do occur.

I look forward to hearing the next two panels in particular to see how the real experts would talk about their adaptation and their preparations for the upcoming storms.

Thank you and I appreciate the opportunity to speak today.

Transcription by CastingWords