SPACE-BASED POSITIONING
NAVIGATION & TIMING
NATIONAL ADVISORY BOARD

NATIONAL SPACE-BASED POSITIONING, NAVIGATION, AND TIMING ADVISORY BOARD

Twenty-Ninth Meeting

December 6-7, 2023

Shore Harbour Resort and Conference Center

League City, Texas

ADM (USCG, ret.) Thad Allen, *Chair*

Mr. James J. Miller, *Executive Director*

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Agenda

(https://www.gps.gov/governance/advisory/meetings/2023-12/)

Wednesday, December 6, 2023 Day 1 Livestream: https://www.youtube.com/@nationalpntboardmeetings822/videos		
9:00-9:05 (5 min)	**BOARD CONVENES** *Call to Order, Logistics, & Announcements*	Mr. James J. Miller, *Executive Director, National Space-Based PNT Advisory Board, NASA HQ*
9:05-9:30 (25 min)	Welcome & Introductions – In Memoriam: Martin (Marty) Faga – Introduction of New Members – Meeting Goals & Objectives	ADM Thad Allen (USCG, ret.), *Chair;* Dr. Brad Parkinson, *1st Vice Chair;* Hon. Jim Geringer, *2nd Vice Chair*
9:30-10:30 (1 hr)	Subcommittee Highlights: (10 min each) – Communications & External Relations (CER) – Education & Science Innovation (ESI) – Emerging Capabilities, Applications, & Sectors (ECAS) – International Engagement (IE) – Protect, Toughen, & Augment (PTA) – Strategy, Policy, & Governance (SPG)	Subcommittee Chairs – Mr. Dana Goward – Dr. Jade Morton – Dr. Frank van Diggelen – Mr. Matt Higgins – Dr. John Betz – Hon. Jeff Shane
10:30-10:45 (15 min)	**BREAK**	
	Theme 1: U.S. Government & Institutional PNT Updates	
10:45-11:00 (15 min)	National Coordination Office Update & Status on PNT ESG Response to 2023 PNTAB Recommendations	Mr. Harold (Stormy) Martin III, *Director, National Coordination Office for Space-Based PNT*
11:00-11:30 (30 min)	DOT PNT Research Priorities, Complementary PNT, and GPS Interference Detection & Mitigation (IDM)	Ms. Karen Van Dyke, *Director, PNT & Spectrum Management, Dept. of Transportation (DOT)*
11:30-12:00 (30 min)	U.S. Space Force (USSF) Update: *GPS Modernization*	Col. Andrew S. Menschner, *Commander, PNT Delta (Prov.), Space Operations Command, USSF (virtual participant)*
12:00-12:30 (30 min)	Results & Outcomes from the International Committee on GNSS (ICG) 17th Plenary Meeting	Ms. Sharafat Gadimova, *Executive Secretariat of the ICG, United Nations Office for Outer Space Affairs*
12:30-1:30 (1 hr)	**LUNCH *(Paradise Reef)***	
	Theme 2: Protect, Toughen, and Augment GNSS for all Users	
1:30-2:00 (30 min)	Critical Infrastructure Augmentation Framework	Dr. John Betz, *Member, PNTAB*
2:00-2:30 (30 min)	Global Differential GPS System (GDGPS) & Galileo High Accuracy Service (HAS) Comparison	Dr. Attila Komjathy, *Supervisor, Near Earth Tracking Systems Group, JPL;* and Dr. Frank van Diggelen, *Member, PNTAB*
2:30-3:00 (30 min)	Low Earth Orbit PNT Landscape – Overview (15 min) Mr. Jeff Auerbach – Technical Discussion (15 min) Mr. Bryan Chan	Mr. Jeff Auerbach, *Senior Foreign Affairs Officer, Office of Space Affairs, Dept. of State;* and Mr. Bryan Chan, *Member, PNTAB*
3:00-3:15 (15 min)	**BREAK**	
	Theme 3: PNT Education & Science	
3:15-3:45 (30 min)	Extreme Relativistic Electron Fluxes in GPS Orbit: *Space Weather Effects on GNSS Users*	Dr. Nigel Meredith, *Space Weather Research Scientist, British Antarctic Survey (virtual participant)*
3:45-4:00 (15 min)	Space Weather Advisory Group (SWAG): *White House Space Weather Survey for GNSS Users*	Dr. Rebecca Bishop, *Member, SWAG, National Weather Service, National Oceanic and Atmospheric Administration (virtual participant)*
4:00-4:30 (30 min)	Challenges in Hiring Geospatial Intelligence Professionals	Dr. J.N. (Nikki) Markiel, *National Geospatial-Intelligence Agency (virtual participant)*
4:30-6:00 (1 hr 30 min)	Member Deliberations, Key Highlights, and Closing Thoughts from Day 1	All members, led by Chair
6:00	**ADJOURNMENT**	

Times indicated in U.S. Central Time

Thursday, December 7, 2023 Day 2 Livestream: https://www.youtube.com/@nationalpntboardmeetings822/videos		
9:00-9:05 (5 min)	**BOARD CONVENES** *Call to Order*	Mr. James J. Miller, *Executive Director, National Space-Based PNT Advisory Board, NASA HQ*
9:05-9:15 (10 min)	PNTAB Leadership Observations from Day 1	ADM Thad Allen (USCG, ret.), *Chair;* Dr. Brad Parkinson, *1st Vice Chair;* Hon. Jim Geringer, *2nd Vice Chair*
	Theme 4: Updates from International Members & Representatives	
9:15-10:45 (1 hr 30 min)	Countries/Associations – Croatia – Australia – United Kingdom (UK Ten-Point PNT Framework) – Resilient Navigation and Timing (RNT) Foundation – Consumer Technology Association (CTA) – International Air Transport Association (IATA)	Representatives (15 min each) – Dr. Renato Filjar – Mr. Matt Higgins – Prof. Terry Moore – Mr. Dana Goward – Mr. David J. Grossman – Hon. Jeff Shane
10:45-10:55 (10 min)	**BREAK**	
10:55-11:55 (1 hr)	Roundtable Discussion & Next Steps	All members, led by Chair
11:55-12:00 (5 min)	Wrap-Up – Determine date & venue for next meeting	ADM Thad Allen (USCG, ret.), *Chair;* Dr. Brad Parkinson, *1st Vice Chair;* Hon. Jim Geringer, *2nd Vice Chair*
12:00-1:00 (1 hr)	**LUNCH – Working as needed *(Paradise Reef)***	
1:00	**ADJOURNMENT**	

Times indicated in U.S. Central Time

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Executive Summary

The National Space-Based PNT Advisory Board (PNTAB) held its 29th public meeting on Dec. 6-7, 2023, at the Shore Harbour Resort and Conference Center in League City, Texas. The meeting was held under the provisions of the Federal Advisory Committee Act (FACA), with appropriate public notification & documentation for the public record. Fact-finding preparatory meeting were held on Dec. 4-5.

This report summarizes the discussions & deliberations during this meeting. For links to the briefings & livestream recordings see: https://www.gps.gov/governance/advisory/meetings/2023-12/.

This meeting focused on reviewing the work of the PNTAB over the past year, status of the recommendations submitted to the PNT Executive Committee (EXCOM), and on updating the supporting material for those recommendations. No new recommendations were approved at this meeting.

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Session of Wednesday, December 6, 2023

Board Convenes
James J. Miller, *Executive Director, PNTAB*

Mr. Miller welcomed everybody to the 29th PNT Advisory Board advisory meeting held since 2007 and the first meeting held in Houston, TX. The board reflects the large and diverse user groups that comprise the very diverse user community who rely upon Global Positioning System (GPS) services for their day-to-day activities, including the many organizations who use these same services to extend their reach to support millions more across our nation and around the world. Today is an especially proud day for the group, as it is collectively able to recognize and contribute towards celebrating 50 full years since the U.S. Government (USG), under the leadership of the PNTAB's First Vice Chair Dr. Brad Parkinson, secured approval for this program which has come to touch our lives from the time we wake up, to the moment we reach our final destination at the end of the day.

Besides Dr, Parkinson's presence, we have as our other leader, our long time Chair ADM Thad Allen, former Commandant of the U.S. Coast Guard (USCG), who deftly led our nation through the twin tragedies of Hurricane Katrina and Deepwater Horizon out of this region. The collective goal of these leaders along with our expert group, is to ensure that critical GPS services remain accessible to all our constituents, as a tool to preserve, protect, and promote our livelihoods, during both bad days and good. GPS has come to reflect a service that is now recognized as a national utility whether we travel by foot, car, train, boat, plane, or even space now-a-days, and so today with expert input, we will further seek to find ways in which to strengthen the reach, capabilities, and benefits to all our citizens who have come to rely upon these nearly invisible signals of strength and resilience.

As we begin our presentations today, let us first recognize the U.S. Space Force (USSF), for acquiring and operating such an amazing national asset for all of us. As a reminder, Board deliberations are governed by the Federal Advisory Committee Act, or FACA, which means that discussions are open to the public, and meeting minutes will be posted online at www.GPS.gov, within 90 days for the record. We also strive to post all briefings within 24 hours of their presentation here, and several may be posted already thanks to the good work of our colleague at the U.S. Dept. of Commerce (DOC), Mr. Jason Kim.

Board Recommendations are provided as independent advice and council, and the USG reserves the right to accept, or not, the input provided by this committee. It is important to the overall process, however, for the Board to continue to receive feedback on what can be supported and what may have to be set aside in times of fiscal constraint.

That said, as members deliberate today, please remember to abide by established ethics laws that require us not to engage in any discussions that may create a potential conflict of interest. If a member does believe that the appearance of a conflict on a particular topic is emerging, we simply request that you clearly recuse yourself from that subject matter.

As a meeting open to the public, it is being livestreamed and recorded.

With this, Mr. Miller certified there was a quorum to begin.

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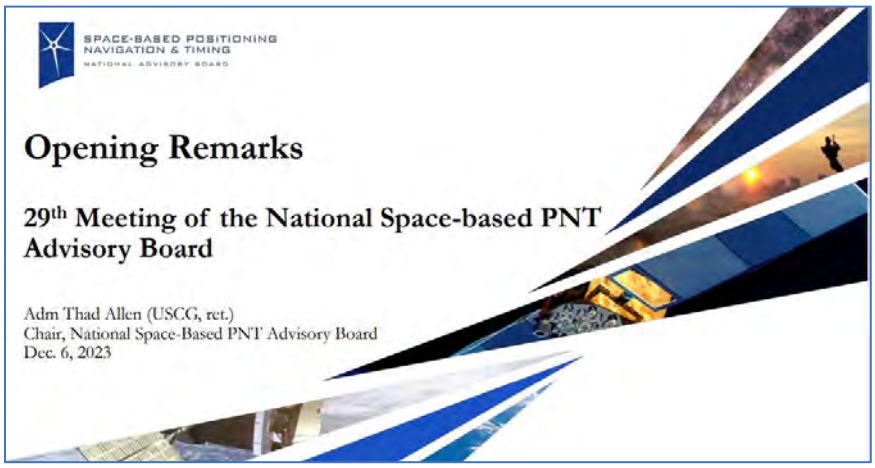
Welcome and Introductions
ADM Thad Allen (USCG, ret.), *Chair, PNTAB*

ADM Allen thanked Mr. Miller for keeping the Board in regulatory compliance and noted that he would provide some opening remarks.



Slide 1

ADM Allen opened by recognizing Mr. Martin "Marty" C. Faga, who passed away in 2023, and what he meant to this country, both in public office and private sector, but the joy it was to work with him as an individual. He then asked Dr. Parkinson if he would like to say a few words regarding the loss of Mr. Faga (Slide 2).

Slide 2

Dr. Parkinson stated that he doesn't "think many people recognize how much [Mr. Fage] contributed to what we are, and I personally appreciated him as a friend and colleague … I'm personally going to miss him a great deal."

Dr. Betz drew attention to the list of Mr. Faga's accomplishments displayed on the slide. He stated, "I knew him as the President and CEO of the MITRE Corporation and what I remember about him most was very quiet, but very effective leadership. He was just the ultimate gentleman. I remember one time I was going to a meeting in the D.C. Area with him and I asked him where I should meet him and he said, I'll pick you up. So, I walked out of the door at Reagan National Airport, and there he was sitting at the curb in his eight-year-old Ford Taurus, putting along [with] no driver. He said, 'come on, John, jump in.' So that's what I remember as a man of very effective, quiet, gentlemanly leadership. We'll all miss him for that."

ADM Allen added that he was a very quiet, self-effacing man who is going to be remembered by the Board for a long time.

ADM Allen then welcomed the three new Board members: General Willie Shelton, Mr. Scott Logan, and Mr. Bryan Chan (Slides 3-5). These new members have extraordinary experience which they already demonstrated in the conversations during the preparatory meeting held on the previous day. He thanked all of them for participating this week.

Slide 3

Slide 4

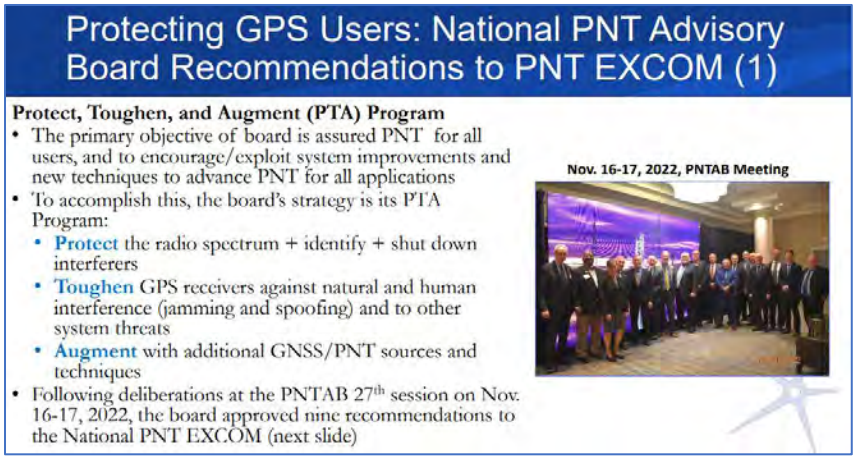
Slide 5

ADM Allen noted that over the last few years, the Board has undergone some governance and structural changes and has had to adapt to organizational changes caused by COVID-19. Travel restrictions have affected the international community, and administration changes led to new policy leaders and presidential directives. The goal over the past few years has been to develop

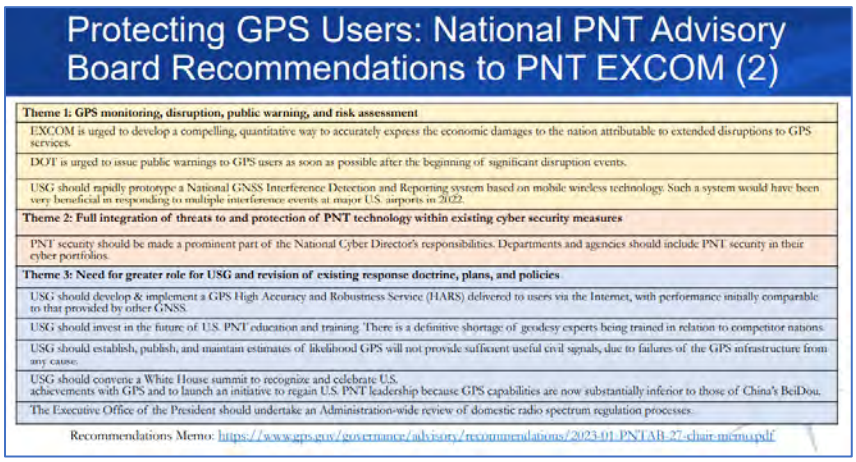
a governance structure for this Board that is self-sustaining (Slide 6). This structure must have long term continuity across changes of leadership in the White House and leaders that are changing their own policy positions. The Board has taken some steps in that direction by creating functional subcommittees.

Slide 6

The Board has discussed long and hard about focusing these meetings on one strategic topic to best provide advice and guidance to the USG (Slides 7-8). Today's meeting is the next step in that process and this Board aims to keep refining this goal, so the public meetings are more structured and focused.

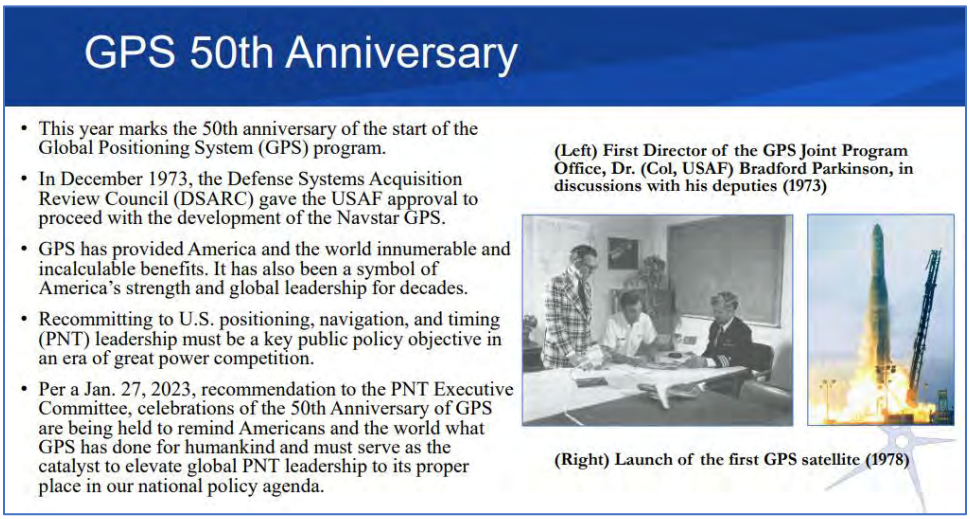


Slide 7



Slide 8

Lastly, this Board has been discussing the 50th anniversary of the creation of the Department of Defense (DoD) joint program office which resulted in the launch of the NAVSTAR Global Positioning System, and which Dr. Parkinson was most responsible for getting that off the ground (Slide 9).



Slide 9

The U.S. may be at an inflection point regarding position, navigation, and timing, especially regards to GPS and other Global Navigation Satellite Systems (GNSS). Regarding GPS, DoD s providing a service, which is now something like oxygen: you don't know you have it until it's gone. The issue moving forward is how to best integrate and manage the civilian sector, which this Board is responsible for, and to evolve the concept of bureaucratic operations on how to provide recommendations to ensure that the U.S. is moving forward in the face of increasing capability competition from the other GNSS.

The U.S. is currently facing growing capability and capacity regarding its GNSS constellation, and it has a unique governance structure with how this program is managed and appropriated. One decision our government should make is if the U.S. is going to maintain its ability to insert technology and make the service GPS provides to the American public more robust with higher levels of fidelity.

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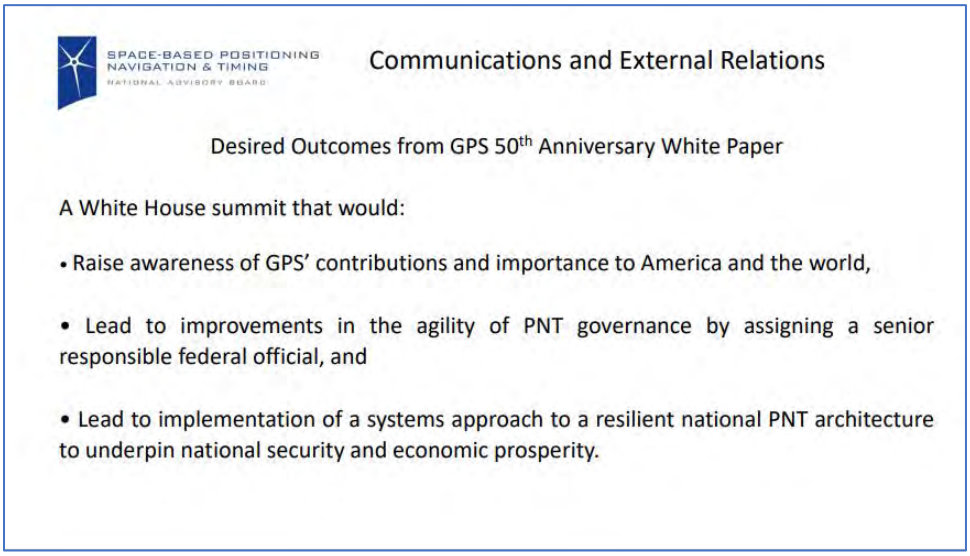
Subcommittee Priority Highlights

1) Communications & External Relations (CER)
Mr. Dana Goward, *Subcommittee Chair*

Mr. Goward noted that Capt. Burns and Ms. Reilly are co-chairs of the subcommittee, although it does not show on Slide 1. The subcommittee has tried to approach its task in a structured way, thinking about who is in this group and who this board is communicating with Director Durkovich at the National Security Council (NSC), who has a direct interest in the matters of this Board, so perhaps she might be a part of the primary or collateral audience. Members of Congress, along with the public, may also be interested in items that this Board discusses.

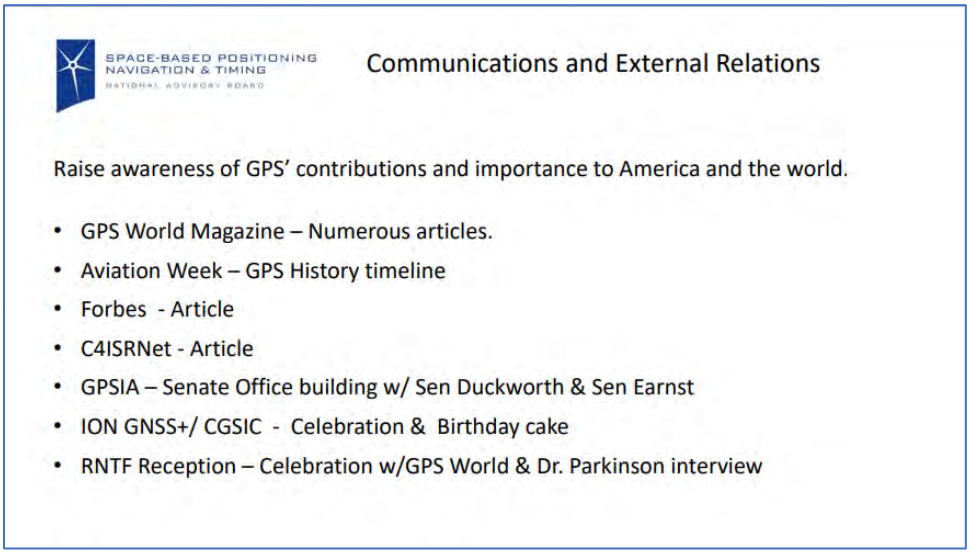
Slide 1

One of the Advisory Board's most recent products was a collaborative effort between the Communications and External Relations Subcommittee and the Strategic Policy and Government Subcommittee has been a White Paper regarding the 50th Anniversary of GPS. The desired outcomes of this White Paper are on Slide 2. To date there has not been a White House summit.



Slide 2

This subcommittee has made some progress in terms of celebrating the 50th anniversary of GPS and raising awareness both of the anniversary and the value of peace in the past (Slide 3). There are a number of articles celebrating the 50th anniversary of GPS. There are other folks that periodically provide the Board with reference material, as well as provide others who might not be part of the community with material. Mr. Goward gave a special thanks to GPS World's Mr. Luchio for his ongoing support of Advisory Board initiatives. The Board also had visibility in Aviation Week with Diana Furchgothroth, formerly of the Department of Transportation, devoted one of her columns in Forbes to the 50th Anniversary. The GPS Innovation Alliance also had a very nice event at one of the Senate Office Buildings. Senator Duckworth and Senator Ernst showed up for cameo appearances. There were celebrations and recognitions at the U.S. Institute of Navigation (ION) and Civil GPS Service Interface Committee (CGSIC) meetings, and the event last night. Finally, there was a reporter from the Wall Street Journal who had previously reported on GPS issues. Although he did not report on the event, Mr. Goward has a continuing relationship with this reporter and believes there may be articles from him on GPS issues in the future.



Slide 3

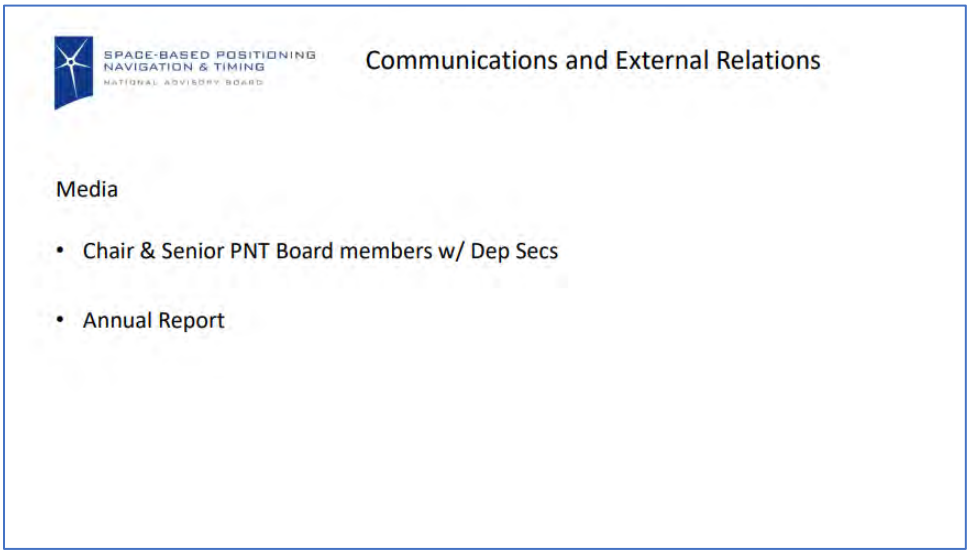
On the previous day, during the subcommittee's working session, they discussed and will continue to be focusing on messaging to the primary audience. Mr. Goward recalled President Lincoln's letter to Grant, which he concluded with, "I'm sorry to write you such a long letter. I didn't have time to write you a short one, so I kind of cobbled this together after the event last night."

Slide 4

The subcommittee also discussed multiple topics regarding their audience, including what kind of hooks would there be and why would two Deputy Secretaries and Ms. Durkovich be interested in discussing these issues with the Board (Slide 5). There are a lot of overlaps but hopefully the Board will find some compelling topics to connect with all audiences.

Slide 5

Mr. Goward asked how the Board would make these communications. The Chair and other senior members of the Board are going to be essential in connecting with the folks (Slide 6). The Chairman's January report to the Deputy Secretaries was a great example of how to do this. There was a suggestion that perhaps there be an annual report that summarizes the kinds of things the Board has been doing and highlights its recommendations.



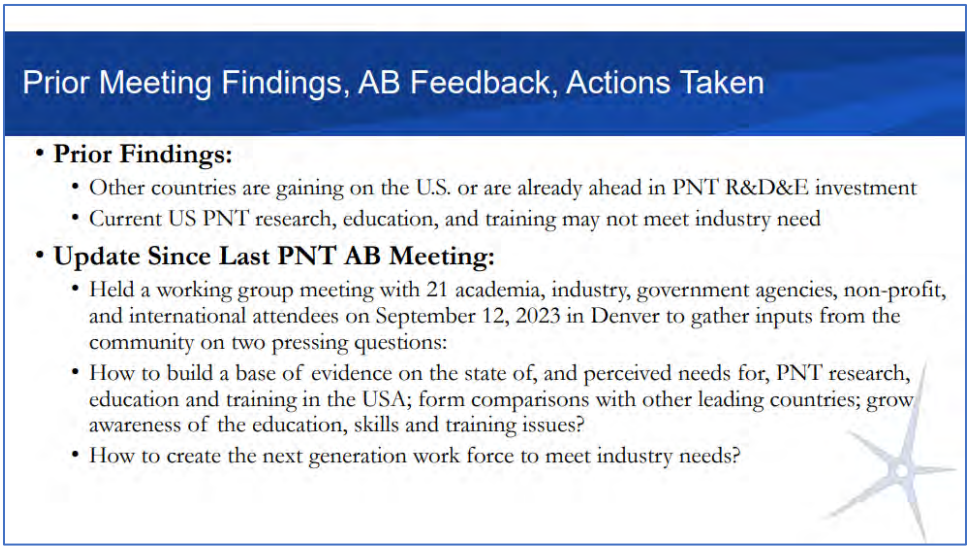
Slide 6

2) Education & Science Innovation (ESI)
Dr. Jade Morton, *Subcommittee Chair*

The ESI subcommittee leadership consists of Dr. Morton as the chair, Prof. Moore as the first chair, and Dr. Grejner-Brzezinska as the second vice chair (Slide 1). The Board has lost Dr. Axelrad, who was a very important member of this subcommittee. However, they've added two new members: Todd Walter and Tim Murphy. Over the last couple of years this subcommittee has refined its focus to the U.S. PNT workforce education and training. Two important agenda items the subcommittee has been discussing are how to assess current and future needs for workforce education and training, and to make actionable recommendations.

Slide 1

So, based on discussions at prior meetings, this subcommittee is concerned that other countries are gaining on the U.S. or are already ahead in PNT research, development, and education investment (Slide 2). Additionally, there is concern that the current U.S. PNT research education training will not meet future industry needs. Since the last Board meeting, the subcommittee has held a working group meeting featuring 21 participants from academia, industry, and government agencies, as well as nonprofit organizations and international attendees (Slides 3). The focus of this meeting was answering two questions: (1) How can we build a base of evidence on the state of, and the perceived need for PNT research, education, and training in the U.S and how do we form comparisons with other leading countries and grow awareness of these issues; (2) How can we create a next generation workforce to meet the industry needs?



Slide 2

1st WG Meeting Attendees

Invited: 51
Attended: 21

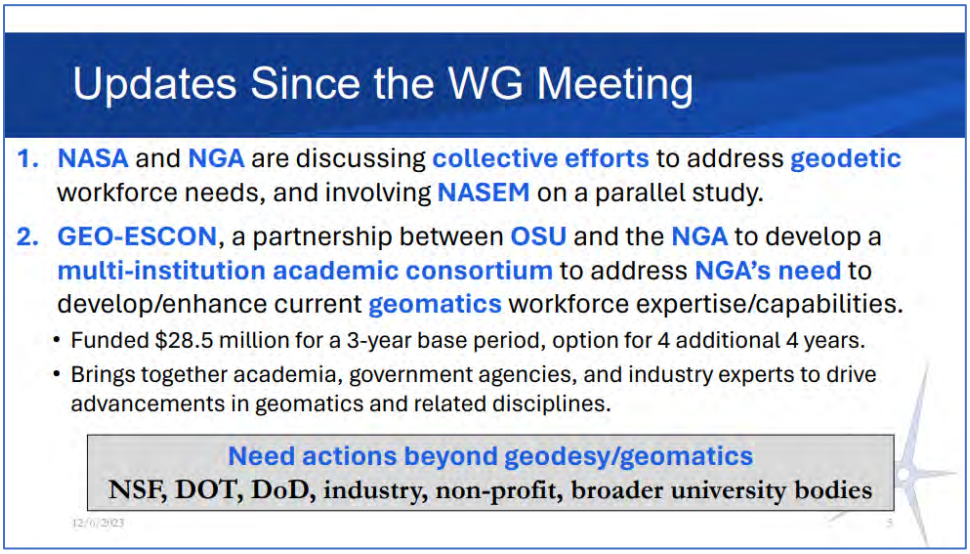
Jade Morton	University of Colorado Bould	Academia
Terry Moore	University of Nottingham, UK	Academia
Dorota Brzezinska	The Ohio State University	Academia
Mike Brassch	Ohio University	Academia
Mark Psiaki	Virginia Tech	Academia
Sherman Lo	Stanford University	Academia
Todd Humphreys	UT Austin	Academia
Zak Kassas	OSU	Academia
Paul McBurney	OneNav	Industry
Tyler Reed	Xona	Industry
Gary McGraw	Collins	Industry
Christopher Hegarty	Mitre	Industry
Tim Murphy	Boeing	Industry
Andrey Soloviev	QNav	Industry
Jacob Campbell	AFRL	Government
Nikki Markiel	NGA	Government
Ryan Gamer	NGA	Government
Joanna Hinks	AFRL	Government
Irfan Azeem	NOAA	Government
Dave Mencin	EarthScope	Non-Profit
Sharafat Gadimova.	United Nation	International

Slide 3

Key feedback from the working group meeting is that the Board needs to voice concern regarding this issue to multiple agencies and push for a commission to collect quantitative evidence on the state of PNT research, education, and training, and of course, ensure that the study is comparing the U.S. with the other leading countries (Slide 4). Also, the USG should form a PNT partnership that can leverage resources from multiple institutions and offer potential means to provide access to PNT education and training to a broader student body. It is very challenging for universities to create slots and offer these kinds of opportunities, but leveraging resources from multiple institutions might be a more effective way of doing this.

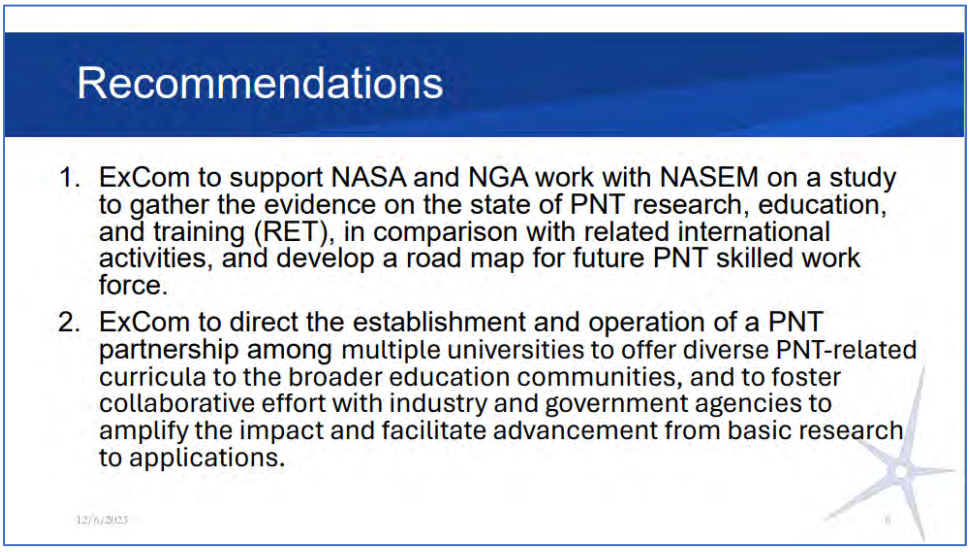
Slide 4

As described in Slide 5, since the working group meeting the subcommittee has learned that the National Aeronautics and Space Administration (NASA) and National Geospatial-Intelligence Agency (NGA) are already working together to discuss collective efforts to address geodetic workforce needs and are involving the National Academy of Science, Engineering and Medicine (NASEM) on a parallel study. Another important development my colleague wrote is here she can provide more elaboration on this is that there is a partnership between Ohio State University, and NGA. This partnership, called Geomatics Emerging Scientist Consortium for Education, Research and Capabilities Enhancement (GEO-ESCON), aims to develop a multi-institutional academic consortium that addresses NGAs' need to develop workforce expertise and capabilities. They have $28.5 million of funding for a three-year period and there's additional optional funding, as well. This consortium allows NGA to bring together resources to drive advancements in geomatics and other related disciplines. The subcommittee would like to stress the need for actions beyond just geodesy and geomatics engineering. We need to bring resources from the National Science Foundation (NSF), U.S. Department of Transportation (DOT), DoD, Industry, and Nonprofit under the broader university bodies to address the need for PNT.



Slide 5

Slide 6 summarizes the subcommittee's proposed recommendations, namely: (1) The Board should support NASA and NGA to work with NASEM on a study to gather evidence on the state of PNT research, education, and training, and compare these findings to international activities to develop a roadmap for future PNT skilled workforce; (2) The Board should ask the EXCOM to direct the establishment and operation of a PNT partnership among multiple universities to offer diverse PNT-related curricula to the broader education communities, and to foster collaborative efforts among industry and government agencies to amplify the impact and to facilitate advancement from basic research to applications.



Slide 6

Discussion

ADM Allen asked if the NASEM study was already funded and who's the lead for that?

Dr. Morton stated that she doesn't know who is funding it, but NGA has already put all the money for the GEO-ESCON consortium at Ohio State University, but a dozen universities are involved in the GEO-ESCON effort. The subcommittee believes that government agencies should also come up with some kind of support. The NASEM activity is a new activity, and she does not believe funding has been set aside yet.

Hon. Shane asked if she believes that having the Board conduct a meeting devoted to these educational shortcomings would help in highlighting the needs and perhaps accelerating a response to your recommendations from the government?

Dr. Morton answered, "yes."

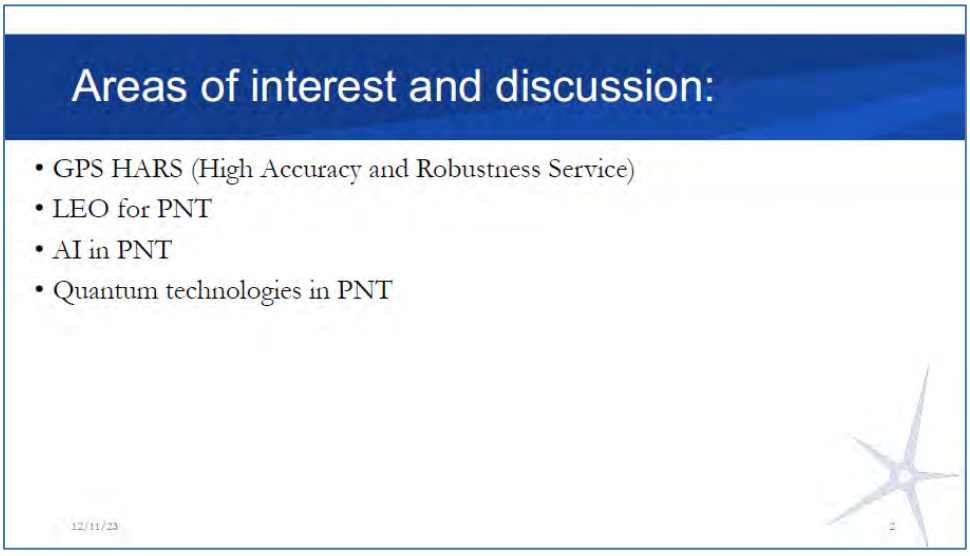
Mr. Goward stated that the Board was glad to be able to have ten students from the University of Texas at the event last night. So, as the opportunity presents itself, perhaps the Board might consider involving students and educators in either our activities directly or ancillary activities that we might engage in.

Dr. Grejner-Brzezinska stated that this afternoon, the Board will hear a presentation from Dr. Markiel of NGA. This will give the Board more details of where they stand right now on the GEO-ESCON, and they have an internal study about the shortage of PNT and geospatial technology. It would be a great opportunity for the Board to ask questions and talk with her and ask her what the most desirable step would be forward and action items for us.

3) Emerging Capabilities, Applications, & Sectors (ECAS)
Dr. Frank van Diggelen, *Subcommittee Chair*

Dr. van Diggelen opened the briefing by describing key areas of interest and discussion at today's meeting, namely: (1) the GPS High Accuracy and Robustness Service (HARS); (2) Low Earth Orbit (LEO) PNT; (3) Artificial Intelligence (AI) and PNT; and (4) Quantum Technologies and PNT (Slides 1-2).

Slide 1

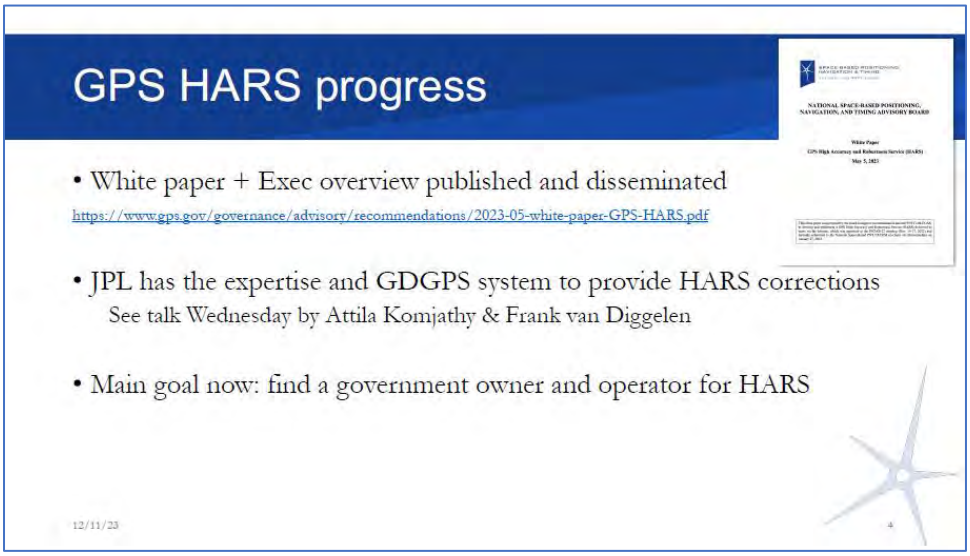


Slide 2

Dr. Van Diggelen also noted his gratitude to Dr. Axelrad, who's been involved with this Board since the very beginning (Slide 3). She was one of the subcommittee's Vice Chairs and Mr. Chan has bravely volunteered to step in as Vice Chair in her place.

Slide 3

This subcommittee has previously discussed a High Accuracy Service similar to what Galileo has in operation already (Slide 4). However, this subcommittee's proposal includes a capability that would add robustness, hence the acronym HARS (High Accuracy and Robustness Service). Earlier this year, the subcommittee published a recommendation as well as a white paper that includes a one-page summary of what this is about. One of the things we've identified through the Global Differential GPS System (GDGPS) study that Dr. Betz led over the last few years is that NASA's Jet Propulsion Laboratory (JPL) has the expertise and the system in place to be able to provide the data that could constitute a high accuracy and robustness service. The main goal of this subcommittee is for this to become a reality; it has to find an owner and operator within the government. The best way the Board can help is to communicate with the people who are in a position to recommend or approve funding for this. Invite those individuals to this talk and share the paper with them. For example, Ms. Van Dyke has brought Dr. Robert Hampshire, the Deputy Assistant Secretary for Research and Development at DOT to this meeting. Mr. Van Diggelen stated that he feels if somebody is interested in buying something and they know that somebody else may buy it, then they get a lot more interested. He also asked the Board that if anyone has contacts in other branches of government or organizations within the government, DoD or DOT for example, that might be interested in running such a service as an enhancement to GPS, then please pass on the information to them, because this is the next big step. Doing the white paper was relatively easy. Mr. Van Diggelen stated that getting somebody to invest money in this is a huge, difficult step of creation that we now have to surmount.

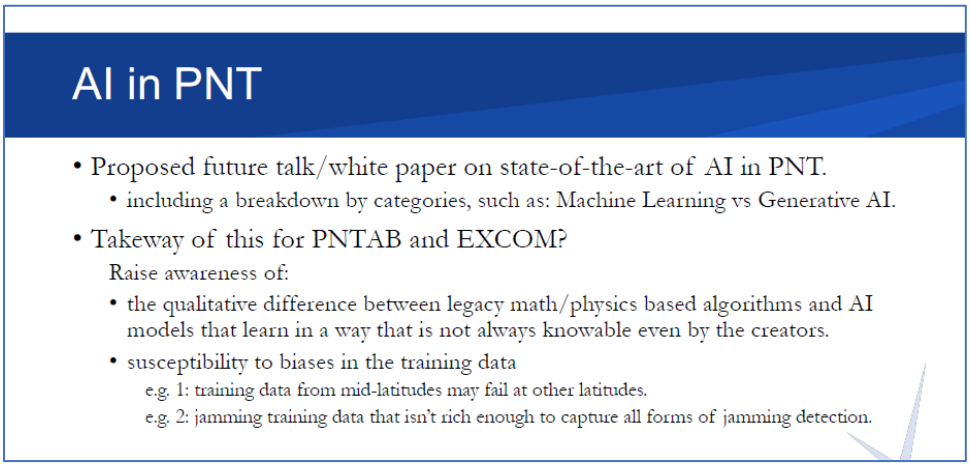


Slide 4

This subcommittee is also looking into other issues that fall under the emerging categories and technologies blanket. LEO for PNT has generated a lot of interest and we're lucky now to have Mr. Chan in our subcommittee, who is one of the founders of Xona Space Systems and has launched a LEO PNT satellite in orbit (Slide 5). The summary of this subcommittee's discussions held on the previous day is that it is very important to point out the significant difference between signals of opportunity in LEO PNT, meaning that you can measure signals from something, such as StarLink, and generate a position. Although this is interesting, StarLink is not robust for PNT because, for example, its clocks will jump without notice. This is a big difference between signals of opportunity and dedicated designed LEO PNT systems, which are now coming online. It is notable that in further development of this, there's been 50 years of evolution in signal processing and computing since the beginning of GPS. Mr. Van Diggelen stated that it's a good idea to not necessarily start at the same point that GPS started, but just to start with the technologies of today.

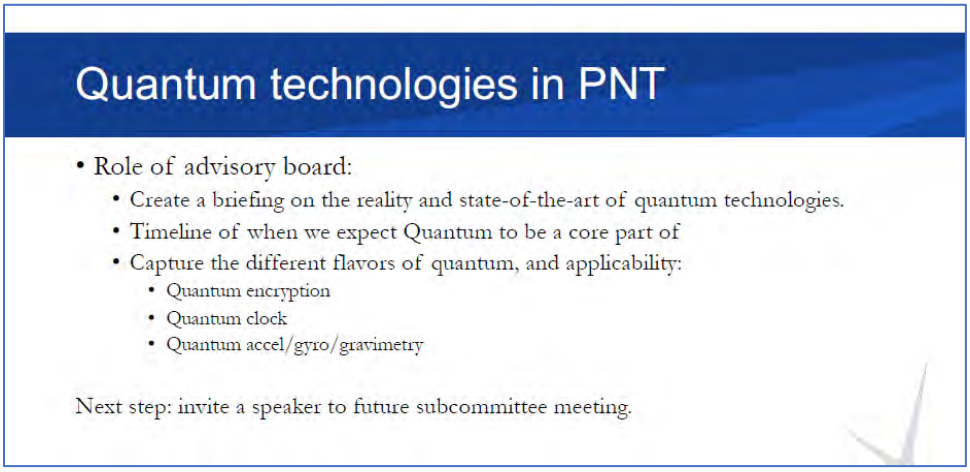
Slide 5

Another area of great interest is AI in PNT (Slide 6). The subcommittee is proposing a future talk and/or a white paper on the state of the art in AI in PNT. Mr. Filjar has volunteered to do this work and present this as soon as the next meeting scheduled for the spring of 2024. One of the reasons why the subcommittee would like to do this is to provide information to the Board and to the EXCOM to "help get through the fog of the hype." Mr. Van Diggelen stated that he saw an advertisement the other day for an AI enhanced golf club. Saying you use AI is almost like saying you use math, which doesn't tell you that much. An example, is machine learning, which is "engineery" by nature. There is also generative AI like ChatGPT, which can write poetry. When discussing and writing about the state of the art, this subcommittee hopes to provide material that addresses these items in the context of PNT to help provide advice as an Advisory Board and draw out things like the qualitative difference between these different algorithms, and to point out the susceptibility of biases in the training data. If you ask AI to explain doctors, it might talk about a medical doctor in the sense of a male medical doctor. If its training data is old and out of date, it may provide several examples of men being doctors. This is an example of generative AI absorbing biases in its training data. Likewise, with PNT, there are many examples where, if you're not careful, you may train an algorithm on data collected in the mid-latitudes that may cause other latitudes to work improperly. AI machine learning systems could be very good at detecting conditions that indicate jamming. To do this, you must ensure that your training data is rich enough that AI didn't merely learn to recognize one kind of jamming. This is what this subcommittee would like to draw out.



Slide 6

Another area that has received a lot of interest and a lot of promise is quantum technologies and PNT (Slide 7). A similar role we see for the subcommittee and for the Board is to create a briefing on the reality and the state of art of quantum technologies. Similarly, to what Mr. Van Diggelen briefed regarding different kinds of AI, there are different kinds of quantum technology. There are quantum clocks, which really means clocks based on light. Quantum encryption and quantum accelerometers, which are all different in nature, have the word quantum in them. This subcommittee aims to point out the difference between what's hype and what's a true potential technology for the future. In this case, the next step is to invite a speaker to a future subcommittee meeting to educate us on this issue. This could rise to being one of the topics that we discuss at a public meeting.



Slide 7

Discussion

Hon. Shane asked Mr. Van Diggelen if he could imagine devoting an entire meeting to these emerging capabilities and doing a deep dive into the topics that you've been discussing? They're endlessly interesting, but the idea would be to highlight the needs in terms of government policy and government attention. "You're recommending inviting a speaker, and it seems that the subject matter is important enough to ask for more than a speaker."

Mr. Van Diggelen stated that Hon. Shane came up with an idea of having themes for the meeting, so the Board doesn't go off in so many different directions at the public meetings. He proposed that AI can be one of the themes for a public meeting in "a year or 18 months from now" because "we don't know what we're talking about yet" in the quantum world.

ADM Allen asked Mr. Van Diggelen to lay out how the Board would want to structure a public meeting with an emphasis on AI and quantum technology. This will be included in the white paper.

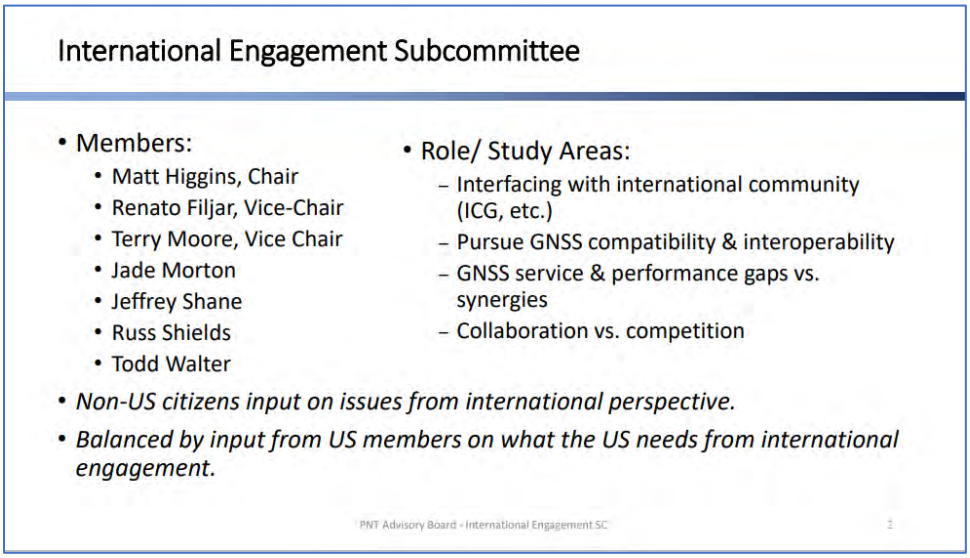
Mr. Van Diggelen noted that Dr. Filjar is writing the white paper.

4) International Engagement (IE)

Mr. Matt Higgins, *Subcommittee Chair*

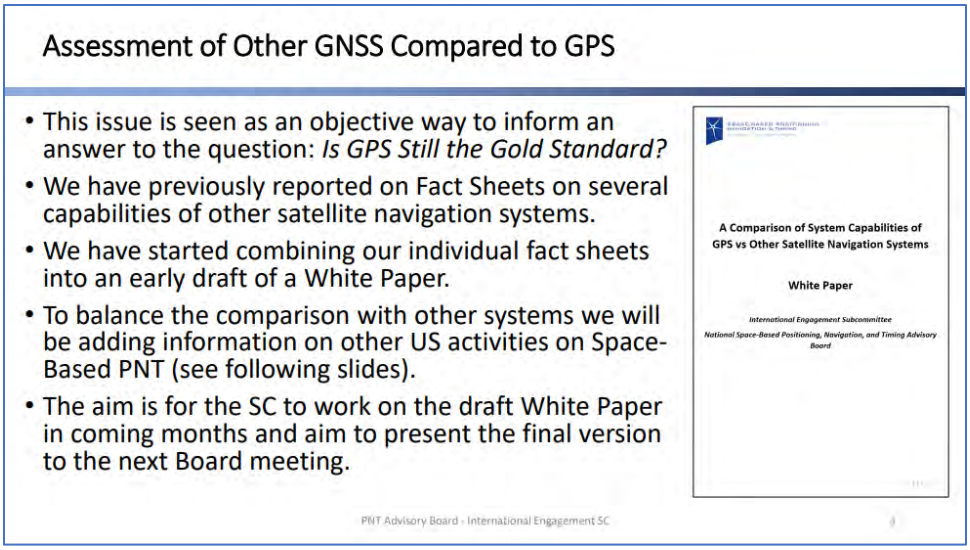
Mr. Higgins introduced the members of his subcommittee and noted that Prof. Moore is the new Vice Chair (Slides 1-2). Mr. Higgins stated that there were representatives from the USG sitting in on the previous day's preparatory fact-finding meeting and he feels that is especially valuable for the international members of the subcommittee because they would like to avoid proposing recommendations that the USG is already doing.

Slide 1



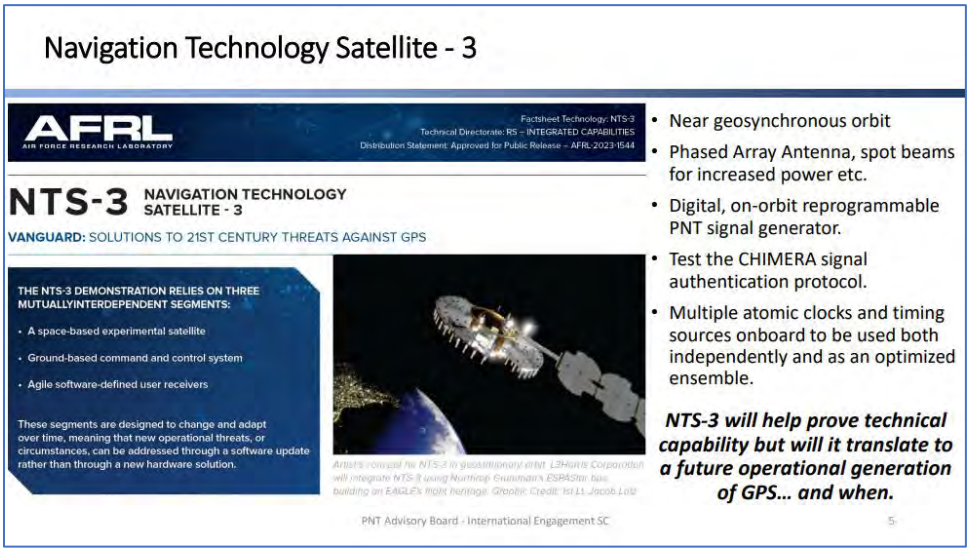
Slide 2

This subcommittee is still concentrating on the topic of GPS and its performance gaps (Slide 3). They've been approaching this by looking at some of the features of other GNSS and comparing those to GPS to try and better answer the question, "is GPS still the gold standard?" This subcommittee is also trying to answer the questions: What are the facts about the different capabilities that other GNSS have? Does it make sense for the U.S. to have it, as well? Does it make sense to have these capabilities somewhere else? The subcommittee has previously reported on several fact sheets that dive into each of those different capabilities, which Mr. Higgins will discuss. The subcommittee has begun to combine these findings into a white paper. The subcommittee is also adding in information about other U.S. activities on the space-based PNT. Mr. Higgins stated that the whole of the U.S. should be trying to solve this problem. It might not just be GPS that needs solving. The subcommittee's aim is to have the white paper ready in coming months for the Board's next meeting.



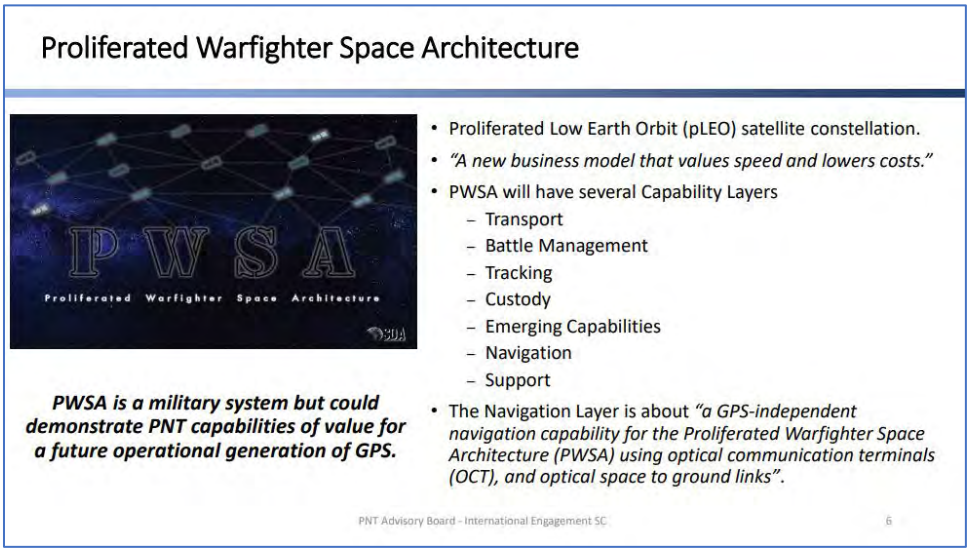
Slide 3

The Air Force Research Laboratory (AFRL) Navigation Technology Satellite -3 (NTS-3) is also mentioned in this white paper (Slide 4). The U.S. members of the Board have had a briefing on NTS-3, but it's worth noting in the context of the subcommittee that this exists with its three mutually interdependent segments of a space-based experimental satellite, ground-based command and control system, and software-defined user receivers. Regarding the satellites developed by L3 Harris Technologies, Inc., they have phased array antennas which enable spot beams to enable increased power for adhesion or more resilience to jamming and targeted authentication services. It also has an on-orbit reprogrammable signal generator. These are examples of capabilities that other systems are starting to have. Why isn't GPS? NTS-3 is only an experimental satellite at this stage, and it will launch in the middle of 2024. The question is how will this translate into the future GPS operational system? When might this happen, and how long will it take?



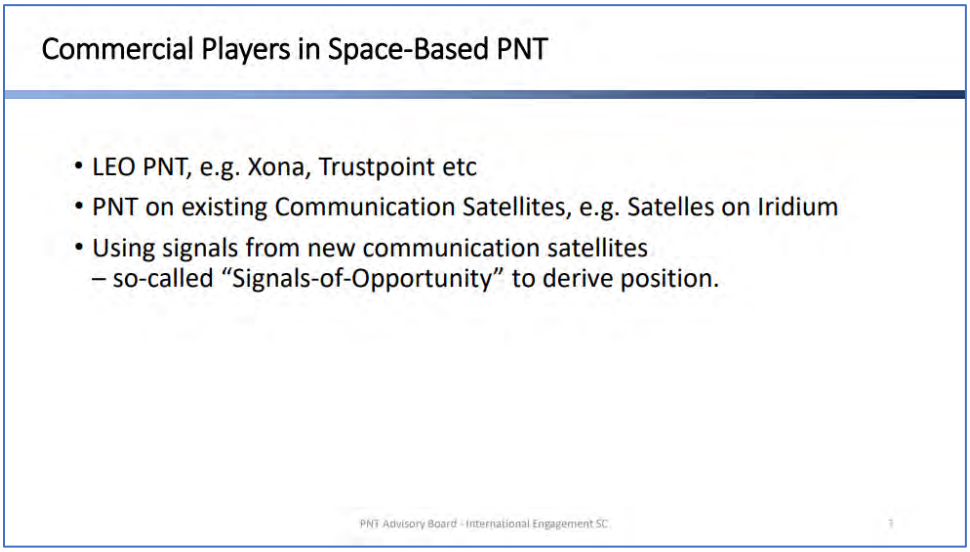
Slide 4

Another interesting topic for the white paper is the U.S. DoD Space Development Agency (SDA) Proliferated Warfighter Space Architecture, or PWSA. (Slide 5). This is a proliferated LEO system providing quicker deployment and lower cost. The navigation layer regards a GPS interdependent navigation capability for PWSA using optical communication terminals and optical space to ground links. T hese are some things that this subcommittee identified in the fact sheets: "what are we doing about the links?" and "what are we doing about programmable systems?" There is legitimate work happening in the U.S. So, saying that nothing is happening would be unfair. Mr. Higgins asked, "how does this translate into future generations of GPS? Will GPS only remain a military system?"



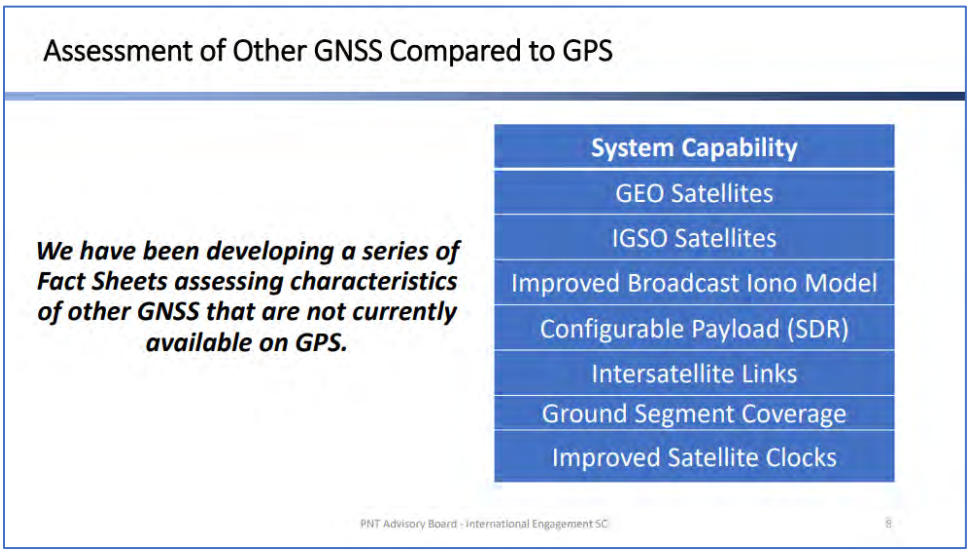
Slide 5

The White Paper also mentions LEO PNT in the private sector and among commercial players (Slide 6). It is important to consider the commercial sector when looking at the status of space-based PNT in the U.S. Also, there are different approaches for LEO PNT within the commercial sector. Some companies use existing communication satellites while others use so-called "signals of opportunity" to derive position. Mr. Higgins stated that the Board needs to be very clear on which ones they're talking about regarding these different approaches.

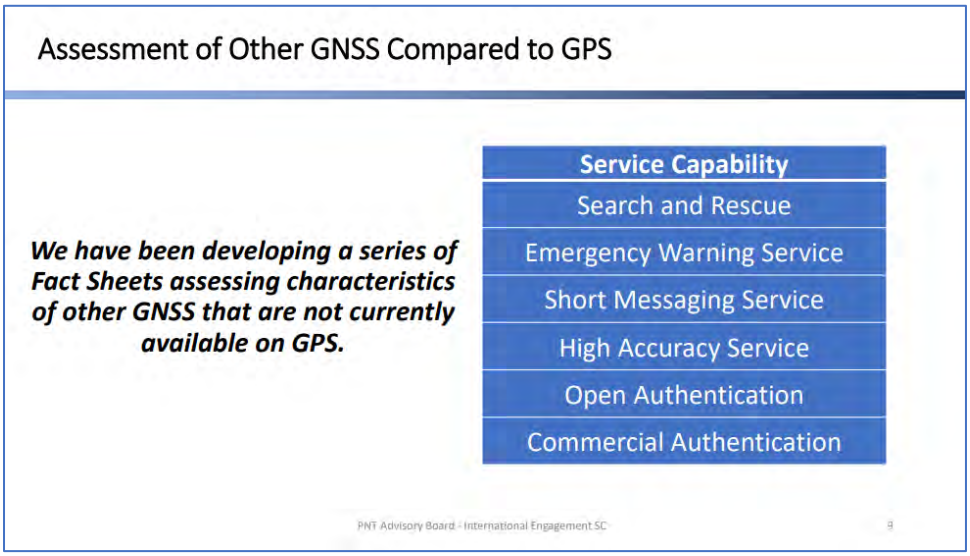


Slide 6

The subcommittee has also been developing a series of fact sheets to assess the characteristics of other GNSS that are not currently available on GPS. These fact sheets cover System Capabilities (Slide 7) and Service Capabilities (Slide 8). So, this subcommittee will be taking the existing Fact Sheets on those and merging them into the White Paper. For example, Galileo Second Generation (G2G) committed to doing some of these things shown on Slide 7, as opposed to testing or experimenting. Furthermore, the white paper will highlight some of these topics shown on the slide.

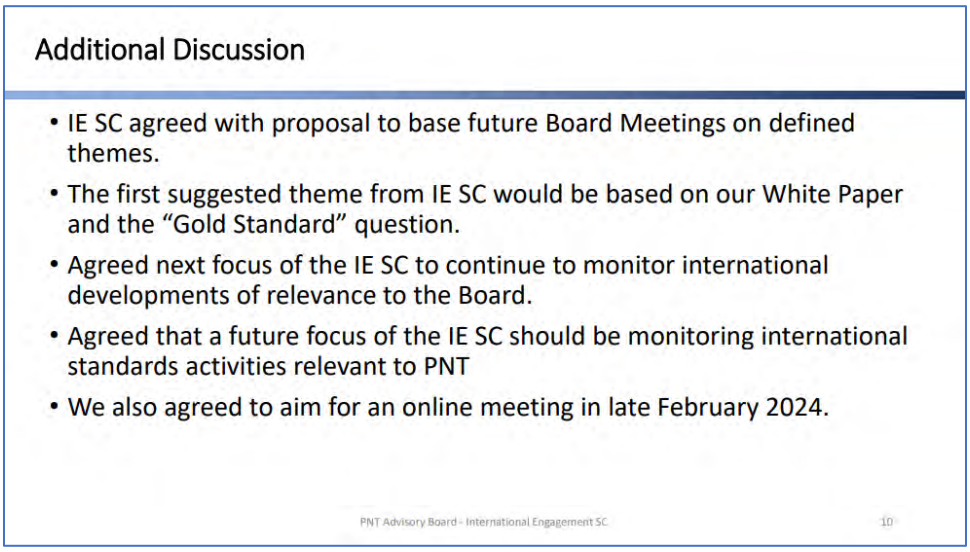


Slide 7



Slide 8

The subcommittee also agrees with Hon. Shane's proposal to base future Board meetings on a defined theme (Slide 9). Therefore, the subcommittee is suggesting that the question "is GPS still the gold standard?" could be a session within the public meeting. Regarding steps forward, this subcommittee will continue to monitor international developments and will be doing more to monitor international standards. The subcommittee has also agreed to have an online meeting in late February, keeping in mind that the International Global Navigation Satellite Systems Conference (IGNSS) will be held in Sydney, Australia in February and some PNT Board members will attend.



Slide 9

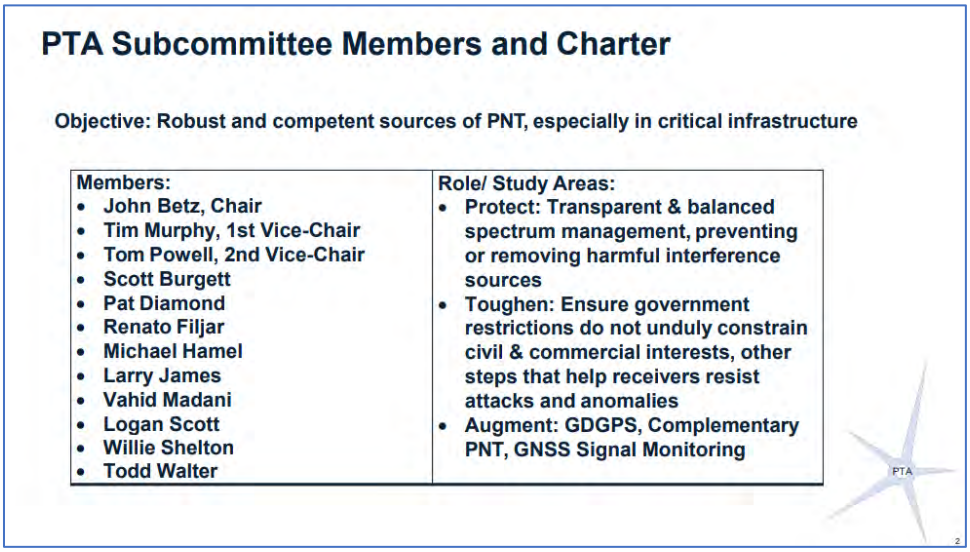
Discussion

ADM Allen suggested that Mr. Higgins disseminate his last summarizing slide as a presumptive outline that previews what the Board will be working on.

5) Protect, Toughen, and Augment (PTA)
Dr. John Betz, *Subcommittee Chair*

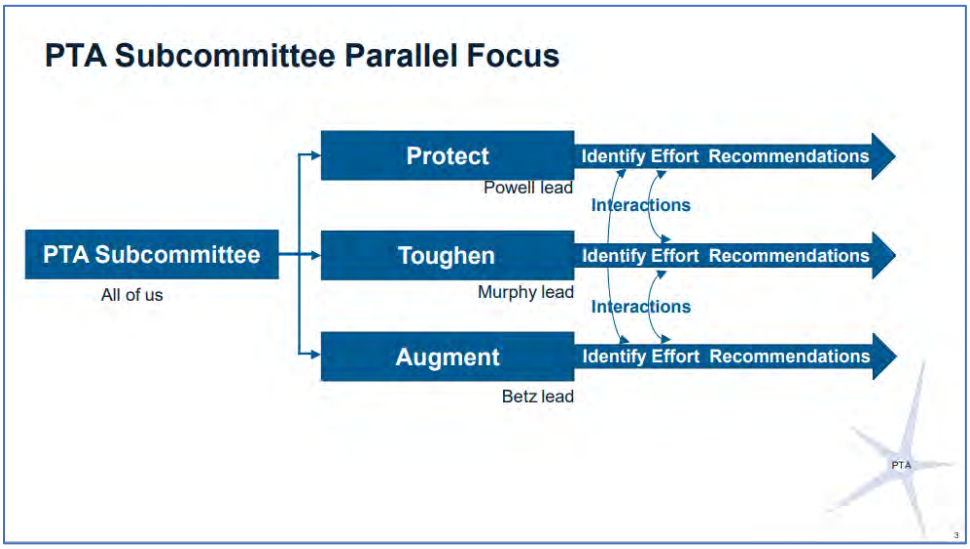
Dr. Betz opened by stating that this is a report on the PTA Subcommittee's activities (Slide 1). Dr. Betz noted that he shares leadership of this subcommittee with Mr. Murphy and Dr. Powell (Slide 2), and they're happy to welcome Gen. Shelton and Mr. Scott as new members of the subcommittee.

Slide 1



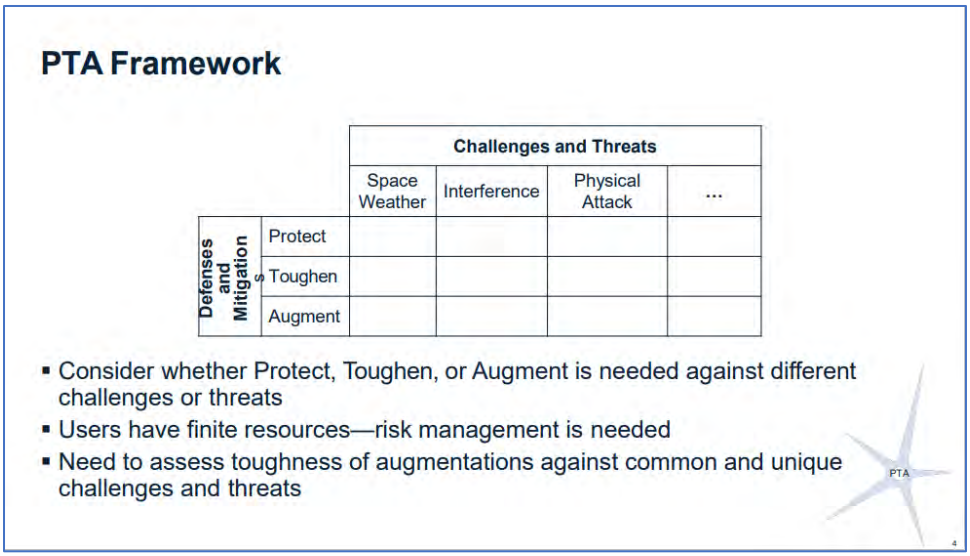
Slide 2

Because of the broad scope of this subcommittee, PTA is separated into three areas, although these divisions work closely together (Slide 3).



Slide 3

The overall work of this subcommittee is outlined on Slide 4. There are a number of challenges and threats to PNT, and "some combination of protect, toughen, and augment are ways to counter those threats and challenges." The real issue is how to allocate those in the most efficient way across the threats and challenges. That is this subcommittee's continuing thought process behind its work expertise.



Slide 4

Another thing that's become clear as a subcommittee has continued its work is that there are several obstacles that PTA faces, particularly as they look at the critical infrastructure applications (Slide 5). Protecting remains a challenge. Still lurking in the background are the possibility of strong adjacent band interference; and the nation's ability to detect, characterize, and remove interference sources to SatNav continues to be less than what the U.S. needs and is not moving as fast as we all would like.

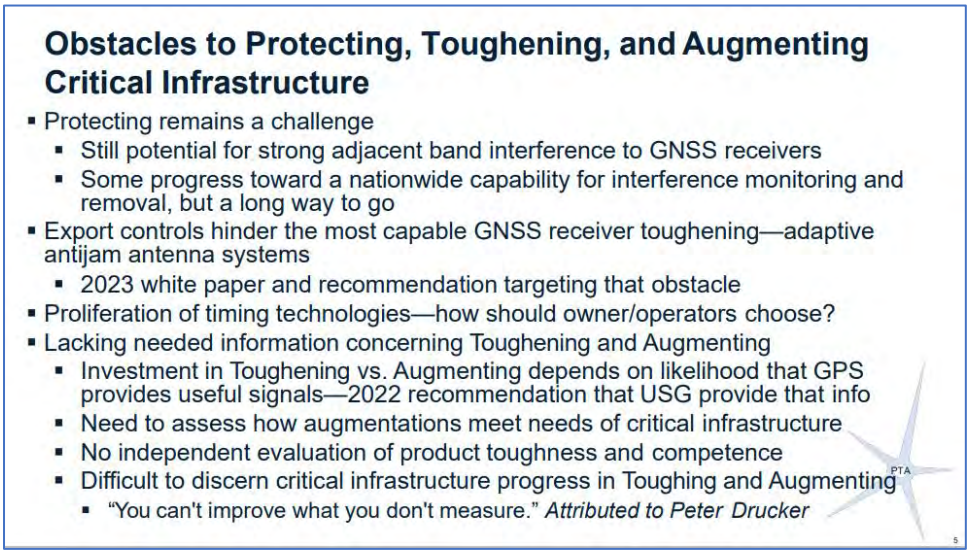
This subcommittee talked in detail at the last meeting about how export control is limiting the ability of the most effective way of toughening SatNav receivers, so Dr. Betz stated that he will talk a little bit more about progress on that. Finally, this subcommittee recognizes that timing to stationary receivers is a very important part of GPS's use in critical infrastructure today. It actually is the easiest problem to solve and there are multiple technologies out there or coming, and one of the things this subcommittee foresees is that owner operators in critical infrastructure could help with some guidance in terms of what timing technology is most appropriate for their needs.

Finally, the PTA subcommittee thinks there are several important areas where information is lacking in toughening and augmenting. If you put yourself in the place of a critical infrastructure owner operator, you can spend your limited resources on toughening your SatNav equipment or augmenting it. Dr. Betz asked, "how do you choose?" One thing that helps make that choice is the likelihood that GPS is going to be providing useful signals, or if the satellites have all gone silent for a day, week, month, or year, in which case augmenting is the only option. This subcommittee has recommended that the USG provide useful guidance on that, and they are currently waiting to hear back regarding that.

There are a lot of augmentations out there and it's important to understand how they match different critical infrastructure needs. There will be a presentation this afternoon that proposes a framework for addressing that question. Critical infrastructure operators are faced with the number of products and there's no independent evaluation to help them understand how well they do with toughening and augmenting.

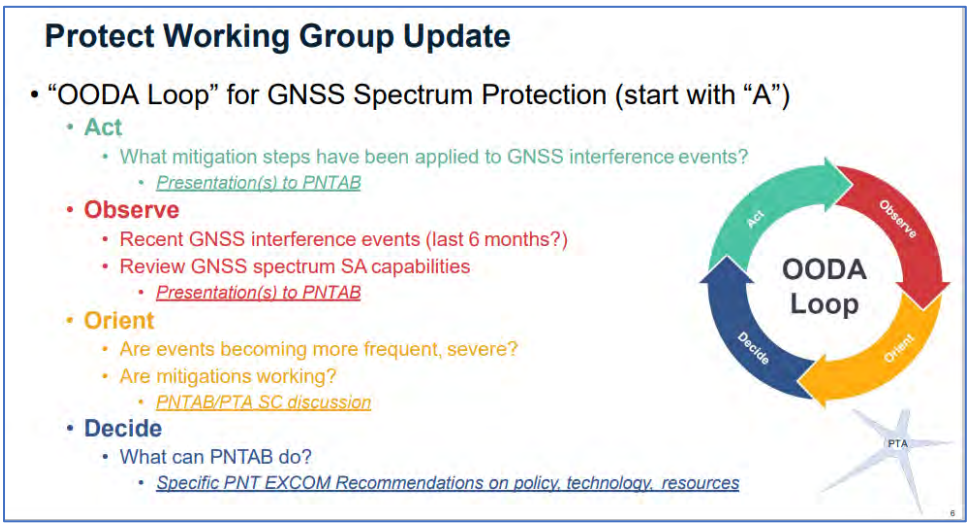
There was a presentation at the last Board meeting which looked at a metric to help measure how well there's progress in critical infrastructure for toughening and augmenting, and the Board found out there is very little or no effort going on in that area. Dr. Betz included a famous quote at the bottom of the slide (Slide 5): "you can't improve what you don't measure."

Dr. Betz stated that this subcommittee is not just admiring these observations, but they have a specific proposal on how to address many of them.



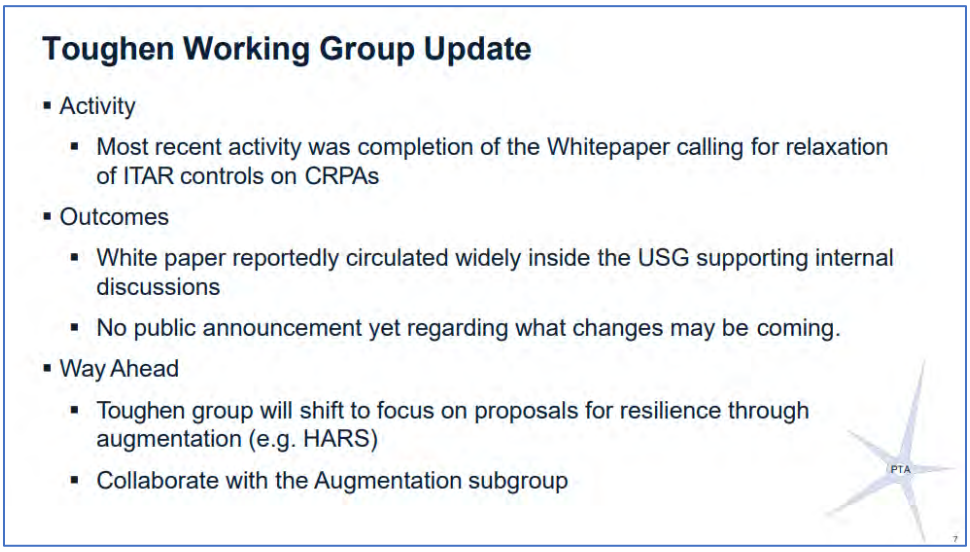
Slide 5

Dr. Betz stated that Slides 6-8 summarize progress across PTA and invited Dr. Powell to speak on the "Protect" slide (Slide 6). Dr. Powell stated that he constructed this way of thinking about the problem based on the term that those in the military are familiar with the Observe, Orient, Decide and Act (OODA) loop. For this application, Dr. Powell slightly adjusted the order to highlight which problems the Protect subgroup should evaluate. The slide shows the topics for each variable and what mitigation steps have been taken so far when it comes to spectrum interference, as well as recent observations. Regarding orienting, are there trends? Are these things becoming more prevalent, more frequent, and more severe? And are there any of the mitigations that are being fielded or proposed working? Based on this information, what specific recommendations could this body make to the EXCOM?



Slide 6

Dr. Betz thanked Dr. Powell and provided a quick summary of Toughen (Slide 7). A significant effort over the past year has been to build a case for relaxing export controls on anti-jam antenna systems, and the White Paper that Mr. Murphy led and did a significant amount of work on himself was fantastic. The highlight of it was an extensive set of references demonstrating the extent that this technology is already available around the world to adversaries as well as friends. Export control does not seem to be accomplishing much that is useful whilst still tying our own hands. This subcommittee is hoping to hear more progress about the USG responding to their recommendation.



Slide 7

Discussion

Dr. Parkinson stated that it is his understanding from Mr. Ken Alexander that this was supposed to be on an agenda item within the Department of State (DOS) in December, and because of priorities, it has been now kicked down into the indefinite future. It's also his understanding that there was no opposition to the relaxation of those controls, although he does not know the degree of relaxation. Dr. Parkinson asked Ms. Van Dyke if or Mr. Martin if they have anything to add regarding this issue.

Ms. Van Dyke stated that she does not have any additional information.

Mr. Martin concurred, saying that he does not have a timeline update. He also noted that Mr. Auerbach, from the Department of State, is in the audience.

Dr. Parkinson asked, "is there a way to get either an update or a confession of ignorance by tomorrow?"

Mr. Martin stated that there is a PNT Executive Steering Group (ESG) meeting coming up next week and they will be discussing International Traffic in Arms Regulations (ITAR).

Mr. Auerbach stated that he was planning to brief this topic this afternoon, but he'll say a few words now. The actual rule is being revised under the review process. He is hopeful the revision will be done by the end of the year, but it will probably be finished early next year. Mr. Auerbach stated that he has not seen the rule and doesn't know what it will say. He does have a sense, but unfortunately cannot share until it's officially released. Since the last Board meeting, there have been meetings with the whole interagency, all of those interested, and they have taken that into account as they do the rule. Input was also received from the public, including members of the Board. Mr. Auerbach stated that he is very hopeful that it will satisfy the views of many of the people here, but again, he cannot comment specifically on what the rule is going to say.

Dr. Parkinson asked Mr. Auerbach if he has seen the draft, to which Mr. Auerbach replied that he has not.

Mr. Auerbach reiterated that he does not have control over the process, and that his office is not rewriting the rule. However, they have been transparent to him and to a few other people in the interagency regarding their plan moving forward.

Dr. Parkinson asked Mr. Auerbach if the Board will be happy.

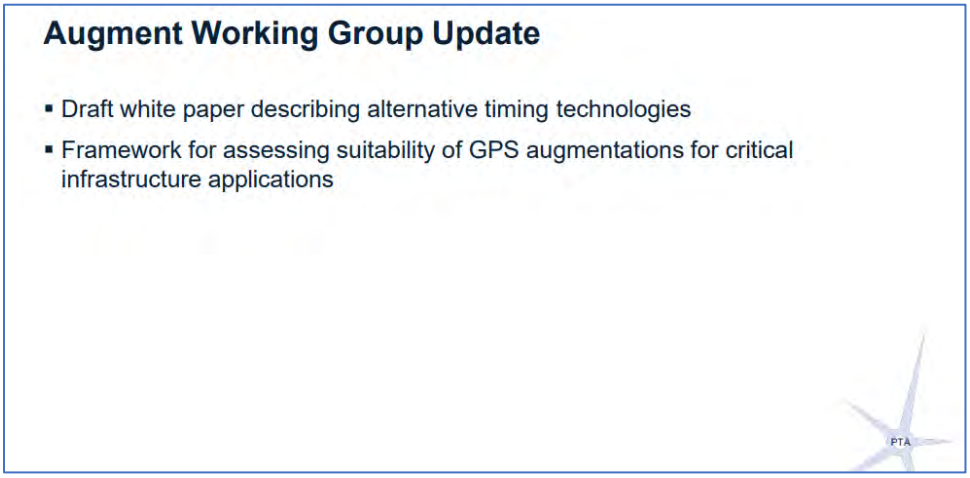
Mr. Auerbach stated that he cannot say but is hopeful that they will.

Hon. Shane commented that Dr. Parkinson will probably never be happy.

ADM Allen requested that DOS give an update if they have a representative attending the ESG later in December.

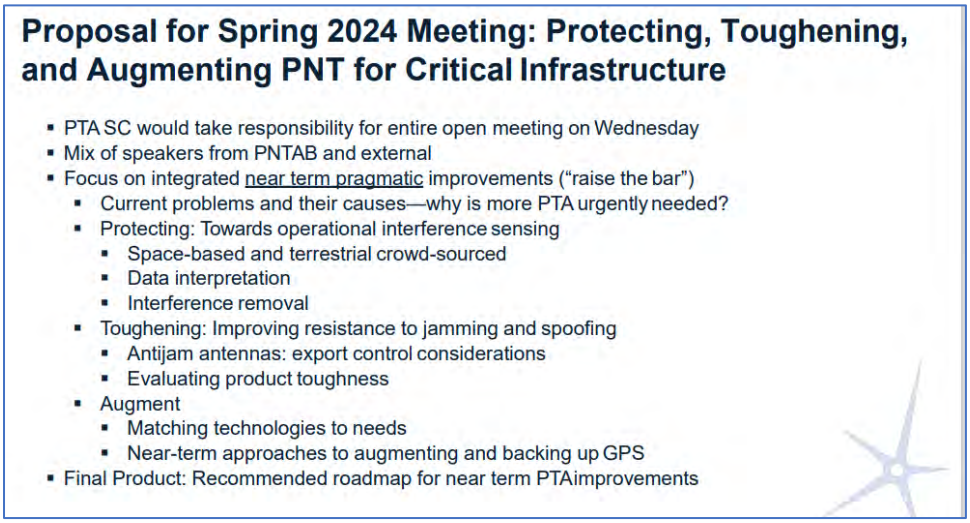
Mr. Murphy commented that he assumes there will be an open comment period once the rule is released.

Dr. Betz then moved on to the topic of "Augment" (Slide 8). The subcommittee has been drafting a White Paper on timing alternatives and has discussions about a framework for evaluating the applicability of different technologies for Augment.



Slide 8

Dr. Betz then proposed that the Advisory Board's spring meeting be dedicated to PTA (Slide 9). The subcommittee can take responsibility for organizing the entire day on Wednesday, and there will be a mix of speakers from within the Board, recognizing the expertise within the room, as well as external subject matter experts. The Board would focus on near-term pragmatic ways of raising the bar in critical infrastructure, and the subcommittee come up with some tentative outline thoughts with the idea to span the space of PTA and come up with very specific thoughts on how to proceed. The idea is the board come up with a recommended roadmap for the near term of PTA for critical infrastructure, which is a very tangible, constructive, and integrated product from this effort. This will be a significant effort on the subcommittee's part, so Dr. Betz would like to receive approval by the end of December if the Board decides to proceed with his proposal.



Slide 9

Discussion

ADM Allen asked the Board members to take Dr. Betz's recommendation seriously and that they will discuss it in further detail tomorrow.

6) Strategy, Policy, & Governance (SPG)
Hon. Jeff Shane, *Subcommittee Chair*

Hon. Shane started by introducing his subcommittee members. He stated that this subcommittee has been looking internally since our last meeting and they've been discussing how the Board can conduct meetings in the most effective way. Today's discussions have been interesting and make very clear the richness and depth of the material that we have before us and the need for deep dives into various aspects, whether it's education, PNT, emerging capabilities, or international discussions.

The Board has the prospect of putting together a unified field theory of where space-based PNT is going. The discussions on the previous day were about how to pull these threads together, and how to make a difference in terms of government policy, which is what an advisory board of any sort in the government should be doing. So, this subcommittee thought that the Board ultimately needs to review the nation's space-based PNT strategy and governance.

This subcommittee is called Strategy, Policy and Governance. During yesterday's discussion, Gen. Hammel pointed out that national policy is a problem. The U.S. has a pretty good national policy. The problem is implementation. The problem is taking these issues seriously and understanding what the challenges are. So, the objective of a meeting in which we reviewed the nation's space-based strategy and governance would be to determine what changes might help the U.S. address perceived challenges more effectively. To do this sensibly, the Board needs to take advantage of the quality of the discussions that were presented today, replicated in greater depth through meetings devoted to each of the topics that were briefed this morning. In other words, the Board should lay the groundwork for a presentation to the government that includes the government. If the Board decided to do this, the speakers and presenters should be those close to the principals' level, if not the principals themselves. And there should be a dialog about where the U.S. is going based on the material that the Board has examined in previous meetings.

This should be supported by a comprehensive white paper. Think about the white papers that have been discussed by each of the subcommittee chairs thus far. Hon. Shane stated that he imagines pulling those papers together as chapters of a comprehensive White Paper on the future of space-based PNT.

The U.S. is looking upon an election at the end of 2024 and there may be a new administration in 2025. This means that there may be people in place who are different from those who are there now. Even if the president is reelected, there will be changes in personnel. This happens every four years, and the Board must keep an eye on that picture to see who it is that we want to address. By the time the Board reaches that point, we will have done a lot of good, credible work in the areas that have been discussed so far. So, the thought is that by that time this body is able to make a powerful presentation to the principals who will be in charge, so the prospects of improving the quality of governance and the strategy to make it more contemporary and responsive to the challenges that we see are dramatically improved.

In addition to meetings, the subcommittee thought it would make sense for the representatives of the Board to pay calls on the principals. At the DOT, one would think that there isn't any need to underscore the importance of reliable PNT to a department that is all about autonomous transportation, autonomous vehicles, and autonomous aerial vehicles, which is the future of transportation. If these haven't already been demonstrated, it will obviously be dependent upon reliable PNT.

The Department of Defense owns and operates the system. They are probably focused on their mission. Hon. Shane stated that he doesn't know if this Board has anything to teach DoD about the importance of the mission. The important conversation with DoD is how can the Board better facilitate crosstalk with the custodians of the civilian user community: DOT? This is all part of the governance conversation.

Hon. Shane stated that the Board does not need to make any decisions now about this meeting proposal because we would want to see the results of the newly formatted Board meetings first. These are the ones that are more specific to topics that were discussed this morning.

Discussion

> ADM Allen commented that due to the last presidential election and transition, the Board knows what the questions are going to be, and we know what the test is going to be. We'll know quite well in advance. What's compelling about Hon. Shane's recommendation is that we look to put together a comprehensive collection of the things we've been discussing today will agree or not agree tomorrow where the Board is going to go with the goal of having a product that's substantial. The Board will aim to have a proactive document that we'll put forward as our advice in the transition, whether it's a new or a current administration. There's a reason to do this now, in ADM Allen's view, because last time the Board was able to get in in pieces during the change of administration. But to have a compelling, overarching view of where we stand makes it much more likely that it will make it through the transfer of administration, and through any traumatic changes that may become a problem.

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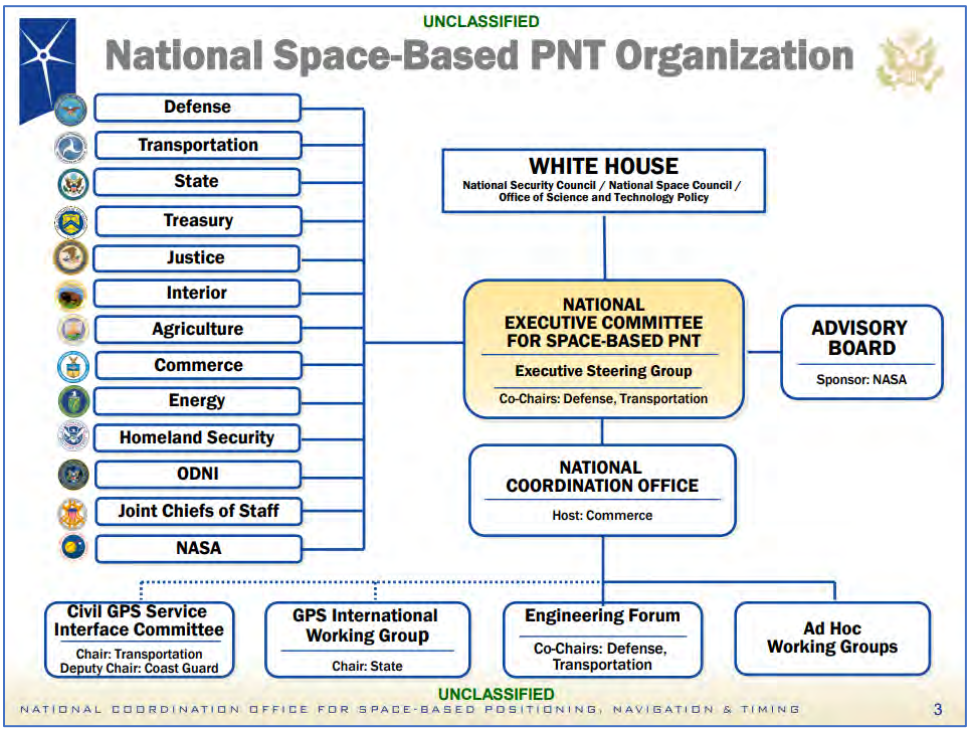
National Coordination Office Update & Status on PNT ESG Responses to 2023 PNTAB Recommendations
Mr. Harold (Stormy) Martin III, *Director, National Coordination Office for Space-Based PNT*

Mr. Martin opened by thanking the Board for inviting him to speak today. He also thanked the members of the Advisory Board for their work and stated, "you are the coalition of the willing for you could be doing other things, but you're here basically working for food because you believe in what we're doing." Mr. Martin also thanked the Board for their recommendations earlier this year, like the one that alerted the USG to the fact that this year is the 50th Anniversary of GPS. The EXCOM acted on that recommendation, forming a GPS 50th Working Group led by the National Coordination Office for Space-based PNT (NCO) across the interagency to plan and coordinate events. He thanked the DoD, USSF, DOT, NASA, and other departments and industry, particularly the GPS Innovation Alliance (GPSIA), as well as Congressional members and their staffs of the GPS Caucus, for working together to hold several GPS 50th events, including those at CGSIC and on Capitol Hill commemorating the achievements in the first 50 years of GPS, and looking to continued U.S. PNT leadership in the future. Mr. Martin thanked Dr. Lisa Dyer and the GPS 50th Working Group for their work in organizing the GPS 50th event on Capitol Hill. There were several speakers, including Senator Tammy Duckworth and Senator Joni Ernst, who are two of the co-chairs of the bipartisan, bicameral Congressional GPS Caucus. They, and others, spoke on the benefits of GPS and commitment to continued U.S. PNT leadership. Dr. Robert Hampshire, the ESG Co-chair from DOT, as well as Brig. Gen. Robert Hutt, the Director of Plans and Programs for USSF spoke as well. Mr. Martin thanked Dr. Parkinson, who gave the origin story of GPS, as well as Mr. Burnett, Dr. Pace and those who played key roles in this event. Mr. Martin thanked the PNT Advisory Board for their recommendation to modify the ITAR restrictions regarding GPS Controlled Reception Pattern Antenna (CRPA) increased anti-jam capability. The EXCOM took action on that, and the DOS has been leading an interagency effort with DoD, Federal Aviation Administration (FAA), and others to review the current ITAR restrictions and try to change them. It's important to note that those items restrictions do not prohibit the civil federal agencies that have a mandate in policy to toughen their GPS receivers. They can use advanced CRPAs, which are not prohibited. Funding for these things is an issue. In the broader sense, this activity to change the ITAR restrictions benefits the U.S. economy because U.S. manufacturers are prohibited from marketing these devices in other countries and prohibited from exporting them. So, they could build them for a USG department, but they cannot export them. That's a level market playing field issue that's important to help conquer. The EXCOM appreciates the Board's recommendation on that and look forward to trying to get those ITAR restrictions changed because the more affordable those kinds of capabilities are, the more likely it is they will be used across U.S. critical infrastructure.

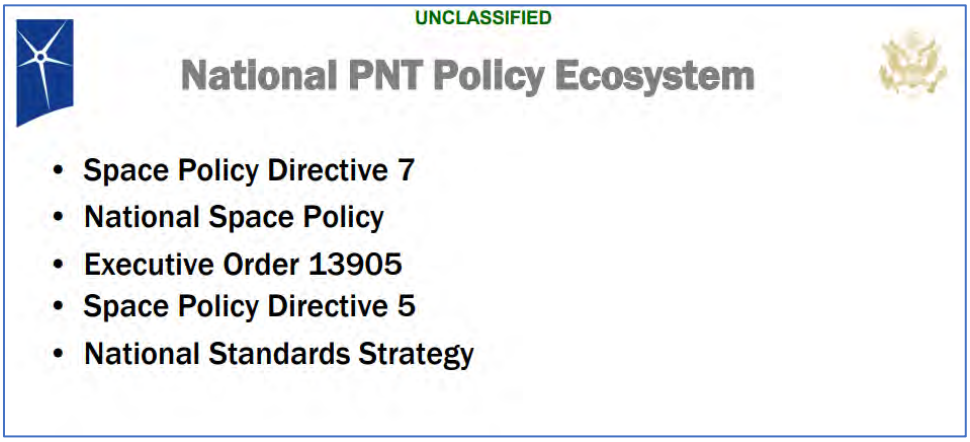
Slide 1

Slide 2 describes the PNT EXCOM's organization. The core departments and agencies are on the left, and the NCO, the main working groups and the Advisory Board fill in the rest of the chart. Mr. Martin thanked the Advisory Board for the other recommendations in ADM Allen's January 2023 letter to the EXCOM co-chairs. The EXCOM tasked the ESG to develop formal responses and get them back to the Board, and the NCO has been coordinating this effort across 13 departments and agencies of the EXCOM. The NCO is close to a final version for ESG co-chair approval, and then they will put it into the public release approval process to be able to send it to the Board and post it publicly on GPS.gov.



Slide 2

The goal of Space Policy Directive 7 (SPD-7) is to maintain U.S. leadership in the service provision and responsible use of GNSS, including GPS in foreign systems (Slide 3). The National Space Policy allows for the continued use of allied and other trusted international PNT services in conjunction with GPS. It also calls on the USG to identify and promote, as appropriate, multiple and diverse complementary PNT systems or approaches for critical infrastructure and mission essential functions. Executive Order 13905 strengthens national resilience through responsible use of PNT services. Additionally, it advocates for complementary PNT systems in critical infrastructure and mandates that for USG departments and agencies. Space Policy Directive 5 (SPD-5) establishes space cybersecurity policy, standards, and risk management practices. This is not just for government systems like GPS, but it also advocates for cybersecurity in commercial space programs, as well. The National Standards Strategy is a new edition that was released in May of 2023.

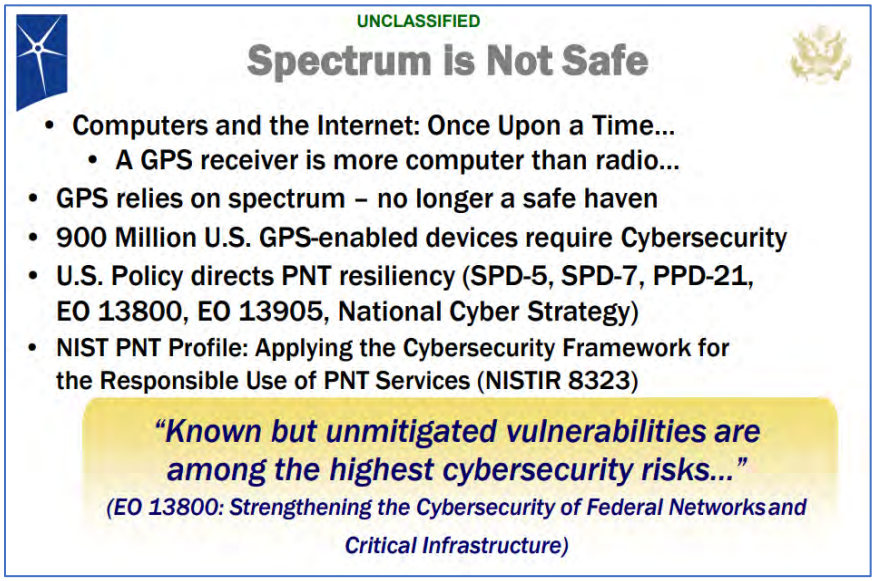


Slide 3

The USG Standards Strategy for Critical and Emerging Technology (CET) was published because standards matter (Slide 4). As stated in the strategy, strengthening standards development has been instrumental to the U.S. global technological leadership. The U.S. will prioritize efforts for standards development for a subset of CET that are essential for U.S. competitiveness and national security. This strategy lists eight areas. The NCO was able to work with the White House and get PNT services included as one of those areas, which as it says, are a largely invisible utility for technology and infrastructure. The strategy has four main objectives: Investment; participation; workforce; and integrity and inclusivity. The strategy is public and available online.

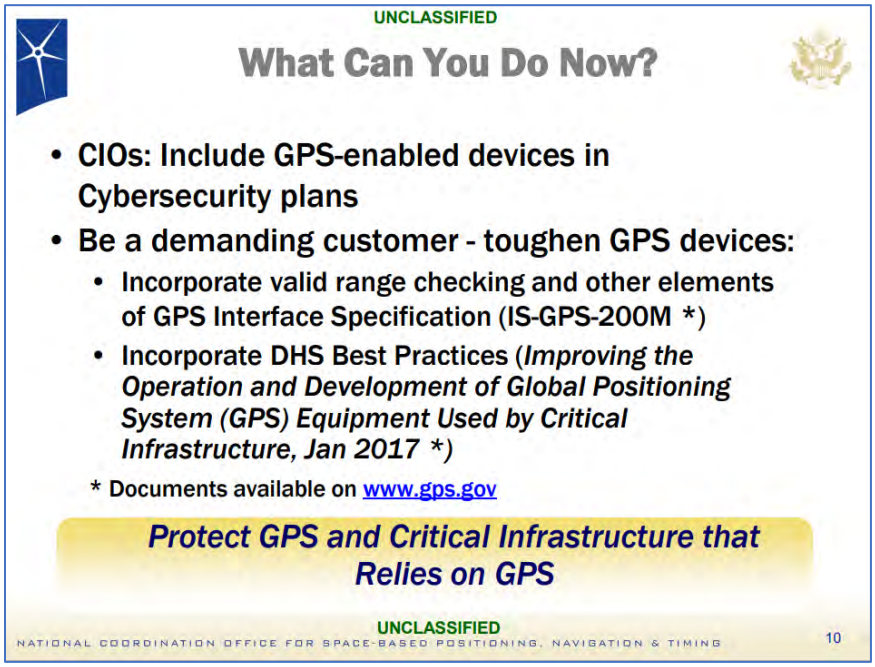
Slide 4

Spectrum is not safe (Slide 5). U.S. policy directs USG departments and agencies to improve the cybersecurity of GPS, its augmentations, and USG-owned GPS enabled devices. Additionally, it calls on those USG agencies to foster private sector adoption of cybersecurity GPS enabled systems. In short, the U.S. needs to toughen our GPS enabled systems against jamming and spoofing.



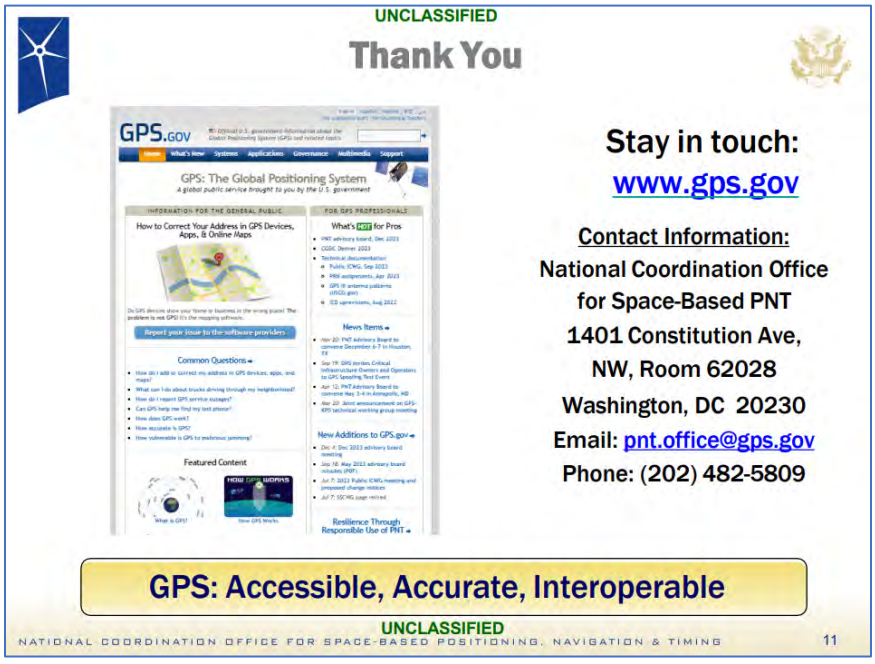
Slide 5

So, what can the Board do (Slide 6)? The Board could be a demanding customer. As development of a new PNT enabled system begins or there are upgrades to an existing one, ask the manufacturer for a GPS receiver that is compliant with the published standard on building GPS receivers: the Interface Control Document (ICD). Additionally, if you're a chief information officer, or work for one, include GPS devices in your cybersecurity plans. Not doing so leaves an unprotected port for your network. Remember, PNT resilience is two parts: (1) Cyber toughen GPS devices that protect against jamming; (2) Spoofing and tested and trusted complementary PNT systems.



Slide 6

Mr. Martin thanked the Board and welcomed any questions or comments (Slide 7)



Slide 7

Discussion

Dr. Parkinson thanked Mr. Martin, and commented that, "a manufacturer could build a multi-element antenna, but he can't install it in an airplane and let that airplane fly out of this country," therefore, "the manufacturers have absolutely no incentive to build something that the airlines cannot use."

Mr. Martin agreed with Dr. Parkinson's interpretation, saying that they can build them, and federal agencies are mandated to toughen their federal systems. There are hundreds of U.S. systems used by the USG that are critical to "mission essential functions," which are listed publicly for each department and agency. They have systems that are PNT enabled that need this sort of toughening. In terms of just the anti-jam, they could choose to install the highly advanced CRPA antenna on those systems and they are not prohibited by ITAR from doing so. The restrictions apply to manufacturers who build a product and then send that product outside of the U.S. This does handcuff U.S. industry in terms of competitiveness. As Dr. Parkinson has pointed out before, there are companies in Europe that are selling advanced CRPAs.

Dr. Parkinson stated that it goes further than that. He said that "if you dig into ITAR, the penalties are really horrendous." Although what Mr. Martin stated is true, a manufacturer would be wary that if he gave a piece of equipment to a government agency, and somehow ended up overseas, they would be held liable. Unfortunately, this is a deterrent to our own industry. So, the previous statement that "they are allowed to do it" does not have much traction.

Mr. Martin agreed, saying that it's a complicated, challenging process.

Dr. Parkinson stated that Mr. Auerbach with DOS may have a better idea of how to unravel ITAR, and Mr. Murphy pointed out that once there is draft wording, are the manufacturers at Boeing, for example, going to be able to review it? Dr. Parkinson urged those who are making these decisions to make certain that the new rule will allow U.S. manufacturers to toughen the receivers the way that they belong. This has been such a mystery process that the new ITAR rule may not accomplish what the Board is trying to accomplish. Dr. Parkinson stated that the lack of visibility in this process will cause this to happen.

Hon. Shane asked if there is a discussion within the USG of whether they can implement a more balanced approach to spectrum allocation, particularly where the equities of other parts of the USG are at stake. Right now, the U.S.'s telecommunications laws vest exclusive authority in the Federal Communications Commission (FCC) for making those decisions. The National Telecommunications and Information Administration (NTIA) represents the Executive Branch, but at the end of the day it's an interested party as opposed to a decision-making body, and sometimes a decision is made with or without their agreement.

Mr. Martin stated that all aspects of the radio spectrum, including how spectrum is allocated, has been in discussion for the past couple of years. The White House recently released the National Spectrum Strategy, which took quite a while to develop and lays out what they're planning to do. Additionally, the FCC is not "completely a part of the Executive Branch" so there is some give and take between the two branches.

Hon. Shane stated that although the National Spectrum Strategy is responsive to a lot of concerns, it would have had no effect on any of decisions regarding the episodes that this Board has looked at for a long period of time, including the Ligado decision and the 5G decision that that called into question the integrity of our aviation system. All these decisions would have been made consistent with the National Spectrum Policy as it's written. Hon. Shane appreciates the emphasis and the intention behind the National Spectrum Policy, and it will undoubtedly produce better results overall, but it's important to recognize that it didn't change the fundamental fact of the exclusive authority that rests in the FCC to make those decisions according to its own best lights.

Mr. Goward commented that the Board agrees that GPS and PNT are a critical part of our national infrastructure, especially the PNT services. Yet there's no mention of that in any of the legislation and little mention of that elsewhere outside of this Board. Similarly, the National Cybersecurity Strategy and Cybersecurity Strategy Implementation Plan make no mention of PNT. In fact, while the cybersecurity plans and strategies say that the USG wants to take the burden off the user because the government and major providers are more capable of providing cybersecurity, essentially the opposite is true with the executive order on PNT that still stands. It says, "you are responsible for protecting yourself in terms of PNT." PNT is a critical cyber component, enabling operation of systems, providing data, enabling communication between systems, and so forth. So there seems to be neglect when including PNT in these critical national considerations.

Mr. Goward asked Mr. Martin if this lack of inclusion or consideration of PNT in these two very important areas, and perhaps others, is a matter of neglect and ignorance or of a deliberate decision on the part of some folks to say "PNT is a whole different horse, and we will deal with it separately from these other considerations?"

Mr. Martin stated that in terms of policy, PNT is not viewed as being the same as Microsoft Windows 10, for example. Although the discussions of PNT cybersecurity have been going on, there's still a separation of policies. Maybe this is an area for work to be done in the future. On the good news front, there is some money coming out to look at PNT resilience. Ms.

Van Dyke is going to talk about some of the university transportation centers who have some grant money for research into PNT resilience. Mr. Martin stated that money is starting to come out from the USG side, but certainly there is a lot of work still to be done.

Mr. Goward asked if PNT is still not in the realm of cyber or infrastructure within the USG.

Mr. Martin answered, saying that it is labeled as a cross-cutting capability across many critical infrastructures that are listed in Presidential Policy Directive 21 (PDD-21). It has not been designated as its own critical infrastructure sector.

Mr. Martin concluded by introducing the NCO's new Deputy Director, Colonel John Dukes.

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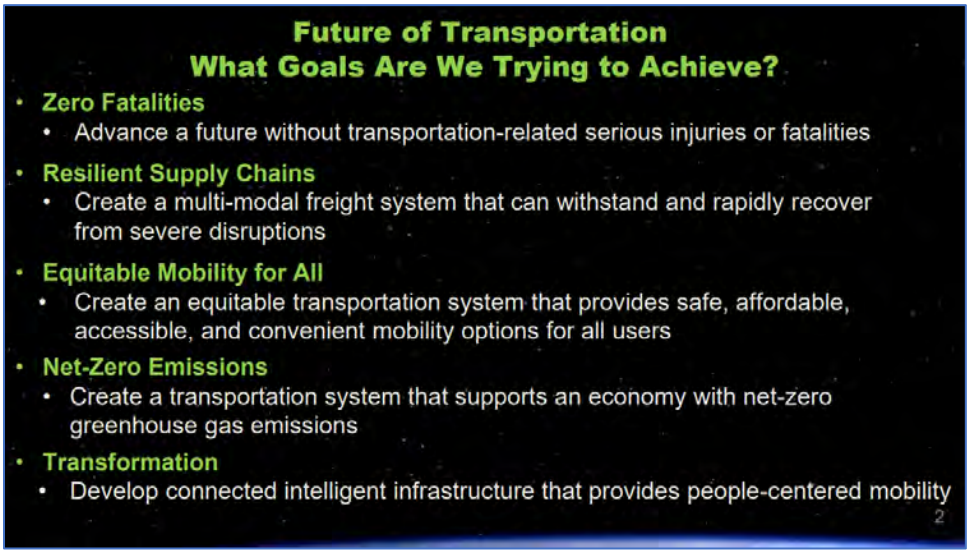
DOT PNT Research Priorities, Complementary PNT, and GPS Interference Detection & Mitigation (IDM)
Ms. Karen Van Dyke*, Director, PNT & Spectrum Management, Dept. of Transportation (DOT)*

Ms. Van Dyke introduced herself as the Director for PNT and Spectrum Management at DOT (Slide 1). Dr. Robert Hampshire sends his greetings; he was delighted to be able to address the PNT Advisory Board at the last meeting.

Slide 1

DOT is the civil lead for PNT, but PNT is extremely important to all missions, and the future direction of transportation safety is always DOT's top priority (Slide 2). A number of DOT's modes have a great safety record, in particular aviation, but at the other end of the spectrum, with vehicles and road fatalities, the U.S. is at an all-time high with over 42,000 fatalities on U.S. roadways. Part of DOT's vision and strategy is to drive toward zero fatalities. Also, resilient supply chains and equity mobility are key parts of transportation. Additionally, transportation contributes significantly to greenhouse gas emissions, so driving toward net zero emissions is a goal of DOT. The Bipartisan Infrastructure Law, this is a once-in-a-generation investment in transportation infrastructure, looking at the transformation of transportation for the future. PNT is the heart of that, as well as the connectivity that DOT sees as part of infrastructure.



Slide 2

Ms. Van Dyke stated that these goals are laid out in DOT's Strategic Plan (Slide 3). DOT also has a Research, Development, and Technology Strategic Plan that goes into the grand challenges that the Department has set out.

Slide 3

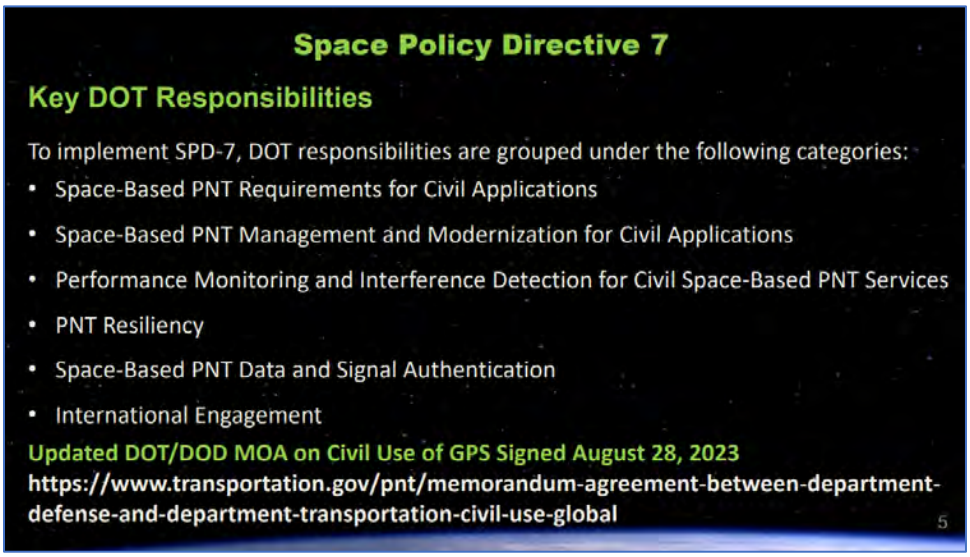
PNT is at the heart of transportation, particularly for safety. Following in the footsteps of the DOT Strategic Plan and the Research, Development, and Technology Strategic Plan, the Department thought it was prudent to put together a DOT PNT strategic plan, which is a work in progress. Several Board members participated in a listening session that DOT held at the end of September 2023. The five goals that DOT has put forward frame what that strategy will entail:

1. Advancing PNT capabilities and services: Looking to the future, what do we need for PNT? Not only for transportation, but for the broader civil leadership role.
2. PNT resiliency: DOT is embracing the PTA aspects of the Board's principles and incorporating those into their strategy.
3. Cybersecurity. Mr. Martin discussed the need for PNT cybersecurity, so this is also a key strategic goal that DOT aims to incorporate.
4. Ensuring that the U.S. has spectrum availability for future PNT services: This is a very exciting time, particularly with LEO PNT and advances in terrestrial systems. So, from DOT's standpoint, part of the National Spectrum Strategy is ensuring that spectrum can be dedicated to those services and protected from harmful interference.
5. Leading U.S. Civil PNT Coordination: DOT's civil PNT coordination role across all departments and agencies, and their partnership with DoD.

DOT is pushing finalize and publish this PNT Strategic Plan.

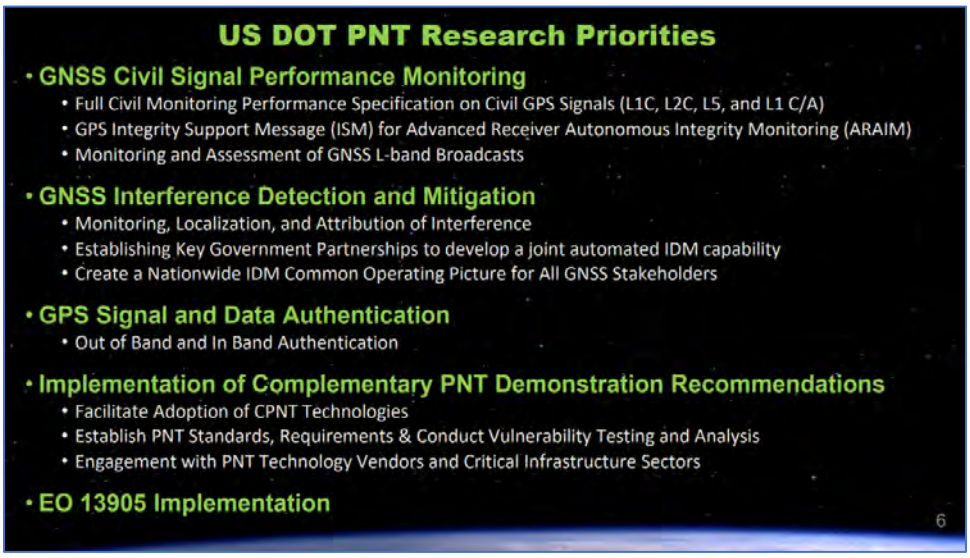
Slide 4

DOT has several responsibilities within SPD-7 (Slide 5). At the end of August 2023, DPT signed a new memorandum of agreement with DoD on civil use of GPS, which embraces the joint partnership with DoD. DOT also has a civil liaison to Space Systems Command (SSC) and Space Operations Command in this memorandum of agreement.



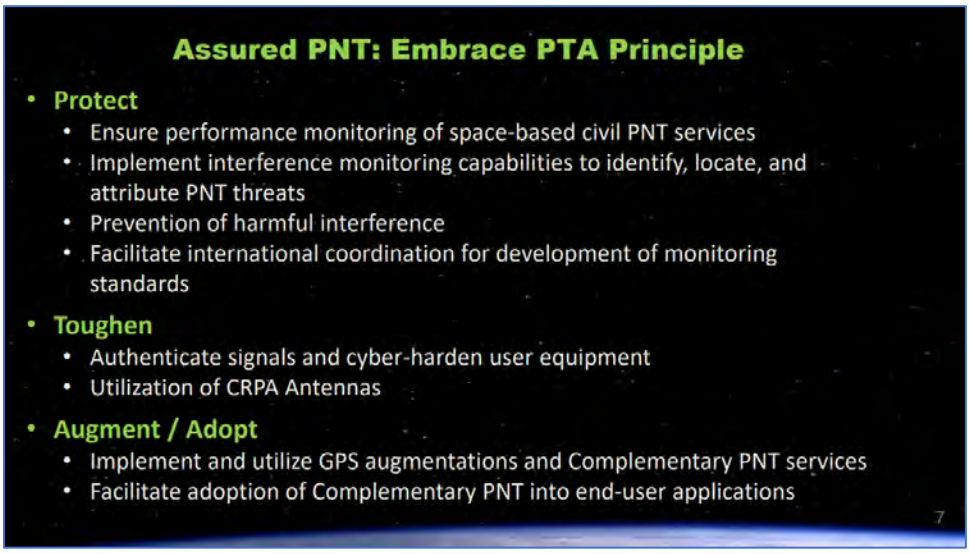
Slide 5

DOT's research priorities dovetail from these SPD-7 responsibilities. There is a lot of ongoing work on GPS signal performance monitoring. There was a lot of discussion yesterday, during the prep day, about getting the new GPS, civil signals operational, and that's certainly something that DOT would like to have happen as soon as possible. Monitoring those signals is key to allowing that capability to move forward with the partnership of the USSF and the GPS next generation operational control system (OCX). Interference detection in mitigation is a top priority that DOT has been investing a lot of their resources. Mr. James Aviles gave a briefing at the May 2023 Board meeting on DOT's efforts. SPD-7 tasks DOT with signal authentication on both out-of-band authentication, where we can authenticate the GPS signals over the internet, and also a longer partnership with the USSF, looking at in-band authentication from the GPS signals in space. Finally, DOT released a Complementary PNT Action Plan in September 2023.



Slide 6

These are all aspects of PNT resiliency that the Board has advocated for (Slide 7). DOT has taken them to heart in terms of protecting the spectrum and toughening receivers both from a cyber hardening standpoint, as well as embracing the use of CRPA antennas. DOT would also like to see the ITAR restrictions removed and are investigating use of CRPA antennas to have that near-term resiliency with the use of GPS. DOT's strategy also embraces complementary PNT to evaluate technologies. Ms. Van Dyke stated that she has added an additional "A"to PTA to get those technologies Adopted, it doesn't do the U.S. any good just to have additional signals and technologies in space if those technologies are not integrated into user applications.



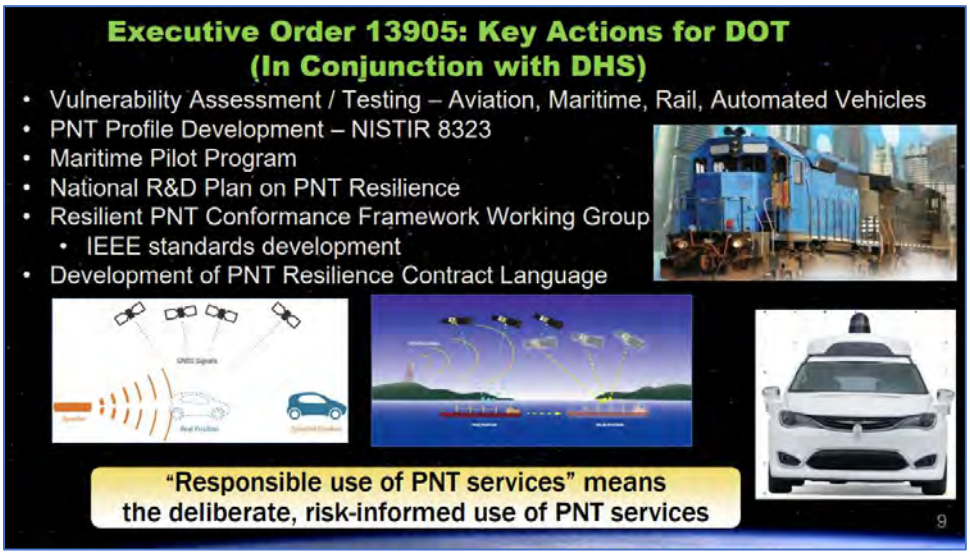
Slide 7

As part of the Bipartisan Infrastructure Law, DOT established two University Transportation Centers (Slide 8). The First one, known as the Center for Automated Vehicle Research and Multimodal Assured Navigation (CARMEN) was put in place in October of 2020. It is now called CARMEN+ and is led by The Ohio State University. The second one is called the Center for Assured and Resilient Navigation in Advanced Transportation Systems (CARNATIONS) and is led by the Illinois Institute of Technology. This is a five-year program with funding of $2 million per year over five years. The key theme is focused on assured PNT. The University Transportation Center program is part of the OST-R portfolio under Dr. Hampshire and includes well over 30 university transportation centers. A key part of all those university transportation centers is workforce development. So, in addition to the technical work, the program focuses on bringing in the next generation.

Slide 8

Executive Order on 13905, "Strengthening National Resilience Through Responsible Use of PNT," says that Executive Branch departments and agencies and the sector risk management agencies need to be able to withstand denial, disruption, or manipulation

of PNT services (Slide 9). This goes to user equipment and ensuring that the USG resilient user equipment deployed for our government applications, with the sector risk management agencies extending that to critical infrastructure. There are a number of programs across DOT that embrace what the executive order says. It starts with determining what the dependencies and vulnerabilities are on PNT, determining the level of risk based on those vulnerabilities, and then asking the question, "can you tolerate that level of risk or not?" If the answer is no, what can be done to mitigate it? This needs to be embedded into our processes going forward to create an evolutionary path to PNT resiliency.

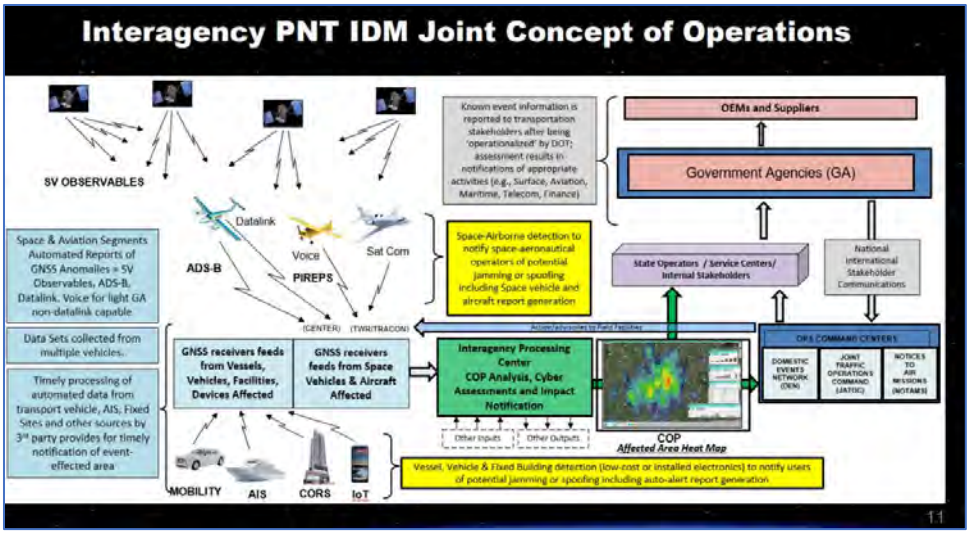


Slide 9

The Board is well aware of some of the high-profile GPS interference incidents that the U.S. has experienced, particularly affecting aviation (Slide 10). SPD-7 tasks DOT to lead efforts in conjunction with DoD and the Department of Homeland Security (DHS) to detect, monitor, and ultimately mitigate the sources of interference. Mr. Aviles has been working at GPS interference detection for over 20 years and has embraced the multi-layer approach of detecting interference, and putting that concept of operations together. He has also worked with partners not only across the USG, but also across state and local levels to mitigate and remove sources of interference.

Slide 10

There is a lot of interest in being able to tackle GPS interference (Slide 11). Several efforts are now being stood up across the USG as well as the commercial sector. Pulling all of those efforts together into operations for is a concept that Mr. Scott has touted, as well as the ability to turn GPS receivers into detection capabilities. The key is to validate Automatic Identification System (AIS) information, information from vehicle navigation, cell phones, and every source that we can incorporate so that we can quickly determine where the interference is coming from. Ms. Van Dyke stated that she has been frustrated for several years that the USG has relied on users to report interference. We don't want to discourage users from reporting, but from a government standpoint, when those reports come in, we should already know that something is going on and we should have a good sense of what geographic area is being impacted. If a user report comes in and there's no corroborating information, maybe the user equipment is faulty.

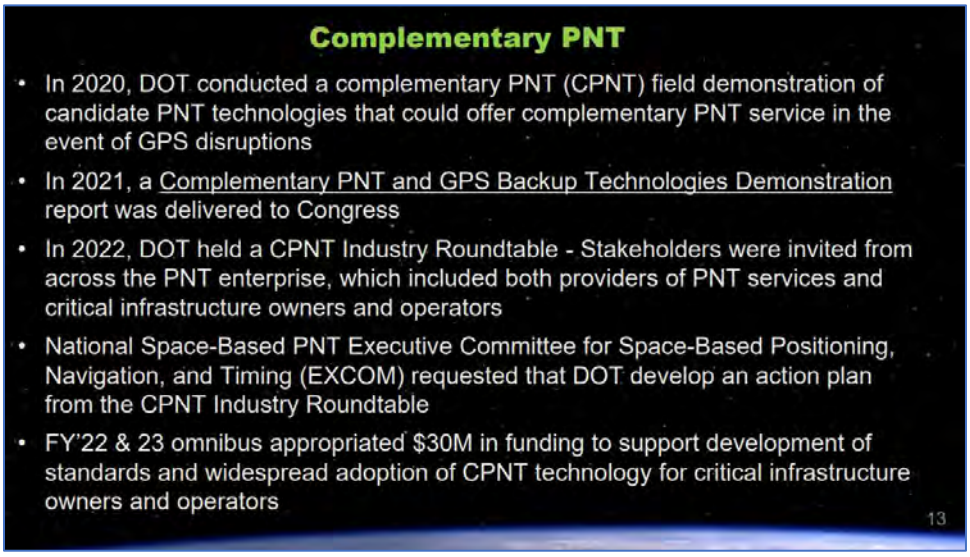


Slide 11

The theme is turning the vulnerability into the solution, harnessing all the information that's out there. DOT has partnered with the Defense Innovation Unit (DIU), who has a program called Harmonious Rook (Slide 11). This was something that DoD started, and DOT has just entered into the second phase of a contract with them that's going to push them into an initial operating capability. This is another topic that will be discussed at the Executive Steering Group meeting next week. One of the challenges going forward is to make sure that we have a sustainable capability, and as we get better at detecting interference, how can the analysts looking at the information then work with the spectrum regulators on the mitigation of that interference? Ms. Van Dyke stated that this needs to be a 24-7 capability.

Slide 12

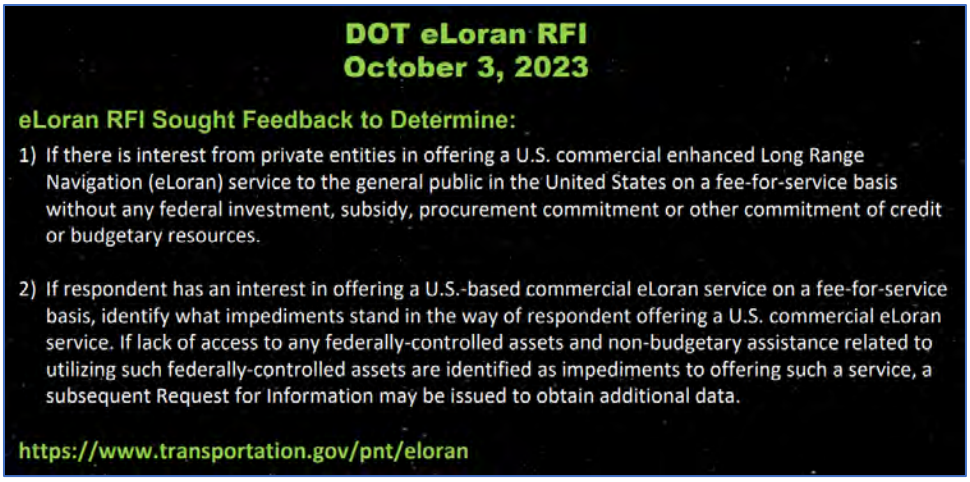
In March of 2020, DOT conducted a demonstration through their Volpe National Transportation Systems Center, which led to a report to Congress in 2021. DOT then held an industry roundtable in the summer of 2022 to bring PNT technology vendors and critical infrastructure owners and operators together to talk about what the barriers are to adoption of complementary PNT (Slide 13). The focus of the discussion was what the USG can do to facilitate the adoption of complementary PNT. The results from that industry roundtable were briefed to the National Space-Based PNT Executive Committee, which then asked DOT to put together an action plan. In parallel with that, DOT was fortunate that in Fiscal Year 2022 (FY22) and FY23, Congress appropriated $15 million above what the Department was asking for. Both the House of Representatives and Senate draft budgets for FY24 also have an additional $15 million.



Slide 13

DOT published this Complementary PNT Action Plan in September 2023 (Slide 14), so it is available online to read. The same day, DOT also issued a request for information of sources sought from the Volpe Center, taking the first steps to implement that Complementary PNT Action Plan by requesting interest from industry of high technology readiness levels. DOT is starting to outfit field test ranges, and are seeking interest in partners for these complementary PNT field test ranges.

Slide 14



Slide 16

Discussion

Dr. Betz thanked Ms. Van Dyke and stated she had mentioned that the Harmonious Rook has a planned initial operational capability. He asked if she could tell the Board more about what that capability will be in terms of geography and function, and what the date for that planned Initial Operations Capability (IOC) is.

Ms. Van Dyke answered, in terms of geography, DOT is focused on the U.S. and for the initial operating capability, their role will be gaps in the capability that will inform future efforts and where we need to fill in those gaps. The validation of the information is key, so taking the time as part of our Phase Two effort in evaluating additional sources of information and corroboration of that information is key. Ms. Dan Dyke's goal is to have it in place by the end of FY24.

Hon. Shane stated that as somebody who's been watching DOT for a long time, more is going on at DOT right now in this space than he's ever seen. In 2008, a panel led by Dr. Parkinson recommended that the best source of complementary PNT would be eLoran. Unfortunately, the OMB didn't listen, and the USCG was ordered to decommission the system. The aviation industry relies heavily on the Automatic Dependent Surveillance-Broadcast (ADS-B) globally to maintain a global map of GNSS outages, not just GPS, but all the systems. The FAA has invested enormous amounts of money in a terrestrial based ADS-B system, but they are not subscribing to the global space based ADS-B system. He asked Ms. Van Dyke if this is correct.

Ms. Van Dyke stated that she does not have an answer. Regarding DOT's interference detection capability, they're not taking in any information on space-based ADS-B.

Hon. Shane confirmed with Ms. Van Dyke that the global ADS-B information is not part of what DOT is relying on in the suite of sources.

Lt. Gen. James asked if there is an integration of DoD's PNT strategy and DOT's PNT strategy. Have DOT and DoD worked together from a PNT strategy perspective? If so, how does that happen?

Ms. Van Dyke answered, DOT's interaction is multi-fold and as we look at our strategy going forward, we, along with the USSF, embrace complementary PNT. DOT and DoD, in line with SPD-7, are making sure that they have good alignment in terms of the U.S.'s future objectives.

Mr. Goward commented that at the industry roundtable, one of the comments from industry was that the USG talks about the need for complementary and resilient PNT but has done little to make its own systems and services resilient. When USGt does that, it will help convince the private sector that this is an issue that needs to be addressed. Additionally, it will signal which systems the government thinks are sufficiently resilient and worthwhile, and also that those systems, because they're being incorporated into the federal enterprise, will be around for a while and they're worthwhile to be incorporated into other enterprises as well. Therefore, the federal leadership role has lots of implications and setting the example is more than just talking the talk.

Ms. Van Dyke replied, saying that was a very key point that came out of the industry roundtable, both from the industry as well as for critical infrastructure owners and operators.

Mr. Murphy asked if the range testing that Ms. Van Dyke previously discussed is Live Sky.

Ms. Van Dyke said that it is to be determined. The first test range is going to be at Joint Base Cape Cod. That's where DOT conducted the commentary PNT demonstration in 2020. DOT's Volpe Center has a long-standing partnership with Joint Base Cape Cod. In terms of how we execute those vulnerability tests, that's probably going to be a challenging location to do Live Sky events. As DOT starts to build out field test ranges, they can at least participate in those Live Sky events to evaluate complementary PNT technologies.

Mr. Murphy followed up, asking if those complementary PNT tests involve any live Live Sky jamming.

Ms. Van Dyke said that the 2020 demonstration was showcasing in the best light possible. DOT wanted technology vendors to show what they could provide, so there was no stress testing of the technologies at all. Now DOT would like to move beyond that, and part of the test plan will be how to execute those stress tests, recognizing that these will largely be commercial PNT technologies, which adds an additional dimension to what types of tests need to be conducted.

Mr. Murphy suggested that civil testing might be something to consider because the jamming and spoofing scenarios at NavFest are aimed at the military and survive an incredible barrage of high-powered jammers type things and not necessarily the best testing you'd want to do for civil aviation.

Ms. Van Dyke stated that that's an excellent point DHS has a GPS. equipment tests for critical infrastructure planned for the fall of 202424, which DOT will participate in. The vulnerability assessment and testing is key because the concern we heard from critical infrastructure is "we don't want to jump out of the frying pan into the fire."

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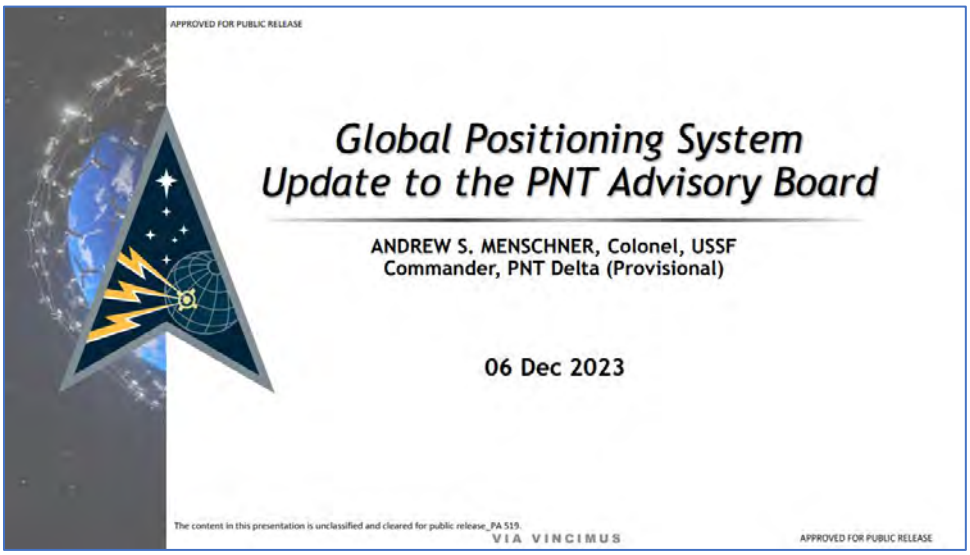
U.S. Space Force (USSF) Update: GPS Modernization
Col. Andrew S. Menschner, *Commander, PNT Delta (Prov.), Space Operations Command, USSF*

Col. Menschner stated that it's always an honor to speak to the PNT Advisory Board and he apologized for not being there in person (Slide 1). He stated that he is calling in from the GPS Master Control Station at Schriever Space Force Base.

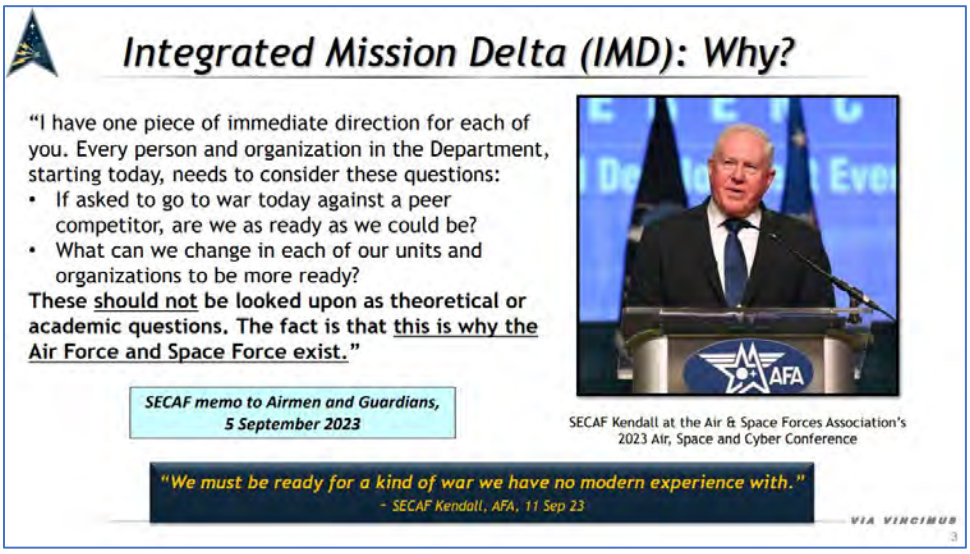


Slide 1

Col. Menschner stated that he will be talking about a major reorganization that the Space Force is undergoing in the PNT area, and he'll talk a little bit about the enterprise status, upcoming capabilities, and major goals for the next year (Slide 2).

Slide 2

In October of 2023, the Secretary of the Air Force and the Chief of Space operations began an effort to organize the Space Force for pure competition. The concept involves what is being referred to as Integrated Mission Delta (Slide 3). The Chief of Space Operations is fond of using an analogy of his time in charge of the service as shifting from the Merchant Marine to the U.S. Navy. His idea is to shift the Space Force from an era where we could consistently deliver services in a noncompetitive environment to a service capable of delivering services in a competitive environment and be able to protect and defend ourselves. So, the Integrated Mission Delta is the first step towards getting after that problem.



Slide 3

The concept behind the Integrated Mission Delta is to organize the people training, sustainment, and equipment for a mission area all under one commander. The idea is to strengthen unity of command for readiness and energize the unity of effort for capability development by making this organizational change (Slide 4). Col. Menschner stated that he'll talk further about the Integrated Mission Delta and the Systems Delta for Capability Development.

Slide 4

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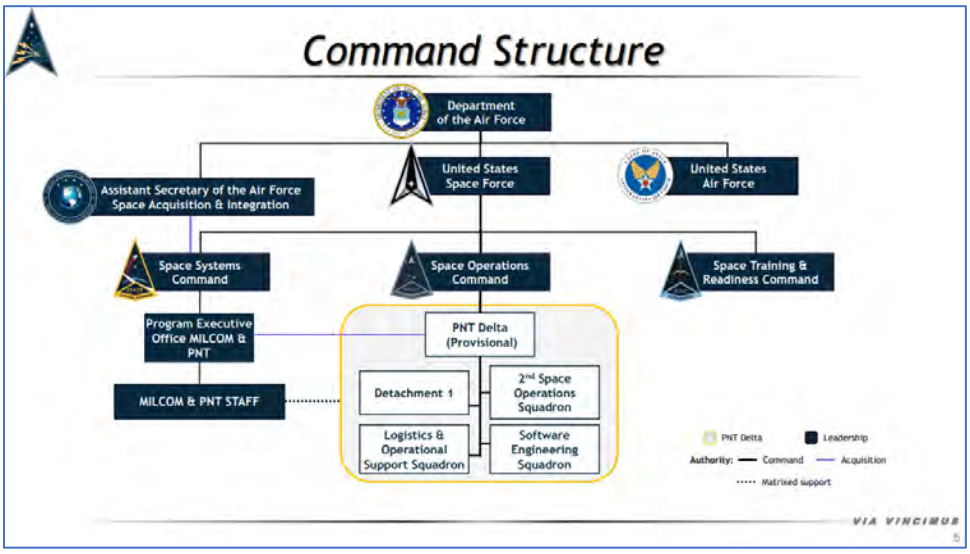
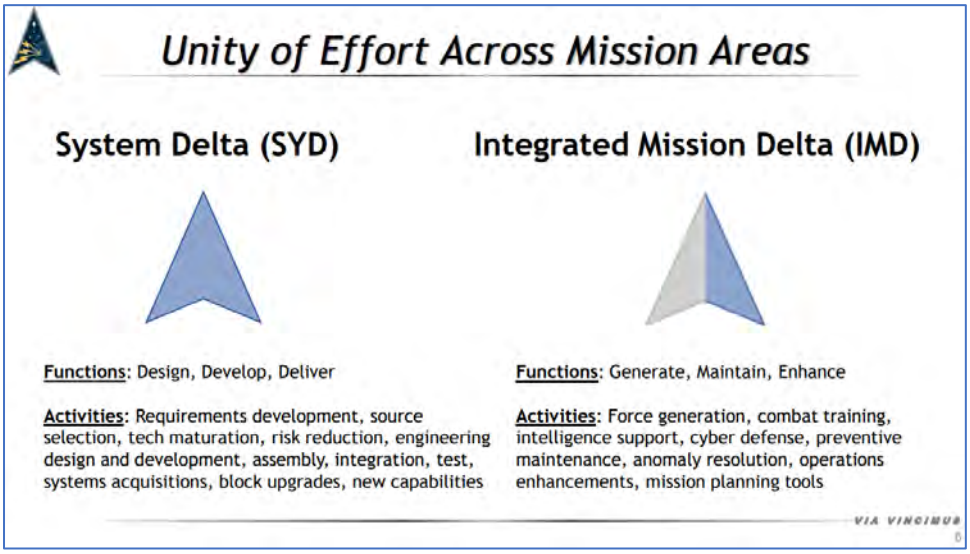
Space Force Deltas operational units are each responsible for a mission area. The PNT Integrated Mission Delta is the newest one of that kind. The goal is to combine all aspects of operations, sustainment, and near-term acquisitions under one commander, who is Col. Menschner (Slide 5). The biggest shift that we've made in terms of organization is that we combined the Second Space Operations Squadron (2 SOPS) with the previous SSC organization responsible for sustainment of GPS, as well as the OCX program office, into new units all under Space Operations Command. This is a big shift, moving the near-term acquisition under Space Operations Command.



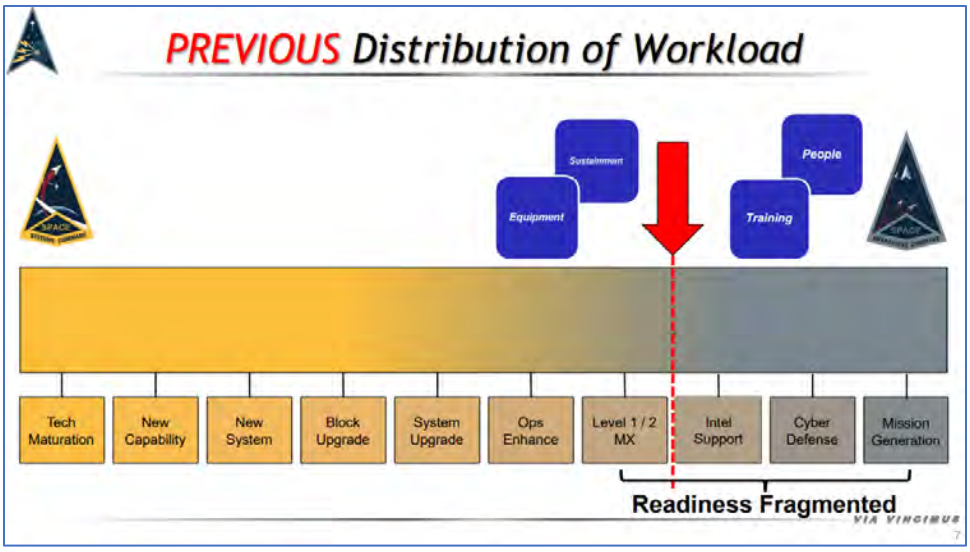
Slide 5

The partner to the Integrated Mission Delta is the Systems Delta (Slide 6). The Integrated Mission Delta is designed for operations and sustainment. The Systems Delta is designed for long-term capability development and any future capability area improvements. The goal is that these two entities, and the two commanders of these Deltas, own a mission area for the Space Force. Col. Menschner's counterpart on the Systems Delta side, which is still being stood up, will have all of the long-term developments, and at some point, in the developmental phase, the program would shift to the Integrated Mission Delta for the completion of development testing and delivery to operations. The idea here is, by better integrating the operations and acquisition side of the house, we speed delivery of capability and optimize it for operations.



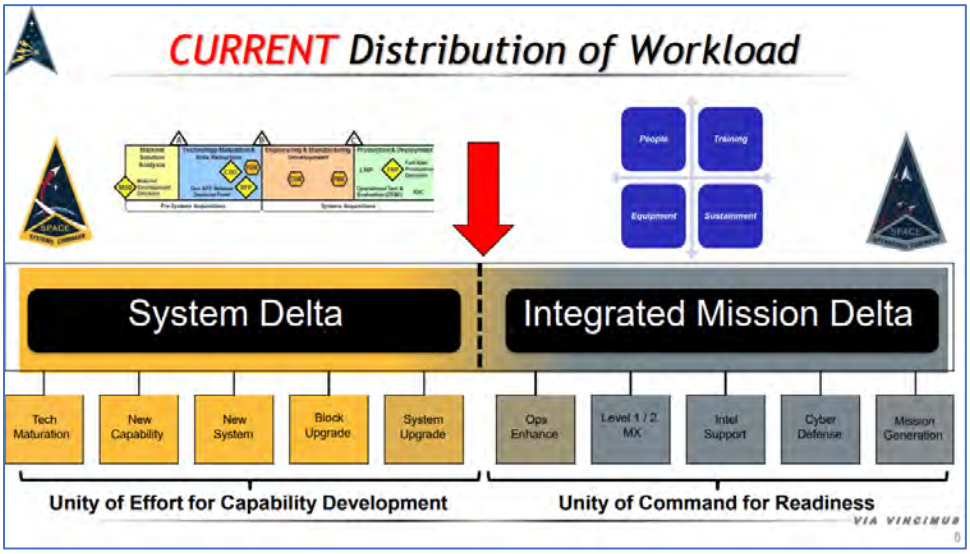
Slide 6

The idea here is to shift the distribution of workload (Slide 7). As previously mentioned, there was a split between who was responsible for people in training and who was responsible for sustainment and equipment. Essentially, that split occurred between Space Operations Command and SSC. When we laid out the distribution of workload, it came to an interesting seam where readiness ended up in a fragmented state.



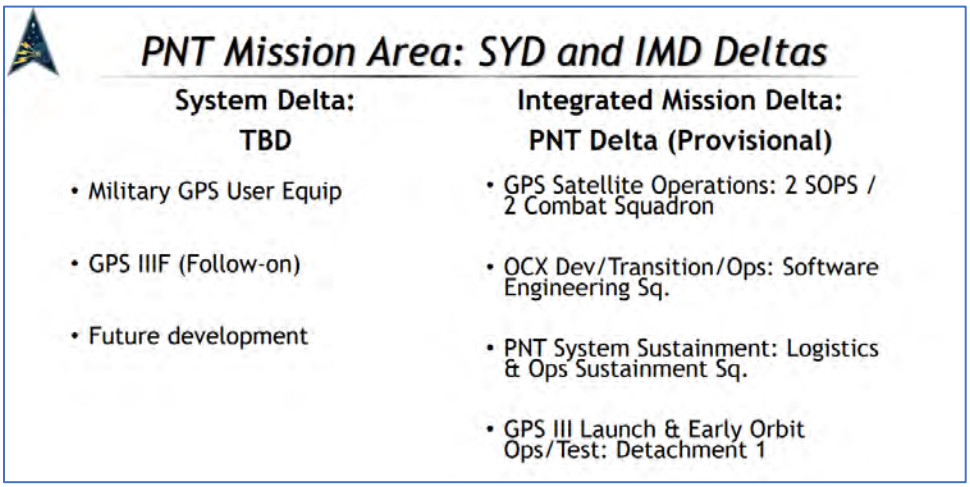
Slide 7

The current distribution of workload that we're working towards is to shift everything from operations enhanced through operations and mission generation into the Integrated Mission Delta (Slide 8). This means that there will be a lot more 2 SOPS operator focus into the near-term acquisition and pushing those operators into the long-term capability development. The goal is to speed capability delivery and deliver it more optimized for operations.



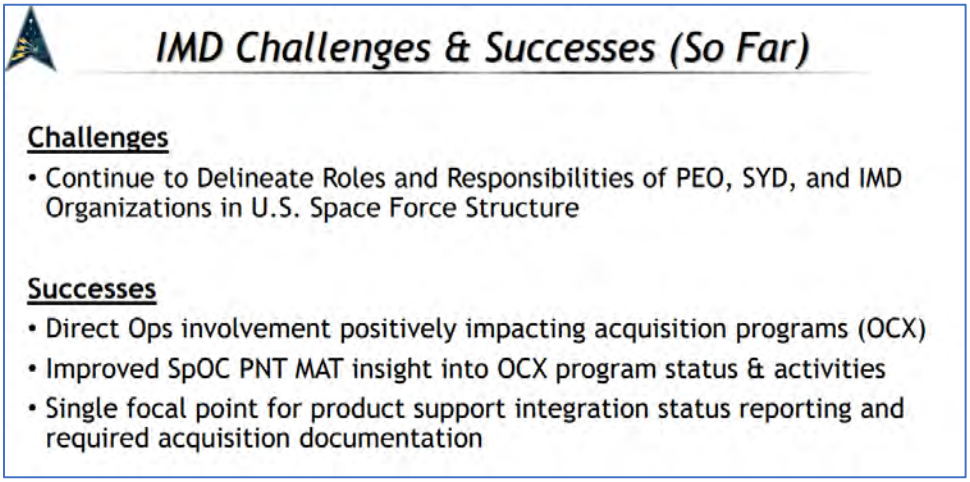
Slide 8

In the Integrated Mission Delta, 2 SOPS, as well as the OCX Program Office, the GPS Sustainment Organization, and what we're calling Detachment One, responsible for GPS III launch and early orbit, are in the Integrated Mission Delta (Slide 9). The longer-term items that would never be delivered to a Space Force Operations floor, like military GPS user equipment, and those other items that are further down the road in development, meaning longer towards delivery like GPS IIIF would stay in the Systems Delta. Systems Delta is also going to be responsible for any future development and working out any future requirements for PNT.



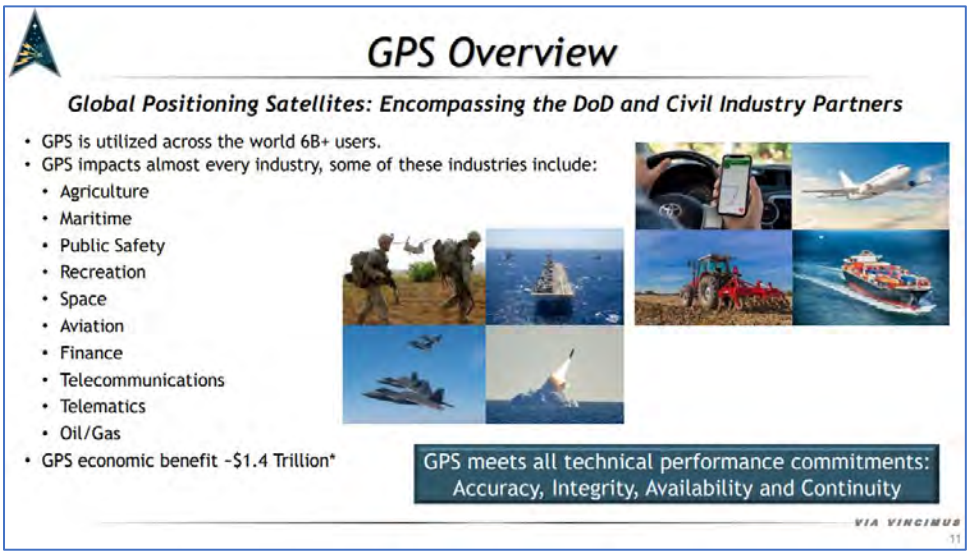
Slide 9

We've had some challenges standing up as an organization. We're going through a rebalancing of the roles and responsibilities across the Space Force Acquisition Enterprise, shifting responsibility for a development program like OCX under the Space Operations Command, while still coordinating through the Program Executive Officer, is a new model and we're working through the process. When the Chief of Space Operations stood up our Integrated Mission Delta, he referred to it as a beta test. So, we are the first of many Integrated Mission Deltas, and part of our job is to prove out the concepts and relationships for all of their mission areas. PNT and electronic warfare from space were two that were selected as beta tests. There's a lot of opportunity there, but it does lead to some uncertainty as we work forward. We've had some very early successes. This gives a direct voice from the operator community into the acquisition process, and that's already proving its worth when it comes to the OCX Program. It has improved the Space Operations Command commander's voice into the acquisition process, specifically the OCX Program. And it's also done very common-sense things, for example, two organizations were previously writing technical orders for the operation of capability. One wrote them for development systems, those that had not yet been fielded, and one wrote them for those that had already been fielded. Not surprisingly, those two organizations, slightly different language and slightly different format, and it was a challenge going back and forth between the two. Now that is centralized under one organization in a way that just wasn't possible before when the workload was balanced differently.



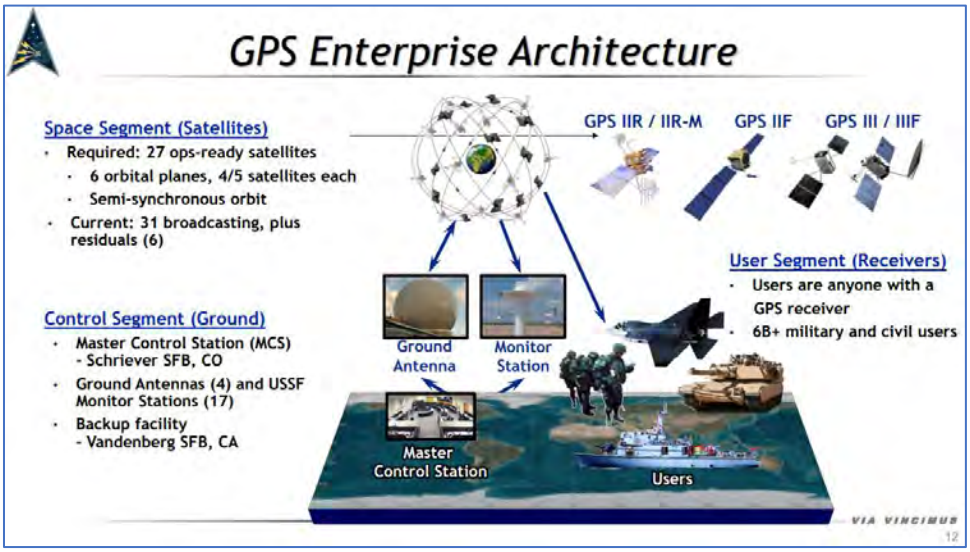
Slide 10

Obviously, the Board is well familiar with the benefits of GPS (Slide 11). USSF continues to meet all technical performance commitments, including accuracy, integrity, availability, and continuity. We understand, as the USSF, the importance of our civil partners, and we are committed to providing as such.



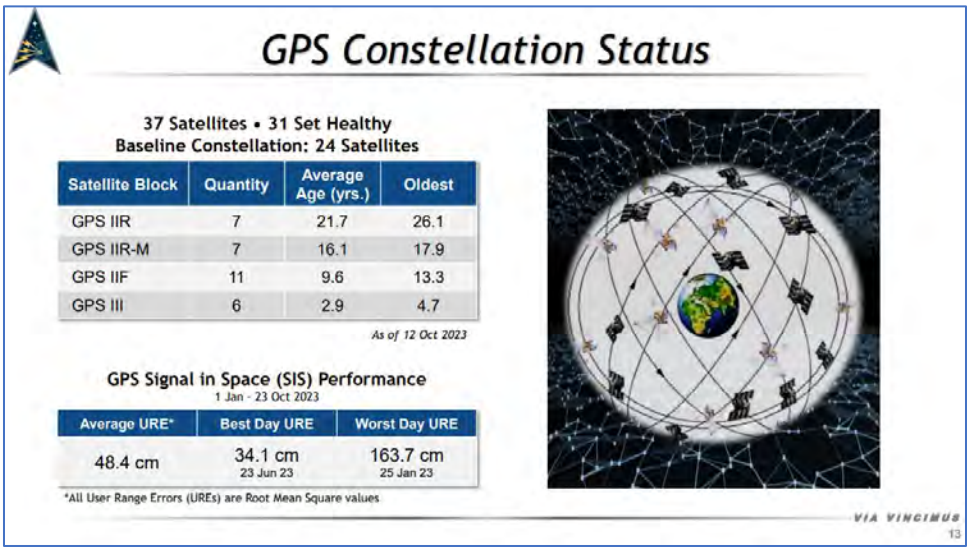
Slide 11

We currently have 31 vehicles broadcasting, plus six residual vehicles (Slide 12). This is unique for the Constellation and certainly lends itself to the idea that GPS is a robust and secure constellation. The Master Control Station, where Col. Menschner is speaking from today, is also taking steps to bolster its resiliency and strengthen GPS against sort of potential challenges that may come in a peer competition.



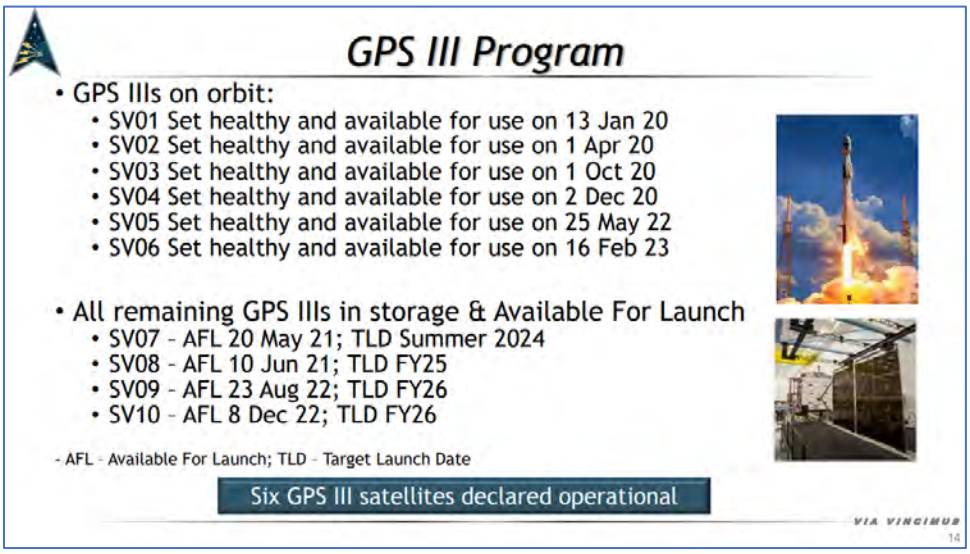
Slide 12

The constellation is healthy and strong (Slide 13). It's an interesting dynamic to see that many of the vehicles being controlled are older than many of the people controlling them from the operations floor. Despite that, we remain well within our performance requirements and well below the minimum acceptable product.



Slide 13

GPS III has put the USSF in a unique scenario (Slide 14). It's not often that we end up with four completed vehicles ready for launch. The four vehicles are with us today, complete and in storage, in Waterton, Colorado. We are ready for them to launch and excited to have them on orbit; we just need a ride. So, as soon as the launch calls come available, we'll be ready to launch those. We're looking forward to having the four GPS IIIs on orbit and the capabilities that they provide.

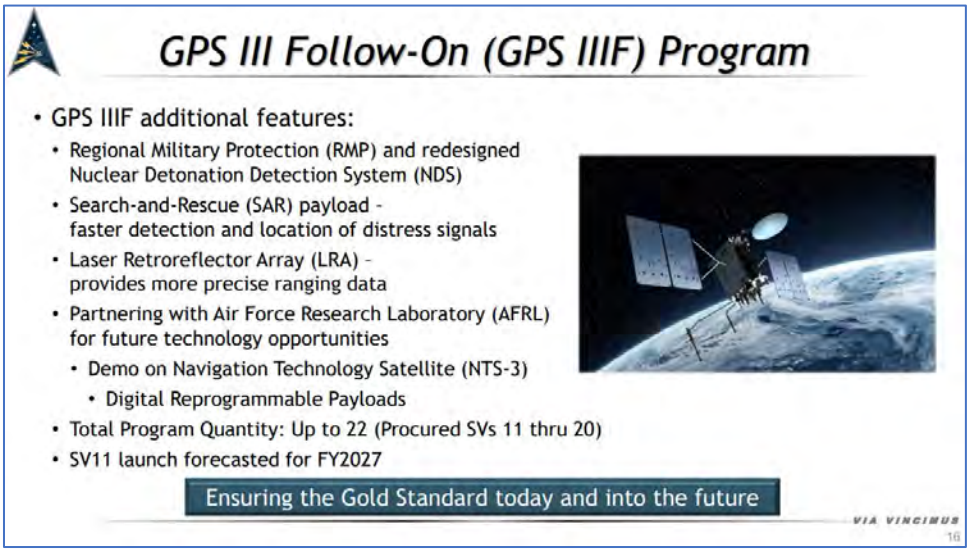


Slide 14

Col. Menschner stated that he wanted to speak specifically about the L5 Safety of Life signal (Slide 15). L5 has been transmitting since 2014 as a pre-operational signal for testing purposes, and it will be set with the OCX operational acceptance in 2025. The OCX Program brings the civil monitoring capability with its delivery, and that's what's required for the healthy designation. In addition, we're looking forward to a full operating capability of 18 space vehicles required for L5 broadcast. Right now there are 17 vehicles, 11 in the IIF family, and six in the GPS III category that are L5 capable.

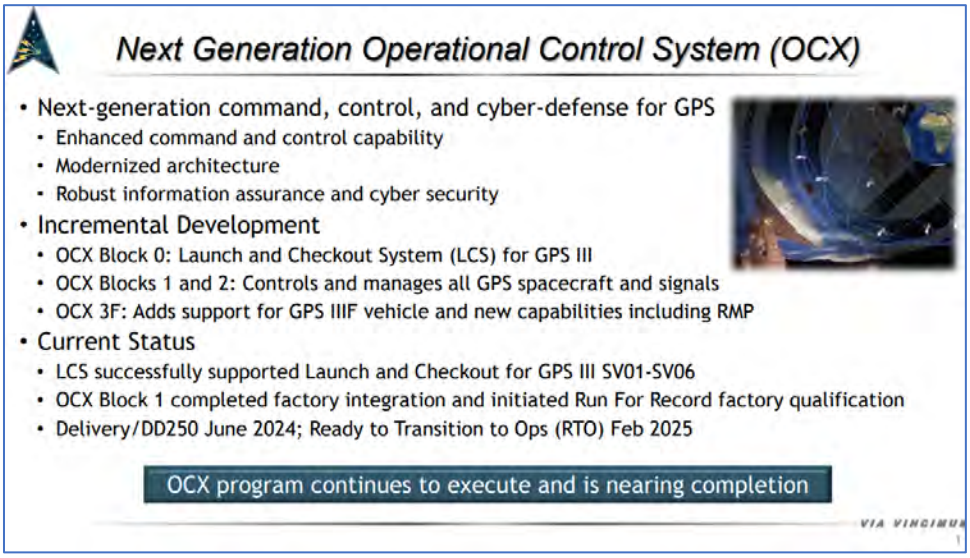
Slide 15

The GPS III Follow-On Program (GPS IIIF) is their next family of satellite vehicles. They're specifically looking for regional military protection, and a redesigned nuclear detonation detection system out of these vehicles. In addition, it will be hosting a search and rescue payload that allows for quicker detection and location of distress. Further, we're partnering with the Air Force Research Lab for future technology opportunities. The way this development is being structured is to allow for technology insertions at key points along the production timeline, and the total program quantity is up to 22 vehicles. They're still forecasting the launch of Satellite Vehicle (11) in 2027 and we're looking forward to helping ensure the gold standard through the GPS IIIF Program.



Slide 16

The USSF was done with development testing of OCX on December 4, 2023 (Slide 17). The Formal Qualification Test Run for Record, which is the last gating event for the factory testing, was completed. So, the development test is complete. The focus now will shift towards site activation, operator training, and operational test activities. Those will help ensure that we can bring on the modernized architecture and the additional cybersecurity that come with the OCX Program. USSF is tracking towards a delivery in June of 2024 and ready to transition to operations in February of 2025. Right now, we're projecting that a constellation transfer from the Advance Evolution Plan (AEP) to OCX would occur in 2025, as well.



Slide 17

Military GPS User Equipment (MGUE) Increment 1 is on track to deliver combat to combat ready platforms in 2025 (Slide 18). MGUE Increment 2, shrinking that electronics package and expanding that capability is proceeding on schedule.

Slide 18

Next year, USSF will continue to reorganize into Integrated Mission Deltas and Systems Deltas (Slide 19). They were able to achieve the Integrated Mission Delta initial operating capability on November 9, 2023. This allowed them to continue a focus on the completion of GPS III, ramping up GPS IIIF, and progressing towards OCX operational acceptance and MGUE delivery. They're going to continue to build and shape the PNT Integrated Mission Delta and Systems Delta constructs, and that'll continue to provide benefits for delivering capabilities faster.

The members of Col. Menschner's team includes the operators of 2 SOPS, the hardworking developers, and the folks responsible for the launch of our vehicles. It's an amazing team and we work very hard every day to provide service to the US Space Force, to the broader DoD community, and to the civil partners.

Slide 19

Discussion

Dr. Parkinson commented that navigation and communications are combined. In the old days, one could identify the belly button of the head of GPS exclusively with a focus on navigation. He asked if this new PNT System Delta is going to recreate such a position, or is it going to continue to be a navigation and communications operation?

Col. Menschner stated that acquisition decisions will still be funneled through Mr. DeLaPena, who, as the Program Executive Officer, is responsible for PNT and communications. The concept moving forward is to push towards a single Integrated Mission Delta and single Systems Delta that are responsible for the PNT capability.

Dr. Parkinson responded, saying the energy associated with advocating for some of the improvements to meet the gold standard, will not be met. Many of the capabilities that the Board is jawboning about haven't reached budget level, and yet they're already incorporated into our competitors' GNSS. For example, the validation of signals. The full activation of L5 obviously has been budgeted, but the budget to launch the last vehicle is not there. In the past there was one US Air Force Colonel whose sole responsibility was pushing for not only the execution of GPS, but also pushing for the advocacy of the things necessary to maintain PNT. Dr. Parkinson stated that from Col. Menschner's charts or from what he has said that any such individual will emerge from the current reorganization.

Col. Menschner stated that the concept of the Integrated Mission Delta is to allow himself, as a commander, to advocate for the things that are necessary to keep the mission area operating and to continue to push capabilities that must be developed in the future. While it looks slightly different, the Integrated Mission Delta Commander is intended to be the PNT mission area advocate, along the lines of the GPS Program Director days. He continued, "it is a concept under development. We are still working through the requirements and still through the processes."

Dr. Parkinson stated that he respectfully disagrees with the fact that the USSF doesn't have anyone that should be advocating the changes necessary within GPS to maintain at least equality with the other GNSS. He stated that he can recite about five or six different technical aspects in which the U.S. is lagging.

Lt. Gen. Hamel commented that the intent is the Systems Delta, and terminology is now being applied so that both the operations and the development side of the Space Force have more aligned roles and responsibilities. What we used to know as either a Special Program Office (SPO) or a Joint Program Office (JPO) will now be termed a Systems Delta. So, there is a colonel that is the commander of that Systems Delta who is responsible for all the execution, but he then reports to the Program Executive Officer, which by law, must be responsive to the service Acquisition Executive. So, some of the stuff dates back 20 or 30 years and everyone may have had some frustrations about the alignments. Nonetheless, the intent is to try to maintain focus and expertise in what heretofore has been referred to as SPOs, but now in the terminology in the Space Force, this would become a Systems Delta.

Dr. Parkinson stated that as of right now, he doesn't see any such individual colonel who is both responsible for the execution of the program record, but also for the advocacy of those shortfalls, which this Board is aware of, in terms of where the U.S. is heading with GPS. Dr Parkinson continued, "if there is a colonel, please give me his name, I'd love to hear from him, but I don't see anyone standing up talking." about the horrible delays in L5, for example, as well as the problems of getting the retro reflectors on, and whether we're going to have some reasonable high-speed communication and ranging capability the way the Chinese do.

Gen. Shelton asked Col. Menschner if he has any acquisition authority. OCX is not in sustainment, by any stretch, "but I also don't see your path to an acquisition authority."

Col. Menschner stated that he is the Senior Materiel Leader responsible for OCX. The Integrated Mission Delta was developed on the 13th of October as a beta test to specifically try to flesh out relationships. Col. Menschner stated that "as the Integrated Mission Delta Commander, he works on a day-to-day basis for General Whiting as Space Operations Command. He is also responsible to Mr. DeLaPena to the Service Acquisition Executive for all acquisition decisions. However, Mr. DeLaPena is not his day-to-day supervisor, Mr. DeLaPena is his decision authority for all acquisition program decisions.

Lt. Gen. Hamel reiterated that Col. Menschner has an operational commander that he works for, but he also has acquisition authority to Space Systems Command. Although it's different from previous years, there is a single colonel who is an advocate.

Dr. Parkinson stated that the "set of alligators may be time consuming. Until you show me a colonel who is advocating for the things that this Board knows should be done, I don't think you've solved the problem yet. And so I understand the relationship. I don't like these dotted lines. I like lines of command myself. Nonetheless, anything will work, provided somebody is pushing to make sure we are always at least number one or tied for number one."

Lt. Gen. Hamel suggested, for the purpose of the Board, it may be worthwhile to ask for an update from the Space Force with respect to how they are organized and what the roles and responsibilities are. As the importance of this elevates and with the creation of the Space Force, trying to figure out who's doing what, there are some important, positive steps that are coming with this. By the same token, the Board needs to understand the organism and how they're intending to operate, because there is so much dependance on the continued delivery of the service and in its modernization. Right now, the Space Force is an unknown entity that's going through a lot of changes.

Dr. Parkinson said to "show me the colonel who is advocating the real future, who is standing up and trying to get counted regarding the things that we think should be done to at least stay equal with BeiDou and Galileo, because right now we're slipping behind peace." Dr. Parkinson emphasized that this is not a reflection on Col. Menschner, "I think this is way above your pay grade. And I really appreciate your coming in here and telling us about it."

Hon. Shane stated that the civilian community has a lot more users and the military does. He asked if there was some way to reference the EXCOM that oversees PNT policy in the U.S.. It's co-chaired by DOT and DoD, and it's supposed to be making strategic decisions in the long term, and the near term. He asked Col. Menschner if there is any crosstalk between the process that you go through for acquisition and the direction that comes from the EXCOM or that should come from the EXCOM. Or is there any direction coming from the EXCOM?

Col. Menschner answered, "Certainly. And it's one of the things that I so enjoy about these types of forums is that I often follow Ms. Van Dyke on the agenda." He stated that his office is aware and marching towards the goals of the EXCOM.

Mr. Miller thanked Col. Menschner for the presentation and stated that he did not notice, besides the retro reflectors and the search and rescue, was any reference to space service volume. There is interest within the government regarding that capability. T he National Space Council (NSpC) Users Advisory Group (UAG), which is composed of all major space companies, are looking to GPS to provide a service way beyond Geosynchronous Orbit (GEO). Mr. Miller continued, saying that he would appreciate it if the government could identify that as a capability. Within the ICG, the International Committee on GNSS, every single PNT service provider has some form of space service volume because of what the U.S. has been able to do. So, as a reminder, please highlight that capability as well, because that capability will continue to expand and that is in the national policy.

Col. Menschner thanked Mr. Miller for the feedback.

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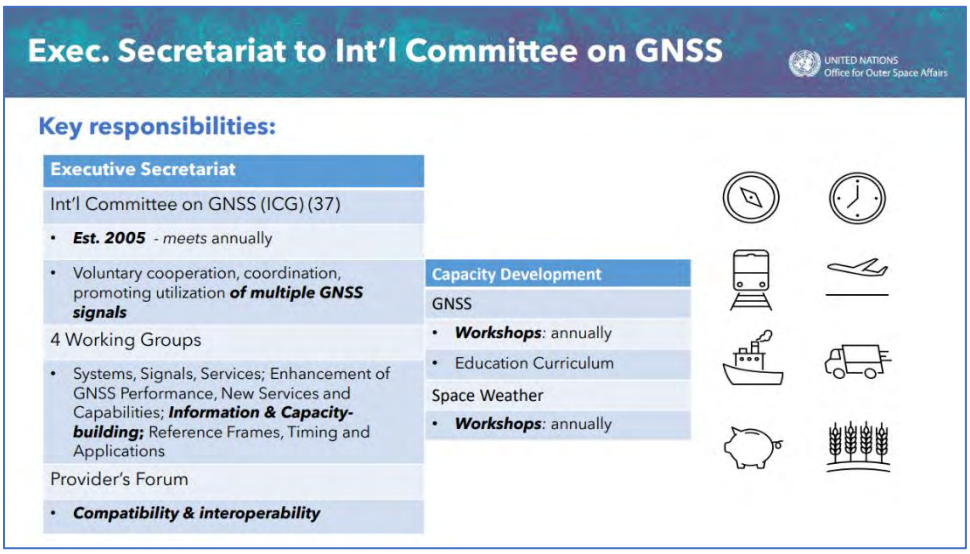
Results & Outcomes from the International Committee on GNSS (ICG) 17th Plenary Meeting
Ms. Sharafat Gadimova, *Executive Secretariat of the ICG, United Nations Office for Outer Space Affairs*

Ms. Gadimova stated that she would be talking about the International Committee on GNSS (ICG) and the latest developments (Slide 1). The Office for Outer Space Affairs is the Secretariat of the Committee on Peaceful Uses of Outer Space (Slide 2). The table shows the main agenda items and what the committee considers. GNSS and Space Weather are highlighted in blue. Ms. Gadimova is responsible for Space Weather activities. The committee meets once per year in Vienna, Austria and it has two subcommittees: a technical subcommittee and legal subcommittee. ICG normally meets in conjunction with these meetings: one in February and one in June. The ICG is not involved in the legal subcommittee.

Slide 1

Slide 2

The Committee on Peaceful Uses of Outer Space is the Executive Secretariat of ICG, which was established in 2005, and the following year it was recognized by the United Nations General Assembly (Slide 3). ICG is a voluntary cooperation, coordinating and promoting utilization of multiple GNSS signals. Its work is carried by four working groups. In 2007, the Providers Forum (PF) within the ICG was established, which consists of only the GNSS providers. Currently there are six countries, including the European Commission. The PF deals with all matters related to compatibility, interoperability, and transparency. Ms. Gadimova's office is involved in the work of ICG and can carry out activities on GNSS and space weather, including the coordination of regional workshops.



Slide 3

ICG promotes the introduction and utilization of GNSS services in developing countries, and assists GNSS users with their development plans and applications (Slide 4). It is open to all countries who are United Nations (UN) entities and either GNSS providers or users of GNSS services.

Slide 4

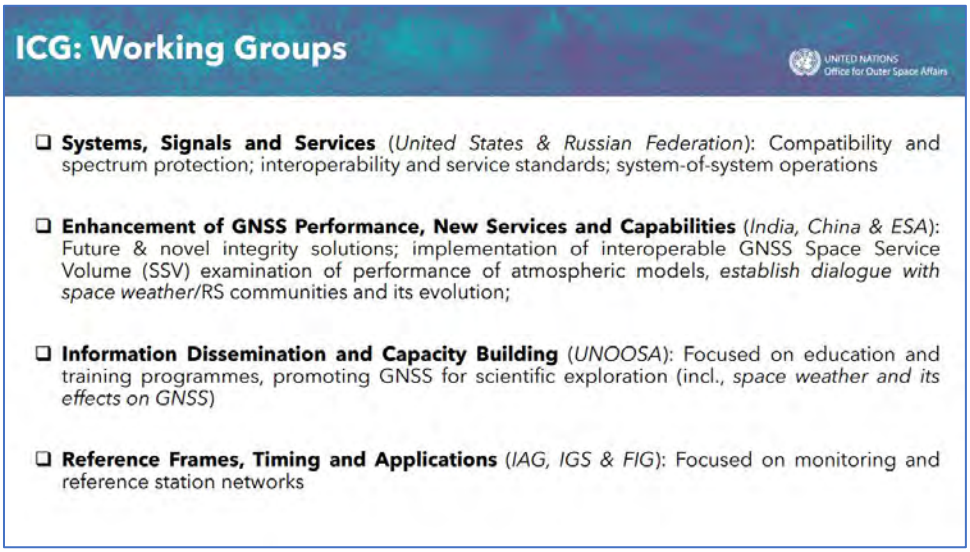
Slide 5 shows the membership of the ICG. There are system providers, as well as the UN Member States, which provide GNSS services and/or applications. This year, two more countries joined the ICG: Algeria and Turkey. And we have several inter-governmental and non-governmental organizations, as well as some United Nations entities, which are part of the ICG as associate members and observers. Ms. Gadimova's office is an associate member of ICG.

Slide 5

The 17th meeting of ICG happened in October of 2023 in Madrid, Spain (Slide 6). It was hosted by the European Union (EU) in collaboration with the Spanish Presidency of the EU.

Slide 6

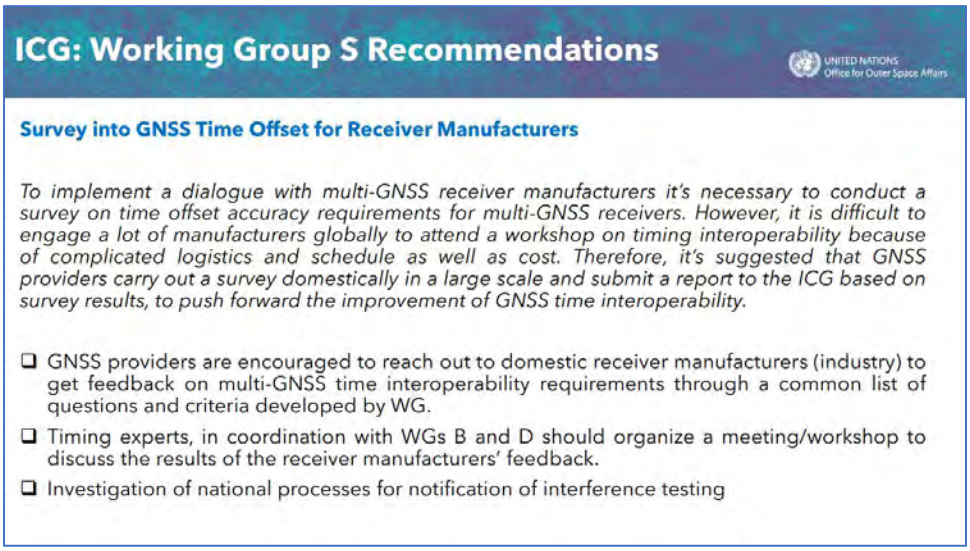
Four Working Groups were established in 2005 to implement the work plan of ICG (Slide 7). Since their establishment, subgroups and task forces were added to these working groups.



Slide 7

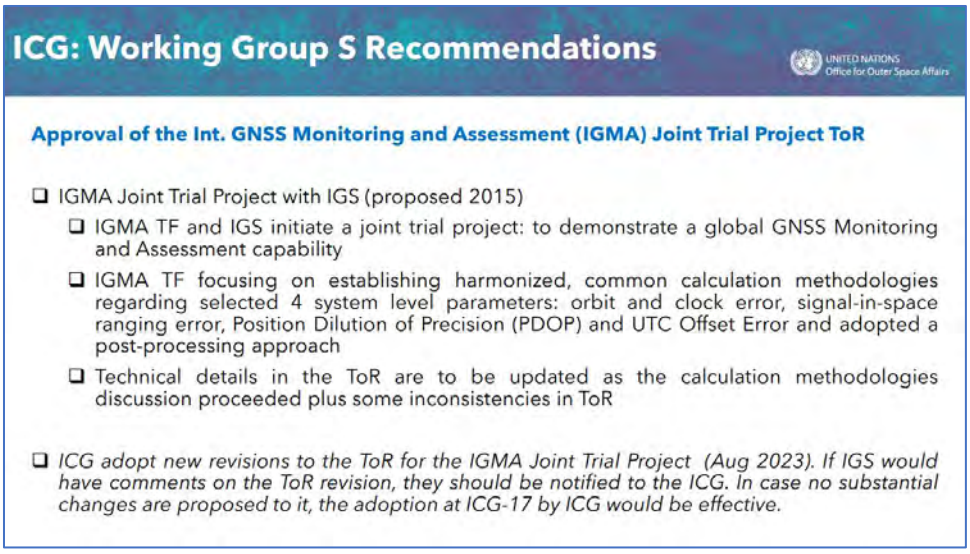
Slides 8-15 summarizes the recommendations that the ICG made at its last meeting.

The first one, from Working Group S (WG-S), is a survey into GNSS time offset for receiver manufacturers (Slide 8). It may be difficult for manufacturers to attend a global workshop on timing for interpretability due to logistics, so it was suggested that GNSS providers carry out a survey domestically on a larger scale and then submit their report to ICG for further consideration. Slide 8 summarizes the recommendation submitted to the ICG.



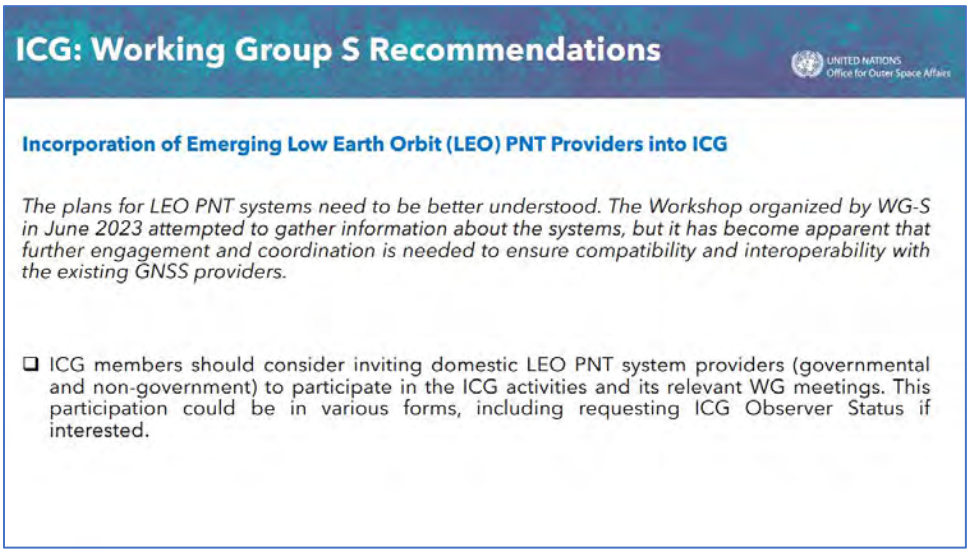
Slide 8

Slide 9 describes a recommendation of WG-S in regards to the approval of the International GNSS Monitoring and Assessment (IGMA) Joint Tail Project Terms of Reference (TOR). They updated their terms of reference to reflect some methodologies calculation regarding system level parameters, which are orbit and clock error, signal-in-space ranging error, Position Dilution of Precision (PDOP), and using a Coordinated Universal Time (UTC) Offset Error.



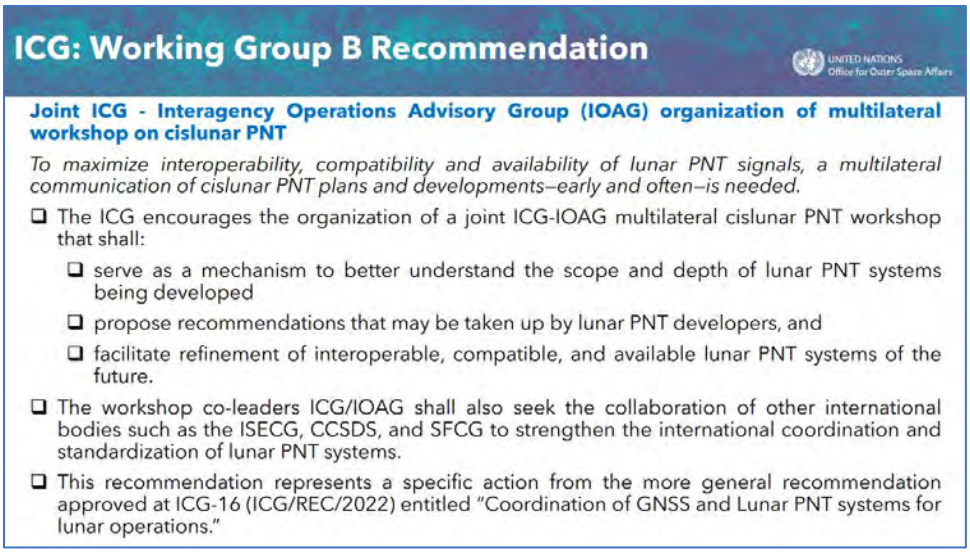
Slide 9

The next recommendation, as shown on Slide 10, is a WG-S recommendation on the Incorporation of Emerging LEO PNT Providers into ICG. There was a workshop where the members of WG-S agreed that to gather information about the systems, further engagement and coordination was needed between them and the LEO PNT providers to ensure that there is compatibility and interoperability with GNSS providers.



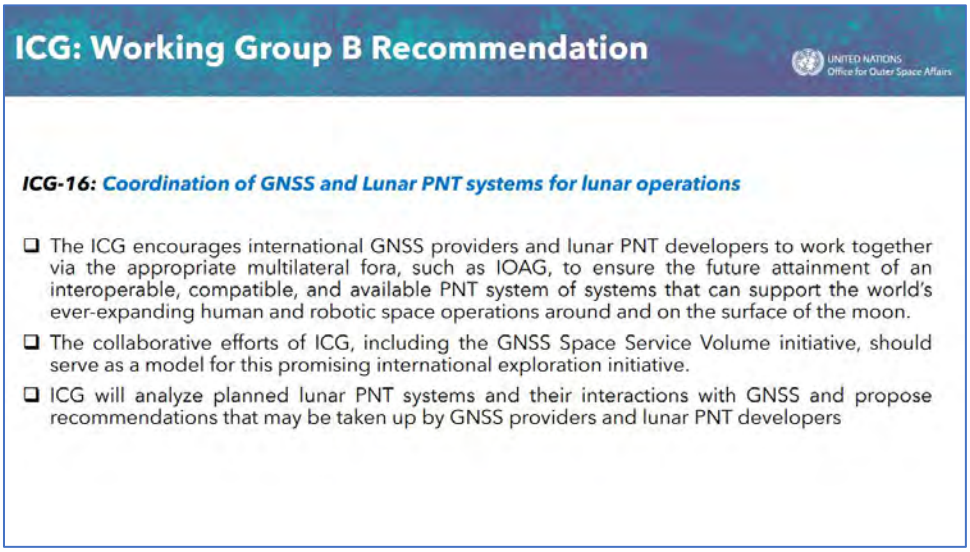
Slide 10

Slide 11 describes a recommendation from WG-B in regard to the establishment of a joint ICG and Interagency Operations Advisory Group (IOAG) multilateral workshop on Cislunar PNT. This is in order to maximize interoperability, compatibility, and availability of lunar PNT signals, as well as multi-lunar communications of circular PNT development plans. This is a follow up on a recommendation that came out of ICG-16, titled Coordination of Genesis and Lunar Systems for Lunar Operation.



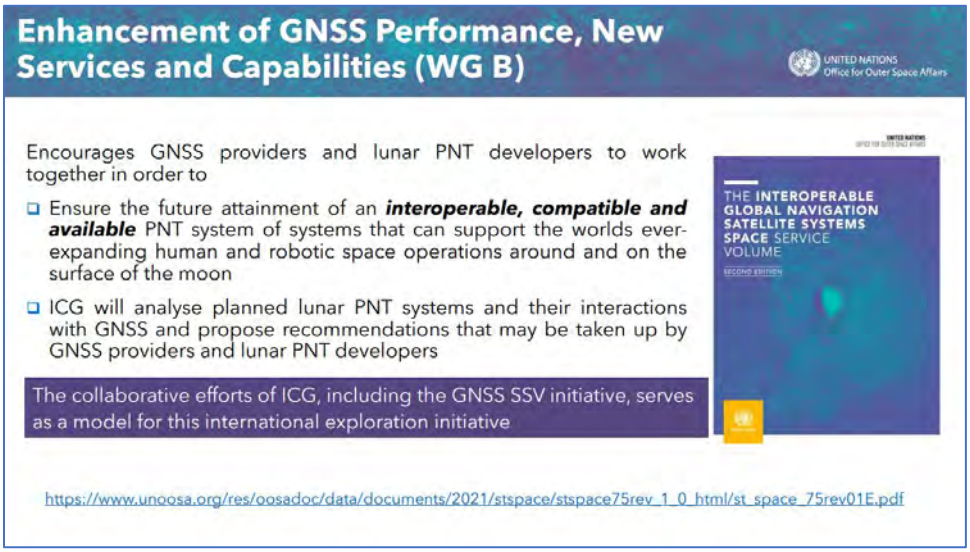
Slide 11

This recommendation follows one that was made at the ICG-16 meeting (Slide 12).



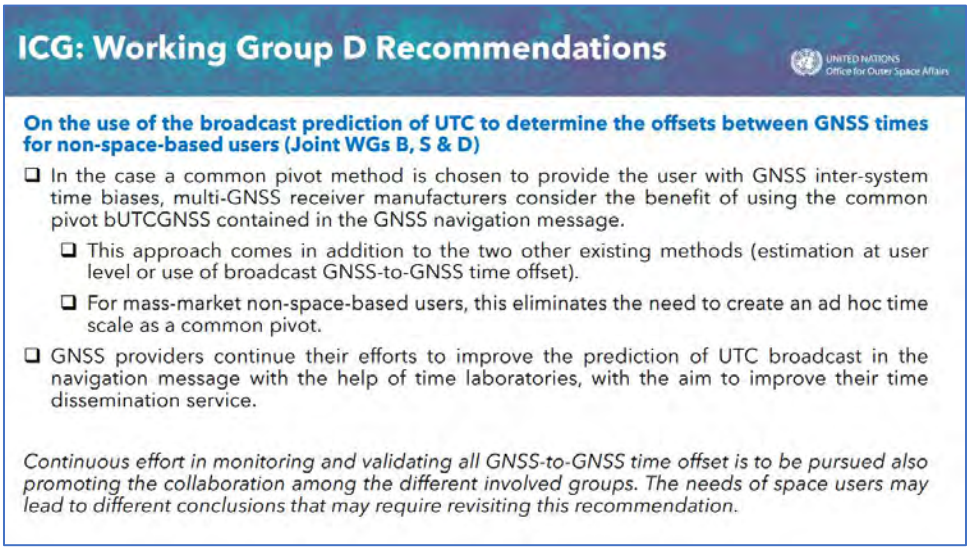
Slide 12

Slide 13 shows the latest publication of WG-B on interoperable GNSS Space Service Volume. This is available on the ICG's website.



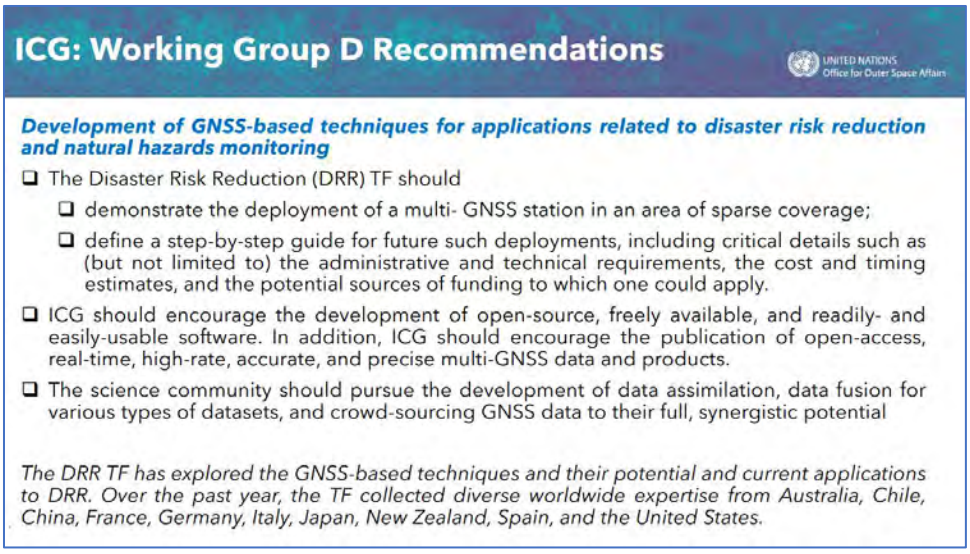
Slide 13

Slide 14 is a recommendation from Working Group D (WG-D) which deals with reference frames and timing, as well as applications. The recommendation regards the use of broadcast prediction of UTC to determine the offset between GNSS times for non-space-based users. It was presented by WG-D in collaboration with all of the working groups. The recommendation is to continue efforts in monitoring and validating all GNSS-to-GNSS time offset to promote collaboration among the various involved groups.



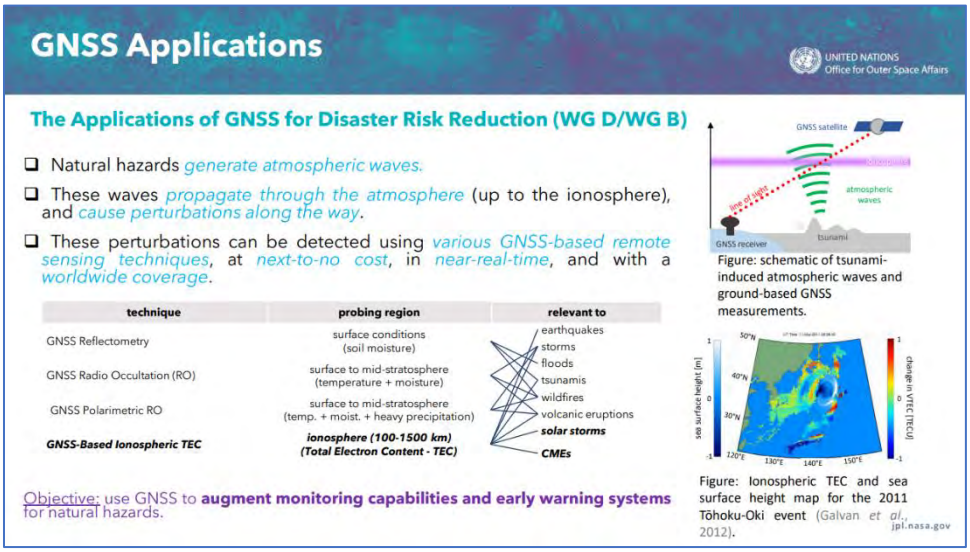
Slide 14

Slide 15 describes the second recommendation from WG-D. It discusses the development of GNSS best techniques for applications regarding disaster risk reduction and natural hazards monitoring. This recommendation is also a follow up to the task force previously established on this topic, and this task force has explored the GNSS based techniques, their potential, and current applications to disaster risk reduction.



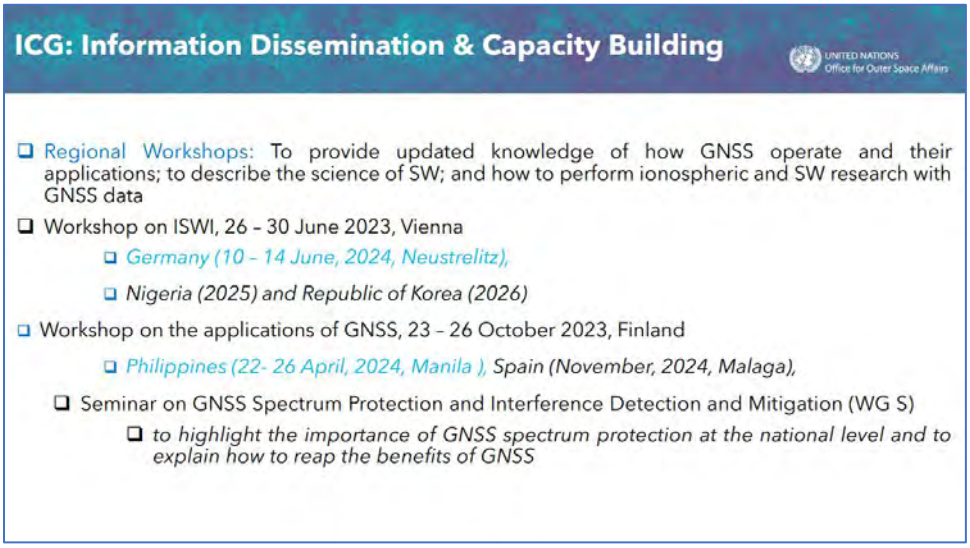
Slide 15

Slide 16 provides background to this recommendation and an overview of the task force. The main objective of this task force is to use GNSS to augment monitoring capabilities and early warning systems for natural hazards. The slide was provided by experts from JPL.



Slide 16

As a lead of one of the Working Groups, Ms. Gadimova helps organize events, mostly in developing countries (Slide 17). This includes regional workshops, which are organized between the United Nations and the host country, to provide updated knowledge on how GNSS operates and what their applications are. There will be a workshop this year in Finland, and there have been expressions of interest from the governments of the Philippines and Spain to have similar workshops next year. In cooperation with WG-S Ms. Gadimova's office organizes seminars on GNSS Spectrum Protection and Interference, Detection, and Mitigation to highlight the impact and importance of GNSS spectrum protection at the national level, and to explain how to reap the benefits of GNSS.

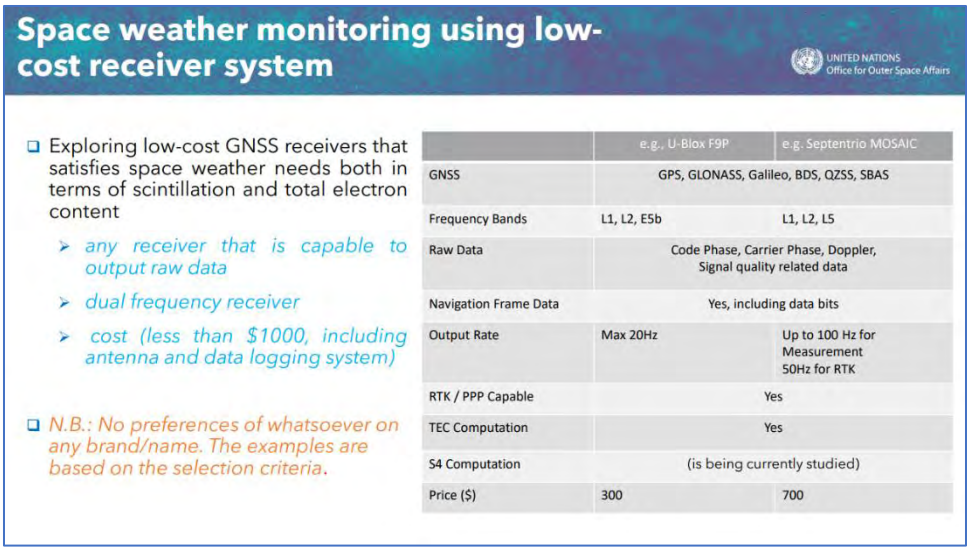


Slide 17

As shown on Slide 18, the ICG also supports several activities in cooperation with associate members or members of ICG, the University of Tokyo. This one is on GNSS data types, GNSS errors, coordinate systems and applications, and low-cost receiver system data. Another set of events is in cooperation with the International Center for Theoretical Physics, which is also a UN entity based in Italy and Boston College. They are focused on activities to enhance capacity building on GNSS for space weather monitoring and other activities. A two-day seminar, which is organized in cooperation with the International Association of Geodesy (IAG) , International Federation of Surveyors (FIG), and International GNSS Service (IGS), happened in conjunction with FIG working week and. Next year, it will be held in Ghana in May.

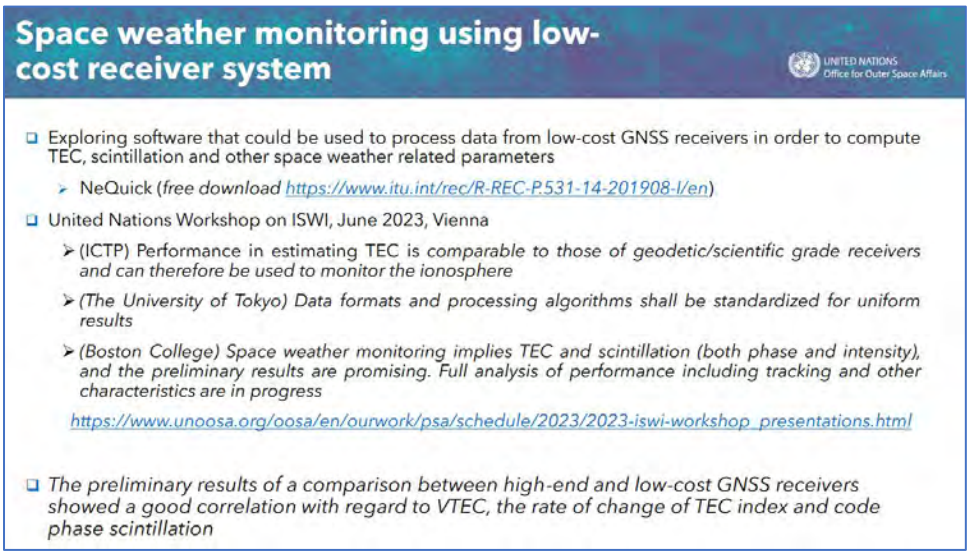
Slide 18

WG-C is led by the UN Office of Outer Space Affairs. Slide 19 describes an effort on space weather monitoring using low cost GNSS receivers. WG-C is also exploring whether it's possible to satisfy all space weather needs in terms of installation and total electron content. The cost of the receiver should be less than $1,000.

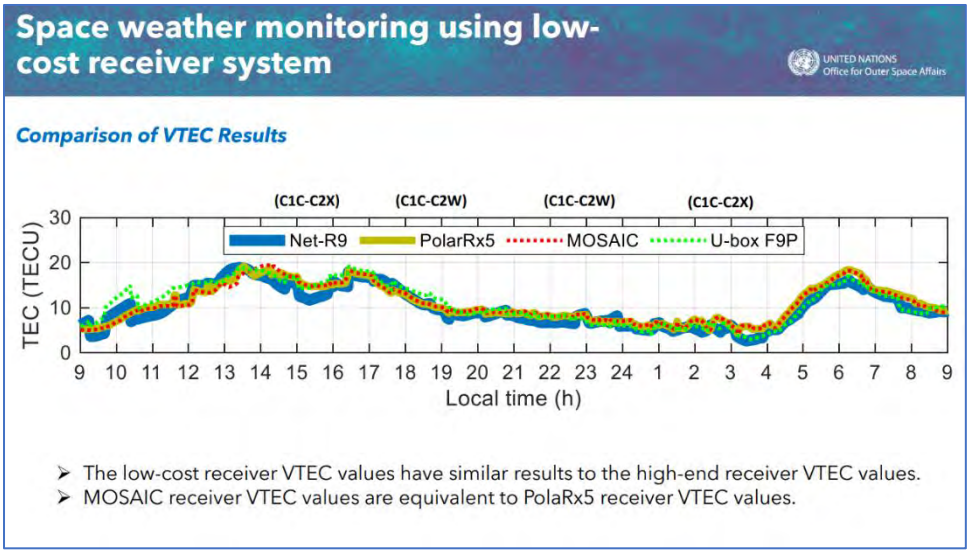


Slide 19

Slide 20 describes a collaborative effort between the ICG, the University of Tokyo, and Boston College. They provided their preliminary results at the last meeting, and the comparison shows that between high end and low cost GNSS receivers, there is a good correlation with regard to vertical total electron content (Slide 21).

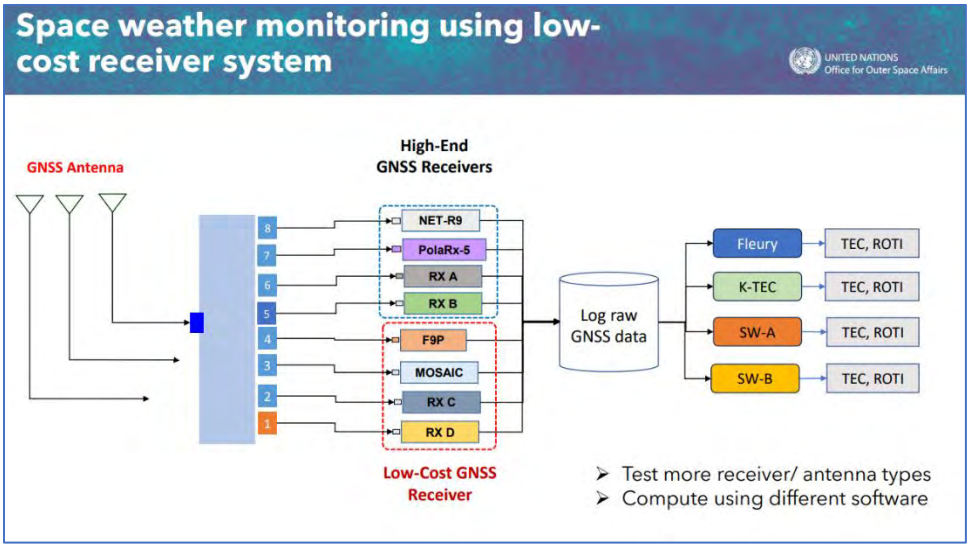


Slide 20



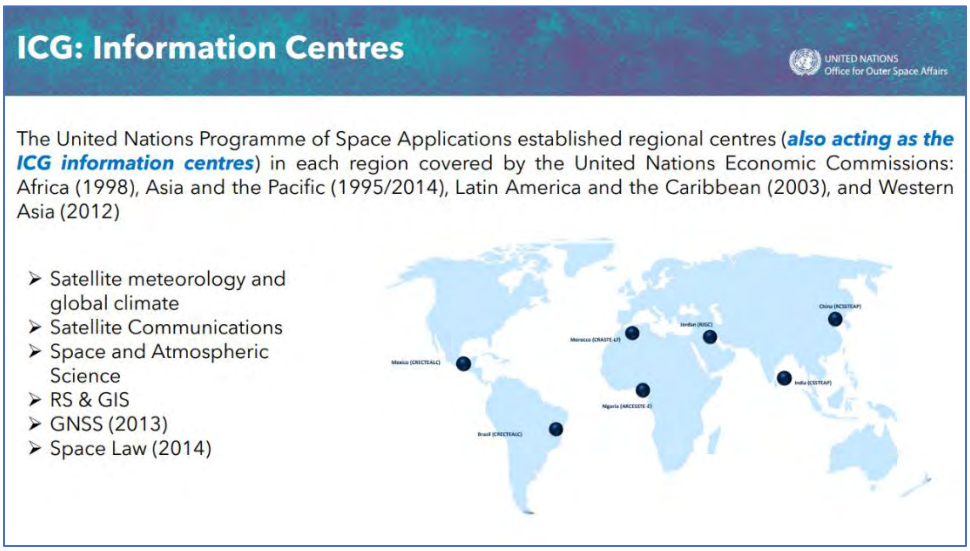
Slide 21

Slide 22 illustrates what a prototype system will look like if WG-C accomplishes everything that they are planning to. Throughout this year they plan to hold more test receiver and antenna types, and as well as compute using different software.



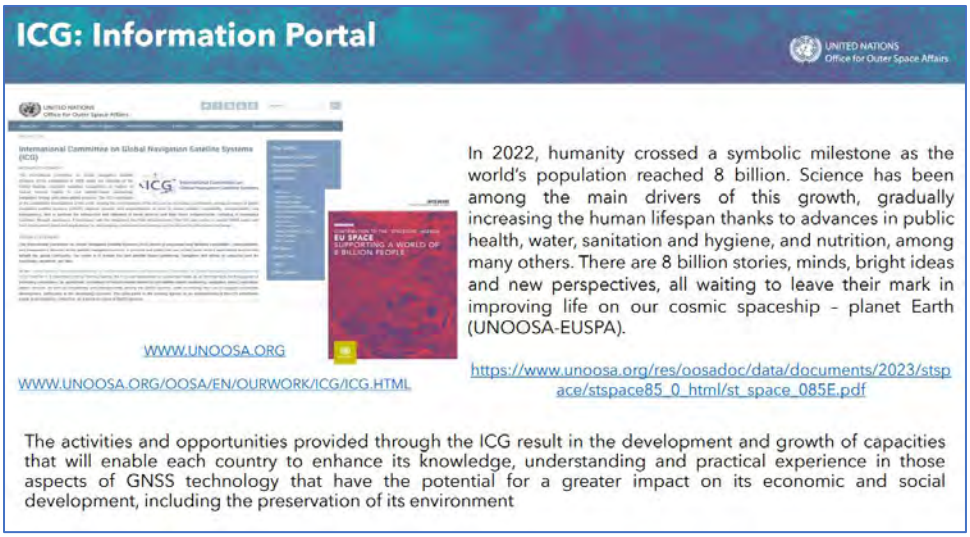
Slide 22

The Regional Centers are located in different regions corresponding to the United Nations Economic Commissions. Slide 23 shows the courses which they carry out on different topics. ICG uses these regional centers as Centers for Information Dissemination regarding GNSS.



Slide 23

Finally, Slide 14 the information portal for the ICG. The publication shown, which Ms. Gadimova's office carried out with the European Space Agency (ESA), demonstrates how space can help humanity. In 2022, the UN Secretary General announced that the World has reached 8 billion people.



Slide 24

Ms. Gadimova thanked the Board and stated that the next ICG meeting will take place in Wellington, New Zealand in October of 2024 (Slide 25).

Slide 25

Discussion

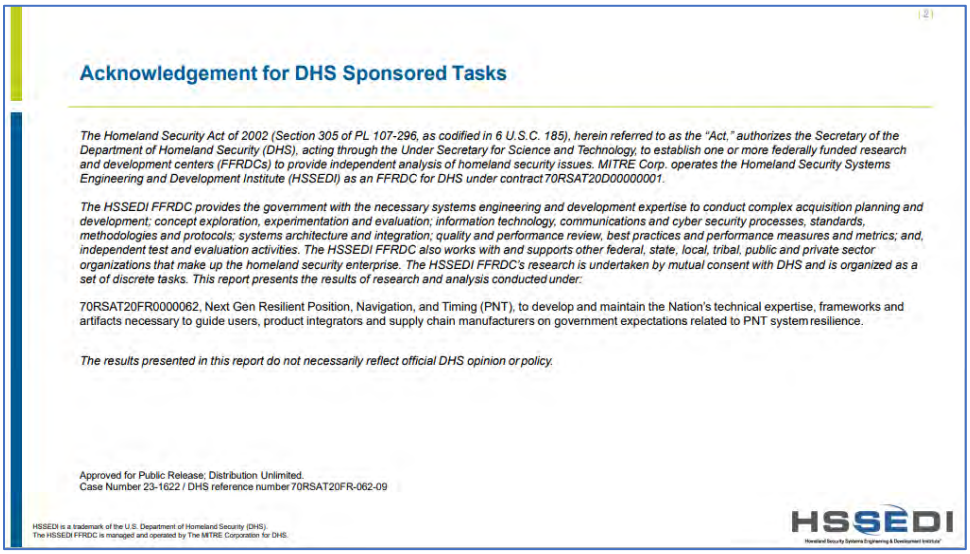
ADM Allen thanked Ms. Gadimova for her presentation.

***

Critical Infrastructure Augmentation Framework
Dr. John Betz, *Member, PNTAB*

Dr. Betz explained the briefing is about work performed for the Federally Funded Research and Development Center (FFRDC) operated by MITRE Corporation for DHS (Slide 1). Slide 2 depicts the acknowledgement for tasks sponsored by DHS.

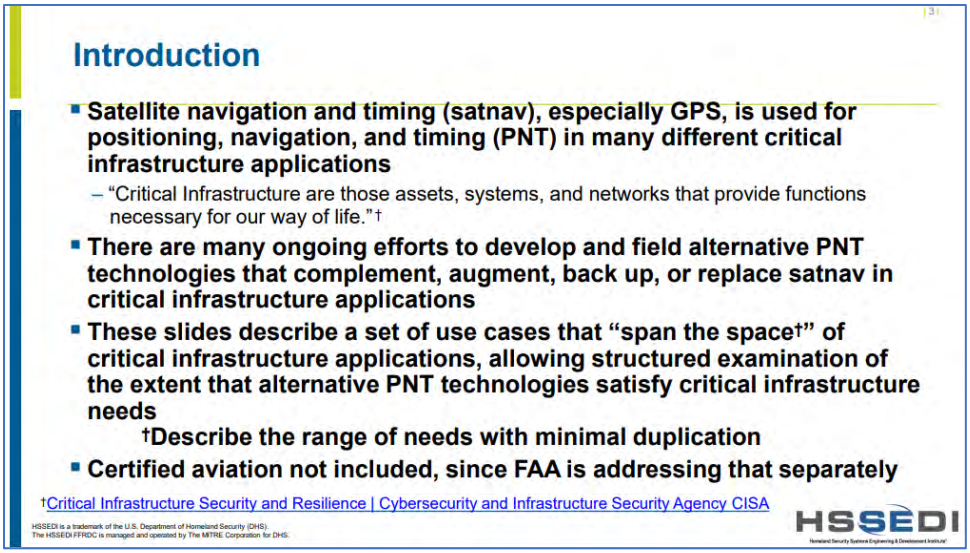
Slide 1



Slide 2

Satellite navigation and timing, or SATNAV, is used extensively through critical infrastructure (Slide 3). In this study, critical infrastructure is defined as, "Assets, systems, and networks that provide functions necessary for our way of life." There are many ongoing efforts to develop and field alternative PNT technologies that either complement, augment, back up, or replace satnav in critical infrastructure applications to ensure we no longer have any single critical point of failure. These slides are an attempt to describe a set of use cases whose characteristics "span the space" of what is needed to complement, augment, back up, or replace satnav. The study does not include certified aviation.

As shown on Slide 4, there are many applications in SATNAV and critical infrastructure, each requiring different levels of Position, Velocity, Time (PVT) or PNT.

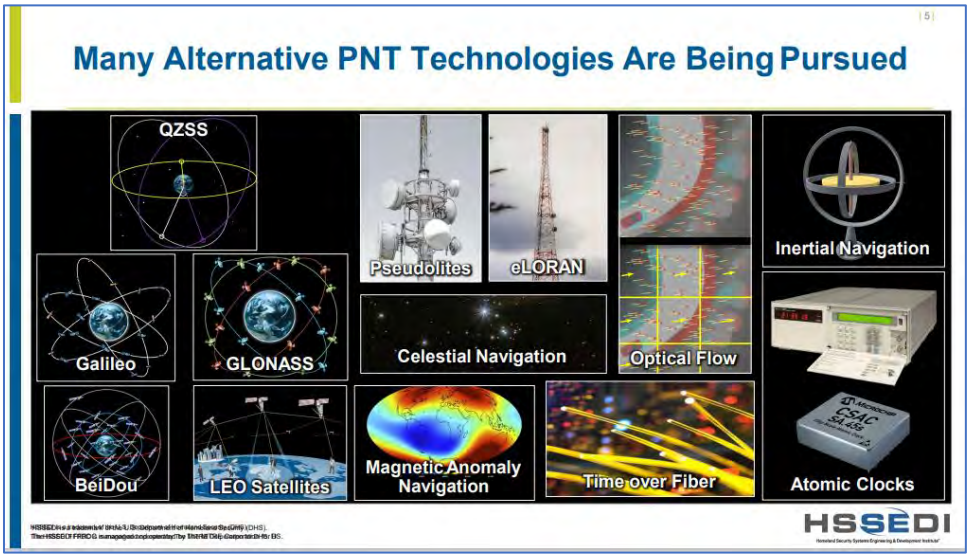


Slide 3

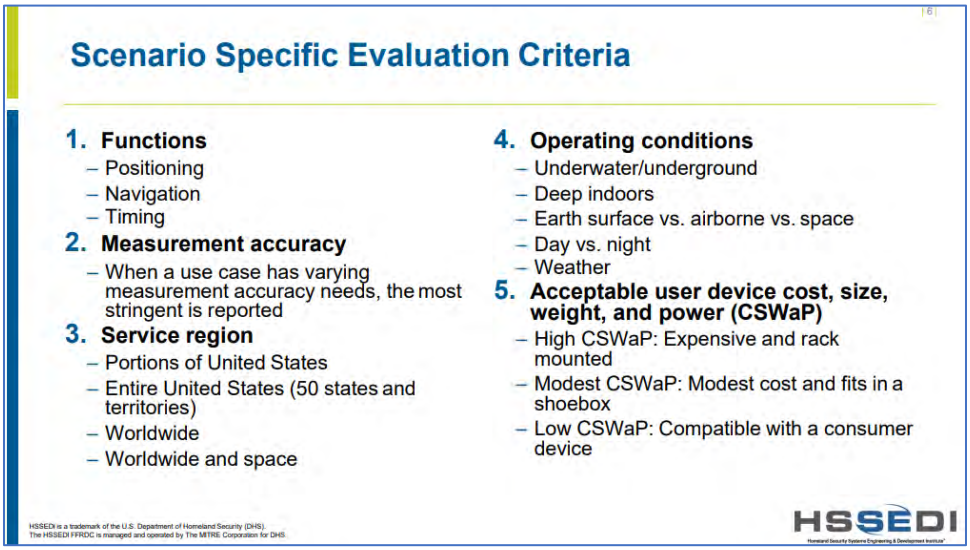

Slide 4

There are also many technologies out there that are trying support this role, or at least parts of it (Slide 5). Not all of them are listed on the slide.

The team took standard evaluation criteria, as depicted in Slide 6. We took criteria used in the Federal Radionavigation Plan (FRP), such as functions and measurement accuracy, and added three more: service region, operating conditions, and acceptable user devise cost, size, weight, and power (CSWaP). For the CSWaP, the team decided not to get into specific numbers and just break it down qualitatively. Also, when defining the service region, the team went further to expand what "service in the U.S." means, whether conterminous U.S., all of the U.S. including Alaska, Hawaii and territories, etc.



Slide 5



Slide 6

Slides 7-9 (next page) describe the proposed use cases. There are 17 use cases in total. The first four (Slide 7) are timing use cases. Note that the 0.1 microsecond use case (second use case on Slide 7) goes beyond the typical one microsecond we usually hear about which is reflective of what we are trying to do here. This requirement is to support 5G cellular base stations that need to be synchronized more closely to each other. The study emphasizes both current and future applications. For other cases, we used defined whether the positioning, navigation, and/or velocity functions are required (Slides 7-9). In Slide 8 note we also discuss space applications. Finally, Slide 9 depicts several maritime applications, a couple Unmanned Aerial Vehicle (UAV) applications, and Emergency 911 (E911). For example, the UAV sensing application cover users such inspecting the health of a structure where there is a need to stitch together an accuracy picture to understand the characteristics of the structure.

Proposed Use Cases (1 of 3)

Use Case	PNT Func.(s)	Meas. Accuracy	Service Region	Operating Conditions	CSWaP	Ref.
Cellular Base Station: Intercell Interference	T	± 1 µs	Entire U.S.	All Earth Surf.	Mod.	1
Cellular Base Station: Carrier Aggregation	T	± 0.13 µs	Entire U.S.	All Earth Surf.	Mod.	2
Phasor Measurement Unit	T	± 1 µs	Entire U.S.	All Earth Surf.	Mod.	3
Financial Trading	T	± 50 ms (US), ± 1 µs (EU)	Urban Areas	All Earth Surf.	High	3, 12
Positive Train Control	P	2D 1 m (2DRMS)	Entire U.S.	All Earth Surf.	High	3
Precision Agriculture, Other Commercial	P, N	±1 cm H, ±1.5 cm V	Entire U.S.	All Earth Surf.	Mod.	–

Slide 7

Proposed Use Cases (2 of 3)

Use Case	PNT Func.(s)	Meas. Accuracy	Service Region	Operating Conditions	CSWaP	Ref.
Driving: Route Navigation	P, N	2D 3 m (2DRMS)	Entire U.S.	All Earth Surf.	Low	–
Driving: Lane Navigation	P, N	2D 1 m (2DRMS)	Entire U.S.	All Earth Surf.	Low	3
Driving: Autonomous Vehicles	P, N	2D 0.1 m (2DRMS)	Entire U.S.	All Earth Surf.	Mod.	–
Space Launch	P, V	3D 5 m RMS, 0.1 m/s per axis	World-wide to GEO	All	Mod.	7, 8, 9
Space Operations	P	3D 1 m (95%) at LEO	LEO to GEO	Space	Mod.	10

Slide 8

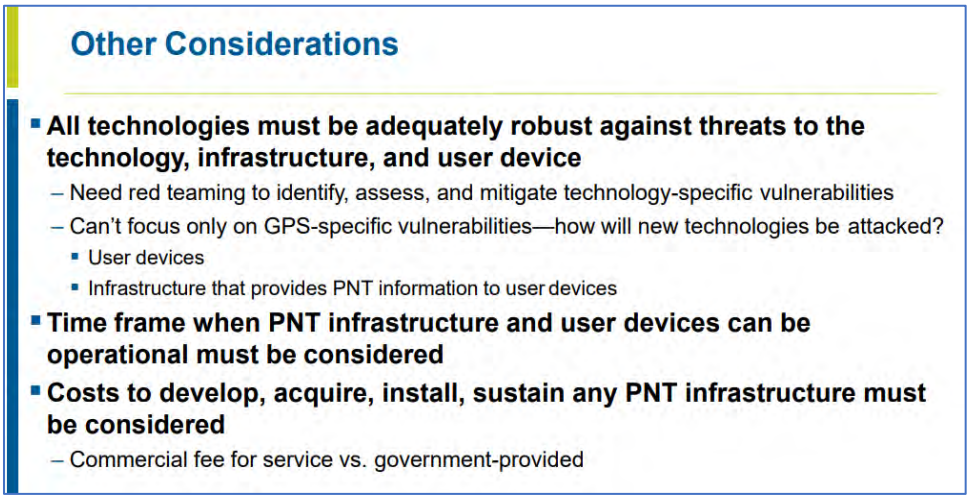
Proposed Use Cases (3 of 3)

Use Case	PNT Func.(s)	Meas. Accuracy	Service Region	Operating Conditions	CSWaP	Ref.
Maritime: Ocean/ Seas	P, N	2D 185 m (2DRMS)	Worldwide	All Earth Surf.	High – Mod.	3
Maritime: Harbors	P, N	2D 8 m (2DRMS)	Entire U.S.	All Earth Surf.	High – Mod.	3
Maritime: Inland Waterways	P, N	2D 2 m (2DRMS)	Entire U.S.	All Earth Surf.	Mod.	3
UAS En Route	N	2D 1 m (2DRMS)	Entire U.S.	Airborne	Mod.	3
UAS Sensing	P	± 1 cm H, ± 1.5 cm V	Entire U.S.	Airborne	Low	4, 5, 6
Emergency 911	P	2D 50 m (for 40% of wireless calls)	Entire U.S.	All Earth Surf.	Low	11

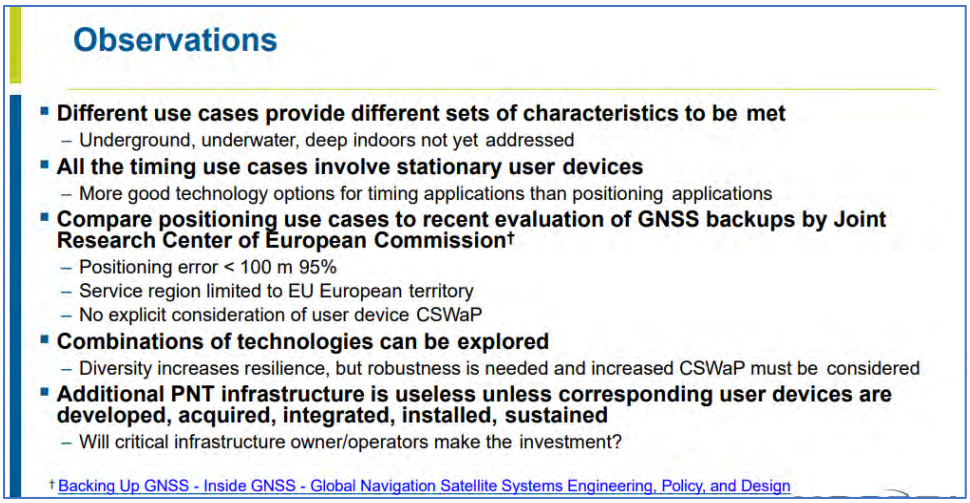
Slide 9

As depicted in Slide 10, there are additional considerations we need to consider. These include continuity, integrity, and robustness, which are hard to define for some new cases. Red teaming is also important because you can't only look at how GPS by itself affects other technologies. We also need to look at how hackers & adversaries might attack different technologies. Also, you need to consider the user devices themselves and the infrastructure providing them PNT information. You may also want to think about the timeframe in which an application can become operational, which could be a decade or so. Finally, we need to consider the cost to develop, acquire, install, sustain any PNT infrastructure must be considered as well as how it is going to be paid for.

If you look across those 17 use cases presented in Slides 7-9 you will see there are many combinations of different characteristics (Slide 11). The study did not include applications that are underground, underwater, or deep indoors. Also, after presenting this work at the ION Joint Navigation Conference (JNC) last summer, the Joint Center of the European Commission presented an initial set of backup technologies. What really surprised is was the criteria they used for acceptability, such as anything providing < 100 meter accuracy being acceptable for consideration whereas in our 13 use cases requiring positioning only one of them could be supported by this requirement. It seems their requirements are much looser when it comes to meeting the backup needs. We will also need to consider using combinations of these technologies, which is a good thing but also adds to the overall cost of the user device and the supporting infrastructure. Finally, any additional PNT infrastructure will be useless if the user devices are not viably employed, whether we follow an "if you build it they will come" approach or whether we want to have some assurance that the infrastructure operators would incorporate these technologies.



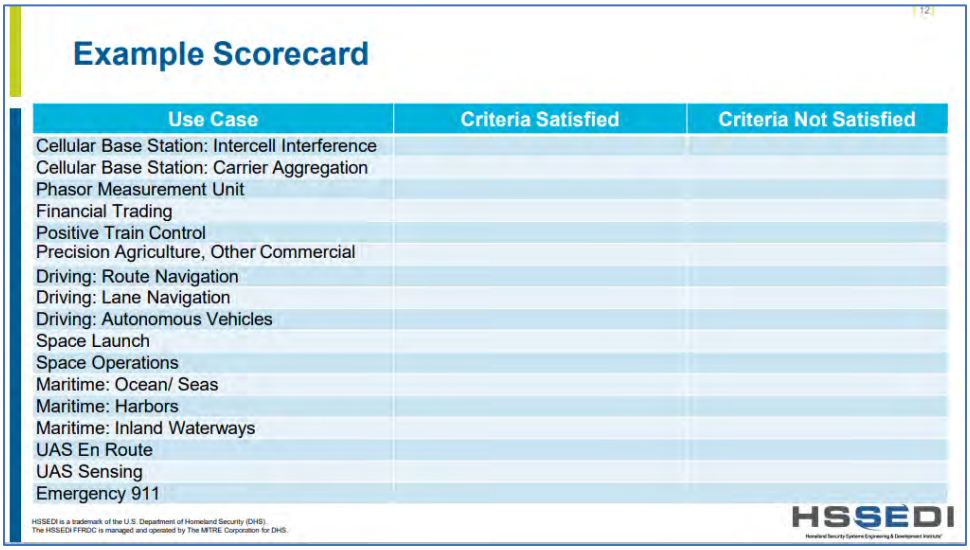
Slide 10



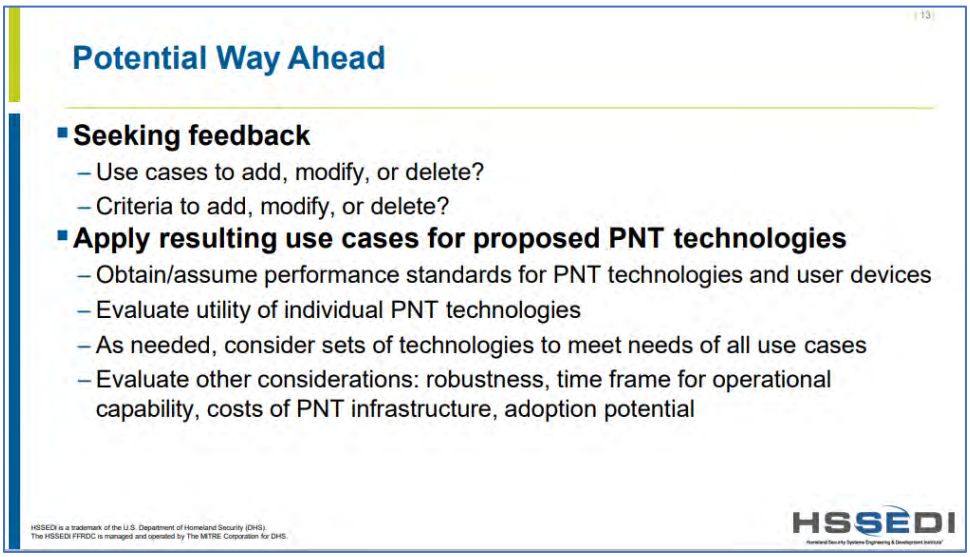
Slide 11

Slide 12 is how we envision these use cases being employed, where each user takes their favored technology and runs it down the use cases to see whether the five criteria are satisfied. If the criteria is not met, they can go back and see which complementary technology will help satisfy the criteria. We can also modify the use cases depending on whether they will be used for a first or a second level screening.

The purpose for presenting today was to get feedback from the board regarding the use cases and criteria we developed (Slide 13). Please let us know if an application is redundant, or if we are missing one you believe is key. The same thing goes for the criteria we used. These use cases could also be helpful to USG agencies to identify gaps in backup and/or complementary PNT.



Slide 12



Slide 13

[Ed. Note: Slide 14 depicts the references]

Slide 14

Discussion:

Dr. van Diggelen noted that WiFi is not mentioned in the scorecard.

Dr. Betz responded that WiFi would t technologies would be one of the backup, complementary, or alternative technologies.

Dr. van Diggelen noted that the WiFi base stations include a GPS receiver, and a complete Wi-Fi based PNT system is currently being designed by the Institute of Electrical and Electronics Engineers (IEEE).

Dr. Betz agreed, it such system could fill in some of the gaps but would be limited in overall coverage across the nation.

Dr. Parkinson asked where his team stands on pushing this out.

Dr. Betz responded that having completed the work for DHS, he would like the board's PTA subcommittee to take over.

ADM Allen noted that the maritime functions in the use cases should be more prescriptive and include use cases such as docking procedures. He will follow-up offline with Dr. Betz.

Mr. Higgins commented that the Australian Homeland Security is going through an assessment of PNT requirements, and the next step would be what we do about it. This study would be very helpful. The equipage problem remains the industry's an issue for critical infrastructures across the world. The more a system is used, the more likely one is going to get viable technologies as backups/complementary technologies. Mr. Higgins said he's happy to go back and bring up this framework to them.

Mr. Madani asked if the use cases in the chart are listed by order of priority.

Dr. Betz responded no.

Mr. Madani added that some applications may have varying degrees of requirements due to, for example, liability issues. There are on-going efforts at IEEE that could be leveraged to support follow-on work.

Dr. Betz agreed, but also cautioned that this framework could get very complicated really fast.

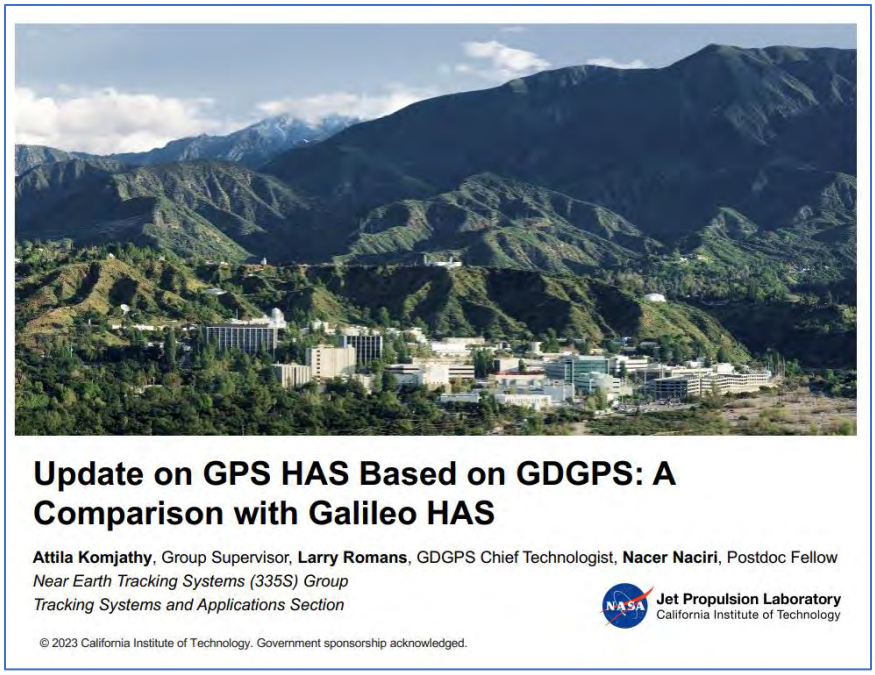
Prof. Moore added that he would also take this back to the UK and bring it up with government representatives.

***

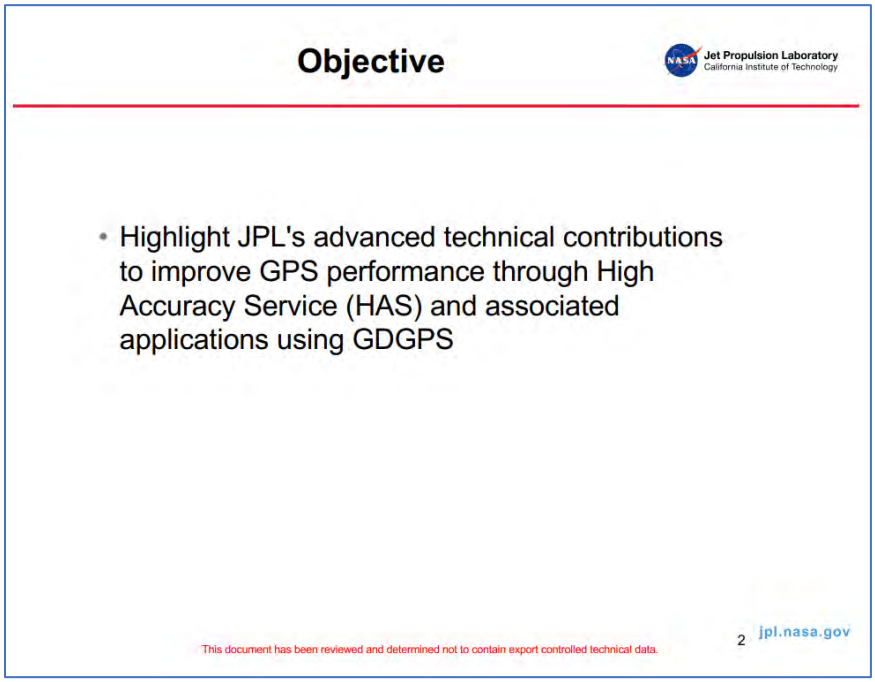
Global Differential GPS System (GDGPS) & Galileo High Accuracy Service (HAS) Comparison
Dr. Attila Komjathy, *Supervisor, Near Earth Tracking Systems Group, JPL*
Dr. Frank van Diggelen, *Member, PNTAB*

Part 1 – Dr. Komjathy

Dr. Komjathy noted that he would be providing an update on how a GDGPS-based augmentation system would compare with the Galileo High Accuracy Service, or Galileo HAS (Slide 1). The objective is to highlight JPL's advanced technical contributions to improve GPS performance through a high accuracy service with corrections distributed via the internet (Slide 2).



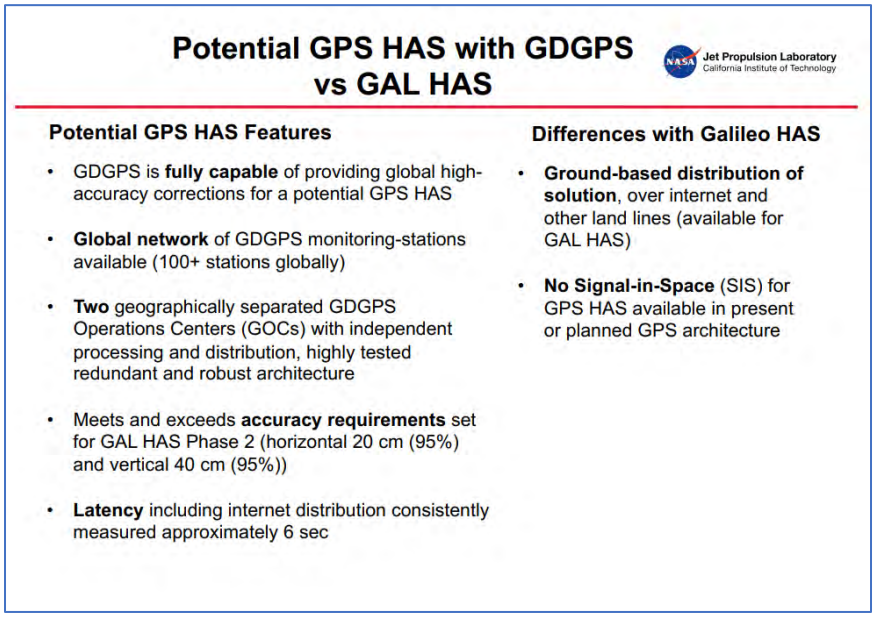
Slide 1



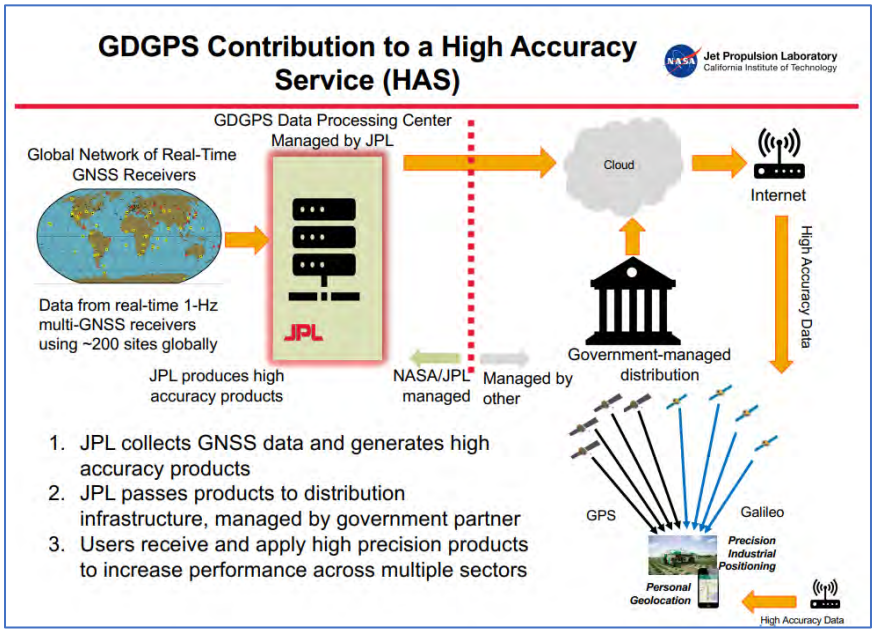
Slide 2

Slide 3 describes the characteristics of the two systems. GDGPS is fully capable of providing correction services. It relies on a global network of over 100 GNSS receivers. It has two geographically separated GDGPS Operations Centers (GOCs) providing independent processing capabilities, redundancy, and robustness. GDGPS also meets the Galileo HAS requirements of 20 cm (95%) horizontally and 40 cm (95%) vertically. Its latency is approximately six seconds. However, there are some differences. GDGPS corrections can only be distributed via the internet, whereas Galileo HAS can distribute the corrections through their satellites.

Slide 4 depicts the system architecture for a GDGPS-based high accuracy service. One the left of the dashed line are the components managed by NASA/JPL, including a global network of real-time GPSS receiver and a GDGPS Data Processing Center. On the right of the dashed line are the components for distributing the data to users. JPL is looking for a USG partner to disseminate these corrections via the internet, and users would then apply these corrections.



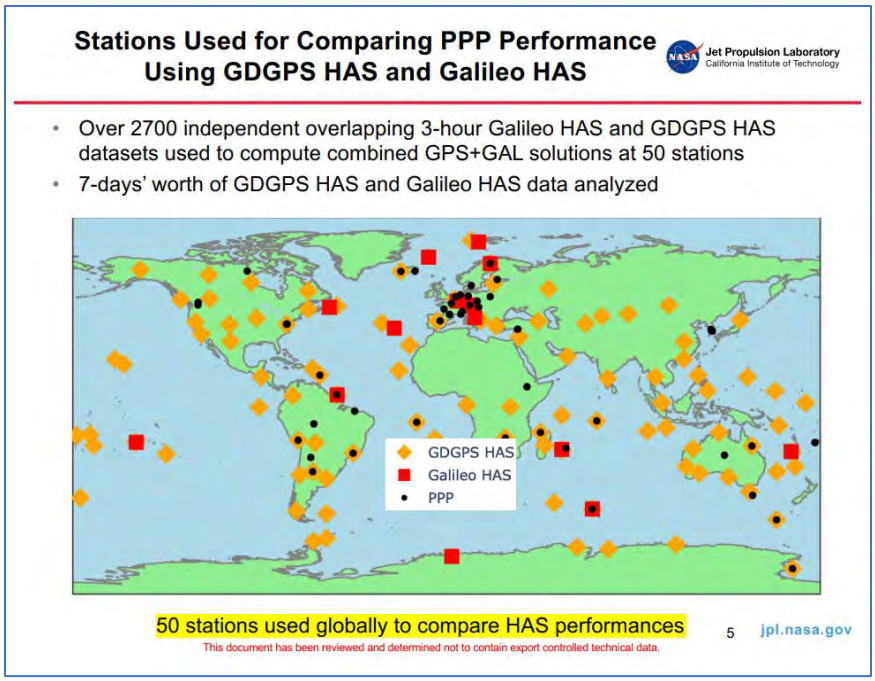
Slide 3



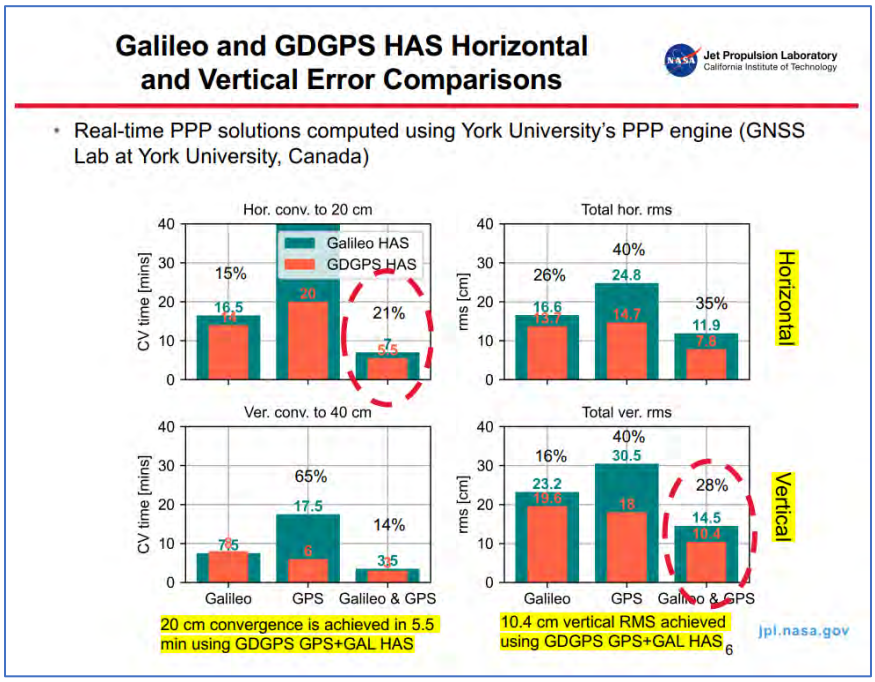
Slide 4

Slide 5 depicts GDGPS and Galileo HAS reference stations used for the comparison. Seven days' worth of data from fifty globally-distributed stations were used in this analysis.

Slide 6 compares the Galileo and GDGPS high accuracy services horizontal and vertical errors.



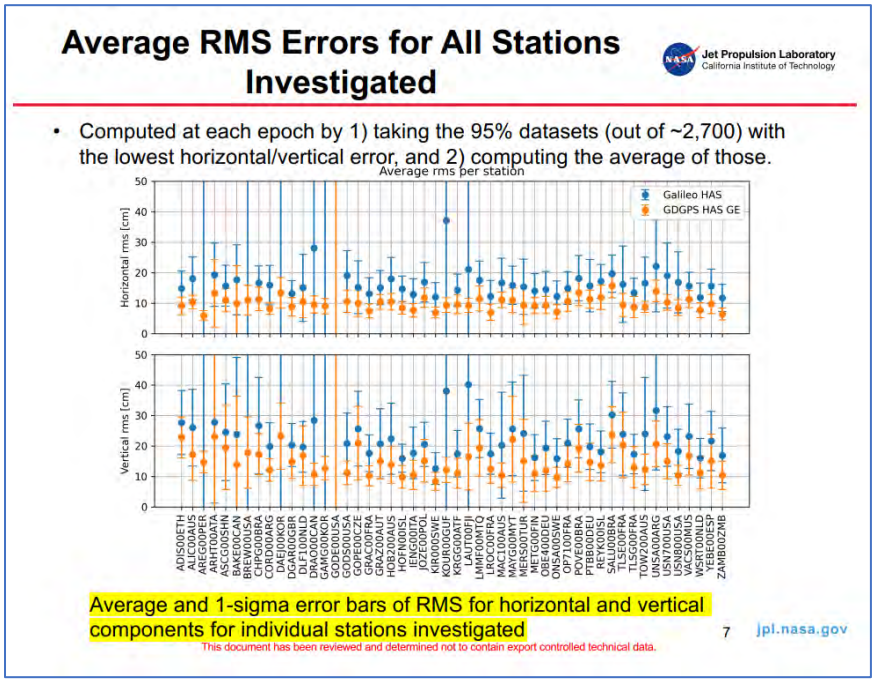
Slide 5



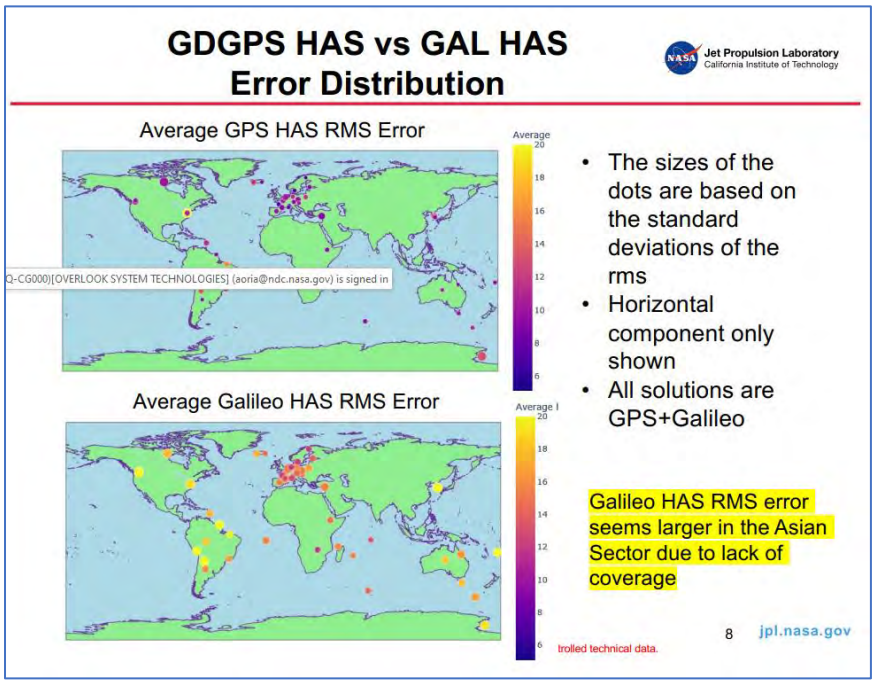
Slide 6

Slide 7 shows the entire data set from 50 stations across the globe and, again, reflects the 30% horizontal, and 20% vertical, improvement of GDGPS over the Galileo HAS.

Slide 8 shows the geographic distribution of errors. For the Galileo HAS, the Pacific Region and Southern Hemisphere has larger Root Mean Square (RMS) errors because it relies on 14 tracking stations in Europe and its vicinity.



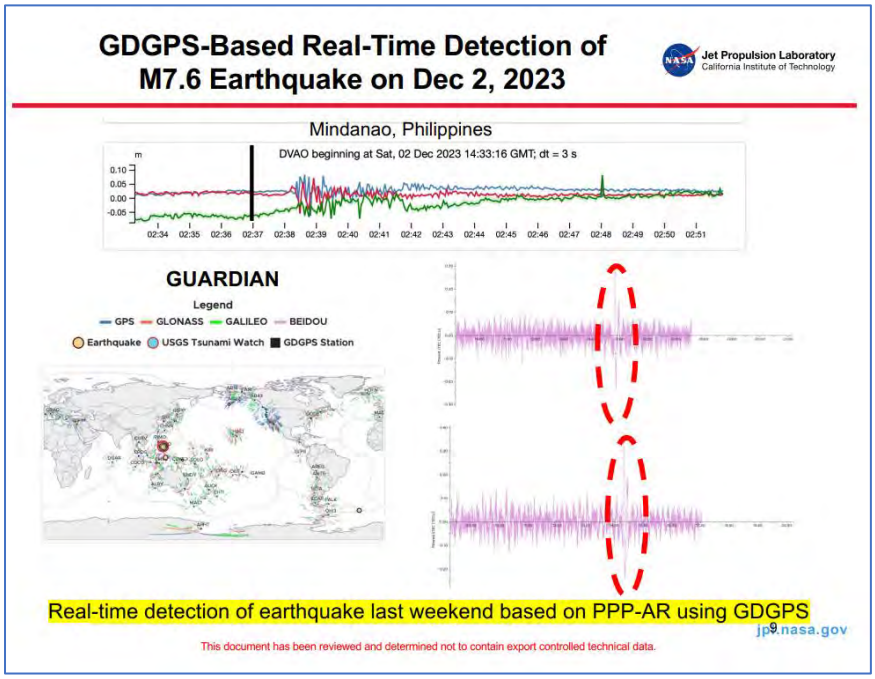
Slide 7



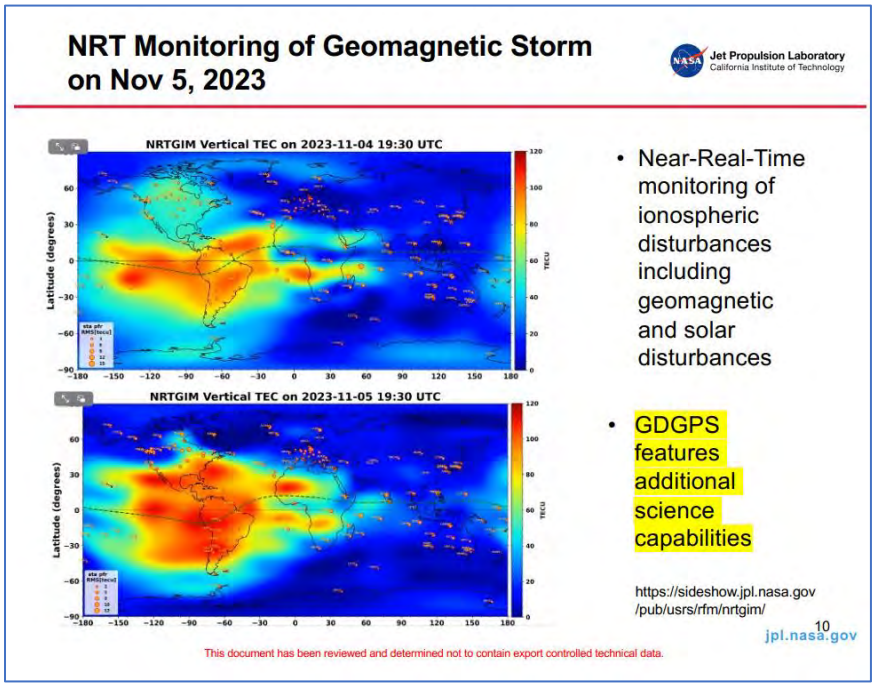
Slide 8

Slide 9 describes an interesting science application for a GDGPS-based earthquake detection on December 2, 2023. There was an earthquake in the Philippines. On the top we can see the centimeter-level real time displacements when the seismic wave reached the nearest GDGPS reference station. On the bottom right, we can see a plot of the ionosphere disturbance caused by the seismic wave.

Slide 10 shows another interesting application, which was the monitoring of the November 5, 2023, geomagnetic storm. The upper panel shows the geomagnetic activity on a quiet day and the lower panel shows the impact of the geomagnetic storm as detected by GDGPS.



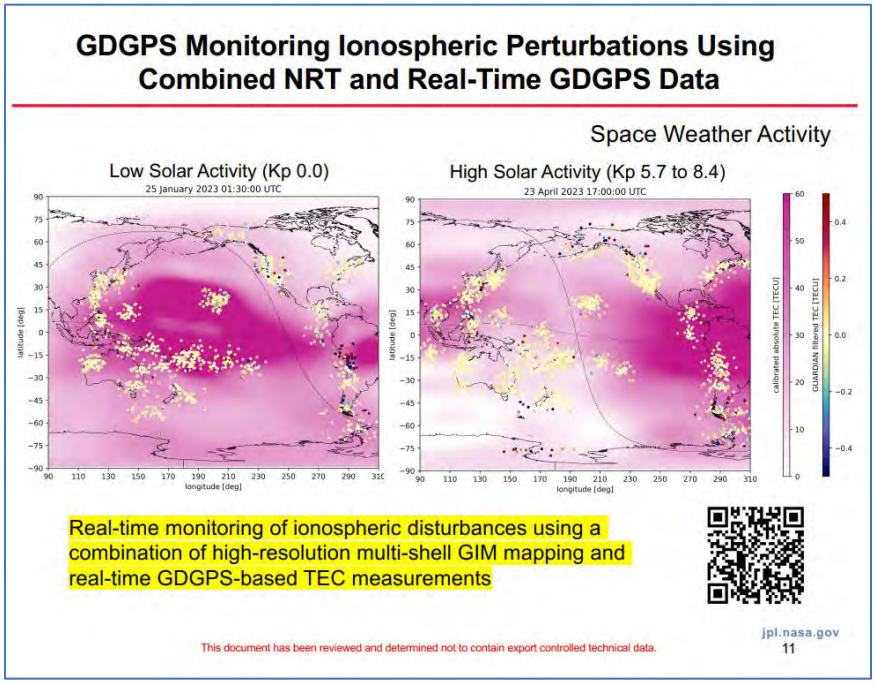
Slide 9



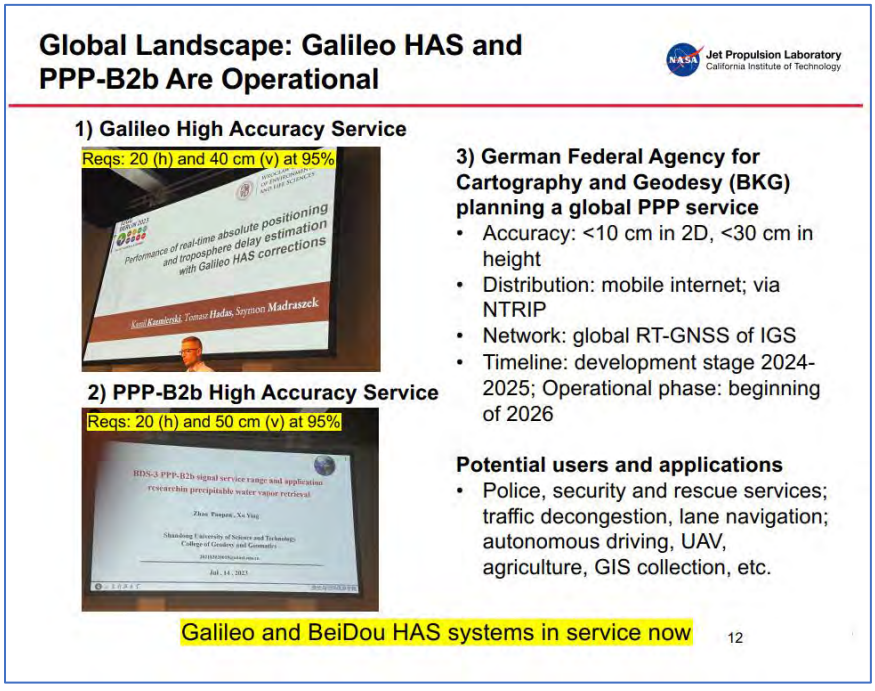
Slide 10

Slide 11 shows combined Near Real Time (NRT) and real-time GDGPS data. Low solar activity is shown on the left, and High Solar activity is shown on the right. Again, we can see how this technology can be used for real-time monitoring of ionospheric disturbances.

Slide 12 describes the global landscape for high accuracy services. Galileo HAS has been in operation since January 2023. The BeiDou Precise Point Positioning (PPP) service provides regional correction services. In addition, Germany is planning to add PPP service for cartography and geography. The point of this slide is to show there is fierce competition across the world for this type of service.



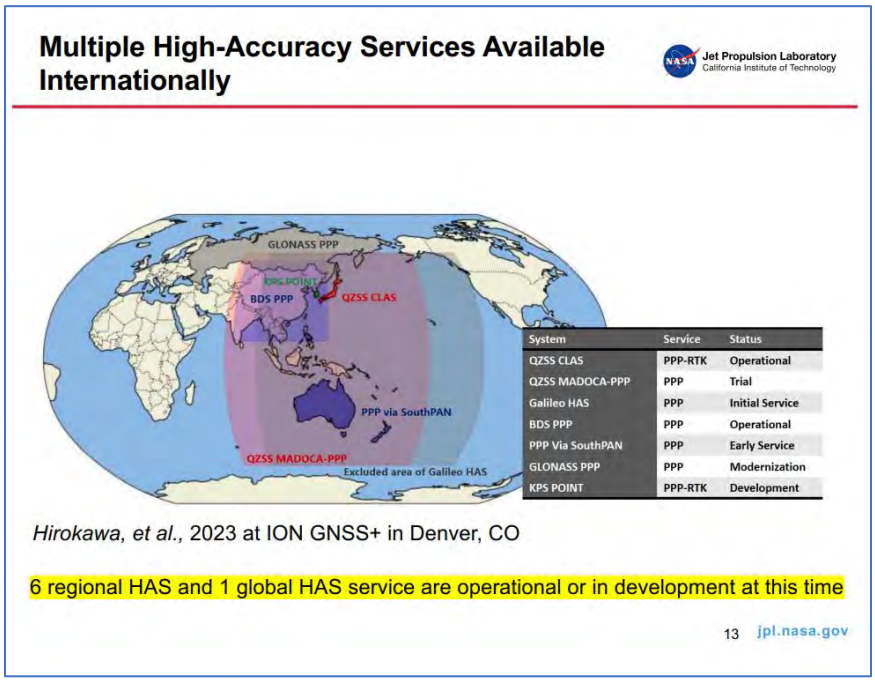
Slide 11



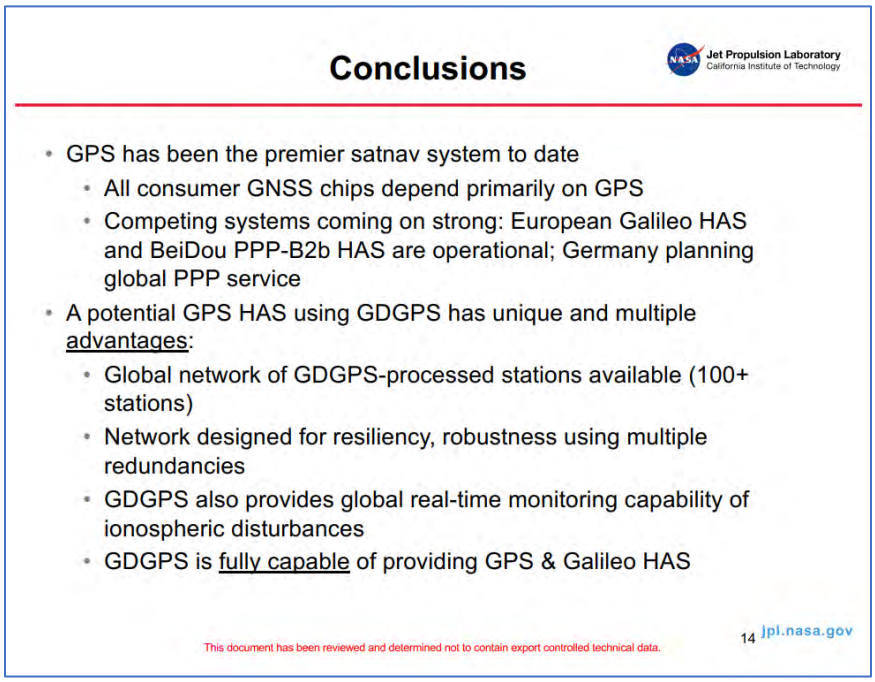
Slide 12

As shown on Slide 13, the Asia region is quite engaged in such services, with six regional high accuracy systems either in operation or in planning stages.

In conclusion GPS has been the preeminent SATNAV system to date, but there is strong competition from other systems (Slide 14). A GDGPS-based GPS high accuracy service would provide unique advantages to ensure GPS remains preeminent.



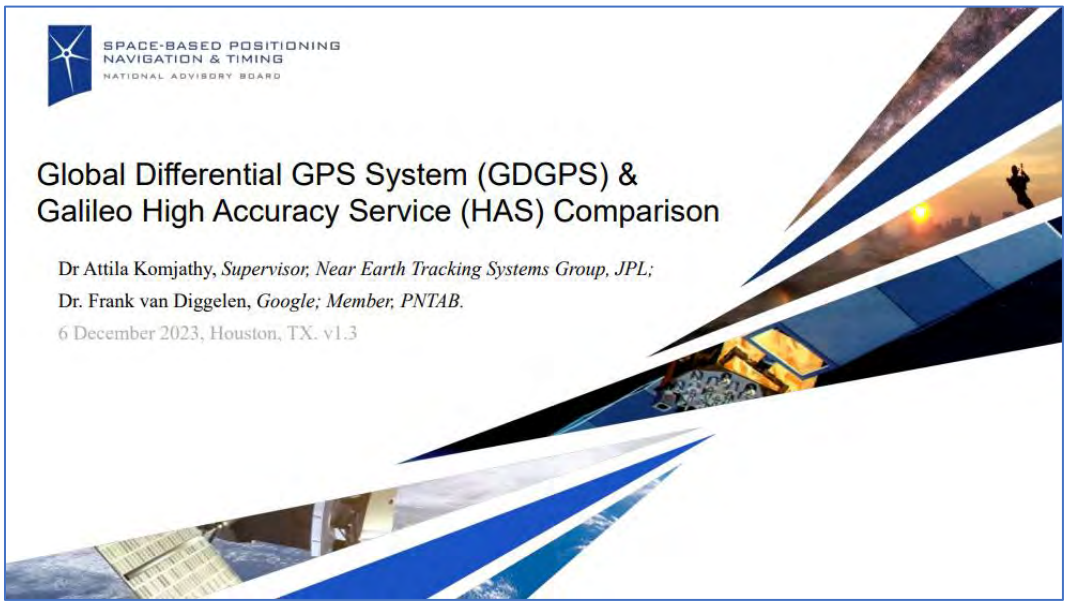
Slide 13



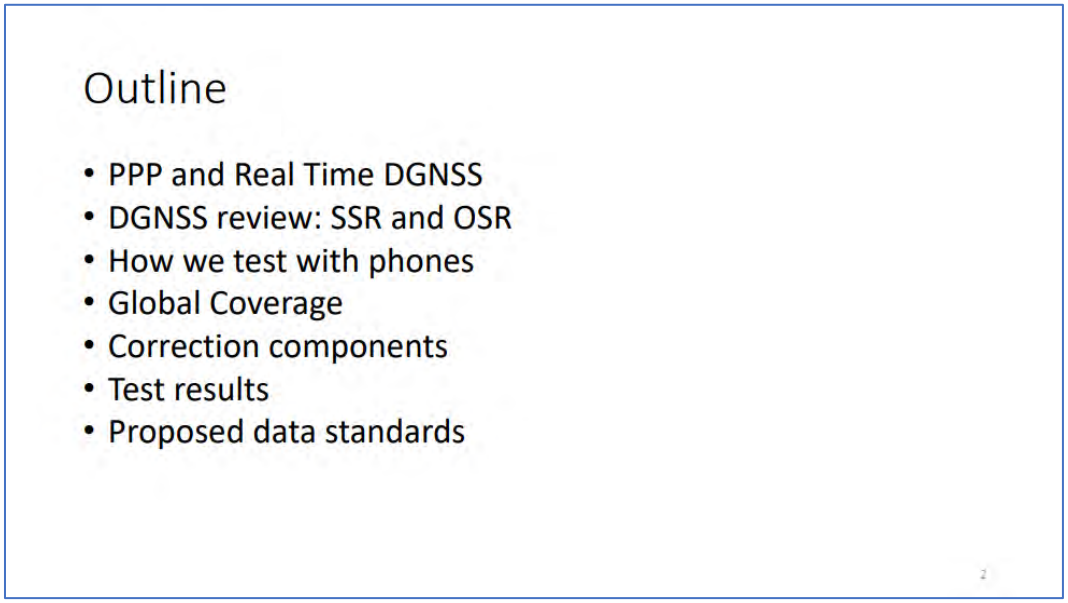
Slide 14

Part 2 – Dr. Frank Van Diggelen

Dr. van Diggelen said he be talking about application of GDGPS and Galileo high accuracy services for cellphones. The briefing covers the following topics: (1) difference between PPP and real-time Differential GNSS (DGNSS); (2) review of the kinds of DGNSS that can be used, and why; (3) how the testing on cellphones was conducted and its results (Slides 1-2).



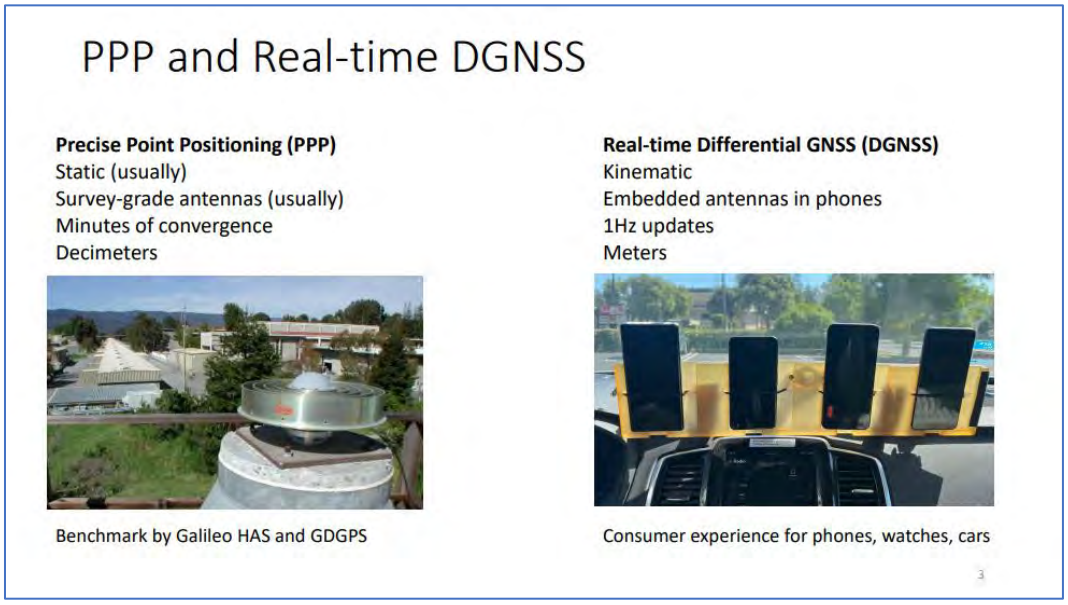
Slide 1



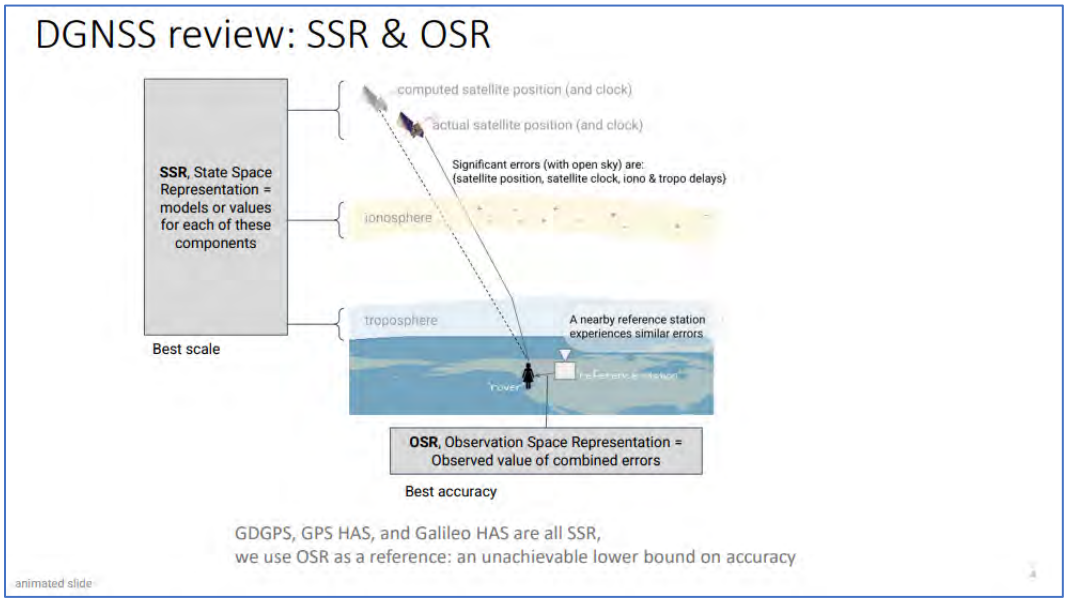
Slide 2

Slide 3 shows the difference between PPP and DGNSS. PPP is usually static, relies on survey-grade antennas (typically at a cost 10x that of a cellphone), convergence time is measured in minutes, and the accuracy is at the decimeter level. This is the benchmark used by Galileo. On the other hand, DGNSS is mostly kinematic, relies on the antennas already embedded in cellphones, updates are provided in real-time at a rate of 1 Hz, and the accuracy is at the meter level.

Slide 4 provides a brief review of how DGNSS works. Error sources include the difference between the computed and actual position and time of a GNSS satellite, ionospheric errors, and tropospheric errors. There are two ways to correct these errors. The first one is the so-called SSR, or Space State Representation, where you represent each one of the states and provide a correction for these errors. The second is called OSR, or Observation State Representation, where a station nearby measures the entire delay and doesn't really care of what the components of the delay are. OSR provides the best possible accuracy since, usually, you have a survey-grade base station. However, this doesn't scale well since you need tens of thousands of base stations to cover the whole globe. SSR gives you a global scale. Both GDGPS and Galileo HAS use SSR. OSR is used to provide benchmark on how well you could do.



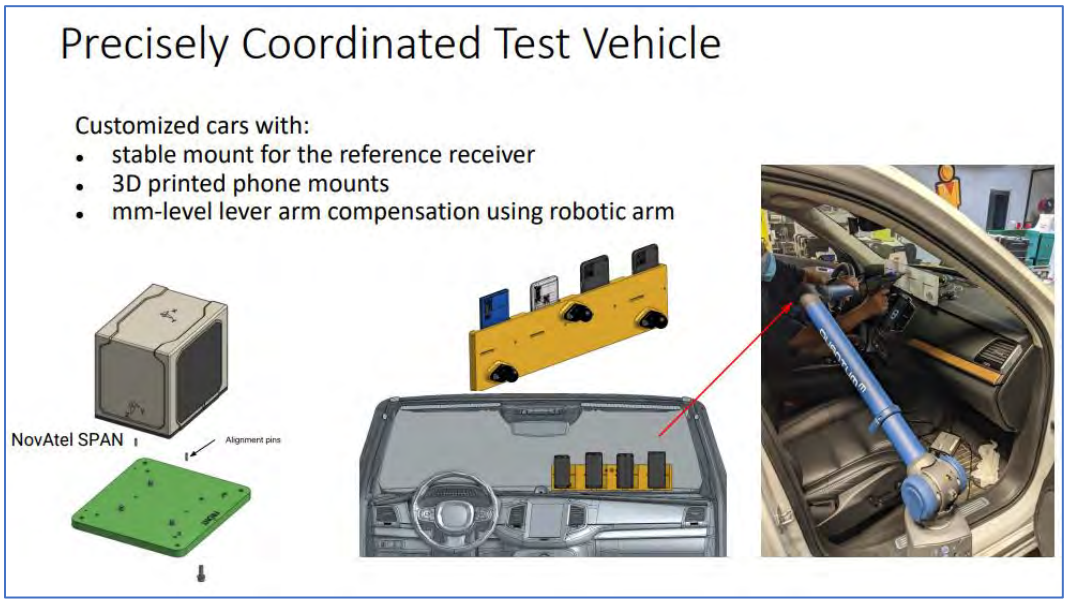
Slide 3



Slide 4

Slide 5 shows how testing is done. Several custom-adapted vehicles are used. Some of the key features are a stable mount for a reference survey-grade receiver coupled with a tactical-grade Inertial Measurement Unit (IMU) to provide a truth reference at the millimeter level for the antenna of the reference receiver. Then you have to adjust for the lever arm where the phones are secured.

A number of tests have been conducted. Slide 6 depicts the test set up. Twenty-five drive traces were done in the San Francisco, VA, Bay area using seven different phone models and three GNSS chip vendors.

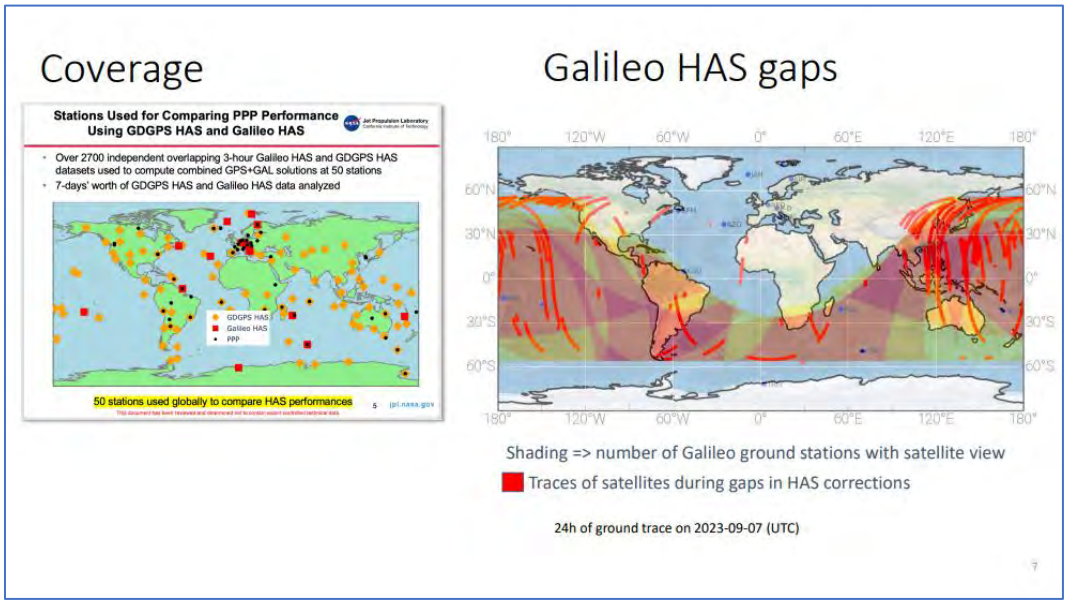


Slide 5

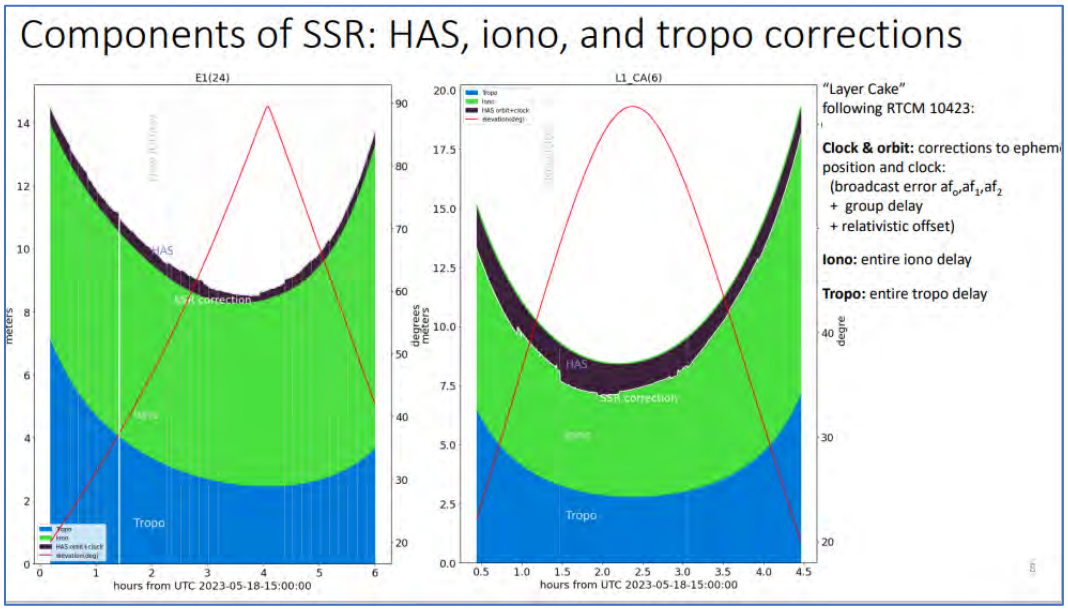
Slide 6

Slide 7 shows the coverage experience during the tests. As expected, there are gaps in the Galileo HAS coverage since its reference stations are located close to the European region. In the graph on the right, the darker a shaded area the fever number of Galileo ground stations can see the satellite. The lines show the satellites being observed during the drive tests but couldn't get Galileo corrections for them. The way SSR works is that it is doing GNSS in reverse. Instead of observing satellites and working out the user location, the ground stations know where they are and will observe the carrier and code from the satellite and work out what the errors are. At some point the solution will start to diverge and the system will stop giving you a correction.

Slide 8 shows the components of the corrections. The brown part shows the orbit and clock correction provided by the high accuracy service. Note how the orbit and clock errors are small compared to the ionospheric and tropospheric errors. Consistently, the GPS orbit and clock errors are larger that Galileo. Thus, GPS needs this kind of system more than Galileo does.



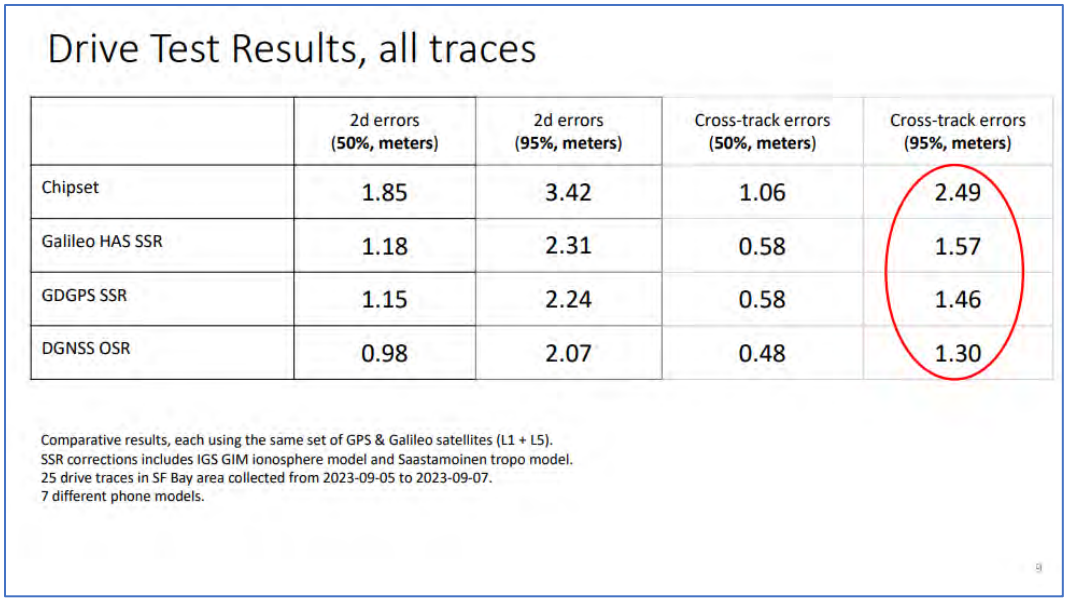
Slide 7



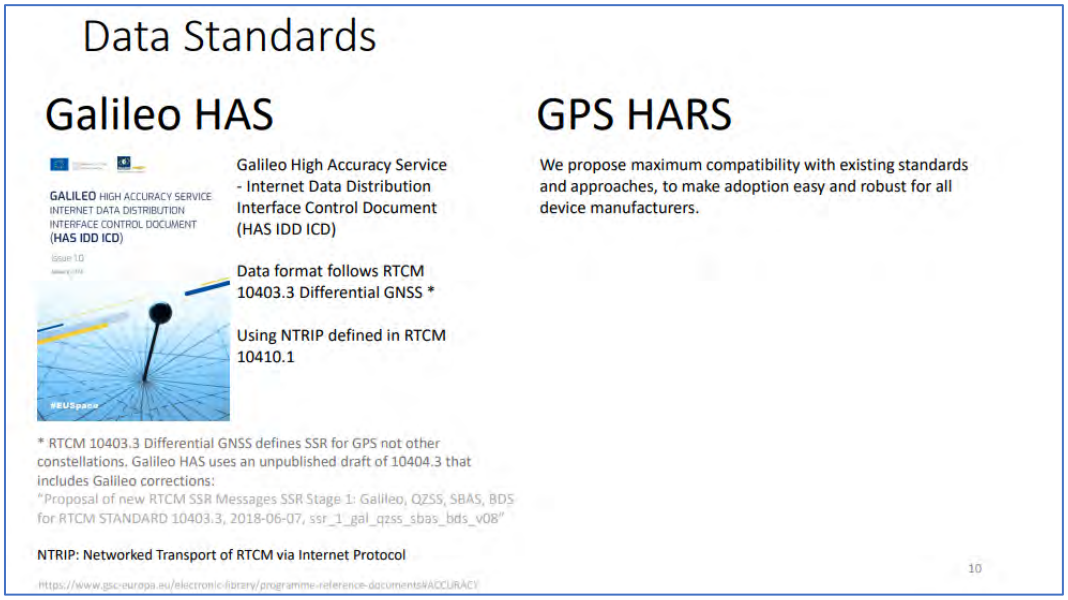
Slide 8

The test results are summarized on Slide 8. It shows the position we could get with just the chipsets (that is, no high accuracy service corrections from either GPS or Galileo), and below what we are getting using a high accuracy service. The table shows the cross-track error since a key application we are looking at is using a cellphone to determine with lane you are in while driving. These results are encouraging. As we refine our models, we are confident these number will continue to improve.

Slide 9 depicts the standards to deliver this data to users. Galileo uses existing standards. Therefore, the ECAS subcommittee proposes that for a GPS High Accuracy Service there be maximum compatibility with existing standards and approaches. This will make its adoption easier and provide robust capabilities for all device manufacturers. NTRIP, or Networked Transport of RTCM via Internet Protocol, is the standard that would be used to distribute corrections via the internet.

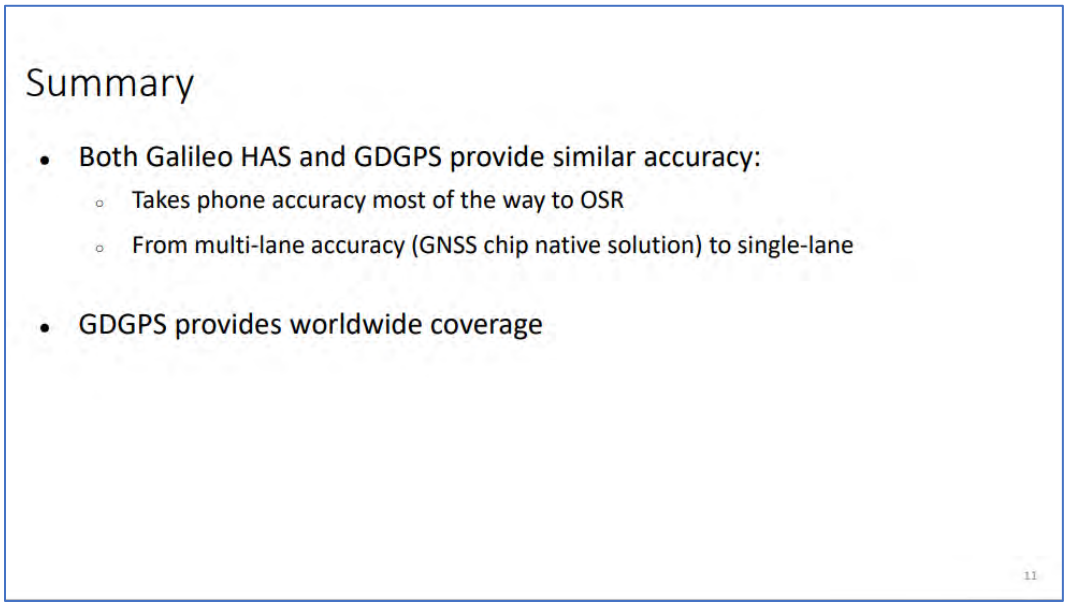


Slide 9



Slide 10

In summary, we've seen that both Galileo HAS and GDGPS provide similar accuracy, and sufficient to go from multi-lane accuracy down to single lane accuracy (Slide 10). However, a key advantage of GDGPS is that it provides worldwide coverage.:



Slide 10

Discussion

Dr. Parkinson expressed concern about having four cellphones this close together during the test. In the past we've seen how, when placed this close, sometimes there can be distortions.

Dr. van Diggelen responded that to mitigate that issue they moved the antennas around during testing. During testing they didn't see a consistent difference depending on where each phone was located on the test rack.

Gen James asked where JPL stands in trying to get the distribution of corrections funded by other USG organizations.

Dr. Komjathy responded that they have begun talking with other USG organizations, and at this point he's optimistic.

Gen James asked J.J. Miller if there has been progress in getting other agencies to take over GDGPS funding.

Mr. Miller said that there are on-going discussions for cost-sharing to provide GDGPS baseline capabilities.

Dr. Betz asked what would be the time to implement GDGPS dissemination via the internet should funding be available?

Dr. Komjathy said it would be within months.

Mr. Murphy noted that while the accuracy levels look great, but what about resilience?

Dr. van Diggelen responded that the resilience would come from providing the broadcast database. That would help to determine if you are being spoofed and then you can do longer coherent integration by wiping out the data bits.

Mr. Murphy noted that another thing to bring out is integrity. Has any thought been put on that?

Dr. Komjathy said that right now JPL is making a transition from commercial sponsorship of GDGPS to government sponsorship. However, also providing integrity is something on JPL's plate to do sometime in the future.

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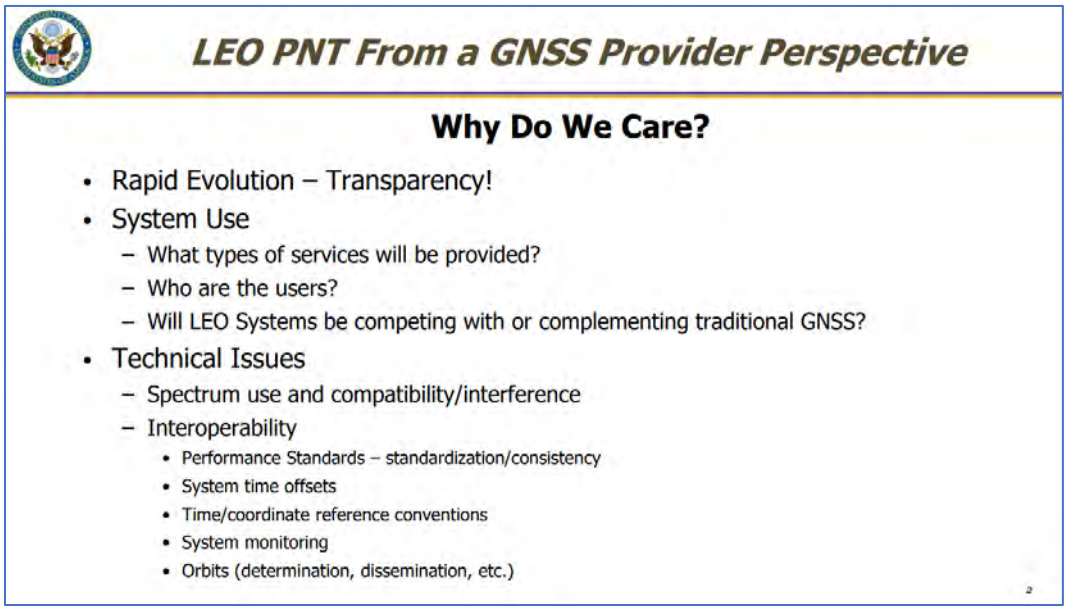
Low Earth Orbit PNT Landscape
Mr. Jeff Auerbach, *Senior Foreign Affairs Officer, Office of Space Affairs, Dept. of State*
Mr. Bryan Chan, *Member, PNTAB*

Part 1 - Mr. Jeff Auerbach

Mr. Auerbach noted he would provide an overview about LEO PNT constellations and related activities at the ICG. As new systems are rapidly coming online we want to ensure there is transparency on what these systems are doing, including the system issues (types of services provides, whether they are competing with or complementing traditional GNSS, etc.) and associated technical issues such as spectrum use (to ensure compatibility and avoid interference) and wherever possible to pursue interoperability through performance standards (for standardization), system time offsets, time/coordinate reference conventions, systems monitoring, data dissemination, etc. (Slides 1-2).

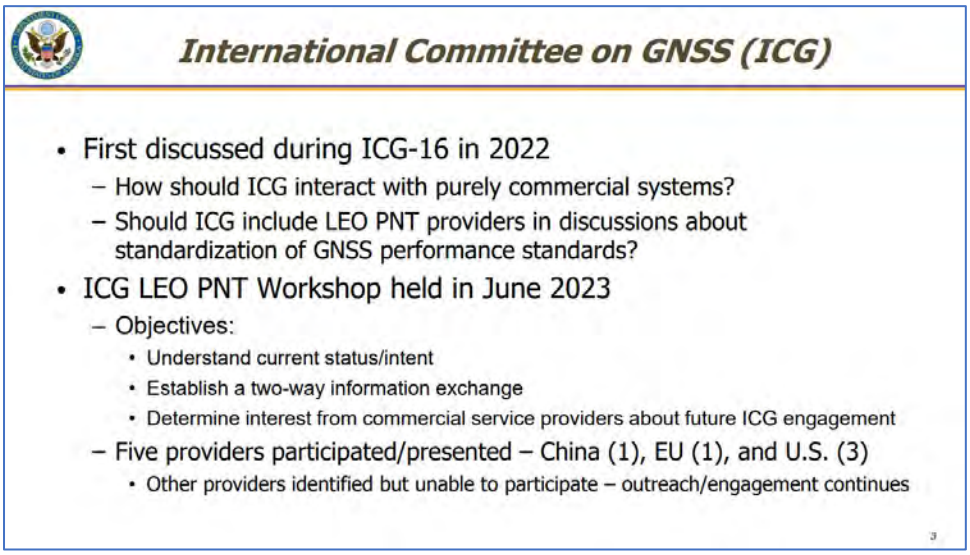
Slide 1



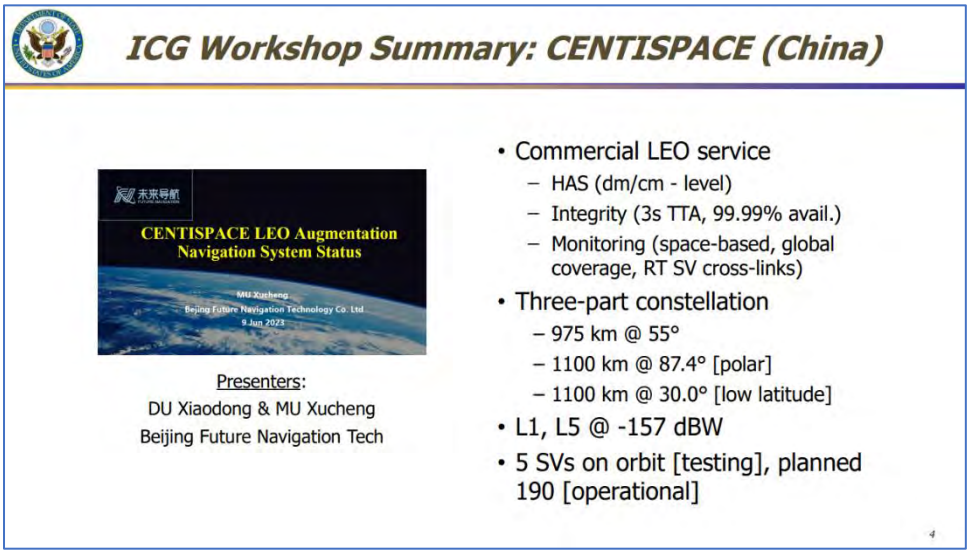
Slide 2

This issue first came up during a discussion within the ICG Working Group S (Systems, Signals, and Services), which is chaired by the U.S., during the ICG-16 meeting in 2022 (Slide 3). The question was on how the ICG should interact with all these other commercial LEO PNT systems and whether they should be contributing to ICG discussions on standardization. This led to an ICG Workshop on LEO PNT in June 2023. LEO PNT providers were invited to this workshop with the objective to understand the status and intent of their systems, establish a two-way information exchange, and determine their interest to keep engaging with the ICG. Five LEO PNT providers participated in this workshop, including one from China (CENTISPACE), one from the EU (FutureNav), and three from the U.S. (TrustPoint, Xona Space Systems, and Satelles). A key issue the ICG had to deal with was how to address concerns about commercial proprietary issues raised by the U.S. companies, so before the workshop we organized separate briefings to U.S. Government people only. Slides 4-9 provide an overview of these systems. The actual presentations are available at the ICG portal (https://www.unoosa.org/oosa/en/ourwork/icg/working-groups/s/wg-s-workshop-leo-pnt-2023.html). Outreach activities will continue with other commercial LEO PNT providers that did not participate in this workshop to, hopefully, engage them in future ICG meetings.

Slide 4 summarizes the capabilities of the CENSISPACE system from China. This system was presented as a commercial LEO service providing a High Accuracy Service, integrity, and space-based monitoring using crosslinks. The system uses the L1 & L5 frequencies. As of June 2023, they had 5 satellites in orbit undergoing testing and they are planning to have 190 satellites.



Slide 3

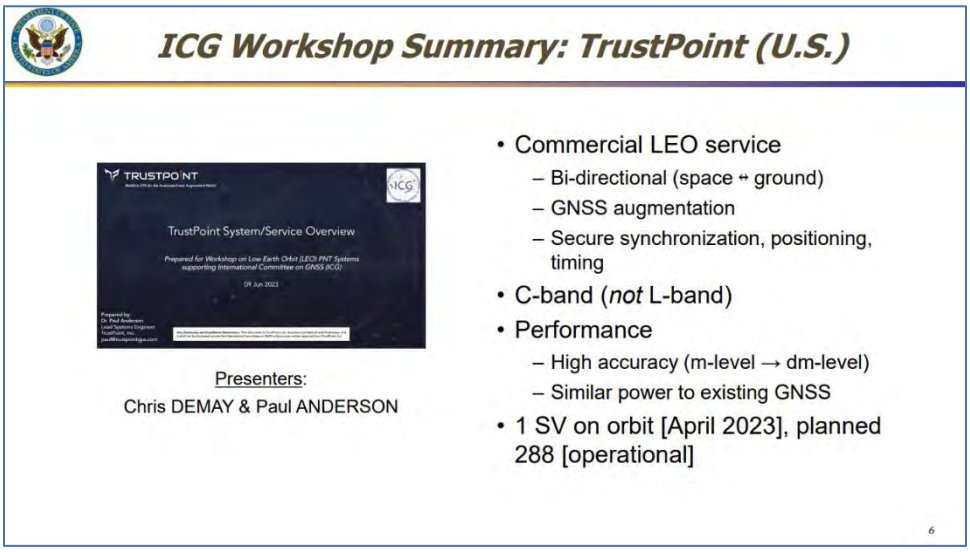


Slide 4

Slide 5 summarizes the presentation from ESA on the FutureNAV, a concept for evolution towards multi-layer PNT. Multiple system concepts were presented, including purpose-built LEO PNT satellites, combination with satellite communications, and using signals of opportunity.

Slide 6 summarized the briefing by TrustPoint, a U.S. commercial LEO service provider. A key difference from other systems is that this one is provided on C-band. It has a High Accuracy Service and as of June 2023 they had one satellite in orbit, and plan for a 288-satellite operational system.

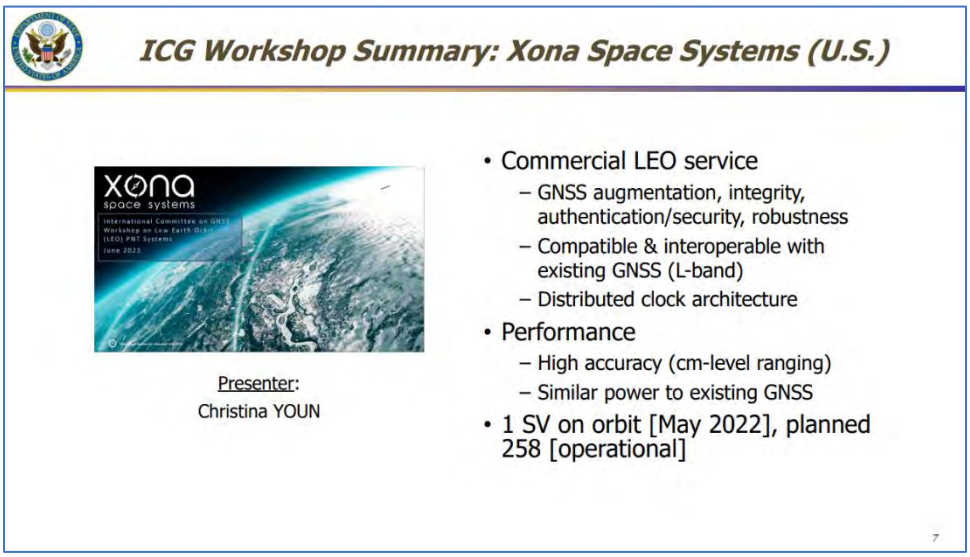
Slide 5



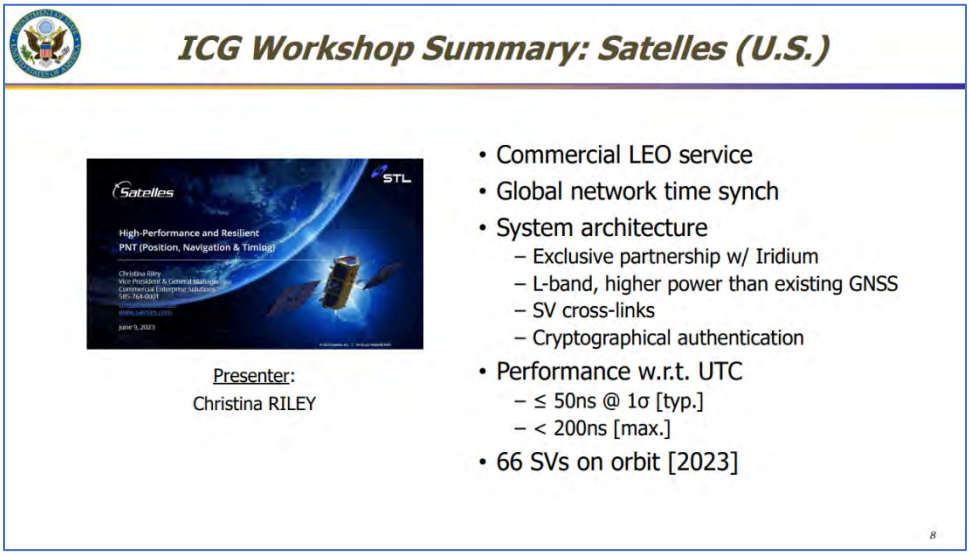
Slide 6

Slide 7 summarizes the briefing by Xona Space Systems, another U.S. commercial LEO service provider. As of May 2022, they had one satellite in orbit, and plan for a 258-satellite operational constellation.

Slide 8 summarizes the briefing by Satelles, another U.S. commercial LEO service provider in partnership with Iridium. This system currently has 66 satellites in orbit.

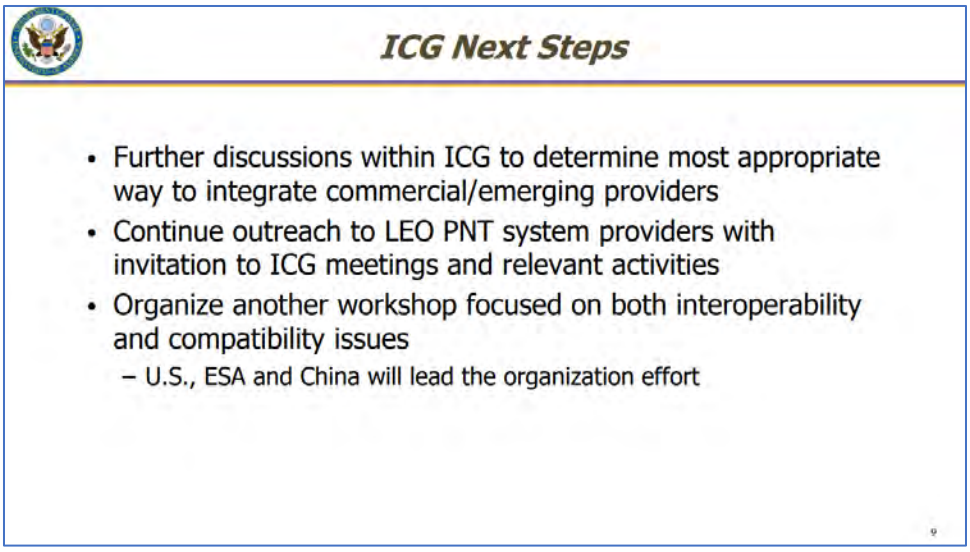


Slide 7



Slide 8

Finally, Slide 9 describes the next steps for the ICG. As noted earlier, the ICG continues to discuss the most appropriate way to integrate commercial / emerging providers. The ICG will also continue its outreach to other LEO PNT system providers with invitation to ICG meetings and relevant activities. A key issue within the ICG is to talk about compatibility and interoperability, and plan to organize another workshop in 2024. The U.S., ESA, and China are leading the organization of this workshop.



Slide 9

Discussion:

Mr. Goward asked Mr. Auerbach if he was aware of other government programs, besides the EU.

Mr. Auerbach responded that the outreach was not limited to government or non-government programs. As for commercial systems, he is aware of at least two other systems, one being a company in Europe and another company in China.

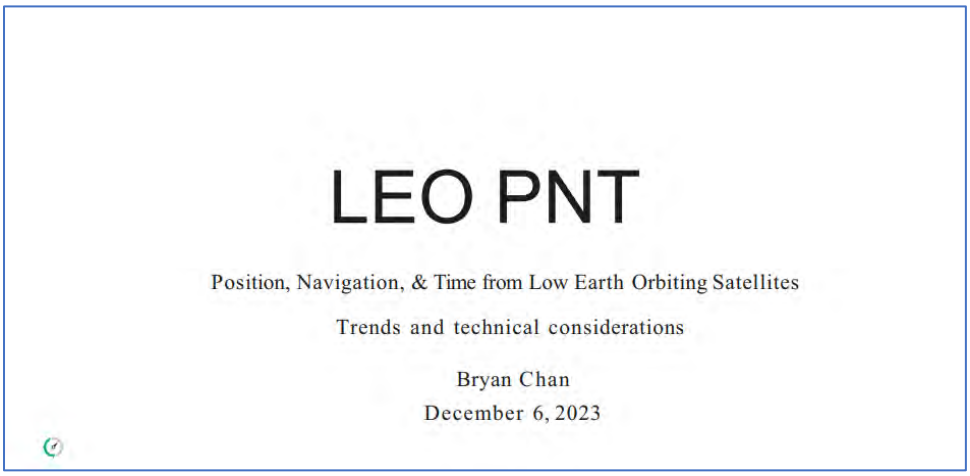
Mr. Goward asked if the other Chinese company is the one associated with a car manufacturer.

Mr. Auerbach said he doesn't believe that is the case. In any case, there may be other companies in China also looking at similar systems. He added that there are also target-of-opportunity systems such as OneWeb and Starlink.

[Ed. Note: See next page for part 2 of this briefing]

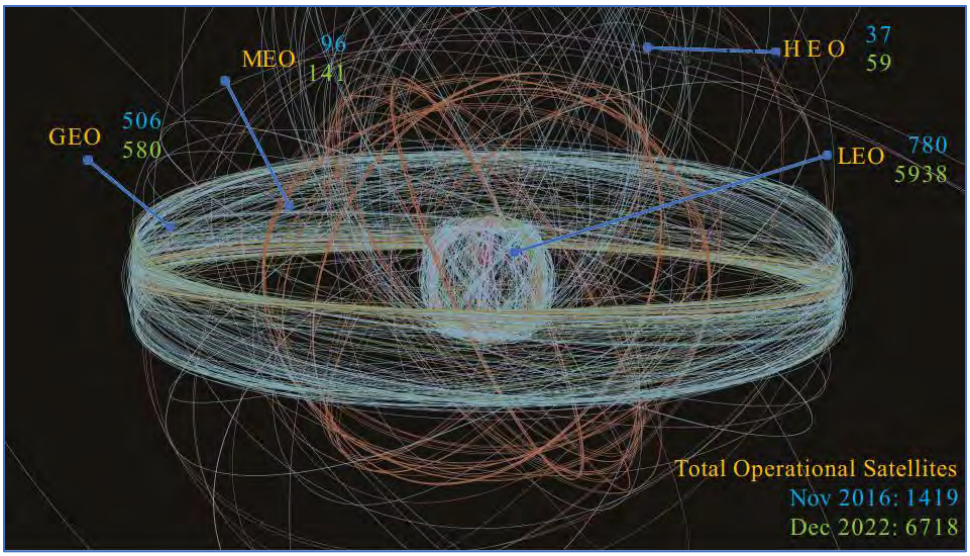
Part 2 - Mr. Bryan Chan

Mr. Chan noted that the goal of his briefing is to provide a high-level update on trends in LEO PNT (Slide 1).



Slide 1

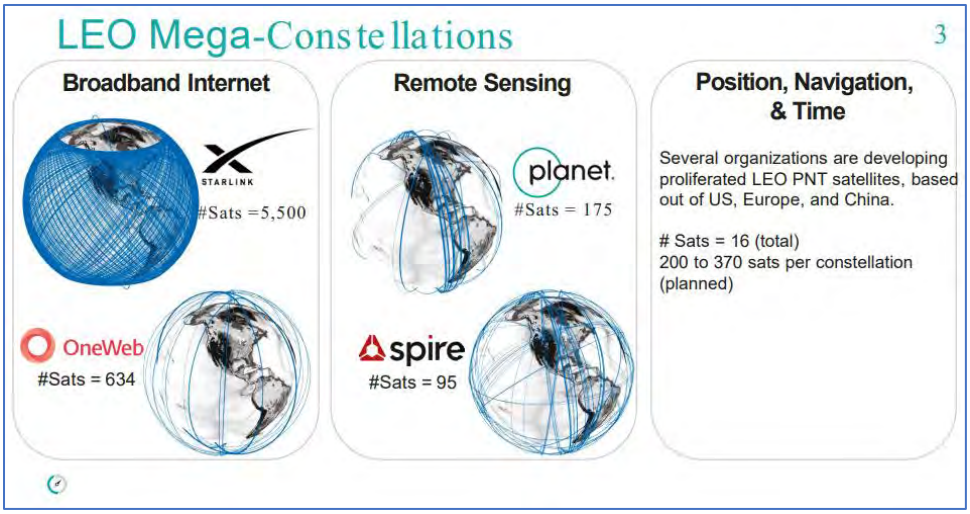
Slide 2 shows the total number of operational satellites in Nov. 2016 vs. Dec. 2022. Note the huge jump in satellites in just six years, the lion's share being in LEO. This chart is already outdated since as of Dec. 2023 there are already well over 7000 active satellites in LEO.



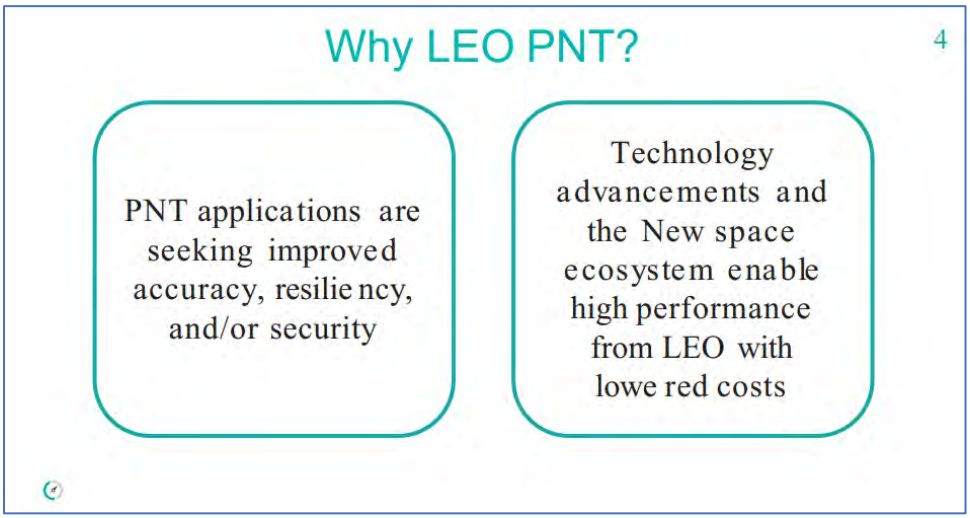
Slide 2

Slide 3 shows what LEO mega-constellations are doing. These have been categorized into three major uses: broadband internet, remote sensing, and PNT. Most of them are Starlink satellites, which currently operates over 5,500 communication satellites, followed by OneWeb with 634 satellites. OneWeb has expressed interest in providing at least timing services with their second-generation payloads. Starlink & OneWeb are just the two main LEO mega-constellations. Currently there are approximately 16 dedicated LEO PNT satellites in orbit, but these could quickly expand into 200-370 satellites per LEO PNT constellation.

So, why LEO PNT and why now (Slide 4)? This comes from the user community, as there are many PNT applications seeking improved accuracy, availability in challenged environments, resiliency, and security. Technology advancements and the new space ecosystem enable high performance from LEO satellites at lower cost for both their components as well access to space.



Slide 3

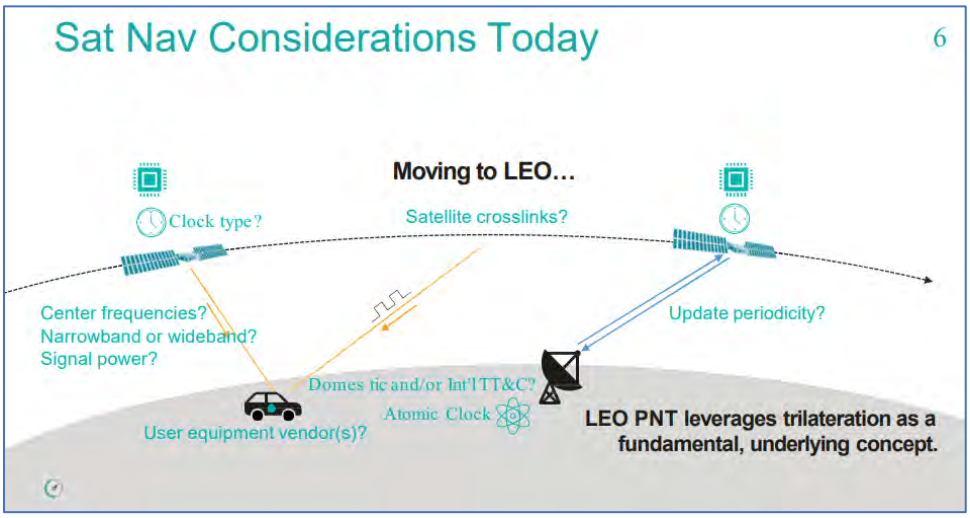


Slide 4

Slide 5 describes the interest in LEO from the ION community. This is based on a keyword search of the technical programs for 2019 and 2022. Note the 3X fold increase in interest in LEO from 2019 to 2022.

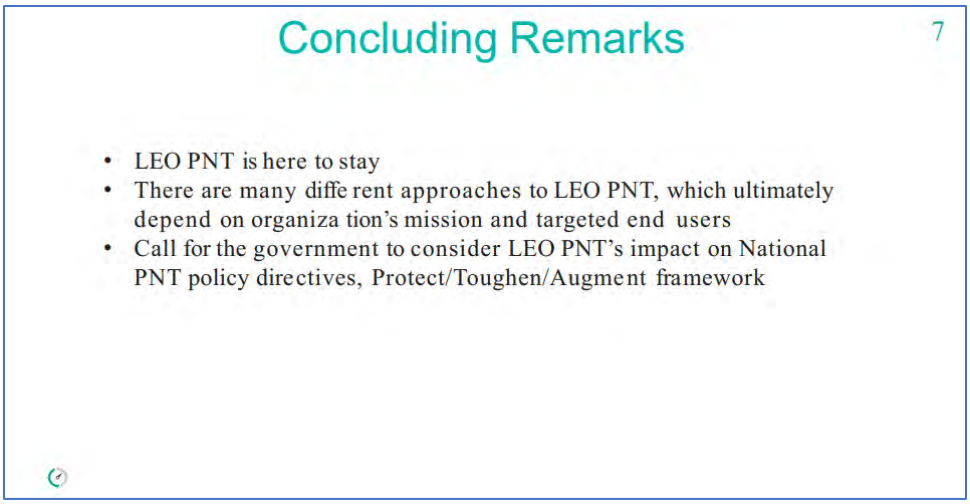
Slide 6 showcases the different approaches operations are looking at and implementing. It comes down to satellite and ground segment architectures and folding in the user equipment side, whether it is something that would fit in one's pocket or more of an industrial scale use.

Slide 5



Slide 6

In conclusion, LEO PNT is here to stay (Slide 7). There is a lot of user interest, many international arbiters, and the stakes are very high. Exactly what form LEO PNT will become remains to be seen. This is something that could be shaped by folks such as the Board. It is essential that the USG consider the impact of LEO PNT on National PNT policy directives. Similarly, such LEO PNT systems can also impact the board's PTA framework.



Slide 7

Discussion:

The Hon. Greg Winfrey asked if there is a deconfliction strategy for having so many satellites orbit, such as Space Traffic Management?

Mr. Chan noted there are plans for deorbiting satellites after their end-of-life. Also, even within LEO there is stratification. For example, the motivation for LEO communication satellites is to operate as close to Earth as possible (200-300 km) in order to minimize internet latency. With PNT it is different. Since it uses a one-way link, such satellites will want to be at a higher altitude in order to maximize their coverage on the surface.

Mr. Higgins noted that a problem he sees is that these LEO PNT systems are in essence competing with free GNSS services.

Mr. Chan responded that, yes, that would be the case if LEO PNT operators were striving to be as good as GNSS. Therefore, there needs to be a step change in performance, such as getting down to cm level with integrity at a global level, including urban and suburban areas. Thus, both government and commercial users can benefit from these. Also, frequency diversity would provide resilience to some of the threats to GNSS.

Mr. Miller noted that going back historically we are all aware of the many satcom companies that had big plans but went belly up. He asked Mr. Chan what he thinks is the threshold for success for these LEO PNT constellations.

Mr. Chan responded that the catalyst is twofold. The first part is the dramatic decrease in launch and component costs. The second part is user interest, in particular commercial users as they incorporate an Internet-of-Things approach to PNT and a need-to-know things such as what side of the street you are on, etc.

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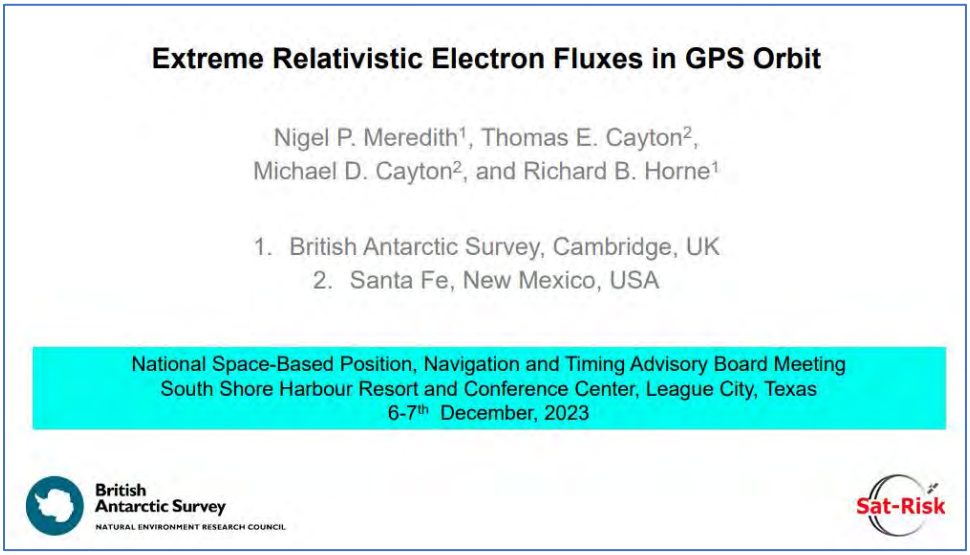
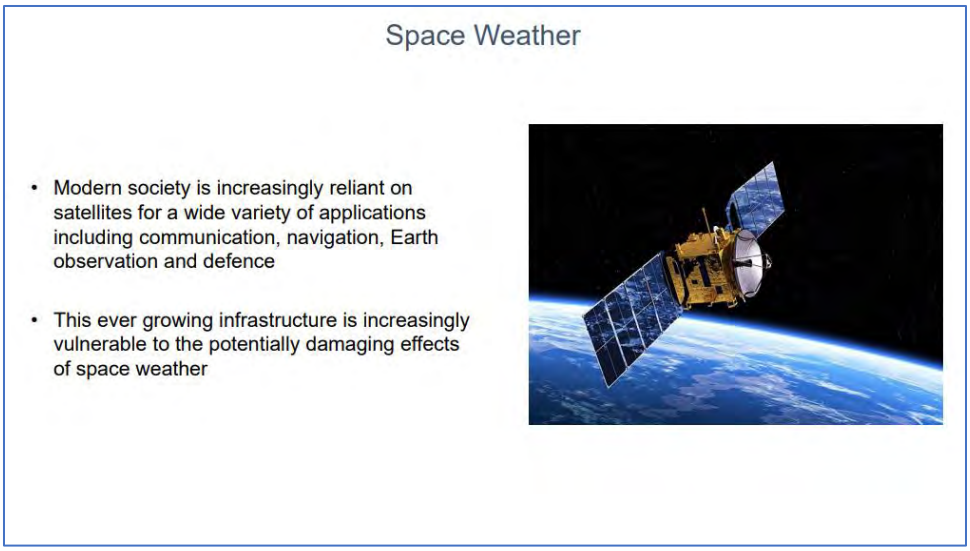
Extreme Relativistic Electron Fluxes in GPS Orbit: Space Weather Effects on GNSS Users
Dr. Nigel Meredith, *Space Weather Research Scientist, British Antarctic Survey*

Dr. Meredith thanked his collaborators on this study, Thomas E. Cayton, Michael D. Cayton, and Richard B. Horne (Slide 1). He noted how modern society is becoming increasingly reliant on satellites for a wide variety of applications including communication, navigation, Earth observation and defense (Slide 2). This ever-growing infrastructure is increasingly vulnerable to the potentially damaging effects of space weather.



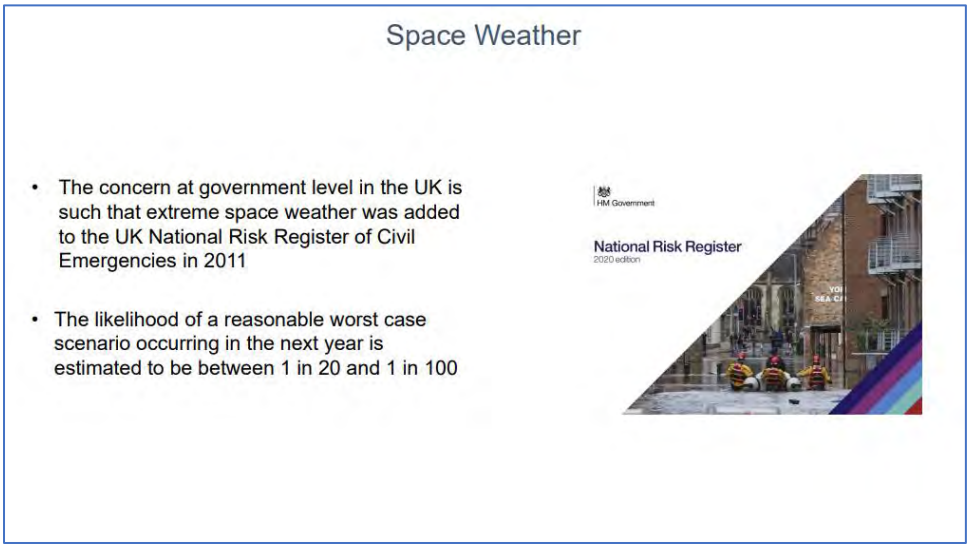
Slide 1



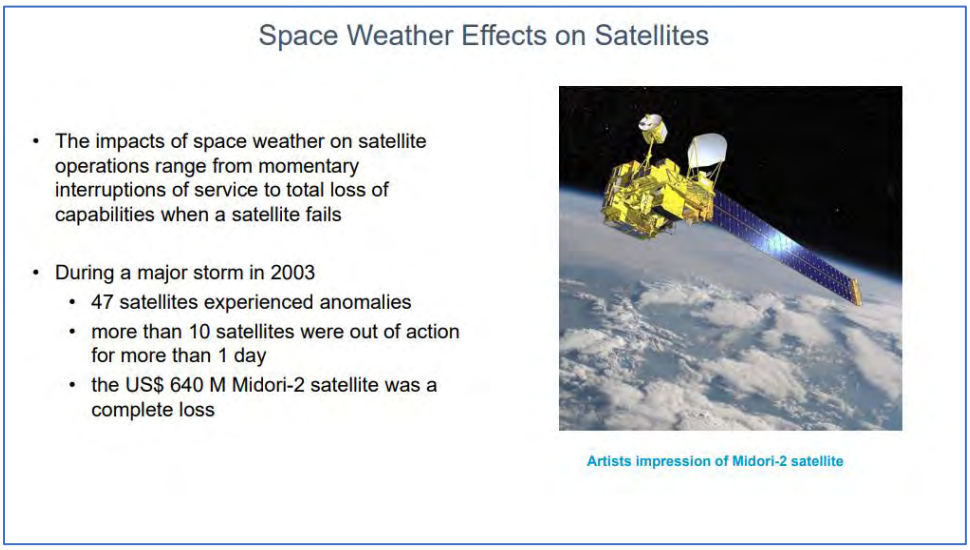
Slide 2

In the UK, the concern at government level is such that extreme space weather was added to the UK National Risk Register of Civil Emergencies back in 2011, where the likelihood of a reasonable worst-case scenario occurring each year is estimated to be between 1 in 20 and 1 in 100 (Slide 3).

The impacts of space weather on satellite operations range from momentary interruptions of service to total loss of capabilities when a satellite fails (Slide 4). For example, during a major storm in 2003, 47 satellites experienced anomalies, more than 10 satellites were out of action for more than 1 day, and the joint U.S.-Japan ADEOS-II (Advanced Earth Observing Satellite-II) / Midori-II satellite (costing US$ 640M) was a complete loss.



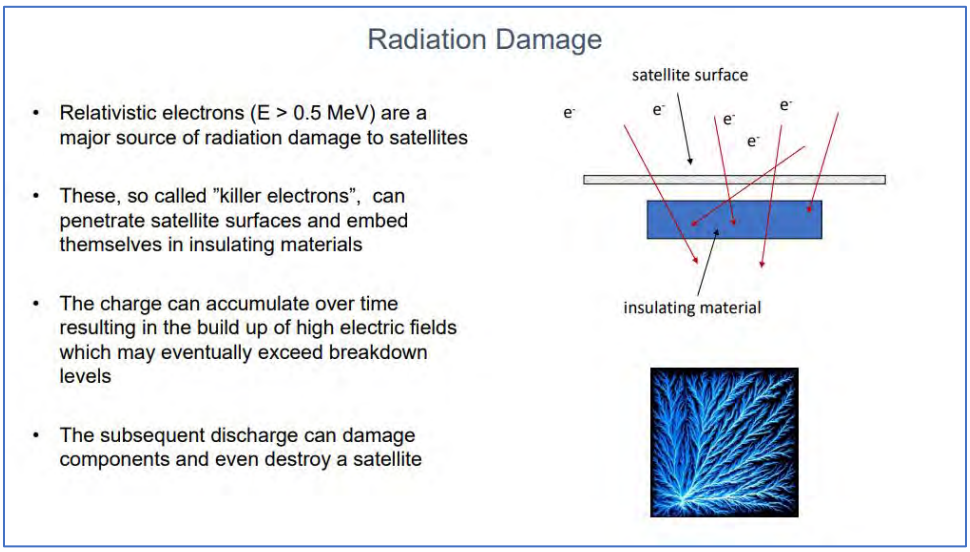
Slide 3



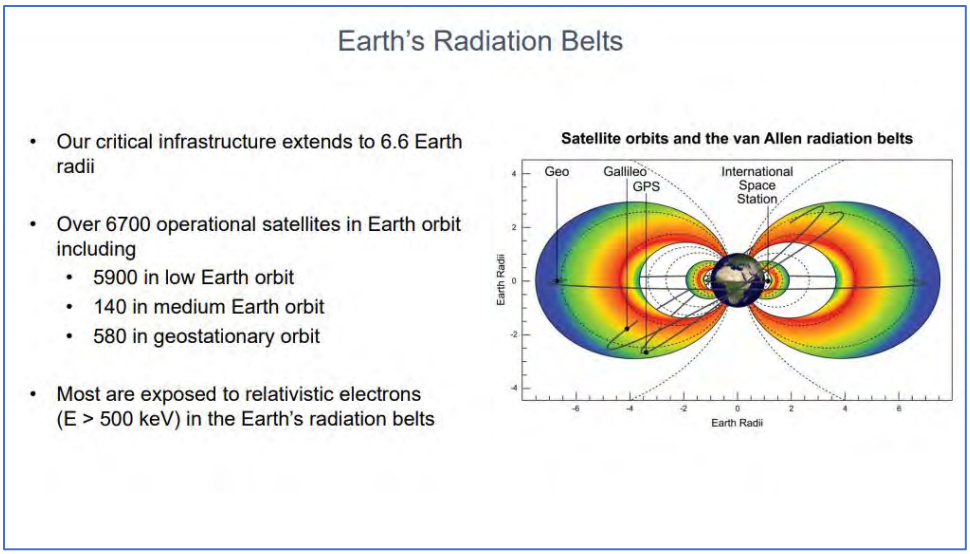
Slide 4

Relativistic electrons are a major source of radiation damage to satellites (Slide 5). These, so called "killer electrons", can penetrate the satellite's surface and embed themselves in insulating materials and ungrounded conductors. The charge can accumulate over time resulting in the buildup of high electric fields which may eventually exceed breakdown levels. The subsequent discharge can cause electric circuit upsets, damage components, and in exceptional cases even destroy a satellite.

Our critical infrastructure extends to GEO, and there are currently over 6700 operational satellites in Earth orbit (Slide 6). Most of these satellites are exposed to relativistic electrons in the Earth's radiation belts at some, or all points, in their orbits.



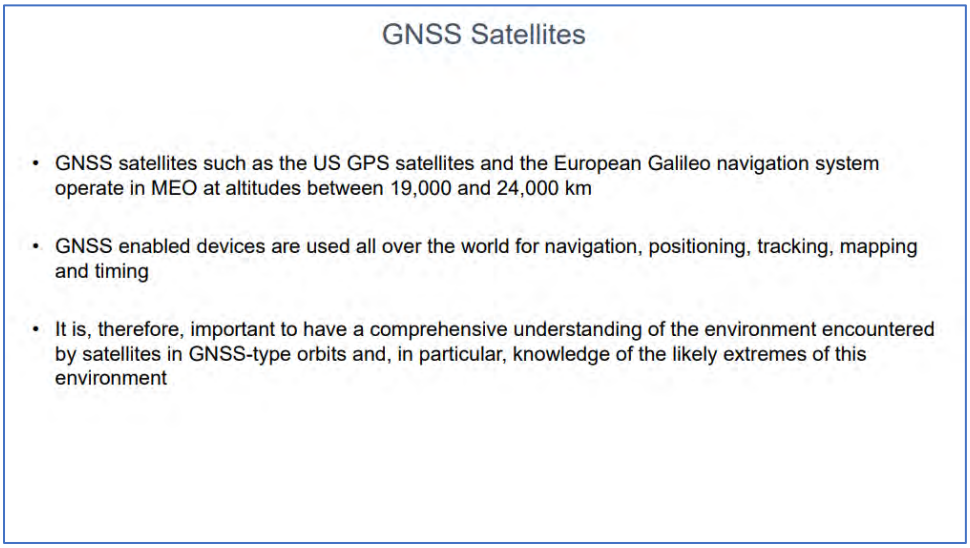
Slide 5



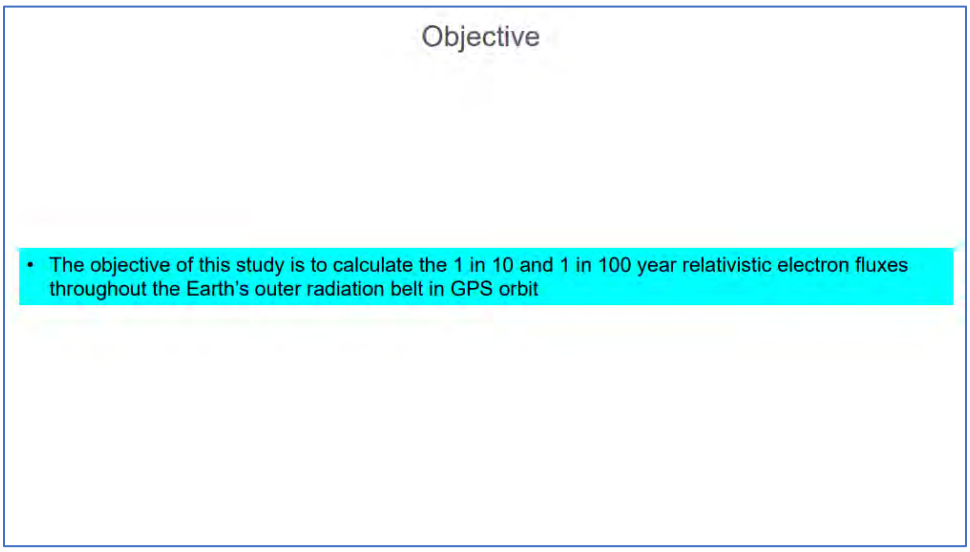
Slide 6

GNSS satellites such as the U.S. GPS satellites, and the European Galileo satellites, operate in Medium Earth Orbit (MEO) at altitudes between about 19,000 and 24,000 km (Slide 7). GNSS-enabled devices are used all over the world for a wide variety of applications including navigation, positioning, tracking, mapping, and timing. It is, therefore, important to have a comprehensive understanding of the environment encountered by satellites in GNSS-type orbits and, particularly, knowledge of the likely extremes of this environment.

The main goal of this study was to calculate the 1 in 10 and 1 in 100 -year relativistic electron fluxes throughout the Earth's outer radiation belt in GPS orbit.



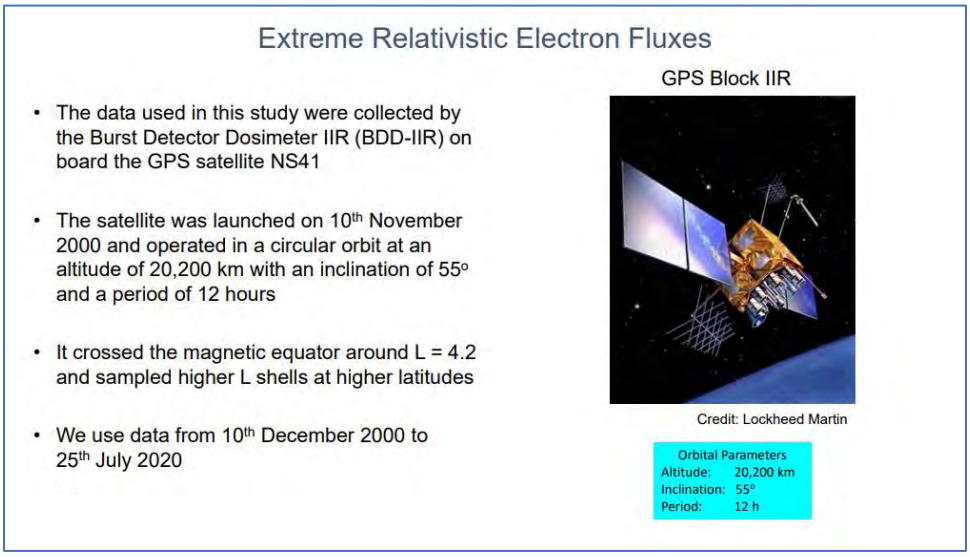
Slide 7



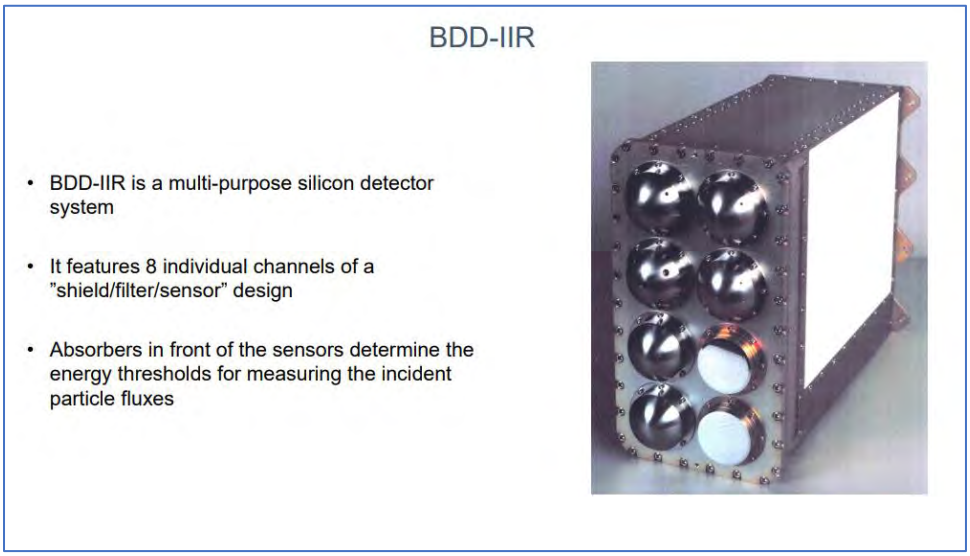
Slide 8

As shown on Slide 9, the data used for this study were collected by the Burst Detector Dosimeter IIR (BDD-IIR) on board a GPS satellite NS41 [Ed. note: SVN41, Block IIR]. This satellite was launched on 10th November 2000 and operated in a circular orbit at an altitude of 20,200 km with an inclination of 55 degrees and a period of 12 hours. It crossed the magnetic equator around L-shell 4.2 and sampled higher L shells at higher latitudes. The L-value describes the set of magnetic field lines which cross the Earth's magnetic equator at a number of Earth-radii equal to the L-value. For this study twenty years of data was used, spanning from 10 December 2000 to 25 July 2020.

The instrument itself (BDD-IIR) is a multi-purpose silicon detector system (Slide 10). It features eight individual channels of a "shield/filter/sensor" design, and absorbers in front of the sensors determine the energy thresholds for measuring the incident particle fluxes.



Slide 9



Slide 10

Slide 11 describes how the data was processed. Differential fluxes at 10 energies in the range between 0.6 and 8 MeV (Million electron Volts) were written into separate files for each crossing of 12 equally spaced L shells ranging from 4.25 to 7. Daily averaged fluxes were then computed for each energy and L shell. Here L is the McIlwain L value computed using the International Geomagnetic Reference Field (IGRF) internal field and the Olson-Pfitzer quiet time external field.

To analyze the data, monthly and annual summary plots were created (Slide 12). The figure shows the annual summary plot at L=4.5 for 2010 for six representative energies together with relevant solar wind and other geophysical parameters (bottom three panels). The symbols represent the daily averages, and the dotted lines in the top six panels represent the 1% exceedance levels. Plots such as this were produced for all the years and every month. At each energy the fluxes are characterized by relatively rapid increases followed by gradual decays lasting many days.

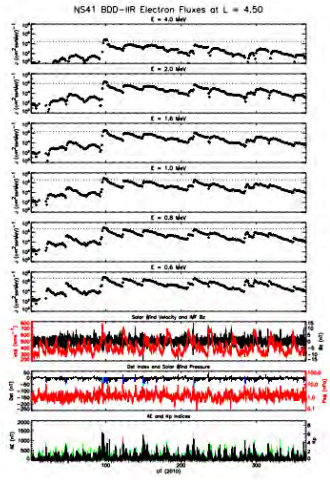
Data Processing

- Differential fluxes at 10 energies in the range $0.6 \leqq E \leqq 8$ MeV were written into separate files for each crossing of 12 equally spaced L shells in the range $4.25 \leqq L \leqq 7.00$
- Daily averaged fluxes were then computed for each energy and L shell
- Here L is the McIlwain L value computed using the IGRF internal field and the Olson-Pfitzer quiet time external field

Slide 11

Annual Plots

- To inspect the data we produced annual summary plots
- This figure shows the annual summary plot at L = 4.5 for 2010 for six representative energies
- At each energy the fluxes are characterised by relatively rapid increases followed by gradual decays lasting many days

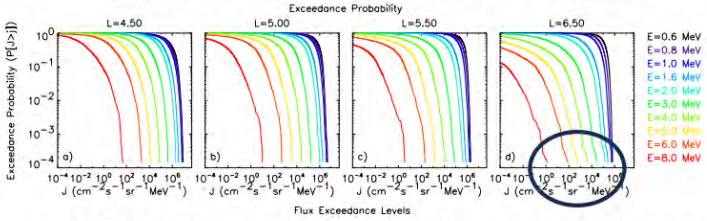


Slide 12

To look at the data, they first plotted the exceedance probabilities as a function of electron flux for each energy and for each value of L (Slide 13). The chart shows four representative values moving from L=4.5 to L=6.5. As expected, the observed flux for any given exceedance probability decreases with increasing energy. In the heart of the outer radiation belt (L = 4.5) the largest observed fluxes cover over five orders of magnitude. At L = 6.5, on field lines that map to geostationary orbit, the largest fluxes are factors of 13 & 34 lower than those at L = 4.5 at E = 0.6 and 8.0 MeV respectively.

The main objective of this study is to determine the 1 in 10 and 1 in 100 year daily average electron flux for specified energies and L shells. Since daily averages were available, and to compare with previous studies, they used the exceedances over a high threshold method. For this approach, the appropriate distribution function is the Generalized Pareto Distribution (GPD).

Statistical Analysis of NS41 BDD-IIR Fluxes



- The observed flux for any given exceedance probability decreases with increasing energy
- In the heart of the outer radiation belt, at L = 4.5, the largest observed fluxes cover over 5 orders of magnitude ranging from 8.9×10^6 $cm^{-2}s^{-1}sr^{-1}MeV^{-1}$ at E = 0.6 MeV to 46 $cm^{-2}s^{-1}sr^{-1}MeV^{-1}$ at E = 8.0 MeV
- At L = 6.5, on field lines that map to geostationary orbit, the largest fluxes are factors of 13 and 34 lower than those at L = 4.5 at E = 0.6 and 8.0 MeV respectively

Slide 13

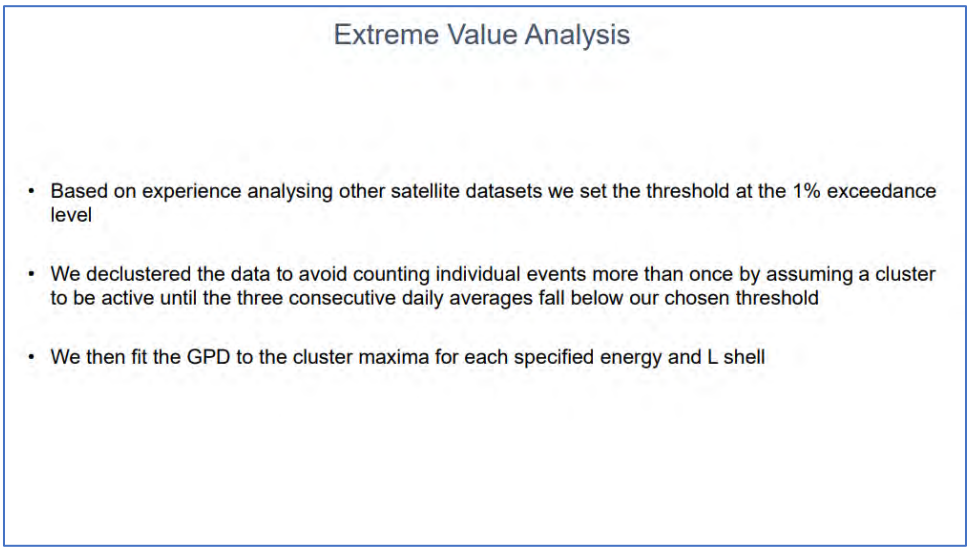
Extreme Value Analysis

- The main objective of this study is to determine the 1 in 10 and 1 in 100 year daily average electron flux for specified energies and L shells
- Since daily averages are available and to compare with previous studies we use the exceedances over a high threshold method
- For this approach the appropriate distribution function is the Generalised Pareto Distribution (GPD)

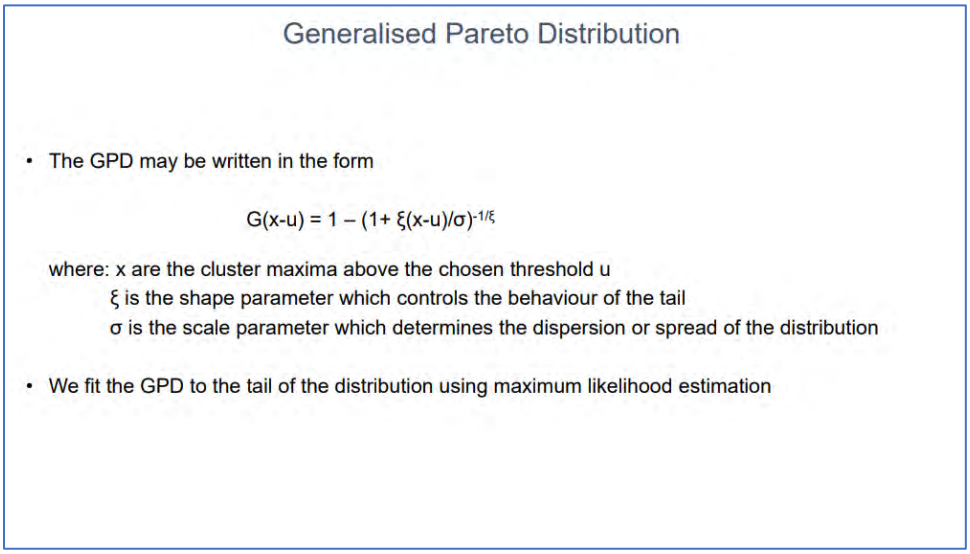
Slide 14

Based on experience analyzing other satellite datasets, for the analysis the threshold was set at the 1% exceedance level (Slide 15). The data was declustered to avoid counting individual events more than once by assuming a cluster to be active until the three consecutive daily averages fall below our chosen threshold. The GPD was then fit to the cluster maxima for each specified energy and L-shell.

Slide 16 describes the GPD function. The GPD was fit to the tail of the distribution using maximum likelihood estimation.



Slide 15



Slide 16

Slide 17 describes how the 1 in N-years event was determined. The plot of the flux against N is known as the return level plot.

Slide 18 shows the E=0.6 MeV daily average electron flux for the entire mission. The 1% exceedance level, chosen as the threshold for the analysis, is shown as the dotted line and the cluster maxima are coded red. The largest flux of E = 0.6 MeV electrons at L = 4.5 are largely seen from 2003-2008 and 2015-2018, during the declining phases of solar cycles 23 & 24. Interestingly, note that the largest event occurred near solar minimum, which shows us that an extreme event can occur at any time within a solar cycle.

Determination of the 1 in N Year Event

- The flux that is exceeded on average once every N years can be expressed in terms of the fitted parameters σ and ξ as:

$$x_N = u + (\sigma/\xi)(Nn_d n_c/n_{tot})^{\xi} - 1))$$

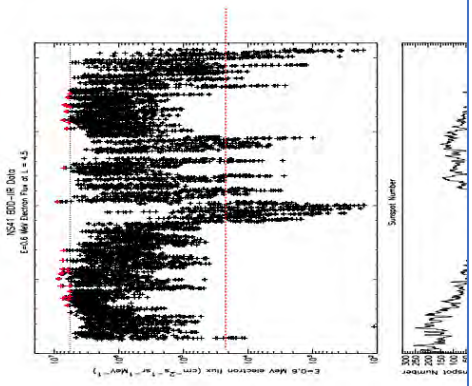
where n_d is the number of data points in a given year, n_c is the number of cluster maxima and n_{tot} is the total number of data points

- A plot of x_N against N is known as a return level plot

Slide 17

E = 0.6 MeV Electrons at L = 4.5

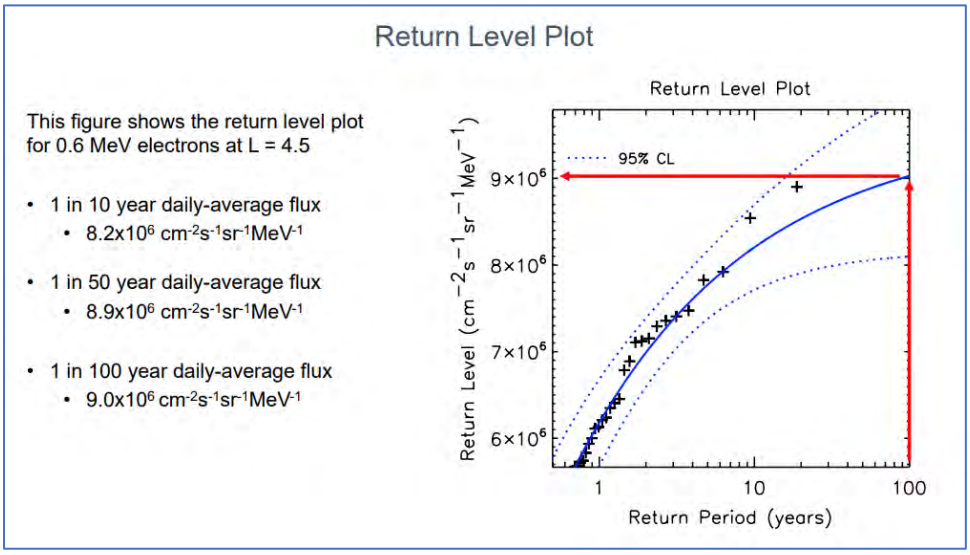
- This figure shows the E = 0.6 MeV daily average electron flux for the entire mission
- The 1% exceedance level, chosen as the threshold for the analysis, is shown as the dotted line and the cluster maxima are coded red
- However, the largest event occurred near solar minimum – showing that an extreme event can occur at any time in the solar cycle



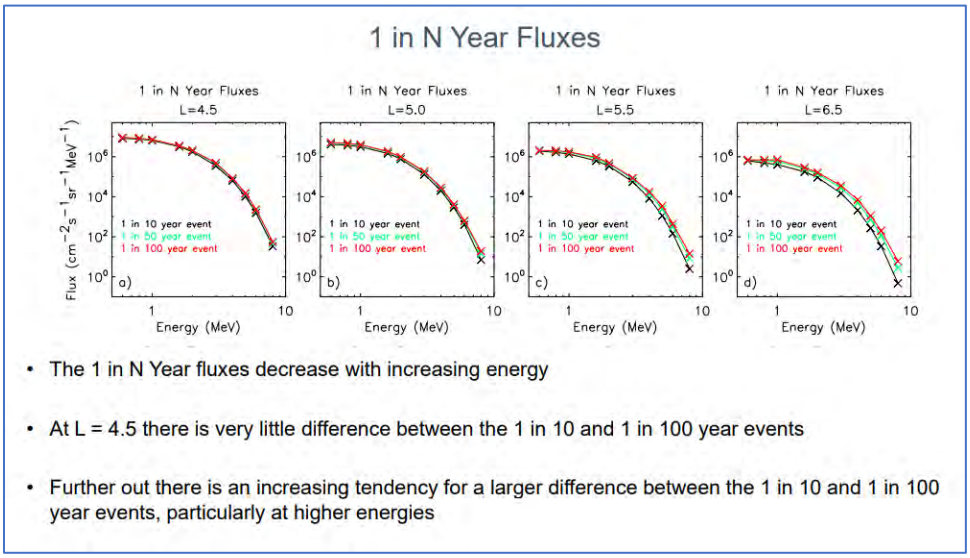
Slide 18

Slide 19 shows the return level plot for 0.6 MeV electrons at L = 4.5. The solid blue line shows the daily return level, the dotted lines show the 95% confidence limits, and the symbols represent the experimental return levels from the data. From this chart we can read the 1 in 10, 1 in 50, and 1 in 100 -year daily average flux.

Slide 20 shows the 1 in N year flux as a function of energy for four different values of L, starting with L=4.5 and ending with L=6.5. As expected, the 1 in N year fluxes decrease with increasing energy. At L=4.5 there is very little difference between the 1 in 10 and 1 in 100 -year events. With an increasing value of L there is an increasing tendency for a larger difference between the 1 in 10 and 1 in 100 -year events, particularly at higher energies.



Slide 19



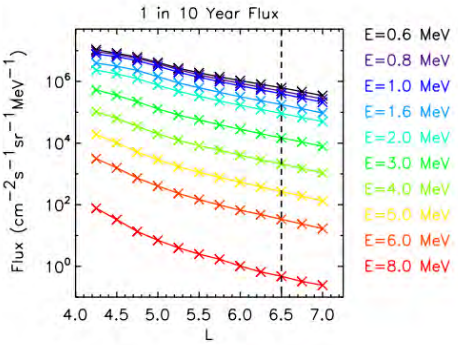
Slide 20

Slide 21 depicts a summary of the 1 in 10 -year electron flux as a function of L for the different energies.

Slide 22 shows the 1 in 100 -year electron flux, which are typically up to a factor of 2 to 10 times larger with the largest differences being at the higher L shells.

1 in 10 Year Fluxes as a function of L and Energy

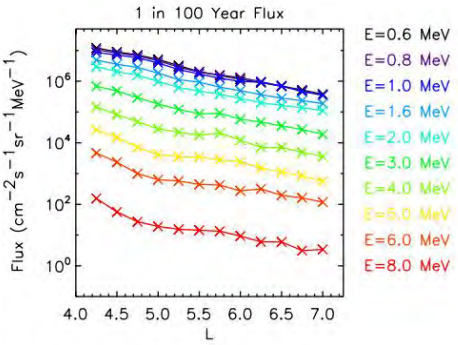
- We can summarise the 1 in N year electron fluxes as a function of L for the different energies
- The 1 in 10 year flux at L = 4.5 ranges from 8.2×10^6 $cm^{-2}s^{-1}sr^{-1}MeV^{-1}$ at E = 0.6 MeV to 33 $cm^{-2}s^{-1}sr^{-1}MeV^{-1}$ at 8.0 MeV
- Further out, at L = 6.5 the 1 in 10 year flux ranges from 6.2×10^5 $cm^{-2}s^{-1}sr^{-1}MeV^{-1}$ at E = 0.6 MeV to 0.47 $cm^{-2}s^{-1}sr^{-1}MeV^{-1}$ at 8.0 MeV



Slide 21

1 in 100 Year Fluxes as a function of L and Energy

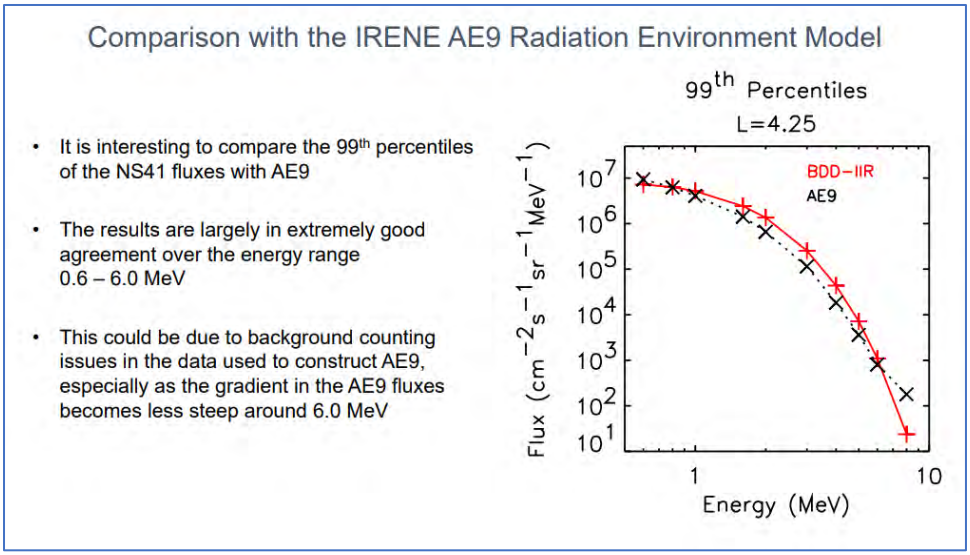
- This figure shows the 1 in 100 year electron flux as a function of L for the different energies
- The 1 in 100 year fluxes are typically up to a factor of 2 to 10 times larger with the largest differences being at the higher L shells



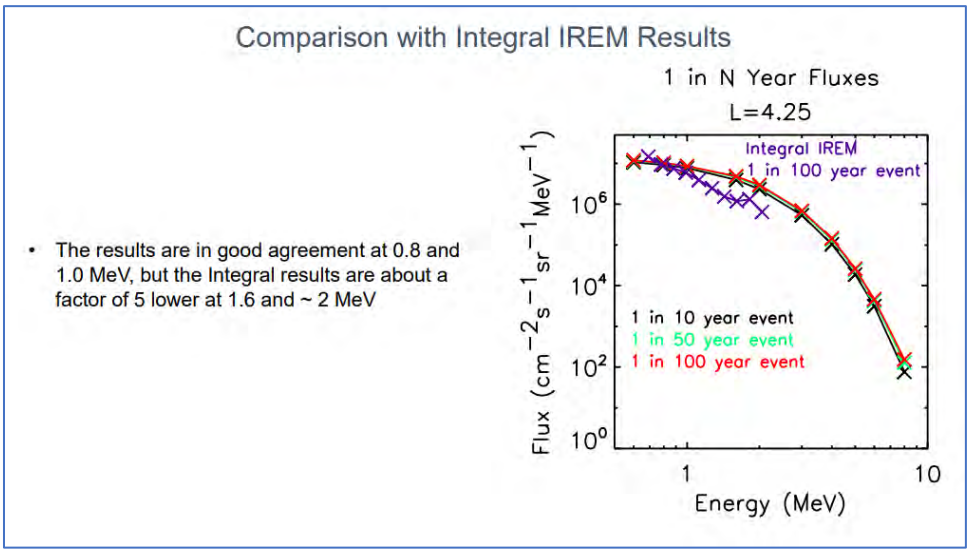
Slide 22

Slide 23 shows a comparison with the IRENE AE9 radiation environment model. When comparing the 99 percentiles, the results are in extremely good agreement over the energy range 0.6 – 6.0 MeV. The 99 percentile fluxes are about an order of magnitude less than AE9 at 8.0 MeV. This could be due to background counting issues in the data used to construct AE9, especially as the gradient in the AE9 fluxes becomes less steep around 6.0 MeV.

Slide 24 shows a comparison with the Integral IREM results. In 2017, an extreme value analysis was conducted using ~ 14 years of data from the Radiation Environment Monitor on board the Integral spacecraft. We can compare these findings with the new results from the NS41 BDD-IIR instrument. The results are in good agreement at 0.8 and 1.0 MeV, but the Integral results are about a factor of 5 lower at 1.6 and ~ 2 MeV.



Slide 23

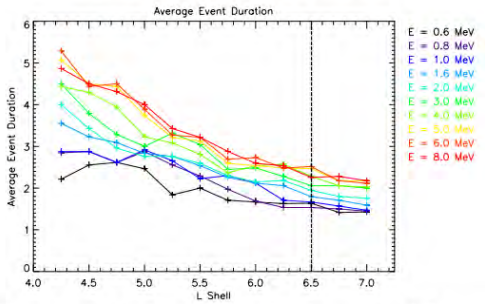


Slide 24

Slide 25 shows the average time the flux exceeds the 1% exceedance level for each of the cluster maxima for each energy as a function of L. The average event duration increases with increasing energy and decreasing L. Specifically, at L = 4.5, the average event duration increases from 2.5 days at E = 0.6 MeV to 4.4 days at the highest energies. Further out at L = 6.5 we see the same trend, but the average duration is smaller ranging from 1.4 days at E = 0.6 MeV to 2.5 days at E = 8.0 MeV. Although we are not fitting timescales the data indicate that, over the range of energies and L samples, the timescale for loss is generally smaller at lower energies and higher L.

As shown on Slide 26, some of the largest daily average fluxes encountered during the entire mission were observed during the 6 April 2010 geomagnetic storm. This was a relatively moderate geomagnetic storm with a minimum Dst of -81 nT on 6 April. Interestingly, the relativistic electron fluxes had started to rise from 2 April, prior to the arrival of the storm due to a period of IMF Bz fluctuating about 0 nT and enhanced geomagnetic activity as monitored by AE.

Average Event Duration

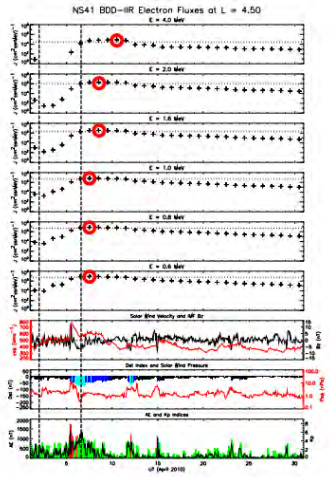


- Specifically, at L = 4.5, the average event duration increases from 2.5 days at E = 0.6 MeV to 4.4 days at the highest energies
- Further out at L = 6.5 we see the same trend, but the average duration is smaller ranging from 1.4 days at E = 0.6 MeV to 2.5 days at E = 8.0 MeV

Slide 25

Largest Event

- Some of the largest daily average fluxes encountered during the entire mission were observed during the 6 April 2010 geomagnetic storm
- This was a relatively moderate geomagnetic storm with a minimum Dst of -81 nT on 6 April
- Interestingly the relativistic electron fluxes had started to rise from 2 April, prior to the arrival of the storm due to a period of IMF Bz fluctuating about 0 nT and enhanced geomagnetic activity as monitored by AE

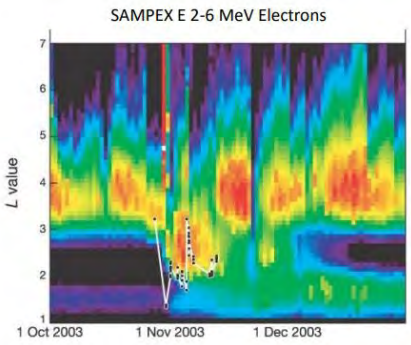


Slide 26

Slides 27 & 28 depict the fluxes during the 2023 Halloween Storm, which was one of the largest geomagnetic storms of the past 20 years. Interestingly, this storm was not associated with large fluxes of relativistic electrons as observed by the GPS satellite, either towards the outer edge of the outer radiation belt at L = 6.5 or at the heart of the outer radiation belt at L = 4.5.

Halloween Storm

- One of the largest geomagnetic storms of the last 20 years was the Halloween storm in 2003, with a minimum Dst of -383 nT on 30th October
- Following the storm a new outer radiation belt formed at low L, peaking in the slot region below L = 3.0

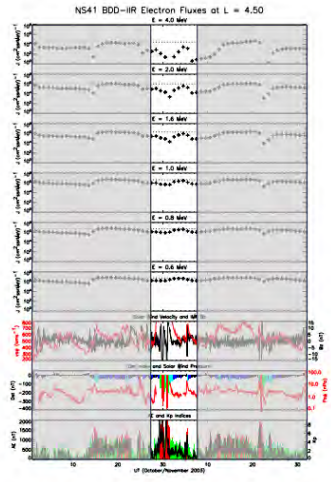


Baker et al., Nature, 2004

Slide 27

Halloween Storm

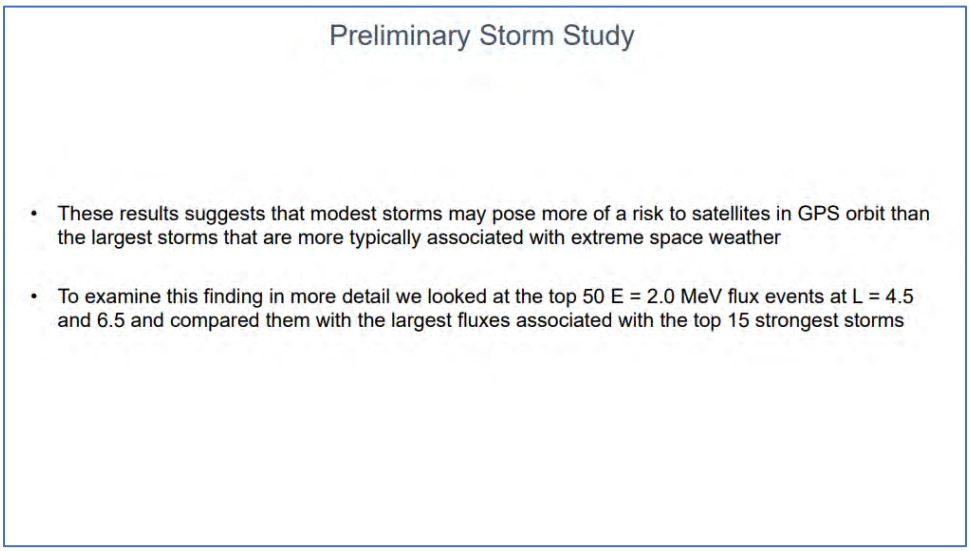
- This storm was not associated with large fluxes of relativistic electrons as observed by NS41, either towards the outer edge of the outer radiation belt at L = 6.5 or at the heart of the outer radiation belt at L = 4.5



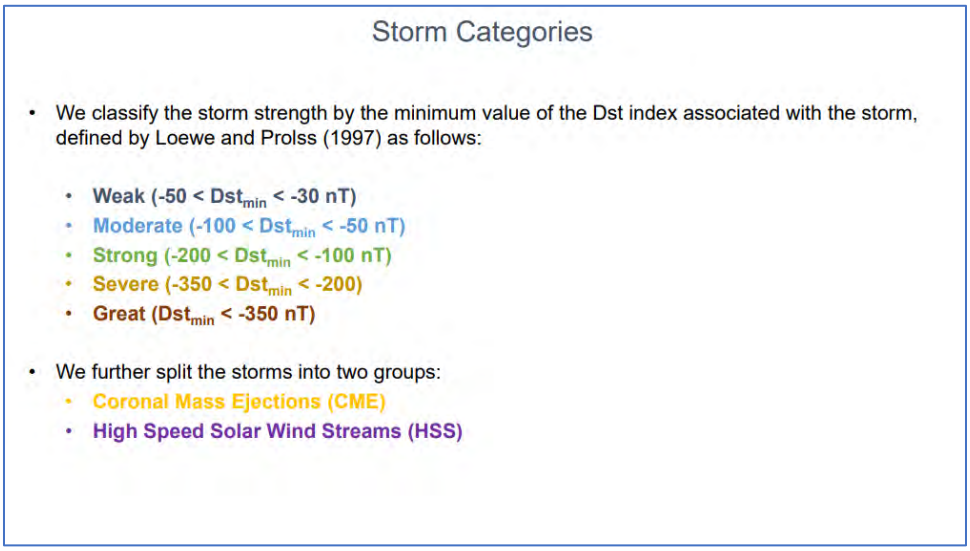
Slide 28

A preliminary study suggests that modest storms may pose more of a risk to satellites in GPS orbit than the largest storms that are more typically associated with extreme space weather (Slide 29). To examine this finding in more detail, they looked at the top 50 E = 2.0 MeV flux events at L = 4.5 & 6.5, and compared them with the largest fluxes associated with the top 15 strongest storms.

The strength of the storms can be classified by the minimum value of the Dst index associated with the storm (Slide 29).

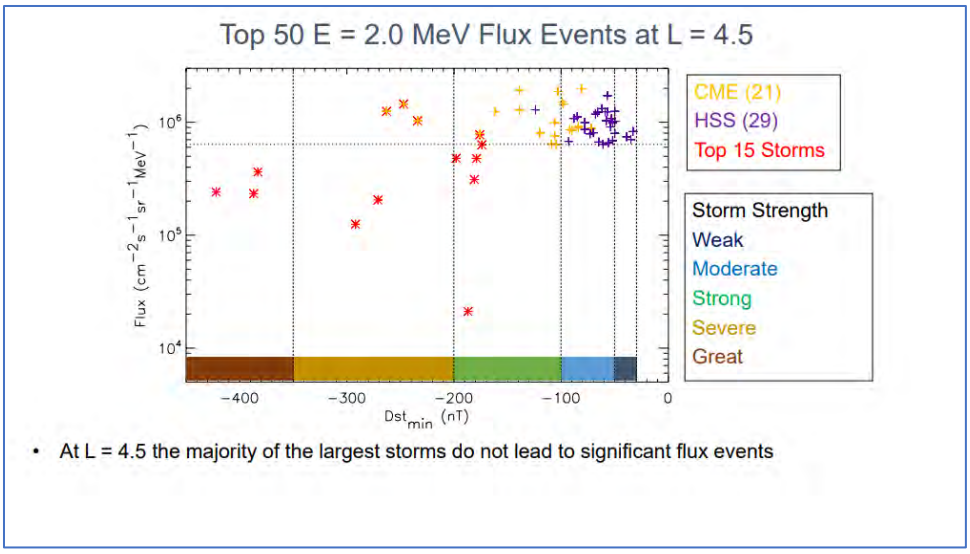


Slide 29

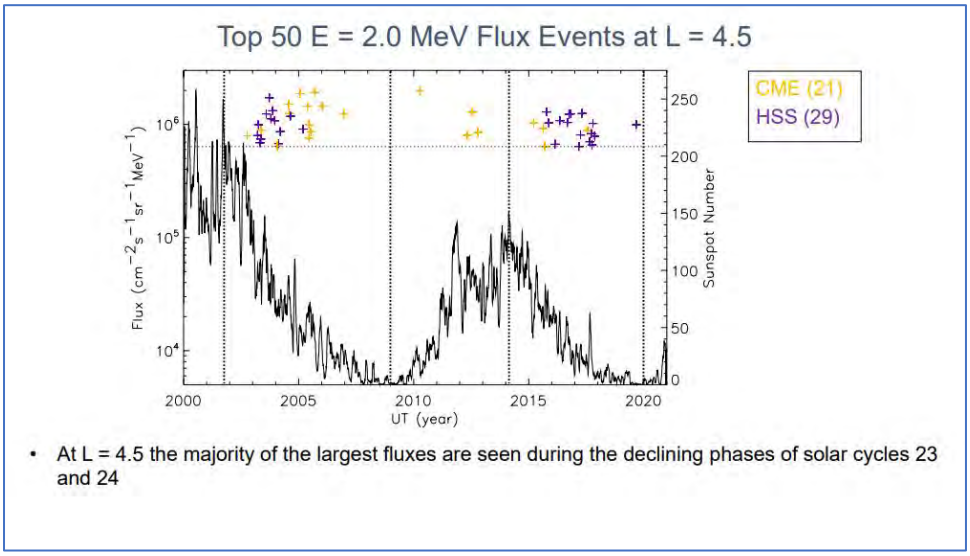


Slide 30

Slide 31 depicts the top 50 E=2.0 MeV flux events at L=4.5. The majority of the largest flux enhancements are associated with weak and moderate geomagnetic storms. While it is possible to have a large flux associated with a severe storm, the latter is not a requirement for a large flux event. This shows that most of the largest storms do not lead to significant flux events. As shown on Slide 32, the majority of the largest fluxes are seen during the declining phases of solar cycles 23 & 24.

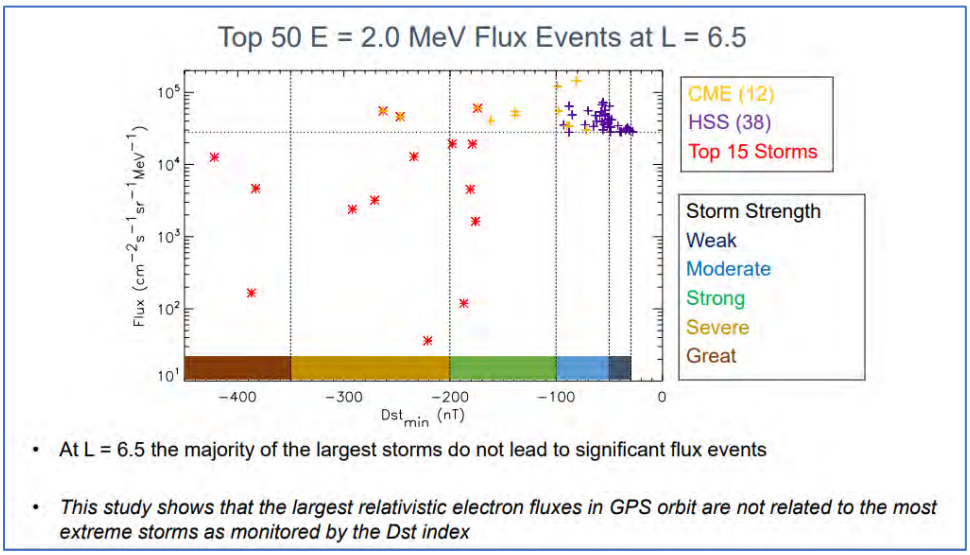


Slide 31

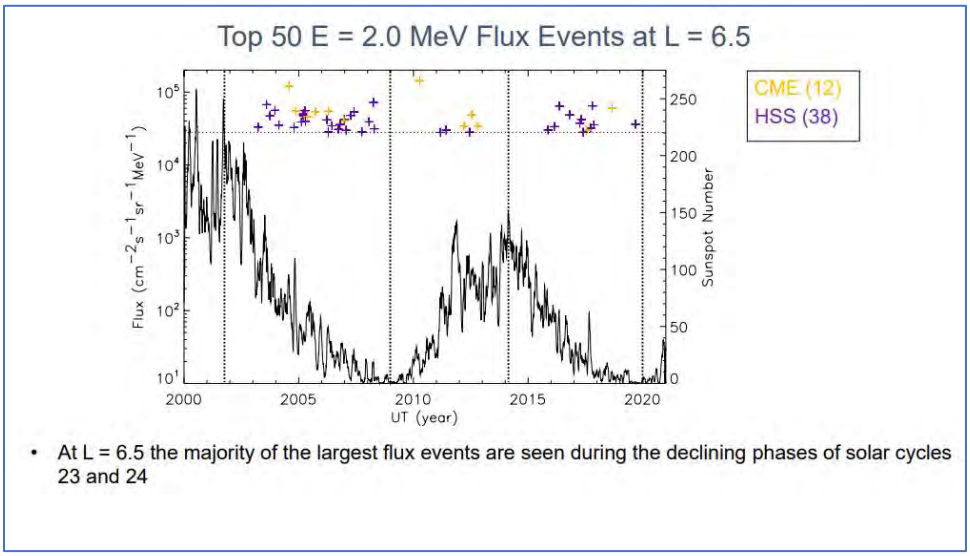


Slide 32

As shown on Slide 33, moving out to L = 6.5 the majority of the largest flux enhancements are also associated with weak and moderate geomagnetic storms. Again, while it is possible to have a large flux associated with a severe storm, the latter is not a requirement for a large flux event. At L = 6.5 the majority of the largest storms do not lead to significant flux events. This shows that the largest relativistic electron fluxes in GPS orbit are not related to the most extreme storms as monitored by the Dst index. As shown on Slide 34, the majority of the largest flux events are seen during the declining phases of solar cycles 23 & 24.



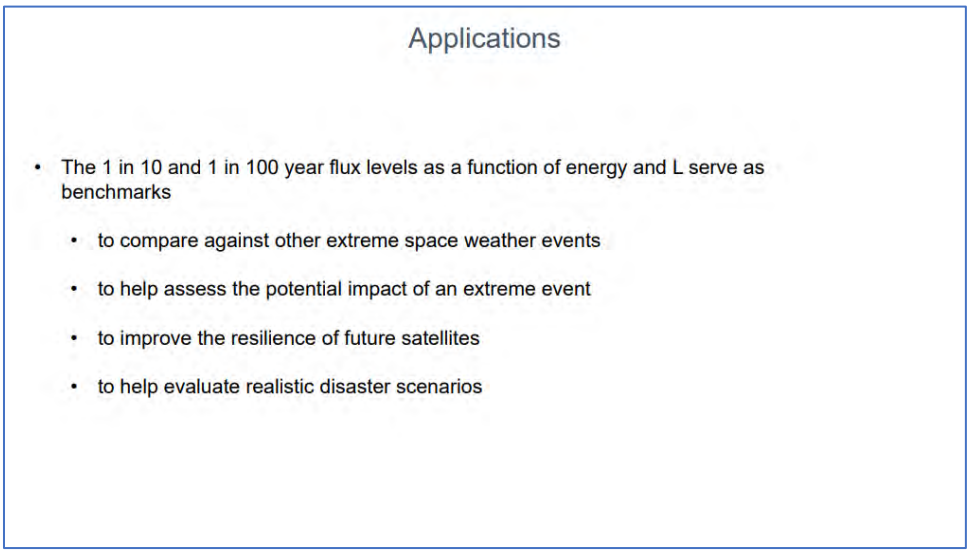
Slide 33



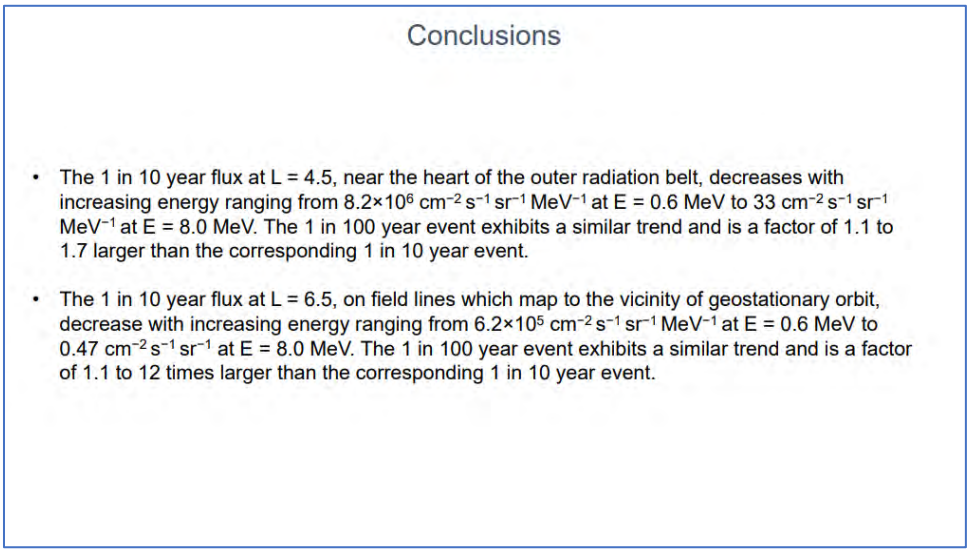
Slide 34

Slide 35 shows some of the practical applications of this study. The 1 in 10 and 1 in 100 -year flux levels as a function of energy and L serve as benchmarks to: (1) compare against other extreme space weather events, (2) help assess the potential impact of an extreme event, (3) improve the resilience of future satellites, and (4) help evaluate realistic disaster scenarios.

Slide 36 shows the key conclusions from this study.



Slide 35



Slide 36

Discussion:

Mr. Logan Scott asked Dr. Meredith to comment on the effects at LEO and GEO.

Dr. Meredith responded that, yes, there are also risks in other orbits. Since GEO is towards the outer range of the radiation belt, the fluxes aren't as extreme. However, as those satellites are outside the magnetic belt, they will be affected more by coronal mass ejections. As for LEO satellites, if the orbit has a large enough inclination, they will transit through the radiation belts.

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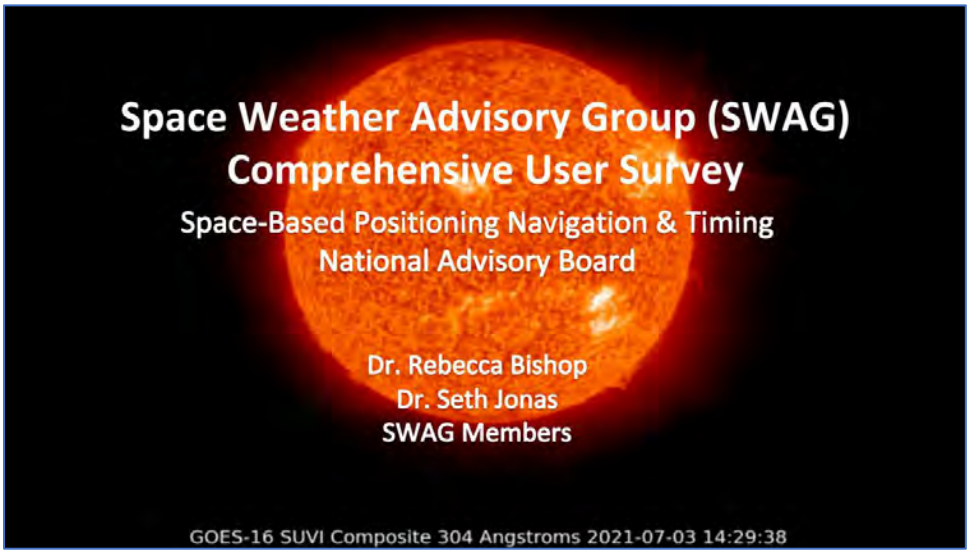
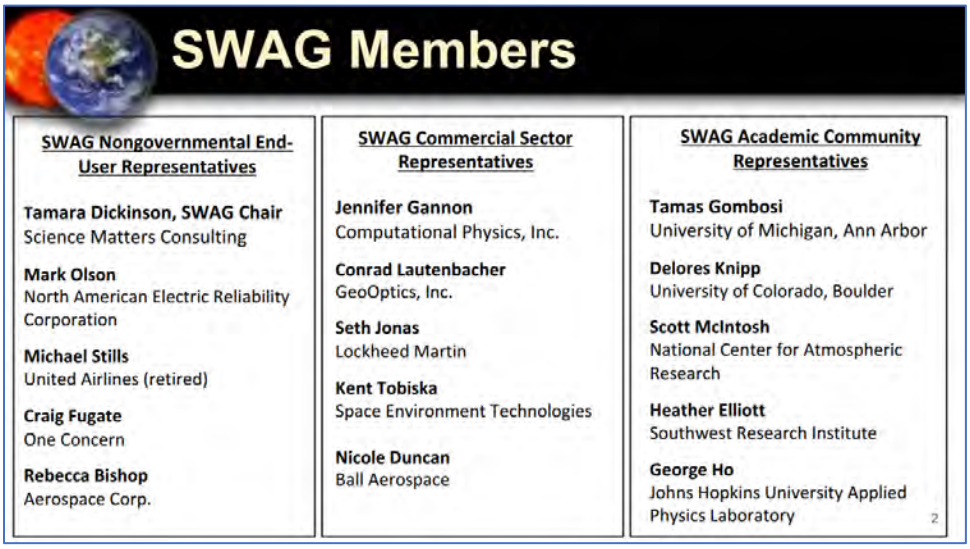
Space Weather Advisory Group (SWAG): Space Weather Survey for GNSS Users
Dr. Rebecca Bishop, *Member, SWAG, National Weather Service, National Oceanic and Atmospheric Administration (virtual participant)*

Dr. Bishop explained that she's a member of the Space Weather Advisory Group (SWAG) and would provide a briefing on a Comprehensive User Survey the SWAG has undertaken (Slide 1). The SWAG is made up of fifteen members, five of which are Nongovernmental End-User Representatives, five are Commercial Sector Representatives, and five are Academic Community Representatives (Slide 2).

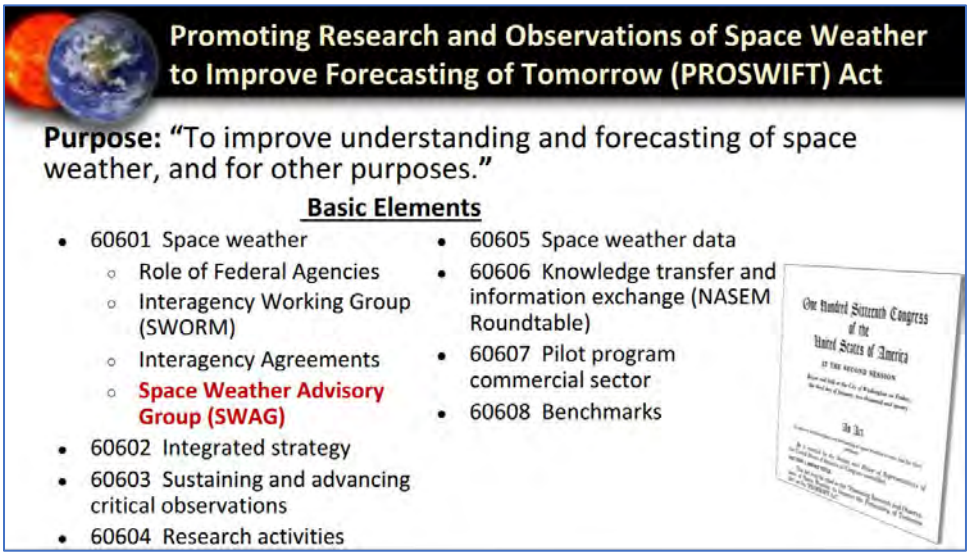


Slide 1

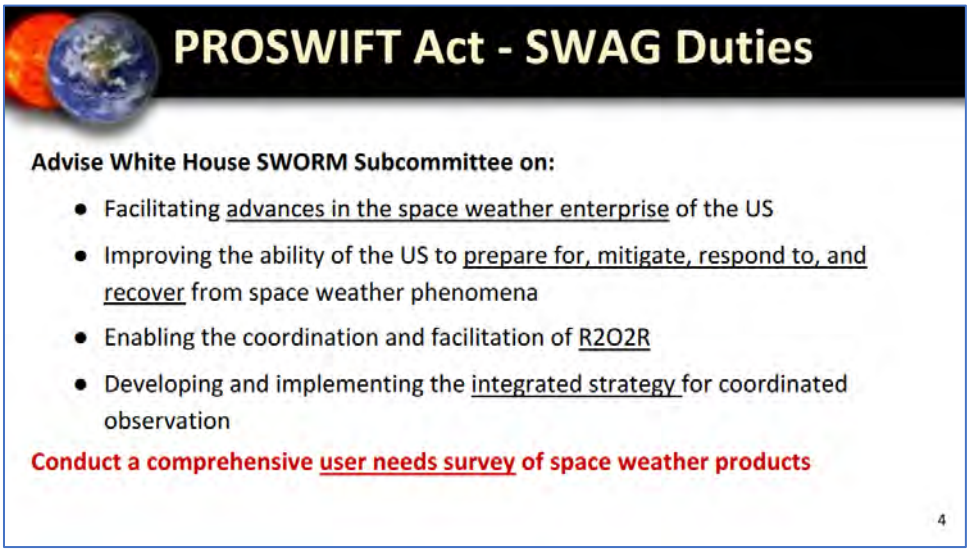


Slide 2

The SWAG comes out of the PROSWIFT Act, whose purpose is to improve understanding and forecasting of space weather, and for other purposes (other than forecasting) (Slide 3). The Basic Element of the PROSWIFT Act is to understand space weather, the different roles of USG agencies, and improve their interactions. Part of the SWAG's duties is to advise the Interagency Working Group (SWORM), which is a White House subcommittee, on advancing on: (1) Facilitating advances in the space weather enterprise; (2) improving the ability of the US to prepare for, mitigate, respond to, and recover from space weather events; (3) Coordinating the full Research-to-Operations-to-Research (R2O2R) paradigm; and (4) Developing and implementing the integrated strategy for coordinated observation. Also, the SWAG's charter specifically asks to conduct a comprehensive users' needs survey of space weather products.



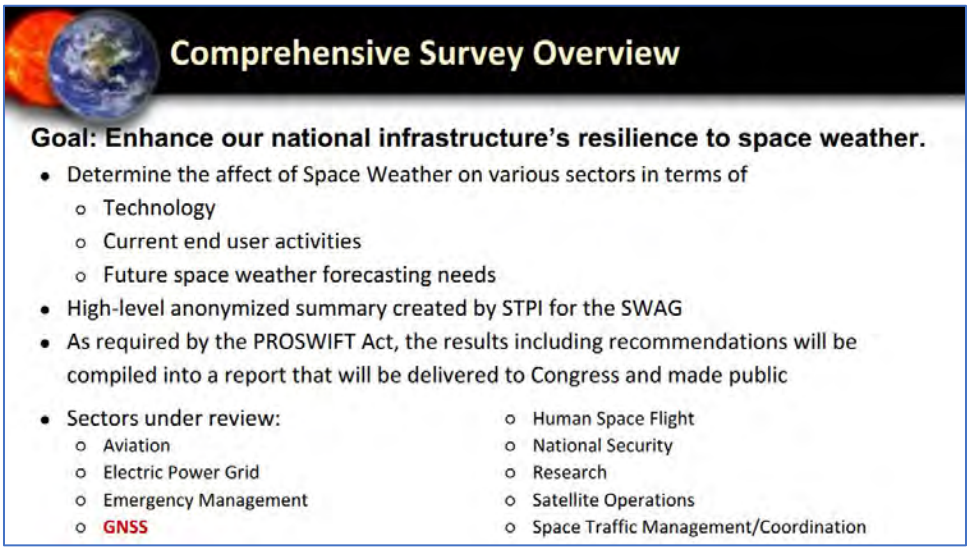
Slide 3



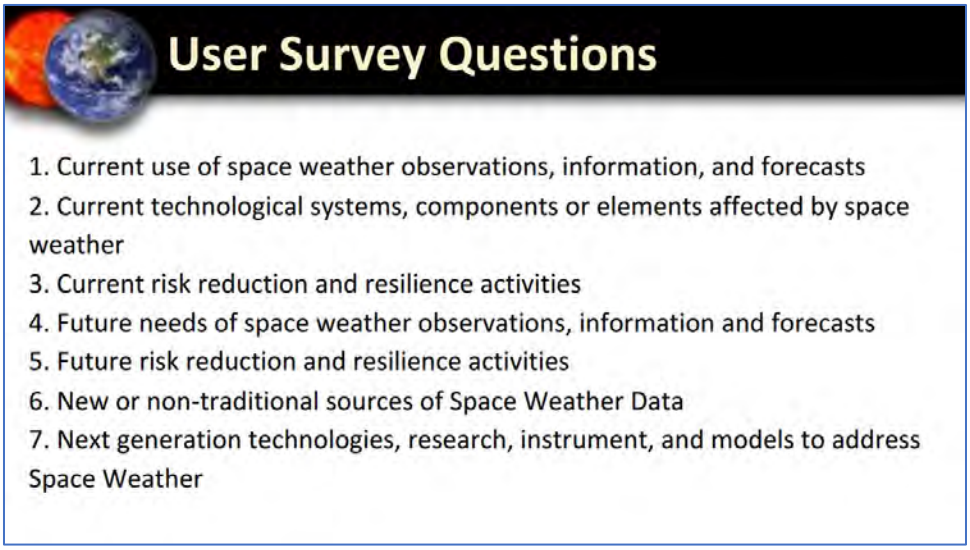
Slide 4

The goal of this survey is to enhance our national infrastructure's resilience to space weather events (Slide 5). The focus is not just on extreme space weather events, but also day-to-day changes in space weather. The survey is intended to determine the effect of Space Weather on various sectors in terms of technology, impact on current end user activities, and determining future needs for space weather forecasting. The survey is going to be anonymous and is being created by the Institute of Defense Analysis (IDA) Science and Technology Policy Institute (STPI), a Federally funded research and development center (FFRDC), for the SWAG. Once the survey is completed, there will be a set of recommendations that will be compiled into a report delivered to Congress and made public. Since this is a big effort, the SWAG decided to break it down into nine sectors, one of which is GNSS. Dr. Bishop is the lead for the GNSS working group within the SWAG.

The survey will include a set of overall questions along with some specifically targeted to a sector (Slide 6). The questions are lumped into seven categories, including: What is the current use of space weather observations, information, and forecasts? How do current technological systems incorporate information and how they are impacted by space weather? What are the current risk reduction and resilience activities related to space weather? What are the needs for future space weather observations, information dissemination, and forecasts? What sort of risk reduction and resilience activities are being conducted, and are they relying mostly on operational modifications or are they investing in specific technologies? How are they gathering space weather data, whether directly or as a bi-product, and would they be willing to share it to help enhance future forecasts? What is the next generation in terms generation technologies and research?

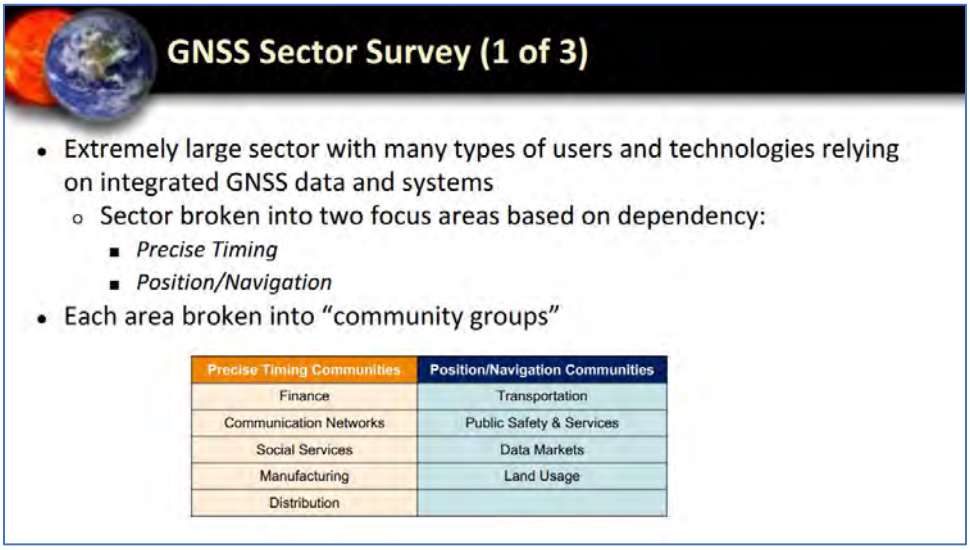


Slide 5

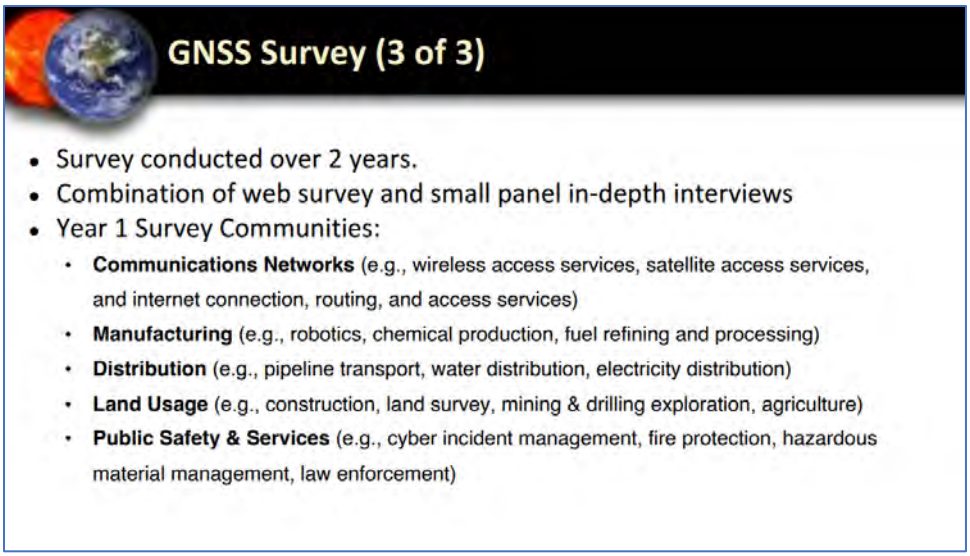


Slide 6

Slides 7-8: Summarize the questions in the GNSS Sector Survey [Ed. Note: There is a typo in the slides that were submitted. The title on Slide 7 should read (1 of 2), and title on Slide 8 should read (2 of 2)]. The GNSS sector was broken down into two focus areas depending on whether they primarily utilize GNSS for precision timing or for position/navigation. In turn, these two focus areas are broken into "community groups", as shown on Slide 7. Each one of these community groups are still rather large, so it is going to be a challenge to get this information to the right people as well as understanding how their GNSS is integrated into their technology systems. The GNSS survey is going to be conducted over the next two years (Slide 8). The first year will survey the following communities: communications network, manufacturing, distribution, land usage, and public safety & services.

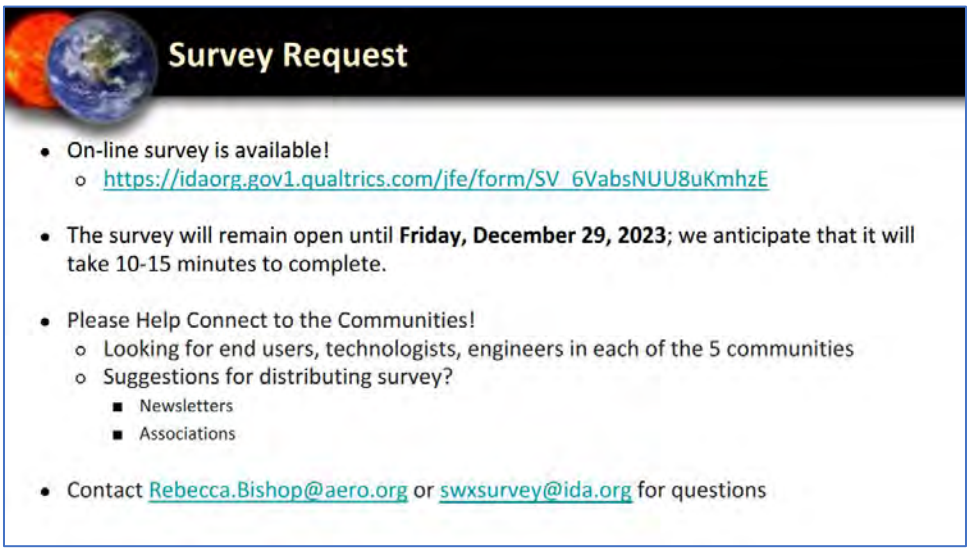


Slide 7



Slide 8

An on-line survey is available at https://idaorg.gov1.qualtrics.com/jfe/form/SV_6VabsNUU8uKmhzE and will remain open until Friday, December 29, 2023 (Slide 9). The SWAG is looking for end users, technologists, engineers in each of the five communities being surveyed in Year 1 of this study. If you suggestions on how distribute/socialize the survey (newsletters, associations, etc.), or any other questions, please contact Rebecca.Bishop@aero.org or swxsurvey@ida.org. For any general questions, please contact the SWAG Chair (Dr. Tammy Dickinson) at dickinson.tamara@yahoo.com.



Slide 9

Discussion:

The Hon Greg Winfree asked if there is anything particular that got those specific community groups into the Year 1 Survey.

Dr. Bishop responded that they tried to find a balance the user community size, and how integrated GNSS is for them, when selecting the specific user groups for Year 1 of the survey.

Dr. Powell asked if Dr. Bishop has received any preliminary responses. He expressed concern on whether many users are even aware of their technological dependency on GNSS.

Dr. Bishop said that at this time they've only gotten a couple of responses. They're hoping to have preliminary Year 1 results available by mid-February 2024, and the results of the survey in April 2024.

The Hon Greg Winfree noted that looking at the "precise timing" communities, where would electric power generation and distribution fall in? Would this fall under the "distribution" category?

Dr. Bishop said, yes. For space weather effects on GNSS, and in turn electric power distribution, as shown on Slide 8 it would fall under "distribution". She also noted that, as shown on Slide 5, "Electric Power" also has its own "sector" to cover issues not related to how they are using GNSS.

Mr. Higgins noted that in Australia's equivalent to the U.S. Dept. of Homeland Security, has also done a risk assessment on space weather and its effect on critical infrastructure. This study could perhaps help inform this survey.

Dr. Bishop responded that's a great idea. In addition, any lessons learned from the Year 1 survey will be incorporated into the Year 2 survey. They believe this survey will be repeated every few years because things change so quickly.

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Challenges in Hiring Geospatial Intelligence Professionals
Dr. J.N. (Nikki) Markiel*, National Geospatial-Intelligence Agency*

[Ed Note: there are no ppt slides for this briefing]

Dr. Markiel noted that NGA for many decades has produced the fundamental models and the fundamental data sets that enable PNT, in particular GPS. There are three key models we need to discuss to set the stage: World Geodetic System 1984 (WGS 84), magnetic model, and gravitational model. First and foremost, WGS 84 is the coordinate system that enables PNT writ large every day. It enables the precision determination of latitude and longitude on a global basis. We all get our locations from GPS. The position of GPS satellites themselves are located within the WGS 84 system, and one of the goals of NGA is to each day determine the orbit determination truth for the USSF. The second and third models are Earth's magnetic and gravitational fields. For the latter, we need to define the very size and shape of Earth, which is proxy for mean sea level, elevation, etc., which leads directly to navigation products under our title and responsibilities. In NGA's direct partnership with its colleagues at the U.S. Naval Observatory (USNO) and the National Institute of Science and Technology, its models are inherently lined to prevision atomic time, and that underpins the 16 components of the U.S. critical infrastructure. The NASA Goddard Space Flight Center (GSFC) also contributes heavily to a lot of aspects of geophysics and Earth's orientation, as well as the national radio astronomy observation which is owned, operated, and funded through the National Science Foundation (NSF).

All these professionals, however, are under an increasingly dire issue which fundamentally is that they're getting old and they're retiring. This is not a particularly new problem. A 2008 report by National Academy of Sciences on information technology and its supporting infrastructure noted that at that time virtually every federal agency had raised concerns about the deficit and well trained and engineers with the necessary knowledge to support the fundamental models we discussed earlier. Unfortunately, 13 years later the situation has not improved. We are living through a STEM crisis, particularly in some of the niche fields being raised here. There is a disparity on the order of 78 to 1 in the number of geodesists graduating in China compared to the U.S. This is not unique. If we look across at other fields, such as electrical engineering, there is also a large disparity at graduate level. Statistics out of the NSF on reflect that non-U.S. citizens at this point comprise 50% of all doctorate degrees, 62% of all STEM graduates, and somewhere between 55 and 81% in the various technical fields that are of interest. Furthermore, if we look at the statistics out of the World Economic Forum, China at this point, according to their statistics, has 4.7 million STEM graduates between the ages of 18 and 60. India is in second place at 2.6 million, while the U.S. is a distant third at 568,000. Thus, our aperture must expand beyond the traditional K-12 students and include the 25- to 55-year-old cohort. It must adapt and encourage adults to consider a shift towards skills that are in demand.

It's worth looking at the research on why people are not going to college. The easy knee jerk reaction is money, but research shows and reflects that that is not the case. The first answer is that no other member of their family has gone to college and, therefore, they do not know what to expect. The second answer is that they do not think that they're smart enough, which is a perception problem and not necessarily a reality. The third answer is that they do not know how to pick a school, and the fourth answer is that they do not know how to pick a program. Finally, the fifth answer are concerns about funding. If we shift our focus again and research as to why folks do not go into STEM, first we find that they do not know that jobs exist and, second, there is an overall perception that STEM is boring. Thus, it would appear there is not in fact a STEM problem by itself but rather a fundamental marketing problem. The challenge is to make them aware, capture their imagination, and most importantly provide a reasonable path to achieve the positions that we have in consideration. If we want to win that war for brains, our efforts must be holistic, deliberative, and sustained.

Now, how do we begin doing this? First and foremost, in the St. Louis, where Dr. Markiel is based, a number of programs are being implemented that are not just focusing on the youth but also the entire support structure around the student's parents, relatives, friends, teachers, and civic groups. If we do not get them hooked on science by age 12, they're highly unlikely to pursue that field. The key is that early on there has to be consistent exposure to demystify and normalize math STEM. Research also reflects that it's all about increasing the size of the hiring pool. Earlier this year we had our first iteration of a high school internship program where juniors and seniors were in fact able to receive Secret clearances and work within our footprint. Last year we also partnered with the T-Rex a non-profit innovation and entrepreneur development center dedicated to strengthening the economic vitality of St. Louis] to what is known as a partnership intermediary agreement. They have a program called Pathways that is targeted program to accelerate trajectory of geospatial professionals into the workforce and proactively manage the future workforce to bolster diversity and inclusion. Another program is Geo Fun, which in K-5 introduces geospatial fundamentals and in sixth grade they transition to geospatial science principle, and then in 9-12 grades they transition to the Geo Impact program which provides a geospatial certification. This is followed up Geo Immersion program, a summer immersion program with our universities, notably our historically black colleges, universities, and other minority serving institutions, that focuses on geospatial methods, tools and technologies. This is being conducted in cooperation and partnership with Harris-Stowe State University. In March 2023 our foundation office provided subject matter experts who conducted seven different interactive sessions with each of those student programs. This includes interfacing not just with students, but also educators so that they can continue that in their coursework with underrepresented communities. Another major tool that we have discovered and are leveraging are the Educational Partnerships Agreements (EPAs) with both the University of Missouri and Arizona State University. These EPAs allow us to engage with academic partners that may not have geospatial science capabilities and provide curriculum and program development

to prepare the faculty and students. Dr. Markiel's team is also engaged in cooperative research and development agreements at the University of Missouri, St. Louis, to provide opportunities for research and projects on the use of artificial intelligence in, for example, in gravity mapping. They have also created a consortium of professionals whose members include some of the nation's top programs, including Ohio State University, Purdue University, and others. Such efforts enable us to understand what we need to know to manage our knowledge across the workforce. It is essential to know how to reach the students, especially in underrepresented communities. One of the key pieces we have identified is that the use of math is a critical rallying point. We need to develop next generation subject matter experts through an integrated research curriculum and develop educators to go about this. These efforts are enabling us to collectively find and implement effective means to foster STEM enjoyment in our communities and provide a model for replication on a national basis. There are also two planned and/or in process activities, one out of the National Academy of Sciences and a President's Science Advisory Board to look at these challenges.

We need to be bold. We need to do things differently and to that end, the elements we've outlined here will provide the mechanism to get there.

Discussion:

The Hon Greg Winfree noted he represents the Texas A&M University System, and asked Dr. Markiel to also provide this presentation to senior leaders there.

Mr. Goward noted that over the last couple of decades he's been amazed at airlines every five years saying they just realized they had a bunch of pilots retiring. Finally, they realized this is predictable and, as such, his son-in-law who is retiring from the Army in five years has been offered contracts by multiple airlines. The point is that if somebody is in charge, they can take a holistic look and take action. Another issue is that we're sort of letting the market decide rather than having coherent and focused leadership.

The Hon Jeff Shane noted he's seen this before, such as when Sputnik shocked the U.S. out of its indolence. Somehow, science and math became a lot more important to Americans than it had been before, and the net result was that we produced a new generation of mathematicians, scientists, and engineers. He wondered if anyone has studied what really triggered that sudden surge in interest. Today we're having a similar challenge, but it appears we are not responding in the same way.

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Session of Wednesday, December 7, 2023

Theme 4: Updates from International Members & Representatives

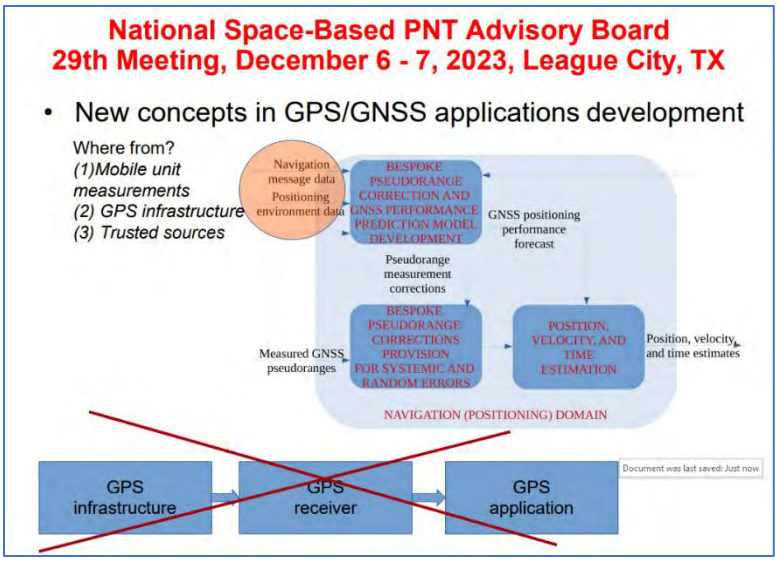
1) Croatia
Dr. Renato Filjar, *Member, PNTAB*

Dr. Filjar reminded the Board of the celebration of the 50th anniversary of GPS and he extended his appreciation to Dr. Parkinson for his ingenuity, perseverance, and commitment to his associates, groups, and agencies that work on GPS, which is now a part of our lives (Slides 1-2). ION has proclaimed October 23rd as International GNSS Day. Quite incidentally, the UN's The Office of the Outer Space of Affairs, together with the government of Finland, was setting up the annual GNSS application workshops on that very day. So, the participants of the UN-Finland Workshop on Applications of GNSS were the first to celebrate this International GNSS Day. GPS is now prevailing. Everyone knows about it, everyone uses it, it is a part of the national infrastructure, it is a part of our daily lives, and it is a public good. Therefore, it is not strange to learn that it has found a place in poetry in the arts.

Slide 1

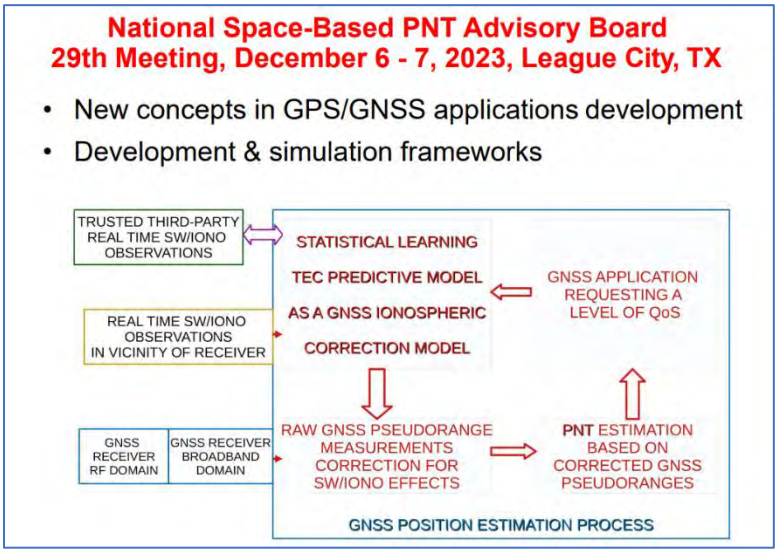
Slide 2

GPS continues to evolve, and there are new developments, especially regarding new applications and new technology (Slide 3). The traditional view of the GPS receiver as a black box is evaporating. There are new ways to utilize GPS's position, navigation, and timing estimation that supports the growing number of GPS applications. In this case, it is important for the Board and the EXCOM to assess the new developments and new lines of development.



Slide 3

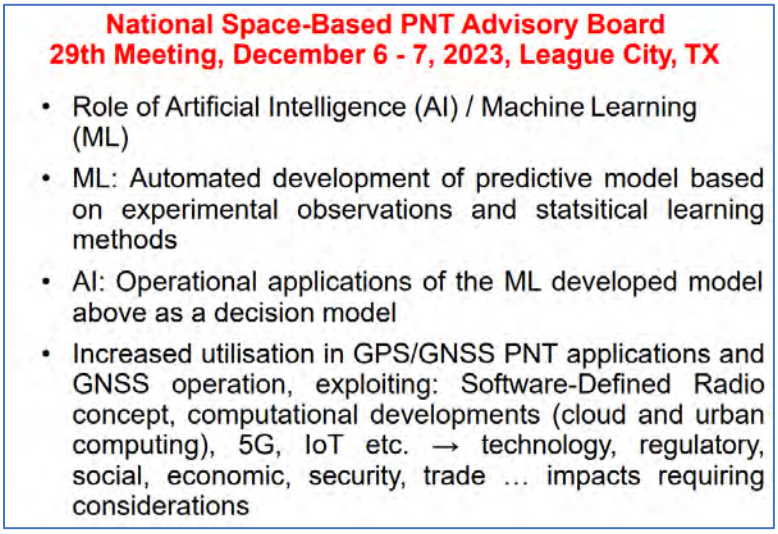
The Laboratory for Spatial Intelligence at his university, along with the many other researchers around the world, are developing new development frameworks, which include new tools to empower the development of GPS applications (Slide 4). They embrace new technologies like software defined radio, improved capacity of telecommunication networks, mobile Internet, and computer science developments like the cloud. Dr. Filjar stated that he has introduced concepts to the Board, such as the concept of the positioning as a service. The framework for the programming is a statistical environment that allows us to use the various statistical methods and models in order to enhance PNT performance, as well as to provide some PTA to future developments and applications that will be developed on GPS. It is not a real-time environment. It was developed in order to test the various methods, especially statistical models, that can enhance and improve GPS PNT, but it is a valuable contribution that will allow breakthrough developments in the GPS position estimation and enhances the capacity and quality of service of different GPS applications.



Slide 4

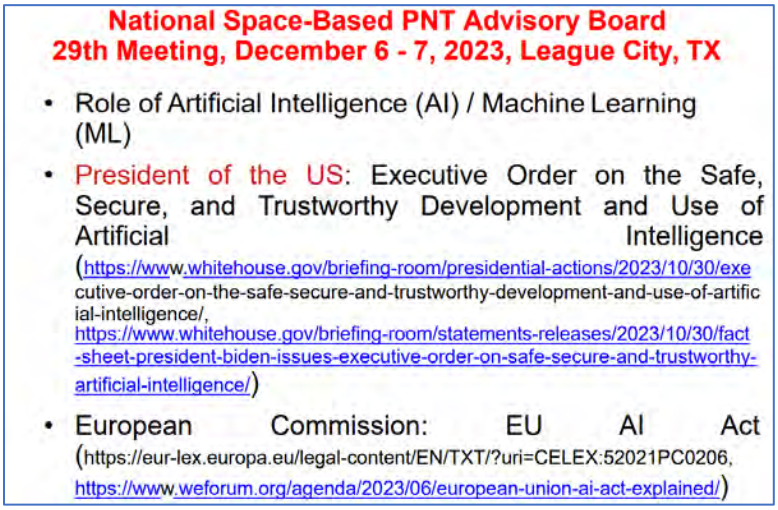
A framework has been developed to utilize artificial intelligence (Slide 5). Dr. Filjar stated he personally dislikes the term because it can mean a lot of things and it can mean nothing. When we talk about statistical learning, we talk about the set of methods to develop the predictive models based on observations, experience, and documented cases from the past. Machine learning is a

deployment of those methods in an automated way to get the predictive models based on the experience and observations. Artificial intelligence is about deploying these automated predictive models to make decisions. This model is embedded into the framework. The complex problems that traditionally are described with a set of partial differential equations, we simply throw them in the machine learning based methods that will give us the optimization of the process and the problems we are going to solve. The Klobuchar Ionospheric Model is a benchmark model. Everything that is under development should be compared with the performance of the Klobuchar Model. So, similar to the Klobuchar Model, they first made the classification of the ionospheric events, then picked the most suitable methods to develop the predictive model that can suit the conditions of the ionosphere, or environment in which the GPS positioning takes place. He stated, "we not only got optimization towards real conditions, but we could also get improvement of the PNT performance, as well as PTA, against the natural sources." This is just an example of how we utilized machine learning and artificial intelligence to improve PNT and performance and accomplish PTA. They engaged different and new technologies like mobile internet and sensing of the environment. Also, the capacity of new computing approaches, such as cloud computing. Because of this, they accomplished a far better performance than in the traditional way.



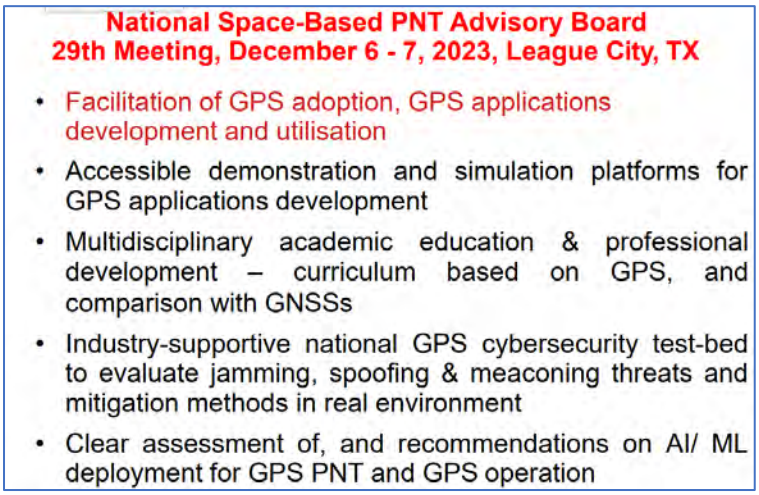
Slide 5

Artificial intelligence is not just a playground (Slide 6). There is a serious concern of how artificial intelligence should be deployed in various ways in the social economy and technological environments. There is a Presidential Executive Order on safe, secure, and trustworthy development and use of artificial intelligence. The European Commission did something similar with the EU Artificial Intelligence Act, and the Prime Minister of the UK also arranged for the world meeting of AI stakeholders to address the importance of the approach technology. This Board should be aware of those initiatives, as well as the rising number of applications of artificial intelligence in GPS.



Slide 6

Dr. Filjar invited Board members to "think of the facilitation made by accessible demonstration and simulation platforms for GPS applications development (Slide 7). There are cases of other GNSS operators providing GNSS application developers with such tools. Why doesn't the U.S. consider doing this as well? The Board has already addressed the opportunity of multidisciplinary academic education and professional development with a curriculum based on GPS in comparison with other GNSS. Why doesn't the U.S. consider putting satellite navigation and PNT into curricula of the various disciplines, including geodesy, electrical engineering, computer science, as well as social sciences and natural sciences? All of these fields are utilizing GPS and taking the benefits of satellite navigation. They should understand what PNT and GPS is and how GPS works. There is also a proposal to consider the development or establishment of the industry support of a National GPS, Cybersecurity TestBed to evaluate jamming, spoofing, and weakening threats of and mitigation methods in the real environment. There are reports of several other GNSS operators for doing this. Dr. Filjar stated that he is aware of the work of the Joint Research Center in Italy for the European Commission, where industry can test their solutions against the jamming and spoofing threats. There was a fantastic report at the UN-Finland Workshop on GNSS Applications from Norway, who set up a facility there and invited industry partners to utilize this for their own applications. Why not consider setting up such an establishment in the U.S. for the GPS, as well? Finally, the Board needs clear assessment on the recommendations of the artificial intelligence and machine learning deployment for GPS and PNT. Several subcommittees have already begun this work and Dr. Filjar will ensure that during the next public meeting of this Board there will be more detailed results and contribution to this very important issue.



Slide 7

Dr. Filjar finished by inviting the Board to visit Croatia (Slide 8). There is a regular annual gathering in Baska on Krk Island in Croatia that will engage the different specialists from the spatial information fusion discipline, which involves satellite navigation, remote sensing, spatial statistical analysis, trajectory analysis, spatial uncertainty, quantification, and other areas.

Slide 8

2) Australia
Mr. Matt Higgins, Member, *PNTAB*

Mr. Higgins noted his briefing would begin with the SouthPAN Project, an Australian-New Zealand project (Slides 1-2). He would then outline the latest developments in the Department of Defence Joint Project 9380 on Assured PNT in a Contested Environment. Then he would cover a few slides on the Department of Home Affairs, critical infrastructure legislation, and that space technology is now recognized as a critical infrastructure. Finally, there are a few slides on various developments within some Australian companies, including some grants that the space agency is utilizing towards PNT in space.

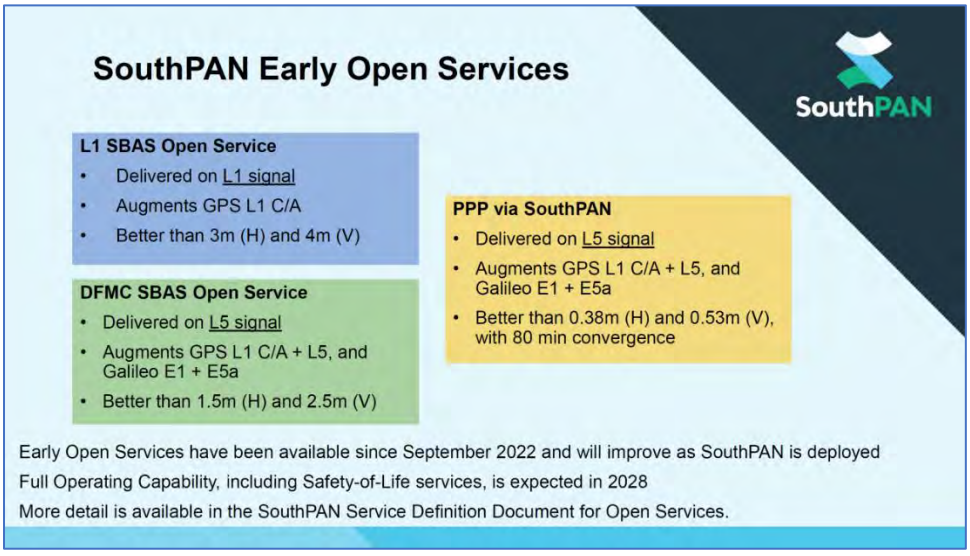
Slide 1

Slide 2

Mr. Higgins noted that Slides 3-11 on SouthPAN were lifted from his presentation at ICG-17.

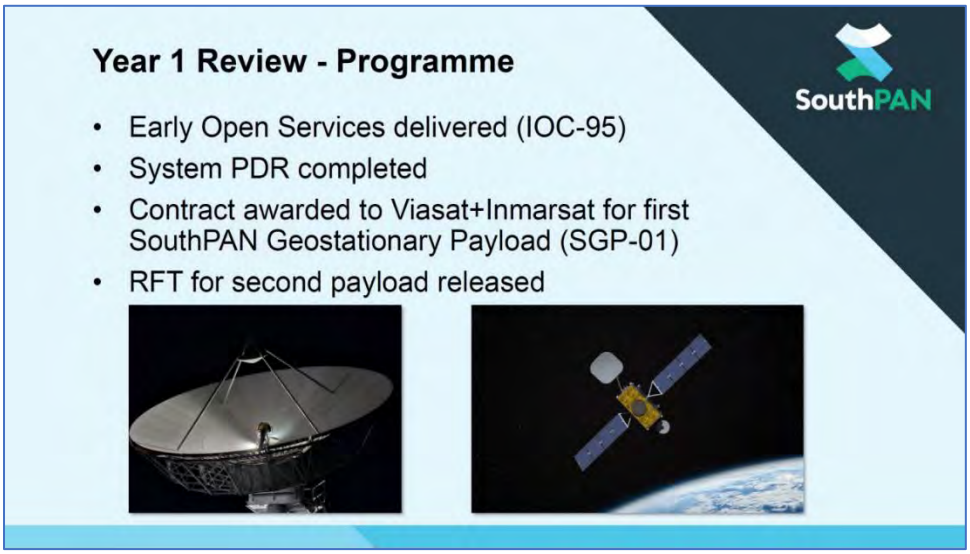
Slide 3

There are three services being developed on SouthPAN (Slide 1). The L1 Space-Based Augmentation System (SBAS) Open Service, SFMC SBAS Open Service, and PPP via SouthPAN, which is a full PPP solution albeit with some limited bandwidth on L5 in terms of delivering the corrections which will improve when we get the new satellites later on. This is being delivered by the Internet, so it's very similar to the HARS description previously presented, and it's compatible.



Slide 4

A contract has been awarded to Viasat+Inmarsat for the first SouthPAN Geostationary Payload (Slide 5). At the moment, SouthPAN is running on an existing Inmarsat satellite, and they've also issued a Request for Proposals (RFP) for the second payload.

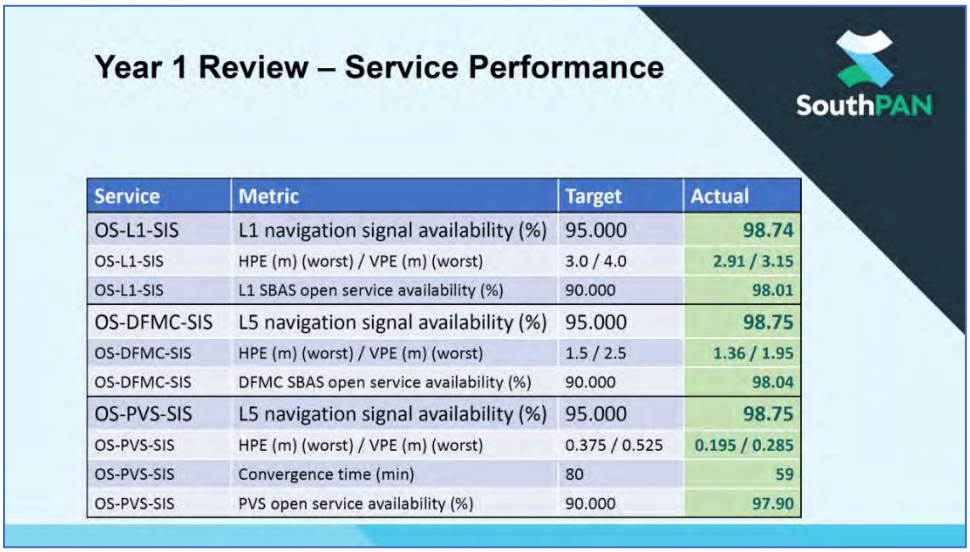


Slide 5

The dish is now up at the Uralla station in New South Wales as of about a week ago (Slide 6). So, they're making good progress on a lot of the ground facilities.

Slide 6

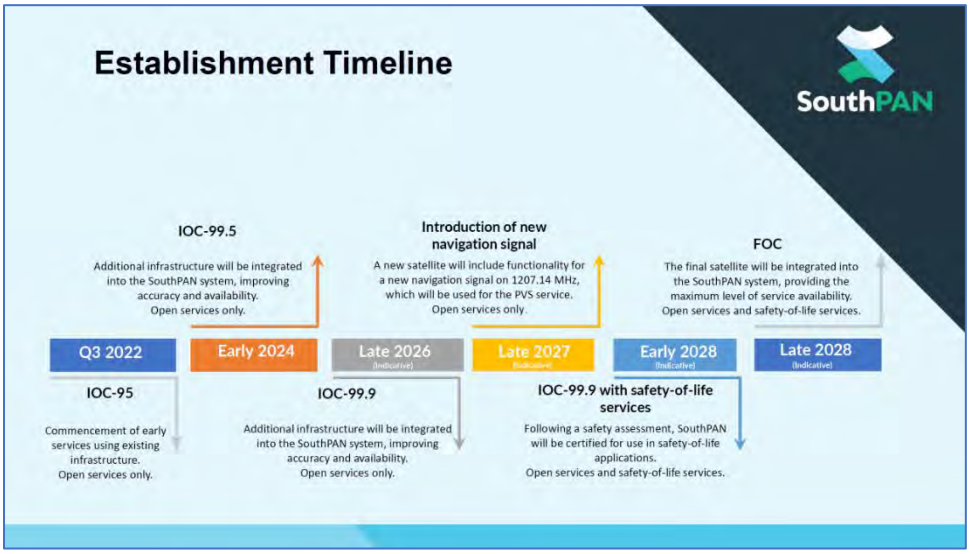
On all three services, even the Open Service, at this stage, is already exceeding expectations (Slide 7). The results are better than the targets on all three services.



Service	Metric	Target	Actual
OS-L1-SIS	L1 navigation signal availability (%)	95.000	98.74
OS-L1-SIS	HPE (m) (worst) / VPE (m) (worst)	3.0 / 4.0	2.91 / 3.15
OS-L1-SIS	L1 SBAS open service availability (%)	90.000	98.01
OS-DFMC-SIS	L5 navigation signal availability (%)	95.000	98.75
OS-DFMC-SIS	HPE (m) (worst) / VPE (m) (worst)	1.5 / 2.5	1.36 / 1.95
OS-DFMC-SIS	DFMC SBAS open service availability (%)	90.000	98.04
OS-PVS-SIS	L5 navigation signal availability (%)	95.000	98.75
OS-PVS-SIS	HPE (m) (worst) / VPE (m) (worst)	0.375 / 0.525	0.195 / 0.285
OS-PVS-SIS	Convergence time (min)	80	59
OS-PVS-SIS	PVS open service availability (%)	90.000	97.90

Slide 7

Slide 8 shows the timeline of the SouthPAN Program through 2028, ultimately getting to a full safety of life service.

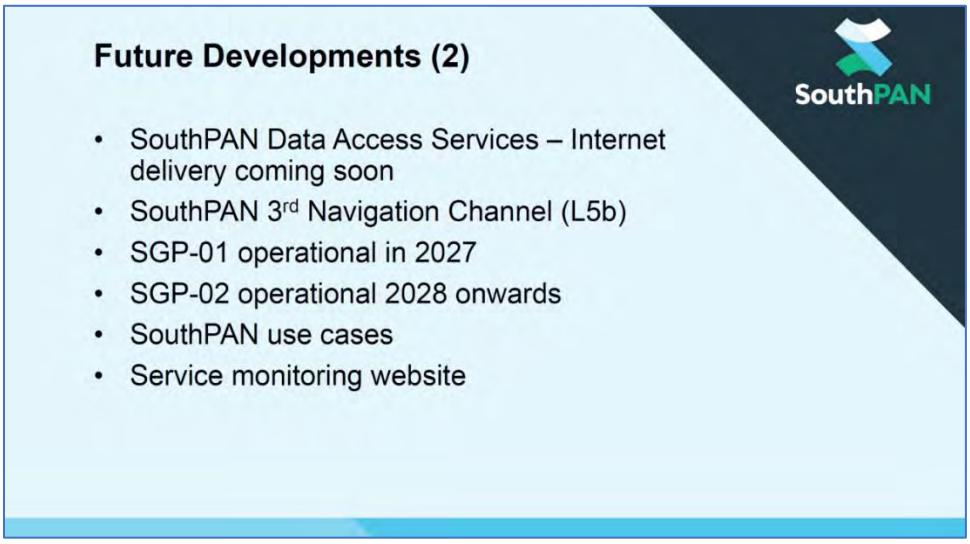


Slide 8

The early open service will improve to a 99.5% level in February, due to some of the developments that are happening now that improve reliability (Slide 9).

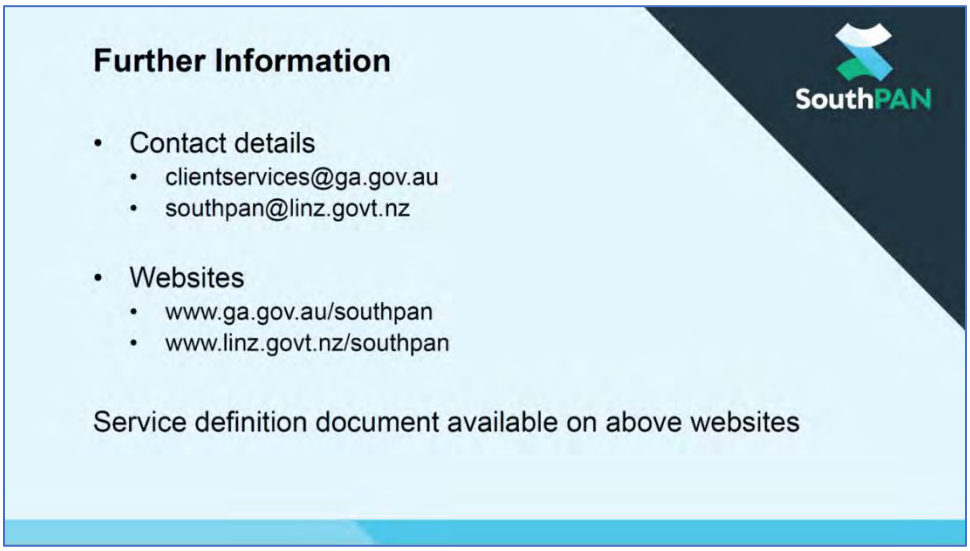
Slide 9

The SouthPAN Data Access Services delivery via the Internet is coming soon, the 3rd Navigation Channel (L5b) is being developed and slide 10 shows the dates that are planned for production (Slide 10).



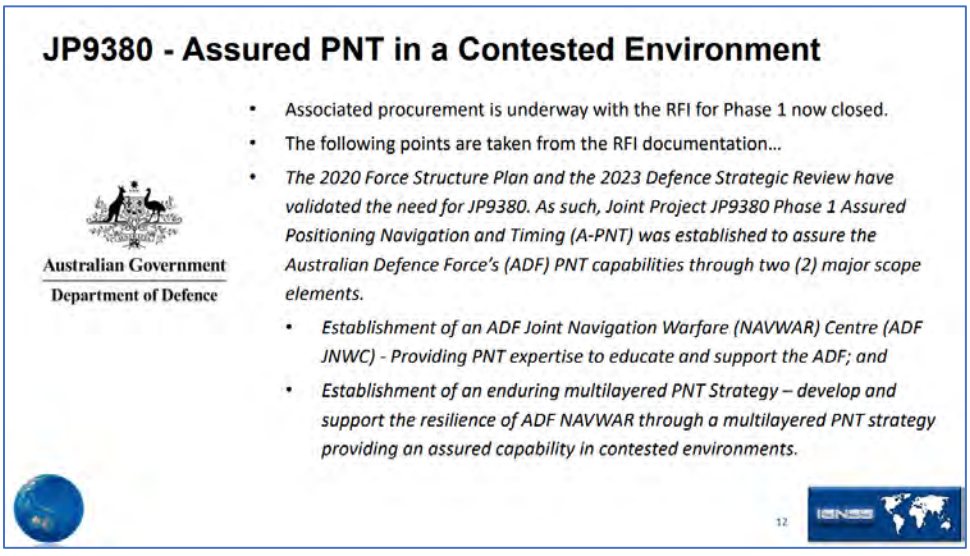
Slide 10

The websites and contacts for both the New Zealand and Australian Government are shown in Slide 11.



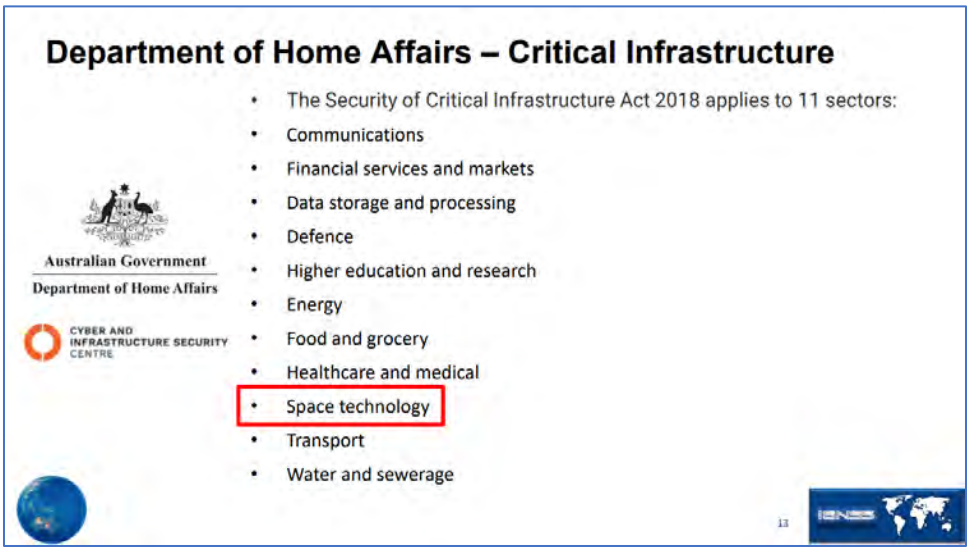
Slide 11

A big influence in defense in Australia is a Joint Project 9380 on Assured PNT in a Contested Environment, and that's been worked on in the background for a number of years, but it's now going to procurement (Slide 12). The RFI was published a few months ago and the decision on the contract is coming soon. For background, the 2024 Structure Plan in the 2023 Defense Strategic Review validated the fact that assured PNT and the need for 9380 is very important. They've moved to phase one and they're working towards capabilities with two major scope elements. The first is the establishment of an Australian Defense Force (ADF) Joint Navigation Warfare (NAVWAR) Center, which will provide expertise, educate, and support the ADF. The second is the establishment of an enduring multilayered PNT strategy to develop and support the resilience of the ADF NAVWAR through multilayer PNT strategy. Phase one is putting in the infrastructure for the rest of the project. The two big things happening in Australia at the moment are SouthPAN in the civil sector and JP 9380 in the defense sector.



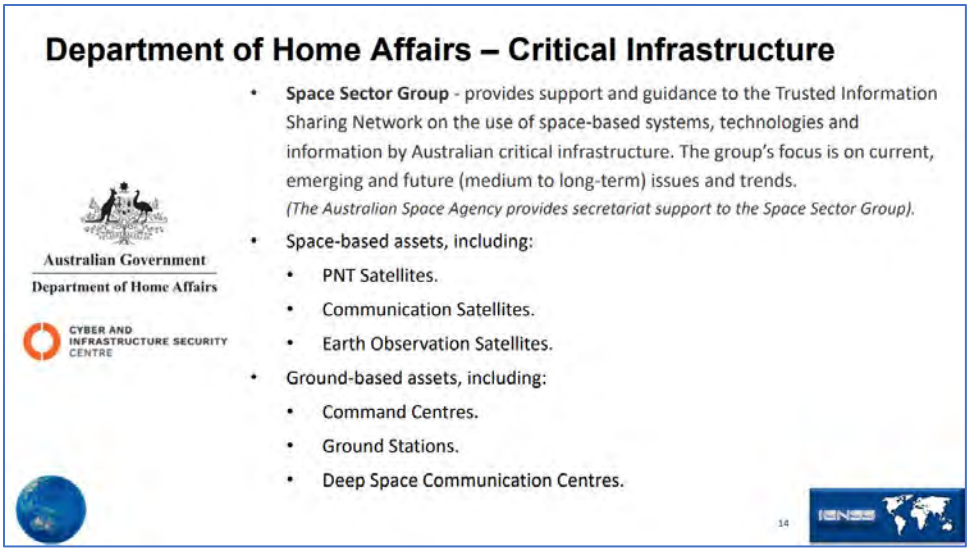
Slide 12

The Australian Department of Home Affairs is equivalent to the U.S. Department of Homeland Security (Slide 13). One of its major acts in terms of Parliament is the Security of Critical Infrastructure Act. It applies to 11 sectors, one of which is recognized as space technology.



Slide 13

Within the process of critical infrastructure, there is a concept of a trusted information sharing network which involves the government, state governments, and the critical infrastructure operators in a trusted environment to share information (Slide 14). This has several sector groups within it, and the space sector group is now up and running and its focus is on emerging and future issues and trends. The Australian Space Agency provides a secretariat for that, and Mr. Higgins is one of the representatives for the agency. Under the act, the definition of space-based assets includes PNT satellites, which, at the moment, is only SouthPAN in Australia. Australia does have communications satellites. They don't have any government-owned earth observation satellites. The economy is very dependent on PNT communications and earth observations and is especially important to Australia because they host a lot of ground stations for all sorts of systems all around the world, including command centers, ground stations, and the Deep Space Communications Center.

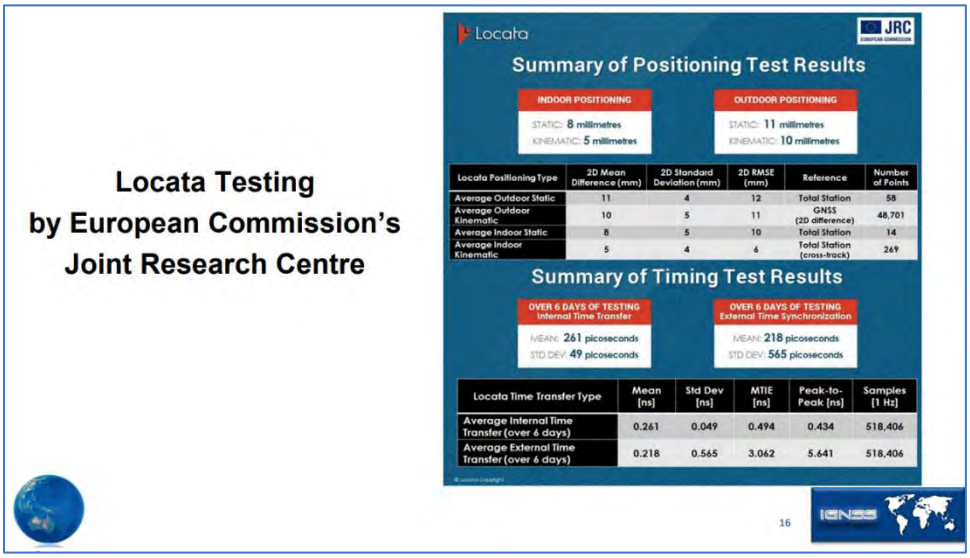


Slide 14

The next section describes some of the Australian Companies Working in PNT (Slide 15)

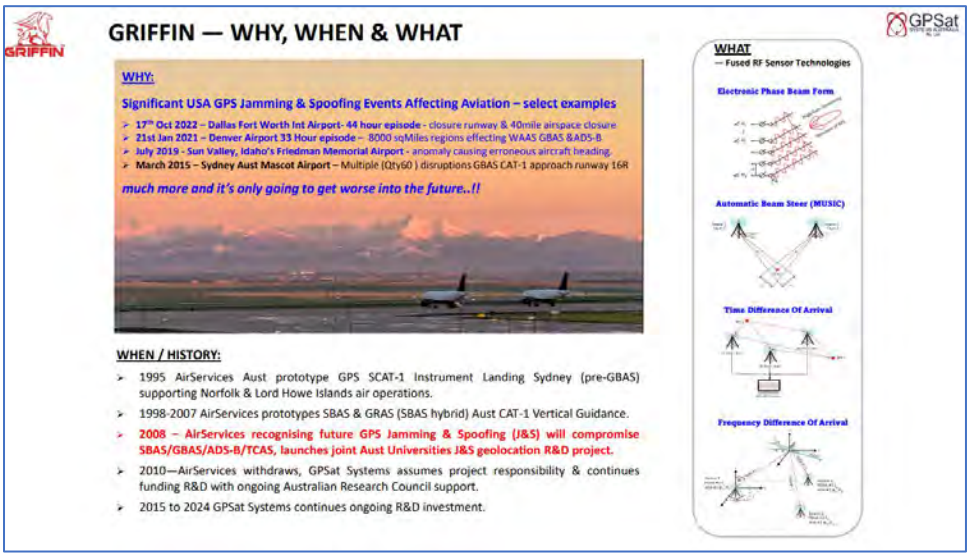
Slide 15

The Locata Corporation from Australia did very well in the European Commission's Joint Research Center Testing (Slide 16). Their indoor and outdoor positioning is at the centimeter or better level and internal time transfer and external time synchronization at the 261, 218 picosecond level. So, it continues to prove itself as a very good technology.



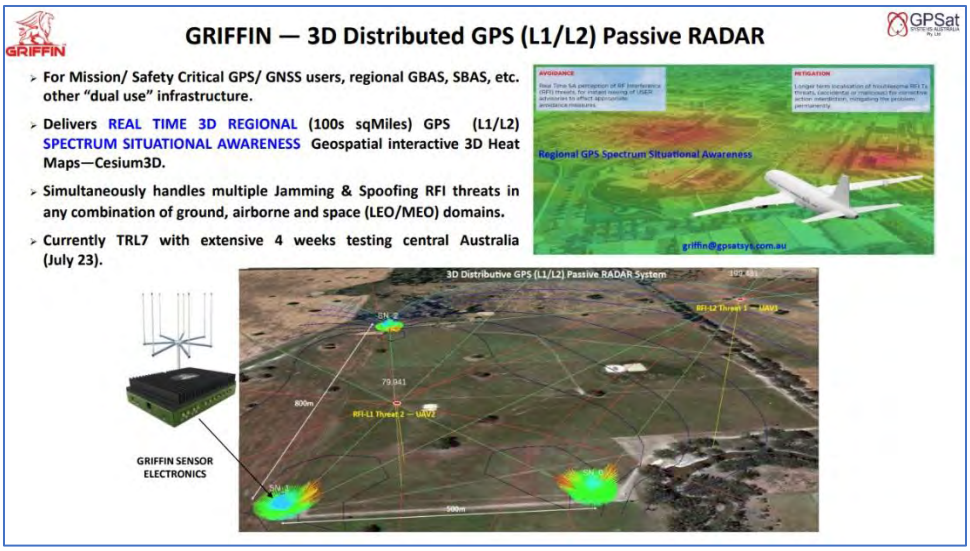
Slide 16

Slide 17 described the GRIFFIN system and why it was developed.



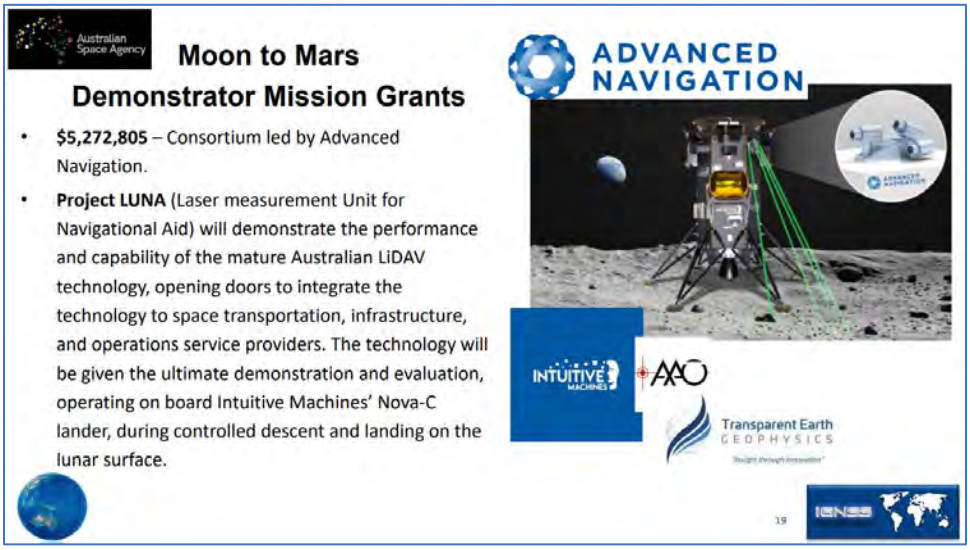
Slide 17

Slide 18 shows how the GRIFFIN system. The jamming signal is treated like a passive radar target. The diagram is of a test that was done on a farm which was about 800 meters, so it's meant to be about the size of a regional airport with three of the GRIFFIN sensors locating two UAVs that are jamming threat targets. Once you have a characterization of the targets, you can then do some mapping of how you would expect that to propagate to turn into heat maps like the one on the top right). It is proving to be a very useful and capable system.



Slide 18

The Australian Space Agency has a number of grant programs and we've recently funded a number of grants: six or seven (Slide 19). Two of these were PNT based. Under the Moon to Mars Demonstrator Mission Grants, a consortium led by Advanced Navigation in Sydney got a grant of $5 million Australian dollars (multiply by six to get US dollars). The LiDAV system consists of three Lidars pointing forward and down to replace landing radars on things like lunar landers. Because it's using Lidar and the way it's doing it, it gets symmetry out of it. Advanced Navigation already had their initial system in the guidance system for Intuitive Machines, who are based in Houston, for the Eclipse lander for a lunar landing. It is likely to be the first Australian technology to land on the moon. This grant is about the LiDAV, which will be used to bench test and as a prototyping exercise.



Slide 19

The second grant was given to Quantx, who has an optical clock (Slide 20). This project is about space qualifying that clock so that we could have the capability to fly an optical clock. This will result in Australia launching one of the globe's most complex quantum devices into orbit.

Slide 20

Finally, Mr. Higgins noted that at the IGNSS conference, Dr. Parkinson will give the keynote speech about the 50th anniversary of GPS. Dr. Van Digglen, Mr. Chan, and Dr. Morton will also participate from the Board.

Slide 21

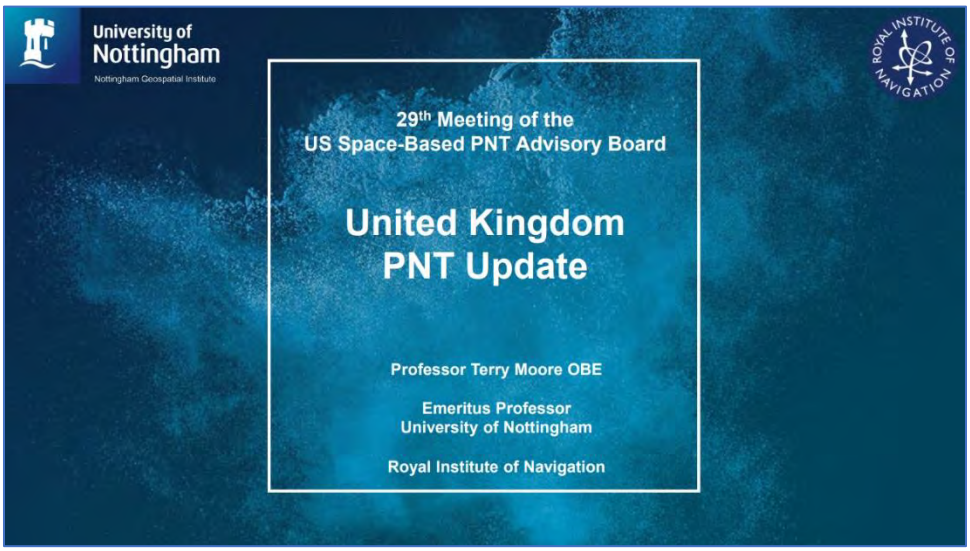
Discussion

Dr. Parkinson asked if Mr. Higgins knows what the L-invariance is at 10-50 seconds in the clock he showed earlier.

Mr. Higgins stated that he does not, but he will send him a number. He also commented that Australia has another "product that's very stable over short periods which is being used over the horizon right out to generate very precise write up signals for the defense."

3) United Kingdom
Prof. Terry Moore, *Member, PNTAB*

Over the past couple meetings, Prof. Moore has been explaining to the Board what's happening in the United Kingdom regarding PNT (Slide 1).

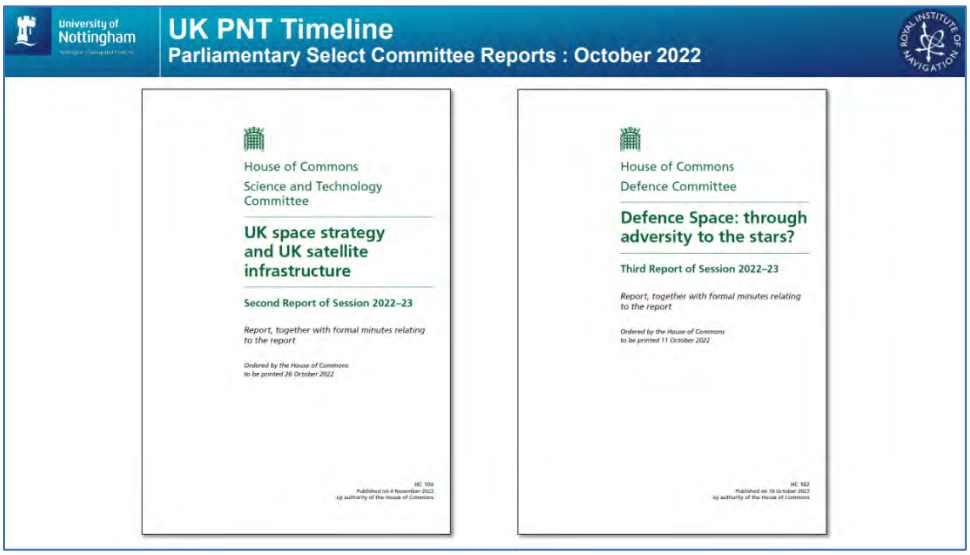


Slide 1

In 2018, the Blackett review investigated all the vulnerabilities that we have in Critical National Infrastructure (CNI) and other applications, and tried to come up with an action plan for how the government should respond to that (Slide 2). This led to the space-based bounty program for which there've been direct questions about that from this board in the past, and Prof. Moore has been unable to answer those. The report was withheld but was finally published in October 2023, so it's all publicly available now. The draft strategy was published in 2021. It was not accepted by the government or implemented by the government and basically sat on someone's desk. But then towards the end of that year, the Integrated Review and then the National Space Strategy, both for the first time, started committing the UK government to doing something about strengthening the resilience of PNT.

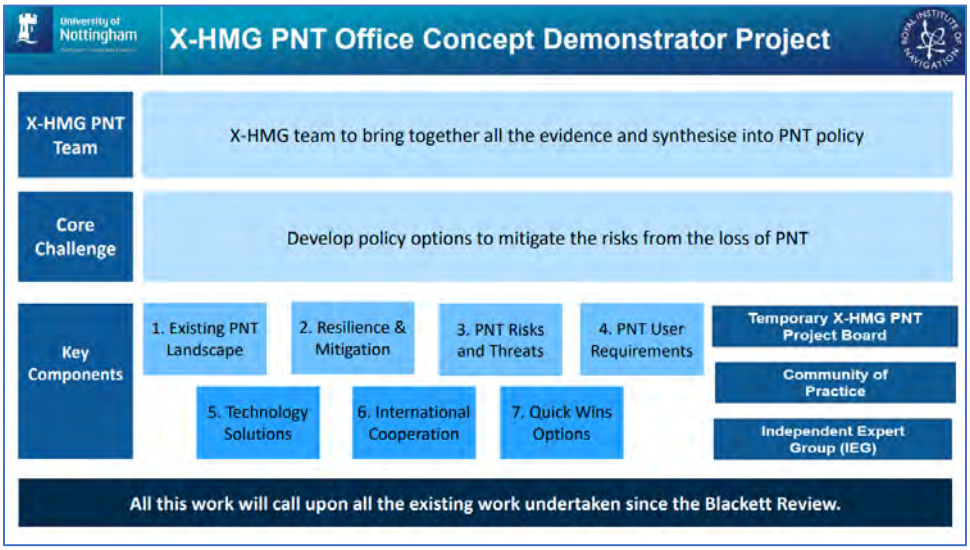
Slide 2

Those messages were reinforced through 2022 in October when two reports came out from two Parliamentary Select Committees on Space Strategy (Slide 3). Both stressed the absolute importance of PNT, the vulnerabilities there, the need for resilience, and the need for the government to actually do something.



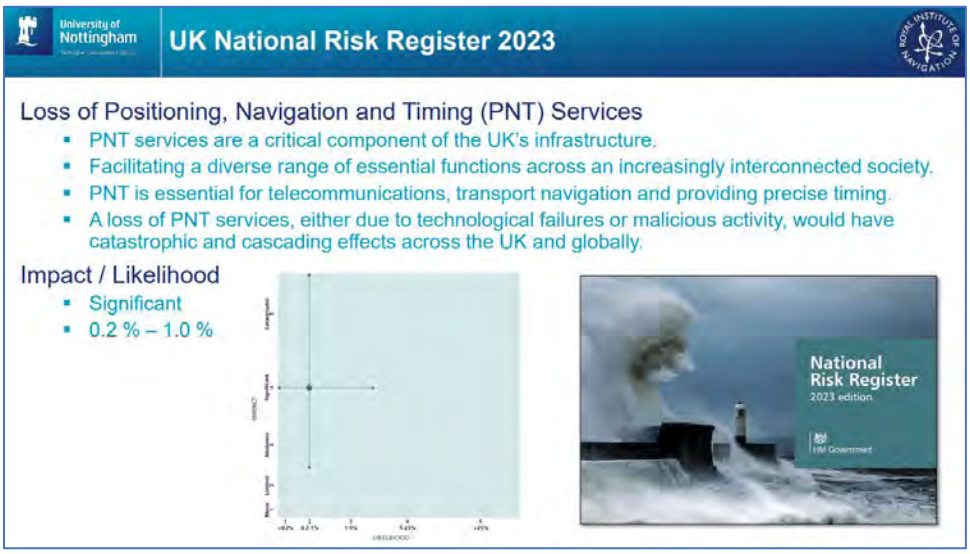
Slide 3

As he reported earlier this year and the end of last year, the UK government put in place a cross-government PNT Office Demonstrator Project, which was trying to bring together all the different department with interest, primarily in CNI and other applications, and to try and develop, for the first time, unified and integrated policies on PNT covering those areas. Slide 4 shows the makeup of the PNT Office Demonstrator Project. The Framework Policy was published in October of 2023.



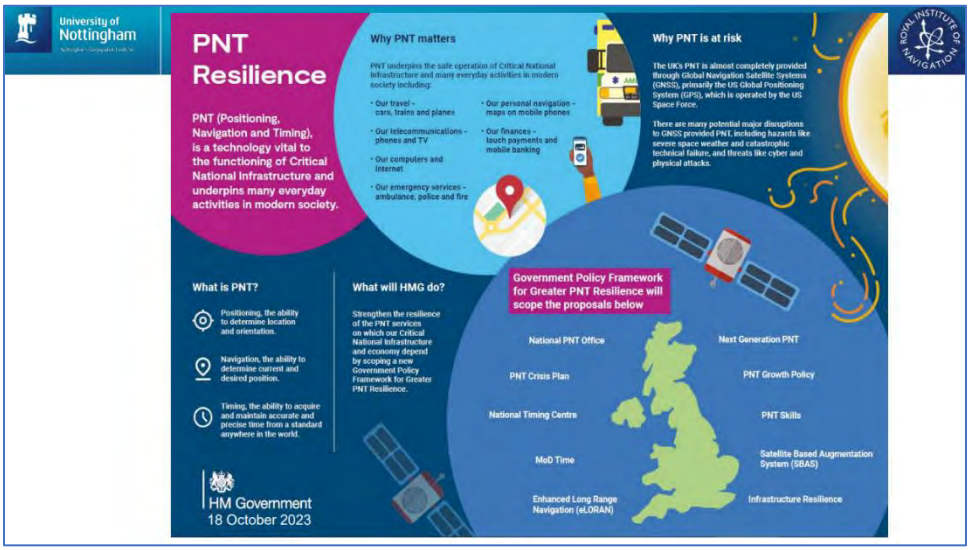
Slide 4

Earlier this year, for the first time, PNT came onto the National Risk Register. Previously the only representation of PNT or GNSS within the National Risk Researcher was space weather. But in 2023, it came into the space register for the first time, recognizing the critical dependance on PNT, what impact that would have, and coming up with a risk matrix, which tries to give an indication in very simple bands of the level of the risk, the likelihood of that, and the likely impact. Slide 5 shows huge error bars, which can go up to absolutely catastrophic. This is shown as two dimensions, but this risk match is not two dimensional. It should have time as the other dimension, because something that's a small interference for a short period of time will have a different impact, but something that's got the duration of days.



Slide 5

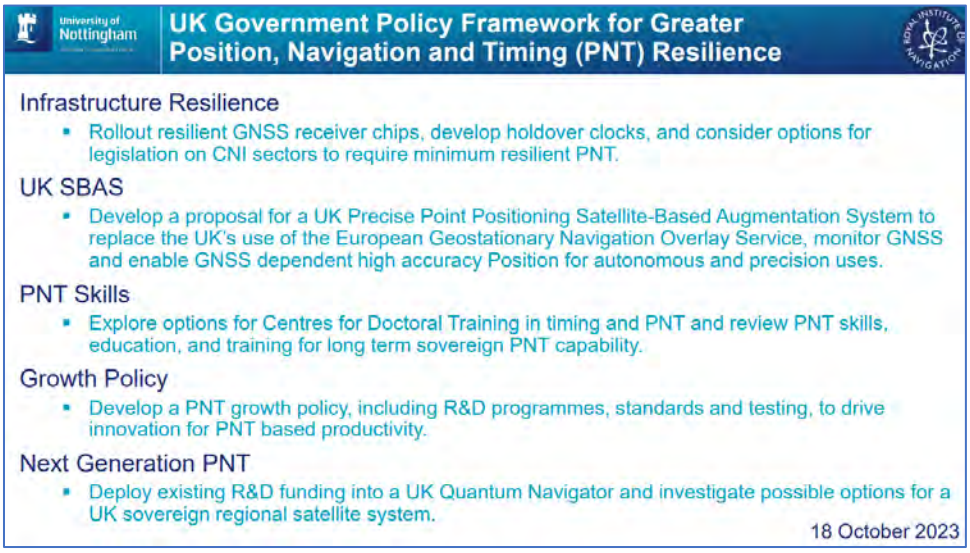
What is PNT? Why is PNT important? What is the risk? What will the government do? The policy framework now says there are ten items. (Slides 6-7). The most important part is to put some people in charge, give them the responsibility, give them the budget, and give them the task of what they're going to be doing. So, the National PNT Office has been established. It's within the Department of Science, Innovation and Technology, led by Dr. Shabana Hack. The current staff is six at the moment, but that would be going to ten by the end of 2023. This office will be responsible for the whole program and framework and continue to develop each of these items. Areas 2-6 include: (2) Developing the crisis plan, which are the short-term mitigations against incidents identified in the risk register, how the government, how the country is going to respond; (3) Recognizing the importance of timing for most of the critical national infrastructure that depend on some PNT, but most of them are dependent on the T rather than the PN; (4) Setting up the National Timing Center, having a stable reference time and distributing that time around the country; (5) Having a backup of that, which is called “MOD Time,” which is within the Ministry of Defense; (6) Reestablishing the eLoran. Developing from the single station, which is still operating, to provide not only timing but providing a positioning reference as well across the nation.



Slide 6

Slide 7

Slide 8 summarizes Areas 7-10, namely: (7) Building resilient infrastructure in terms of the receivers, receiver chips, the antennas; (8) Developing a UK independent space augmentation system. This has been an operation as an experiment for the last 18 months. Developing that further, so it is a fully operational SBAS in terms of civil aviation. A secondary aspect of this is a precise point positioning service, a free nationwide decimeter level, precise point positioning service delivered from space; (9) Developing skills and recognizing the skills shortage that we've had. Developing the doctoral level at Centers for Doctoral Training where there is training from apprenticeships all the way up through the PhD training. How does this then fit into policy in terms of the growth of industry, the growth of the country and the national growth? Part of this is work on standards and testing frameworks for devices; and (10) There is a lot of work to be done regarding the next generation. Looking at the Quantum Navigator and the Quantum Point program is already significantly funded within the United Kingdom. The UK is not talking about a global satellite navigation system, but perhaps a regional deployment, perhaps something like Japan's QZSS.



Slide 8

The Council for Science and Technology wrote to the Chancellor of the Exchequer and the Secretary of State in charge of the Department of Science, Innovation and Technology (Slide 9). Looking at key priorities for strengthening UK sovereign space capability, four priorities were identified, number one is PNT. This stresses the importance of the further investment in the UK sovereign space capability and also terrestrial complementary technologies. The Quantum Spectrum Strategy was published in the last couple of years, and the current round of funding priorities within that have come out, as well. And the fourth mission of those is directly related to quantum-based navigation technologies. IT says that quantum navigation bases will be deployed and flown by 2030.

Slide 9

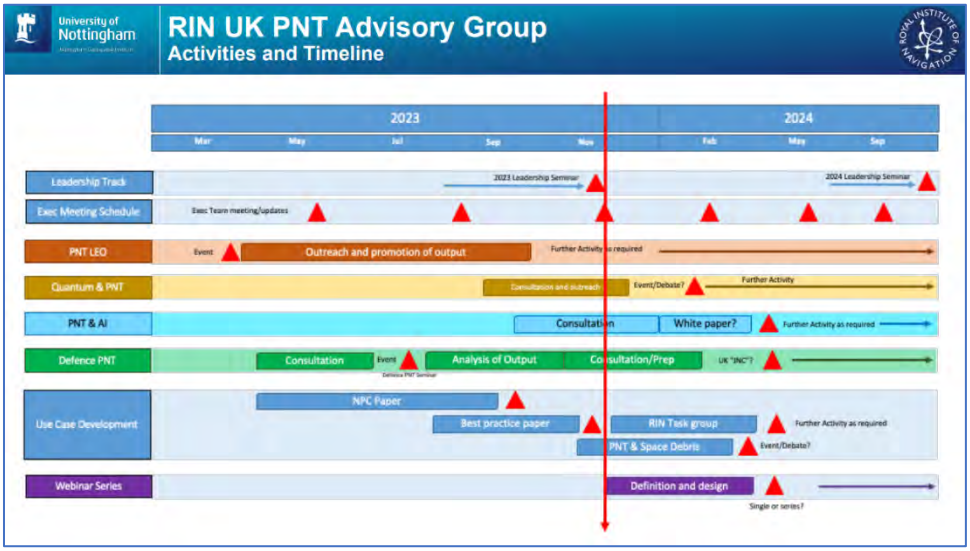
The Royal Institute of Navigation set up the PNT Advisory Group to try to support the UK government with independent advice (Slide 10). There was a LEO PNT event on March 7, 2023, in London, which was very well supported and covered many of the discussions that we were just having yesterday in terms of LEO PNT, looking into the technology and the business cases from that. There was a defense PNT event in July of 2023, trying to get together the defense and civil sectors in the UK. This will grow into a much larger event over the next couple of years. The UK's first PNT and AI working group meeting was held a couple of weeks prior to this Board meeting, trying to explain what machine learning data science means and how PNT fits within those. Also, a Best Practices white paper was published, and with the National Preparedness Commission, a report was published in October of 2023.

Slide 10

Both reports are freely available (Slide 11). So, the white paper looked at the state's standards and best practice documents across the world and tried to bring those together to show the importance of developing standards and best practice for PNT to increase resilience. This comes with a key recommendation that something should be done. The Royal Institute of Navigation (RIN) has a leading role within that. The National Preparedness Commission paper confirms that the government should take a leadership role and take on the responsibility for PNT.

Slide 11

As shown on Slide 12, the Royal Institute of Navigation also held an annual GNSS leadership seminar, which took place on November 7, 2023. The Minister then at that time, George Freeman, announced the PNT framework and the head of the PNT Office gave a presentation. The RIN is looking at Quantum as well, but they don't have an event scheduled for that yet. But, they will be looking at quantum technologies and PNT.



Slide 12

Prof. Moore encouraged the Board to look at the European Navigation Conference (Slide 11). This will be held at the European Space Research and Technology Centre (ESTEC) in the Netherlands in May of 2024. In 2023, the conference was oversubscribed. We're getting back to having a good, stable, and meaningful European Navigation Conference. Prof. Moore thanked the Board.

Slide 13

Discussion

Dr. Betz thanked Prof. Moore for the presentation. He stated that he observed that "having PNT is kind of thought about as a binary thing. And of course, knowing what time it is within a year is not like knowing what time it is within a microsecond." He asked if there is deeper thinking about the quality of the PNT. Is that something where the Royal Institute of Navigation is helping inform the bureaucrats about the more subtle but important issues?

Prof. Moore agreed, saying that the words of the framework are chosen quite carefully. It is not the policy, it's not the strategy, it's a framework. And each of those items will be developed in more detail. The RIN is working to provide advice on understanding the depth and the detail of it, and the best practice aspect to it, because it's how you respond to different levels of threat and different levels of accuracy requirements across all the different use cases. Every use case will have potentially different levels of requirements in response to that.

ADM Allen commented that the Board may want to question whether "space-based" should be in front of this body's title.

4) Resilient Navigation and Timing (RNT)
Mr. Dana Goward, *Member, PNTAB*

Mr. Goward thanked the members of the Advisory Board for welcoming the RNT Foundation, himself among your number these many years and for putting things on the record, as the Admiral says, we at the foundation advocate for policies and systems to protect GPS, satellite, signals, and users. When we go to talk to Congress and advocate for budgets, policies, and the kinds of things that the PNT Advisory Board talks about, and when we go to talk with the Executive Branch and advocate for those things, having those things on the record, and having a group of experts and their documents to point to and say, "look, it's not just us." The smart people also want you to do this. This is what needs to be done. So, it is very helpful to be able to refer to the protect, toughen, and augment kinds of things that are documented here in other forms. And we're not the only ones that do that, we are relentless in doing that whenever and wherever we go.

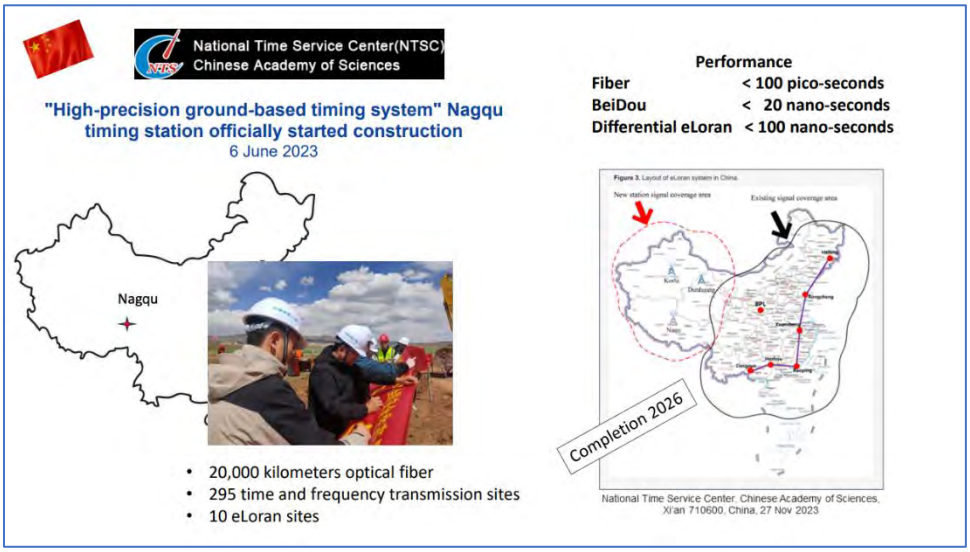
Mr. Goward also thanked the RNT Foundation members. They have several individual members who work on behalf of protect, toughen, and augment. This includes Pat Diamond, who does a lot of pro bono work helping develop systems that can be complementary and augment GPS and other agencies. He broke ground with the Canadian government recently, and along with Mr. Goward, attended the first, that we know of, PNT resilience event in Canada. They both played roles in that presentation and found a welcoming reception and it is one of those instances where really smart people have the light bulbs go on and say 'yeah, this is a problem, this isn't something we had thought about before' In addition, Humber College in Toronto, Canada, looks to become a center of excellence for PNT and PNT resilience within Canada, and it's the first of its kind.

He also thanked the 38 corporate members for several reasons, certainly for their support. They are a scientific and educational, public benefit charity. So, they are prohibited from supporting their interests. Despite that, they help pay the foundation's bills and help put on events such as the one on the previous evening.

In addition to talking about PTA and things that are going on in the U.S., the Board would like to keep an eye on what's going on in the rest of the world. The Board has celebrated the UK and Prof. Moore's accomplishments in advancing PNT over there. That is an important benchmark for what the U.S. could and should do, and know what others are doing.

At the last meeting Mr. Goward talked a bit about China's unforgettable humiliation and their motivation to become independent of the U.S. and independent in space. China has become what the DoD calls its "pacing threat," and there are some new announcements and developments. There have been two press releases about their high precision ground-based timing system, which is a little bit of a misnomer because it's designed to integrate satellite-based information, broadcast information, and fiber information all in a comprehensive whole. As shown on Slide 1, it is an incredibly comprehensive system with targets for incredible performance in terms of delivering time.

Mr. Goward asked the question: "why in the world are they doing this?" This is a lot of time, effort, and money. What possible benefit could China see from establishing this kind of system? What kind of internal benefits could they get? What kind of international benefits and advantages would they have?



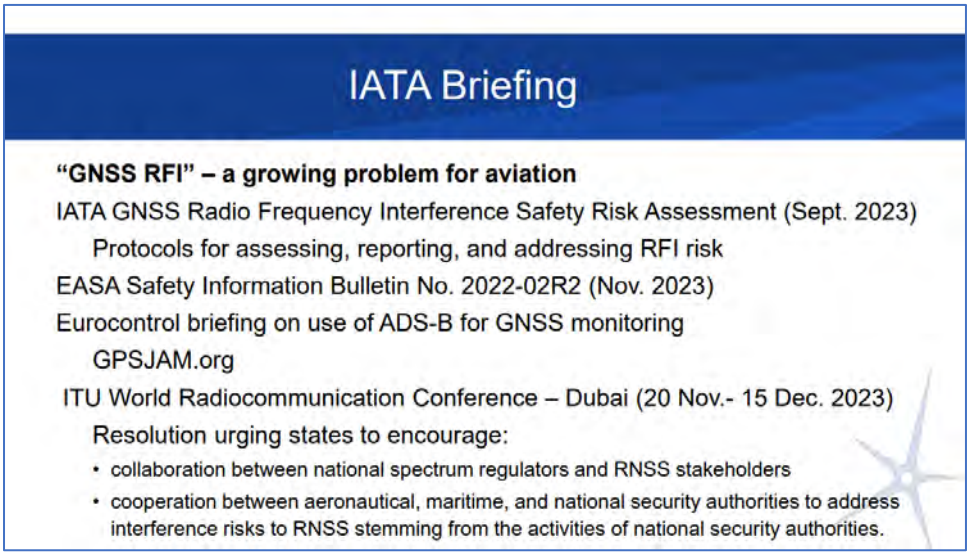
Slide 1

5) Consumer Technology Association (CTA)
Mr. J. David Grossman, *Member, PNTAB*

[Ed. Note: Mr. Grossman was not available.]

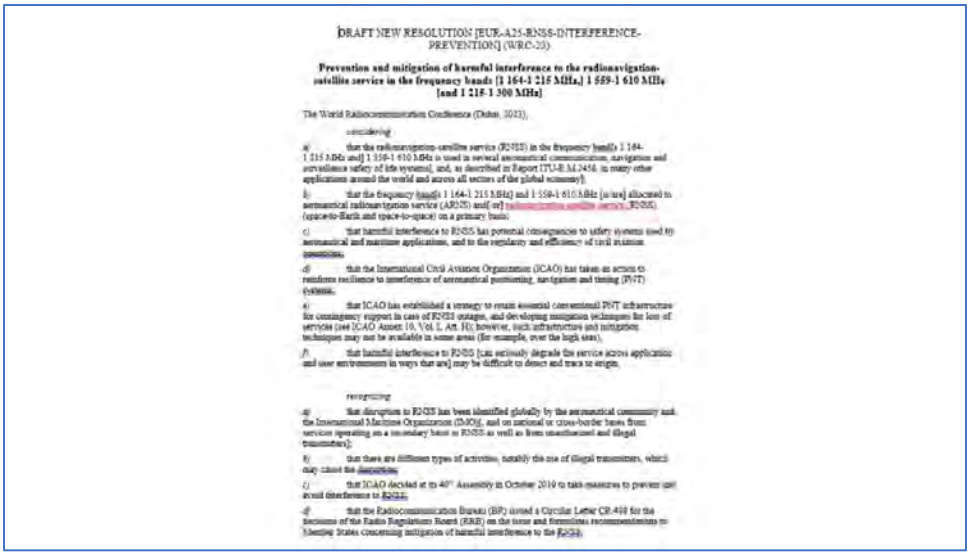
6) International Air Transport Association (IATA)
Hon. Jeff Shane, *Member, PNTAB*

Hon. Shane stated that he would discuss concerns about the integrity of GNSS, GPS in particular, from the perspective of aviation. IATA, who Hon. Shane is representing. IATA is suddenly taking GNSS outages very seriously. Increasingly, the default mechanism for air navigation today is ADS-B. The FAA mandates it within the U.S. ADS-B is predicated on GPS signals in the U.S. and other GNSS outside of the U.S.. It depends on GPS for location and the ADS-B mechanism parlays that signal into a broadcasting of the identification, speed, and location of the aircraft. If GPS is not reliable, ADS-B isn't working. As a result of noticing that not just GPS but other GNSS around the world are not entirely reliable, the IATA has put out a safety risk assessment called GNSS RFI (Slide 1), which means GNSS Radio Frequency Interference. The safety risk assessment is a set of protocols that IATA recommends to its 290 airline members around the world for assessing, reporting, and addressing the risk. Should one feel in danger in an aircraft because GNSS might not be entirely reliable, they shouldn't ecause there is such redundancy in navigation systems on an aircraft that, as long as the light deck knows that there's an outage, they can work around that outage without too much difficulty. Because of this ADS-B has become a very convenient way of identifying outages in the world. ADS-B has an integrity monitoring facility and if it knows that it's getting a signal that is not quite consistent with where the airplane knows it is, it is automatically reported as an outage. The European Aviation Safety Agency, EASA, has put out a safety information bulletin, talking about the same thing, and doing what the IATA Safety Risk Assessment Paper does. EUROCONTOL has a very good briefing on the use of ADS-B for GNSS monitoring. Hon. Shane asked Ms. Salem to pull up GPSjam.org and put it on the screen. The map is done daily on the basis of crowdsourcing. People are asked to report to the ADS-B exchange.



Slide 1

The International Telecommunications Union (ITU) has a World Radio Conference (WRC) every year, which is currently going on. It started on November 20, 2023, and it will go on for another week in Dubai, United Arab Emirates. IATA is there, along with lots and lots of other delegations. There, a resolution is being discussed in which they identify GNSS outages as a serious problem (Slide 2). They are currently departing whether the ITU should "urge" states to deal with it in a sensible way, or should they "encourage" states to do it or "should they urge them urgently to do it?" ICAO, the International Civil Aviation Organization, has also urged and encouraged states. Hon. Shane stated that he will send these documents to the Board for information. They are simply identifying the problem and describing ways of addressing them. They do not provide a solution to the problem other than being aware of the problem such that the problem doesn't cause any serious damage. Everything else that we do here is to try to solve the problem.



DRAFT NEW RESOLUTION [EUR-A25-RNSS-INTERFERENCE-PREVENTION] (WRC-23)

Prevention and mitigation of harmful interference to the radionavigation-satellite service in the frequency bands [1 164-1 215 MHz,] 1 559-1 610 MHz [and 1 218-1 300 MHz]

The World Radiocommunication Conference (Dubai, 2023),

considering

a) that the radionavigation-satellite service (RNSS) in the frequency band[s 1 164-1 215 MHz and] 1 559-1 610 MHz is used in several aeronautical communication, navigation and surveillance safety of life systems[, and, as described in Report ITU-R M.2456, in many other applications around the world and across all sectors of the global economy];

b) that the frequency band[s 1 164-1 215 MHz] and 1 559-1 610 MHz [is/are] allocated to aeronautical radionavigation service (ARNS) and[/or] radionavigation-satellite service (RNSS) (space-to-Earth and space-to-space) on a primary basis;

c) that harmful interference to RNSS has potential consequences to safety systems used in aeronautical and maritime applications, and to the regularity and efficiency of civil aviation operations;

d) that the International Civil Aviation Organization (ICAO) has taken an action to reinforce resilience to interference of aeronautical positioning, navigation and timing (PNT) systems;

e) that ICAO has established a strategy to retain essential conventional PNT infrastructure for contingency support in case of RNSS outages, and developing mitigation techniques for loss of services (see ICAO Annex 10, Vol. I, Att. H); however, such infrastructure and mitigation techniques may not be available in some areas (for example, over the high seas);

f) that harmful interference to RNSS [can seriously degrade the service across applications and user environments in ways that are] may be difficult to detect and trace to origin,

recognizing

a) that disruption to RNSS has been identified globally by the aeronautical community and the International Maritime Organization (IMO)[, and on national or cross-border bases from services operating on a secondary basis to RNSS as well as from unauthorized and illegal transmitters];

b) that there are different types of activities, notably the use of illegal transmitters, which may cause the disruption;

c) that ICAO decided at its 40th Assembly in October 2019 to take measures to prevent and avoid interference to RNSS;

d) that the Radiocommunication Bureau (BR) issued a Circular Letter CR/458 for the attention of the Radio Regulations Board (RRB) on the issue and formulates recommendations to Member States concerning mitigation of harmful interference to the RNSS,

Slide 2

Discussion

Dr. Walter commented that what they've seen regarding the interference near Houston is that it's caused by high performance trainer aircraft that are doing maneuvers that are causing them to lose GPS instead of being caused by interference. So, if you look at GPSjam.org, which is a fabulous resource, those occur every weekday, not on the weekends. And they're limited to these very high-performance aircraft flying very circular routes that no doubt causes them to go inverted or lose GPS. The White Sands stuff is probably interference, but the South Texas stuff is most likely not interference.

Hon. Shane stated that he's glad Dr. Walter mentioned that because one of the big problems that IATA has called attention to both at ICAO and the ITU is what you might call intentional interference. Things the government does which have unexpected consequences for the integrity of GPS and GNSS signals. In the resolution that's pending right now at ITU, they're urging states to be careful about that, not to compromise navigation, even though they are pursuing legitimate ends. They need to be careful about what they do with signal propagation. Hon. Shane said that he fought very hard at IATA to get a resolution adopted that encouraged states to take seriously the potential for damaging the integrity of GPS through things that it's doing that they might be doing in the interest of national security.

Mr. Miller stated that his team will include that information that you provided for the record. In 2000, in Istanbul, he was elected by all the major airlines to be the spokesperson to the U.S. Ambassador for IATA when he was working for United Airlines. Looking back 20 years ago to now, where they have a tool that they're advertising, is very large progress and it is very much appreciated that you bring it to our attention.

Hon. Shane stated that, Capt. Burns understands this stuff thoroughly and would be able to do it in more than one syllable.

Mr. Scott stated that he finds it amazing that this GPSjam.org is providing situational awareness globally. He asked if it is a hobbyist activity. Is one guy running it?

Hon. Shane stated that he thinks so, but that's not what people are relying on. That's just fun to look at because you can play with it.

Mr. Scott stated that this really reflects on global situational awareness coming out of some guys' hobbyist activity.

Mr. Goward stated, "It shows how easy it is to do and kind of shames the government that that the government's not doing it selves." Mr. Goward read a comment from one of the RNT Foundation members reminding everybody that the ground aviation navigation infrastructure in the U.S. is quite old, some of it 40 plus years old. So, we need to keep in mind it's a systems approach and that the alternatives and complementary systems need to be as fresh and as current as the primary ones are.

Hon. Shane stated that we could have a whole different conversation about how old all of the equipment on the ground is, particularly in the U.S. Because of the integrity of GNSS signals, one or more resolutions and papers coming from official,

international sources, urges or encourages states to maintain their ground infrastructure as a backup. This is a problem for OMB, because OMB would love to decommission all the radar systems that are around the country.

Mr. Madani asked what the source of the monitoring is.

Dr. Walter stated that it's an ADS-B exchange. So, it's a collection of ground stations that are collecting ADS-B data. What they really offer is this brilliant visualization that makes it so easy. However, ADS-B was not designed to do interference detection and what its reporting is where the GPS is inaccurate, and there are many reasons GPS could be inaccurate. Many instances are caused by non-interference events. Dr. Walter stated that "we're setting up our own website where we separate out these other aircraft known as bad aircraft; helicopters often have experimental aircraft, frequently have misreporting. When you remove those, you get a somewhat different looking picture. Then you want to open up and say, 'here are the actual events,' because test events occur pretty regularly, and those are real interference events, and we'd like to identify those and highlight those in that."

Mr. Goward asked if it's an open broadcast, so anybody can get a receiver and pick it up. All these hobbyists have done that and then they aggregate their data. You can do the same thing with AIS. There are companies that aggregate that data, who have their own receivers. They also have satellites that pick-up information and they display it. You can go to the maritimetraffic.org and see it. That is the beauty of and disadvantage of an open broadcast.

ADM Allen commented that there's an organization called Ships Body that uses AIS and people along the coastline send in pictures of when the ships are going through the Bosphorus Straits (Turkey), for example, and it's pretty accurate.

Dr. Van Diggelen asked, "looking at the frequently asked questions of GPSjam.org, it looks like there's this thing called navigation accuracy for position, that's just a self-reported estimated accuracy of, you know, levels less than three meters, than ten meters, less than 30 meters. Is that what they are?"

Dr. Walter stated that the ADS-B format has some quality indicators in it. The NAC, which is the navigational accuracy category, and there's a NIC, which is the navigational integrity category, and there's a SIL, which is the service integrity level. So those three parameters are performance ones. We have found that the NIC is a good one, and that's probably what ADS-B exchange is using because it's linked to the horizontal protection level. Largely, it'll be tied to the geometry. So as the geometry degrades, which you would expect under interference, it goes away entirely. The higher the NIC value, the better your performance. And if you go to a NIC of zero, it's saying it has an unknown integrity. What the ADS-B exchange is reacting to is when an aircraft reports a NIC value of zero, it will label that as interference. Sometimes that's true, sometimes that's not true. So, if you use other indicators and other information to separate those, then this is a very powerful one. When you get to places like Ukraine and Syria where there's a lot of interference, you can see like almost all aircraft are going to be reporting uncertain integrity levels. But in the U.S., where it's much less of an impact we have these other ones coming in, it's a little harder to distinguish them. So, a lot of times what I see is interference is an aircraft with a bad transponder or a bad GPS unit.

Dr. Van Diggelen commented that GPSjam is a bit of a clickbait name.

Dr. Walter stated that what they did is fabulous, they have this beautiful interface and aggregates 24 hours of data. It's not a real time indication of what's going on. But they have a history, so you can go back to when there was a report, you can see if there was jamming. It was very useful during the Dallas and the Denver events; those had a huge impact. If you go back and look at the Dallas event and see what that looked like.

Mr. Goward asked Dr. Walter if they used ADS-B to locate the Denver source.

Dr. Walter said that Denver was a known issue and Dallas is still unknown and one thing that's interesting with Dallas is there was very little observed on the ground. There's almost no interference observed there during that event. But the aircraft are very good at seeing upward transmitted interference. ADS-B is better in that sense than AIS because it can see a very broad area and it's very good at seeing interference. In Denver, we saw effects on the ground, and it was that one was ultimately traced to a source. With Dallas, nothing was observed on the ground. From our observations, it was intermittent. It was moving at times, and it also probably employed a directional antenna. That one may have been more intentional and there may have been an attempt to deceive.

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Roundtable Discussion & Next Steps
All members, led by the Chair

Following some discussion between board members, ADM Allen said that the next PNTAB meeting will be held on the week of April 22nd in the Colorado Springs, CO, area. The preparatory days will also include fact-finding meetings to venues such as 2 SOPS. He also noted that he has begun working on a Memorandum to the PNT EXCOM co-chairs as follow up to the one he sent in January. Over the holidays he will send a draft to Board members. ADM Allen noted that he's begun working on a Memorandum for the PNT EXCOM. He also believes that the focus of the next meeting should be on the Board's PTA framework. The issue would be to fill such framework with the stuff we've been talking about that fits in against that high accuracy services, and so forth.

Lt. Gen. Hamel commented that Mr. Higgins may be leaning into the idea of trying to do a bit of a comprehensive stocktaking in terms of where GPS is today vis a vis the other systems in the world. The board has come up with categories of improvements, but it needs to answer why it needs to be taken seriously.

Adm. Allen stated that the Board should start with that topic as a scene-setter.

Mr. Goward reminded the Board that it didn't get the outcome it wanted regarding a White House summit for the 50th anniversary of GPS. The board was looking for two outcomes. First, to improve the agility and focus of leadership with a single federal official responsible. Second, moving towards an integrated and resilient national PNT architecture. The topic of focused leadership could be an opener for the next meeting. The root cause is that we don't have focus and leadership, and as a result of that, we need to do all of these things in the framework which we recommend but are pending.

ADM Allen said that advice is only as good as the organizational structure is prepared to receive it, understand it, and potentially act upon it. When taking an overarching kind of approach, like determining who we intend to advise, the discussion quickly shifts to specific topics such as who really owns a high accuracy service. That should be part of the scene-setting that would move us forward. Whether it's a policy position, authorization, or appropriation, everybody subscribes that this is good stuff, but when passing around the collection dish things get difficult.

Dr. Betz suggested that the Board's recommendation regarding 'interference detection and reporting' be modified to say 'interference detection and removal'. While it's nice to know if interference is happening, we need to remove it in order to be effective. Also, there seem to be fundamental privacy issues and concerns regarding mobile wireless technology. Dr. Betz asked if the Board wants to amend its recommendation.

ADM Allen responded that the recommendation is already on record as it went out January of 2023. At this time NCO is putting together a response.

Hon. Shane stated that he likes the idea of proceeding more inductively. In other words, we've been articulating these conclusions for a long time in various formats to various people, and we're all familiar with the frustration that we feel because we don't get a direct response very quickly. The concept of having a meeting next time that really was focused on PTA. Following that, a meeting focuses on the capabilities of other GNSS with compelling evidence of where the differences and shortfalls are to make an evidentiary and provable case that we need something more. When you then follow that up with recommendations and you point to the evidence that supports those recommendations, it seems to me that it's impossible not to respond.

ADM Allen stated that the scene-setter would be the White Paper that the International Engagement subcommittee is working on. Key issues are how GPS compares to other GNSS, and what is the demand for action that leads us to PTA.

Dr. Parkinson asked Mr. Higgins if he is going to coordinate with Dr. Betz on this effort.

Dr. Betz asked if that's something different. That's not meeting the Gold Standard as much as serving critical infrastructure needs right?

Dr. Parkinson stated that they're two separate but quite closely related topics. The question is to what degree does what you do overflow into what he does?

Mr. Higgins stated that we're fundamentally doing is to improve the capabilities of the system and its services. What Dr. Betz is talking about is the user end of the problem and making sure users have resilience.

Dr. Parkinson said that Dr. Betz's subcommittee has an overlay that is a metric for the augmentations, but it is also an overlay for the fundamental system."

ADM Allen said that Mr. Higgins' subcommittee is providing the background for presentation.

Dr. Betz said his proposal had been to focus on PTA. If we also include the issue of the Gold Standard, it seems we're going to have a dual message or dual topics."

Dr. Parkinson said he thought the preamble was going to be our current situation with what we have in terms of the GPS system, how it compares to things that we might be able to do, and then hand it over to Dr. Betz's subcommittee to determine what we are going to look at in terms of P, T, and A.

ADM Allen said he needs a piece upfront, so when he writes a memo after this is done, we put everybody on notice of some of the problems in their environment and the political context that we're dealing with. He believes we need a scene setter that actually talks about the degree of difficulty in getting these things done."

Dr. Betz stated that they could apply the metric to current GPS and its current augmentations.

Dr. Parkinson thought that was going to be discussed by Mr. Higgins. Is that correct?

Mr. Higgins replied that his subcommittee is looking at characteristics of other systems that aren't currently on GPS. So, it was very much a stock take against the Gold Standard question. Irrespective of what needs to happen to GPS in terms of competition to other systems, you still have the PTA problem. So, they can be handled quite independently. The other is whether we are talking about two themes at the meeting or just one. If it is just one, that would be more effective.

Dr. Parkinson stated that he thought the preamble would be an initial look as how we stack up in terms of the GPS system."

ADM Allen said that Mr. Higgins's subcommittee is the preamble.

Mr. Higgins reiterated that irrespective of what you do with GPS in the future, PTA is a problem anyway. It's not necessarily a scene-setter.

ADM Allen said that we've got to attack this mindset of the gold standard and everything's okay. It's not okay, and Mr. Higgins' subcommittee is going to tell us why."

Mr. Higgins expressed concern that tackling too many issues as one meeting might result in not getting anything done.

ADM Allen said that there is still time to work out the details.

Dr. Betz agreed. There's plenty to motivate a near term urgency for a PTA without comparing current GPS to other current GNSS, which seems to him like a distraction. We're starting to get into multiple topics again instead of a single topic.

Mr. Higgins said that both points are extremely important.

Dr. Parkinson stated that he would like to hear what Mr. Higgins assessment is in a 30- or 45-minute brief, for example, that becomes a preamble to what we're going to do in terms of PTA.

ADM Allen agreed, saying that Mr. Higgins has the basis for a narrative we need to have with people that are looking at the work we're doing.

Mr. Higgins stated that everything is urgent, and we've only got one day. We could perhaps do the preamble where we normally do the subcommittee report.

ADM Allen stated that he doesn't have any problem with read-aheads. They can become a basis for discussion rather than having to tell everybody at the meeting.

Mr. Higgins stated that his subcommittee can have the white paper ready by the next meeting, but it will not have been reviewed by the Board.

ADM Allen stated that they can take in draft form.

Mr. Higgins said that if we want to flag other things that are important, we could do that in that where we currently have the subcommittee reports.

ADM Allen said that Mr. Higgins could generate a list of things we want to address and following meetings after we focus on PTA. However, he'd like to get that into the public record.

Dr. Betz said that the PTA subcommittee would not need to give a subcommittee report, so Mr. Higgins would have double the time during the subcommittee reports to provide that piece of things.

Mr. Murphy asked if the Board could move this topic to the prep day. They're not completely unrelated issues because one part of his matrix should probably show that these other systems are already tougher.

Adm. Said that the Board could cover this stuff in the prep day and then present it as the output of the Board for the record. There are lots of ways you can put it together and we can work on that between now and April."

Mr. Miller noted that we can't just say these are issues. We have to come up with some recommendations to improve that. We have to be very specific and concrete in our recommendations and how do we fix these issues so that we don't continue to fall behind.

Mr. Goward noted that we have identified the fact that we would like a high accuracy and resilience service for GPS. He asked if the Board needs to be more specific and make a recommendation to the Deputy Secretary of Transportation, or other agency, that the department include a set amount of funding per year and agree to be responsible for the system.

Mr. van Diggelen stated that he wouldn't want to put a number on it yet because as Lt. Gen. Hamel noted, you really want to have someone own this ideally and do it properly. They need to scope out the integrity issues, not just tacking on the improvements. There are very valuable accuracy improvements which you could get very quickly from JPL, but it is important that someone want to own this.

ADM Allen agreed. The recommendation should be that somebody needs to own it, and here are the three or four issues that are not being addressed that need to be, such as including signal integrity. We need to give clear and unambiguous advice.

Lt. Gen. Hamel commented that this is developing the menu of things that can and should be done. What are these pragmatic, practical things? This discussion about high accuracy may be one that says, "given all the mandates and responsibilities assigned to the departments today, we believe such and such department undertake a program definition for how it would operationalize this, and to strap this on with all the budgetary, alternatives, whether you contracted out, or do you own it? Those are the discussions that can get translated into language over on Capitol Hill with authorizing committees.

Hon. Shane stated that from his experience with DOT, there is a cultural issue in the Executive Branch that the subject matter just isn't getting the attention that it needs. It's hard to put it in any other way, and what he learned from my little research about what's going on in aviation right now is that you're beginning to see the confluence of a lot of activity, more so than we've seen before. It's always been around little pockets of activity here and there, but it's coming together in a more coherent way for the aviation sector. That's why you're seeing all these internationals basically saying the same thing. He's sure there are pockets of activity around within the federal government and we celebrate them, and we thank the heavens that there are heroes that keep the flame alive. But we haven't really caught the imagination of the White House in a serious way. He doesn't think there's a center of gravity in Congress. There are committees that are responsible for it, and they do some good things every now and then. But this Board, by continuing to hammer points in an intelligent way, can really contribute to that cultural change that makes a difference. But, we can't pretend that it's going to happen quickly, and we can't pretend it's going to happen because of our suggestions.

ADM. Allen stated that we need a narrative and a base to say we're only meeting the pewter standard. That'll get somebody's attention that doesn't understand this.

Mr. Miller reminded the group that when Dr. Schlessinger was the chair, water on a rock is how they described their work. You keep dripping until you break that rock.

ADM Allen asked the Board to give him the means to have that higher level discussion. While it may not seem like they are links, what Mr. Higgins is doing and what Dr. Betz is proposing allows me to create a coherent, integrated narrative. He is willing to write something and publish it in advance. He and Dr. Parkinson have published things before, and they've discussed him writing a follow-on article to the 50th Anniversary that he wrote called The Lonely Halls.

Dr. Parkinson asked whether Gen. Lyles of the National Space Council, with his visibility and altitude above this Board's, could somehow get this to become a celebrated cause of his. He's trying to think of how to get higher visibility."

ADM Allen stated that he is prepared to move ahead and write the paper.

Dr. Goward noticed that Gen. Lyles had a National Security Subcommittee. It may be appropriate for some Board members to talk to the National Security Subcommittee and get their sense of how this plays and integrates with what they're doing at the White House.

Mr. Miller noted that Gen. Lyles chairs the UAG and its National Security Subcommittee. There are also people that also work for the Defense Science Board that have similar interests that have been discussed here. So, there's a true synergy to be had.

ADM Allen reviewed the discussion so far: scene-setter, narrative, cause for action, get people on the Hill excited, pass it off to the focus for the meeting, which is PTA. We decided how we want to distribute the type of information. As part of that, we can come in after the fact and take a look at what Dr. Betz and his subcommittee are doing compared to the gold standard that we're going to use upfront as a cause for action. If that's a general flow that works with everybody, we can work this virtually offline. He doesn't want to leave here without everybody understanding where we're going to go and then give the committee some autonomy to move ahead. He will start crafting a Memorandum for the PNT EXCOM co-chairs.

Mr. Higgins asked if the prep session at the next meeting will be the status of GPS, and then the two public sessions cover PTA?

ADM Allen said that the sequence will be: White Paper, International Engagement subcommittee presentation on the prep day, and then accepting it by the Board on the public days. We can do that publicly, so we have an output. Then the program will be structured around PTA. Ultimately, he'd like to see a trail into the fall for either a second administration or a new administration."

Mr. Goward stated that he liked the idea of having a docket. So, if people want to tell us things they just put on the docket and it would become public, but we don't have to endorse it. We could use the docket if some of the subcommittees wanted to select people to come and talk to us. The most effective presentations were the ones we gave to each other as opposed to the ones that people from outside who didn't know what we were really interested in gave to us."

ADM Allen asked if we can put out as part of the Federal Register Notice (FRN) of the meeting that we are going to establish a docket for submissions? We haven't done that before. His guess is that they can. We need to find out exactly how that works."

Mr. Goward said that there can be a two- or three-minute comment period for anybody that wants to register and get approved for a comment.

ADM Allen said that he'd rather have it done on paper.

Mr. Miller stated that we already have the email that we can receive comments at time. What we could do is put out an FRN saying we're soliciting input from the public to prompt people to solicit additional information.

ADM Allen said that would require us to do something we haven't done before and that's come up with the overall and the agenda of the meeting. So, they would know what the topics they were addressing were. We don't normally do that right now.

Dr. Parkinson asked who's going to respond to that? Who's going to go through all that and sort it out?

Mr. Miller said his staff can take care of it. It's important to note that we're in a race right now. GPS is losing the race. In order to get the urgency that we're all pushing for, he believes we need to compare the various GNSS. Otherwise, why do you want to do all the PTA activities that we've been talking about? So, he believes t's very important to kind of lay that out because otherwise there will be no urgency.

ADM Allen and Dr. Parkinson agreed.

Hon. Shane stated that another thought we had in terms of organizing meetings around a single theme was we would actually give each meeting a title. When you announce the meeting publicly, you will get an engaged audience and perhaps a lot of input that you can use.

Mr. Higgins stated that rather than have the email and docket concept be preempting, we could have it as feedback. What do you then do about it? If we're being more organized in what we say at the meeting, we could also be more organized in what we ask for as feedback.

Lt. Gen. Hamel stated that Mr. Martin and Ms. Van Dyke's presentations had a lot of useful information. Unfortunately, we had spent the day prior to that talking to ourselves about a variety of things that we didn't meet but weren't even informed by what's already going on. So, can we get some kind of update of what's going on inside of the government before we come to the table?

ADM Allen reiterated that the Board needs to make better use of read-ahead briefings and other preparatory to maximize the time available for discussion at the meetings.

Lt. Gen. Hamel stated that the Board should have an update from the NCO before the next meeting.

Mr. Miller said that Mr. Martin and Ms. Van Dyke are always available so they could brief the Board a couple of weeks prior to a public meeting.

Lt. Gen Hamel asked that this be done routinely, and ensure that the DoD is always at the table.

Mr. Higgins commented that the USSF update still needs to be in the public record, because there are people in Australia who use that information as an update on GPS.

ADM Allen agreed and thanked the Board for its input.

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Wrap-Up
ADM Thad Allen (USCG, ret.), *Chair*
Dr. Brad Parkinson, *1st Vice Chair*
Hon. Jim Geringer, *2nd Vice Chair*

Adm. Allen stated that there are ups and downs when planning meetings, but the Board is getting better at it including more conversations and lively sidebars. Board members are also establishing much needed relationships. With this, ADM Allen and Dr. Parkinson thanked the Advisory Board and adjourned the meeting.

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Appendix A: National Space-Based PNT Advisory Board Membership as of the 29th Meeting

Special Government Employees

SGE's are experts from industry or academia who temporarily receive federal employee status during Advisory Board meetings.

- **Thad Allen** (Chairman), 38th Commandant, U.S. Coast Guard
- **Bradford Parkinson** (1st Vice Chair), Stanford University
- **James E. Geringer** (2nd Vice Chair), Environmental Systems Research Institute (ESRI)
- **John Betz**, MITRE
- **Scott Burgett**, Garmin International
- **Joseph D. Burns**, The Airo Group
- **Patrick Diamond**, Diamond Consulting
- **Dorota A. Grejner-Brzezinska**, The Ohio State University
- **Michael Hamel**, Former Commander, Space and Missile Systems Center
- **Larry James**, Jet Propulsion Laboratory
- **Vahid Madani**, GridTology
- **Jade Morton**, University of Colorado Boulder
- **Timothy A. Murphy**, The Boeing Company
- **Tom Powell**, Aerospace Corporation
- **Eileen Reilly**, Global Train Services
- **T. Russell Shields**, Former President and CEO, RoadDB
- **Gary Thompson**, North Carolina Geodetic Survey
- **Frank van Diggelen**, Google
- **Todd Walter**, Stanford University
- **Gregory D. Winfree**, Texas A&M Technology Institute

Representatives

Representatives are individuals designated to speak on behalf of particular interest groups.

- **Renato Filjar,** University of Rijeka (Croatia)
- **Dana Goward**, Resilient Navigation and Timing Foundation
- **J. David Grossman**, Consumer Technology Association
- **Matt Higgins**, International GNSS Society (Australia)
- **Terry Moore**, University of Nottingham (UK)
- **Jeffrey N. Shane**, International Air Transportation Association (IATA)

Executive Director

The membership of the Advisory Board is administered by a designated federal officer appointed by the NASA Administrator:

- **James J. Miller**, Executive Director

Appendix B: Sign-In Sheets

28TH PNT ADVISORY BOARD MEETING

CROWNE PLAZA, ANNAPOLIS, MD

General Session Wednesday – May 3, 2023

	NAME	ORGANIZATION	E-MAIL
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28TH PNT ADVISORY BOARD MEETING

CROWNE PLAZA, ANNAPOLIS, MD

General Session Wednesday – May 3, 2023

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28TH PNT ADVISORY BOARD MEETING

CROWNE PLAZA, ANNAPOLIS, MD

General Session Wednesday – May 3, 2023

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28TH PNT ADVISORY BOARD MEETING

CROWNE PLAZA, ANNAPOLIS, MD

General Session Wednesday – May 3, 2023

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28TH PNT ADVISORY BOARD MEETING

CROWNE PLAZA, ANNAPOLIS, MD

General Session Thursday – May 4, 2023

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28TH PNT ADVISORY BOARD MEETING

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General Session Thursday – May 4, 2023

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Appendix C: Acronyms & Definitions

$	U.S. Dollar Currency
2 SOPS	Second Space Operations Squadron
5G	5th Generation Mobile Communications Standard
ADEOS-II	Advanced Earth Observing Satellite-II
ADF	Australian Defense Force
ADS-B	Automatic Dependent Surveillance-Broadcast
AEP	Advance Evolution Plan
AFRL	Air Force Research Laboratory
AI	Artificial Intelligence
AIS	Automatic Identification System
BeiDou	China's GNSS
BDD-IR	Burst Detector Dosimeter IIR
C- Band	Range of electromagnetic frequencies used for various telecommunications purposes, including satellite communications
CARMEN	DOT Center for Automated Vehicle Research and Multimodal Assured Navigation
CARNATIONS	Center for Assured and Resilient Navigation in Advanced Transportation Systems
CEO	Chief Executive Officer
CER	Communications & External Relations (PNTAB Subcommittee)
CET	Critical and Emerging Technology
CGSIC	Civil GPS Service Interface Committee
CNI	Critical National Infrastructure (UK)
CRPA	Controlled Reception Pattern Antennas
CSWaP	Cost, size, weight, and power
DGNSS	Differential GNSS
DHS	Department of Homeland Security
DIU	Defense Innovation Unit
DOC	Department of Commerce
DoD	Department of Defense
DOS	Department of State
DOT	Department of Transportation
E911	Emergency 911
EASA	European Aviation Safety Agency
ECAS	Emerging Capabilities, Applications, & Sectors (PNTAB Subcommittee)
EPA	Educational Partnerships Agreements
ESA	European Space Agency
ESG	Executive Steering Group
ESI	Education & Science Innovation (PNTAB Subcommittee)
ESTEC	European Space Research and Technology Centre
EU	European Union
EUROCONTOL	A pan-European, civil-military organisation dedicated to supporting European aviation.
EXCOM	National Space-Based PNT Executive Committee
eV	Electron Volt
FAA	Federal Aviation Administration
FACA	Federal Advisory Committee Act
FCC	Federal Communications Commission
FFRDC	Federally Funded Research and Development Center
FIG	International Federation of Surveyors
FRN	Federal Register Notice
FRP	Federal Radionavigation Plan
FY	Fiscal Year
G2G	Galileo Second Generation
Galileo	European GNSS
Galileo HAS	Galileo High Accuracy Service
GDGPS	Global Differential GPS System
GEO	Geosynchronous Orbit
GEO-ESCON	Geomatics Emerging Scientist Consortium for Education, Research and Capabilities Enhancement
GNSS	Global Navigation Satellite System
GOC	GDGPS Operations Centers
GPD	Generalized Pareto Distribution
GPS	Global Positioning System

GPS IIF	GPS Block II Follow-On
GPS IIIF	GPS Block III Follow-On
GPSIA	GPS Innovation Alliance
GSFC	Goddard Space Flight Center
HARS	High Accuracy & Robustness Service
HAS	High Accuracy Service
Hz	Hertz
IAG	International Association of Geodesy
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IDA	Institute of Defense Analysis
ICD	Interface Control Document
ICG	International Committee on GNSS
IDM	Interference, Detection and Mitigation
IE	International Engagement (PNTAB Subcommittee)
IEEE	Institute of Electrical and Electronics Engineers
IGMA	International GNSS Monitoring and Assessment
IGNSS	International Global Navigation Satellite Systems Conference
IGRF	International Geomagnetic Reference Field
IGS	International GNSS Service
IMU	Inertial Measurement Unit
IOAG	Interagency Operations Advisory Group
IOC	Initial Operations Capability
ION	U.S. Institute of Navigation
ITAR	International Traffic in Arms Regulations
ITU	International Telecommunications Union
JNC	Joint Navigation Conference
JPL	Jet Propulsion Laboratory
JPO	Joint Program Office
L1 C/A	1st GPS Civil Signal (C/A = coarse acquisition)
L5	3rd GPS Civil Signal (safety-of-life / aviation)
L-band	Operating frequency range of 1–2 GHz in the radio spectrum
L-value	Set of magnetic field lines which cross Earth's magnetic equator at a number of Earth-radii equal to the L-value.
LEO	Low Earth Orbit
M	Million
Lidar	Light Detection and Ranging
MEO	Medium Earth Orbit
MGUE	Military GPS User Equipment
NDAA	National Defense Authorization Act
NASA	National Aeronautics and Space Administration
NASEM	National Academies of Sciences, Engineering, and Medicine
NAVWAR	Navigation Warfare
NCO	National Coordination Office for Space-Based PNT (hosted at Dept. of Commerce, Washington, D.C.)
NGA	National Geospatial-Intelligence Agency
NGS	National Geodetic Survey
NIC	Navigation Integrity Category
NRT	Near Real Time
NSC	National Security Council
NTRIP	Networked Transport of RTCM via Internet Protocol
NSF	National Science Foundation
NTIA	National Telecommunications and Information Administration
NTS-3	Navigation Technology Satellite -3
OCX	GPS Next Generation Operational Control System
OMB	Office of Management and Budget
OODA	Observe, Orient, Decide, and Act
OST-R	DOT Office of Research and Technology
OSR	Observation State Representation
PDD-21	Presidential Policy Directive 21
PDOP	Position Dilution of Precision
PF	GNSS Provider's Forum
PNT	Positioning, Navigation, and Timing

PNTAB	National Space-Based PNT Advisory Board
PPP	Precise Point Positioning
PTA	Protect, Toughen, and Augment, or referring to the PTA Subcommittee
PVT	Position, Velocity, and Time
PWSA	Proliferated Warfighter Space Architecture
QZSS	Japan's Quasi-Zenith Satellite System
R&D	Research and Development
RFI	Request for Information or Radio Frequency Interference
RFP	Request for Proposals
RIN	Royal Institute of Navigation (United Kingdom)
RMS	Root Mean Squared
RNT	Resilient Navigation and Timing Founation
RTCM	Radio Technical Commission for Maritime Services
SatNav	Satellite Navigation and Timing. Sometimes referred to as SATNAV.
SBAS	Space-Based Augmentation System
SDA	U.S. DoD Space Development Agency
SIL	Service Integrity Level
SouthPAN	Australian Southern Positioning Augmentation Network
SPD-7	Space Policy Directive 7 for U.S. Space-Based PNT
SPG	Strategy, Policy, & Governance (PNTAB Subcommittee)
SPO	Special Program Office
SSC	Space Systems Command
SSR	Space State Representation
STEM	Science, Technology, Engineering, and Math
STPI	Science and Technology Policy Institute
SV	Satellite Vehicle
SWAG	Space Weather Advisory Group
TOR	Terms of Reference
TRL	Technology Readiness Level
UAV	Unmanned Aerial Vehicle
UK	United Kingdom
U.S.	United States of America
UN	United Nations
USCG	U.S. Coast Guard
USG	U.S. Government
USNO	U.S. Naval Observatory
USSF	U.S. Space Force
UTC	Coordinated Universal Time
WGS 84	World Geodetic System 1984
WRC	World Radio Conference