SPACE-BASED POSITIONING
NAVIGATION & TIMING
NATIONAL ADVISORY BOARD

NATIONAL SPACE-BASED POSITIONING, NAVIGATION, AND TIMING (PNT) ADVISORY BOARD

Ninth Meeting

November 9-10, 2011

Crown Plaza Hotel -- Washington Ballroom
901 North Fairfax Street
Alexandria, VA 22314

Meeting Minutes

Bradford Parkinson

Bradford W. Parkinson
Vice-Chair

James J. Miller
Executive Director

National Space-Based Positioning, Navigation, and Timing (PNT) Advisory Board Agenda

Ninth Meeting
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Wednesday, November 9, 2011

9:00 - 9:10	**BOARD CONVENES** Call to Order	Mr. James J. Miller, PNT Advisory Board Executive Director, NASA
9:10 - 9:30	Introductions, Announcements, & Agenda Finalizing Recommendations for December 14 PNT EXCOM	Dr. James Schlesinger, Chair Dr. Bradford Parkinson, Vice-Chair
9:30 - 9:45	PNT Executive Committee Update Activities & Current Policy Issues	Mr. Tony Russo, Director, National Coordination Office for Space-Based PNT
9:45 - 10:00	U.S. National Space Policy Update White House Perspective on Future PNT Policy Actions	Mr. Chirag Parikh, Director, Space Policy, National Security Council
10:00 - 10:20	GPS Constellation Update & Modernization Plans Progress & Challenges for Legacy and New Segments	Brig Gen David Thompson & Col Harold "Stormy" Martin, Air Force Space Command
10:20 - 10:30	National PNT Architecture Goals & Evolution Identifying Synergies to Address Capability	Ms. Karen VanDyke, Director for PNT, DOT Research & Innovative Technology Administration
10:30 - 10:45	**BREAK**	
10:45 - 11:05	Analysis of Alternatives (AoA) for Future GPS Architecture Options & Flexibility for Back-Ups	Mr. Kirk Lewis, Senior Advisor, Institute for Defense Analyses

11:05 - 11:20	Alternative Positioning, Navigation, and Timing (APT) Plans for Ensuring National Airspace System PNT Services	Mr. Leo Eldridge, Satellite Navigation Manager, Federal Aviation Administration
11:20 - 11:35	GPS Time as Critical Infrastructure Application Robust Time Dissemination & Chip Scale Atomic Clocks	Dr. Robert Nelson, President, Satellite Engineering Research Corporation
11:35 - 11:50	U.S./International Initiatives & Partnership Opportunities Update on Bilateral & Multilateral Developments	Mr. Ray Clore, Senior Advisor, Office of Space and Advanced Technologies, Department of State
11:50 - 12:00	Morning "Wrap-Up" Discussion	All PNT Advisory Board Members
12:00 - 1:00	**LUNCH – (Annual Ethics Briefing)**	Mr. Adam Greenstone, NASA General Counsel
1:00 - 1:20	Department of Homeland Security (DHS) National Risk Estimate: Risks to U.S. Critical Infrastructure from GPS Disruptions	Mr. Brandon Wales, Director, Homeland Infrastructure Threat & Risk Analysis Center, DHS
1:20 - 1:30	Update on U.S. Interference Detection & Mitigation Plan Patriot Watch & Critical Infrastructure Protection	Mr. John Merrill, PNT Program Lead, DHS
1:30 - 1:45	Receiver Certification: Making the GNSS Environment Hostile to Jammers & Spoofers	Mr. Logan Scott, LS Consulting
1:45 - 2:00	GPS Commercial Receivers: Specification Compliance & Certification	Mr. Jules McNeff, Vice-President, Overlook Systems Technologies, Inc.
2:00 - 2:15	**BREAK**	
2:15 - 4:50	**Panel Discussion -- LightSquared Compatibility with GPS** Testing, Analyses, & Proposed Solutions for LightSquared (LS^2) Effects on GPS Infrastructure & User Applications	

	Introduction by Mr. Kirk Lewis, Institute for Defense Analyses	
	Presentations w/Open Mic for Q&A's with PNT Board & Public	Mr. Thomas Stansell, Stansell Consulting
	How did we get here? Where do we go from here?	Mr. Jim Kirkland, Vice President and General Counsel, Trimble Navigation
	Are terrestrial broadband and GPS space signals technically compatible? At what cost? Who pays? What is lost/gained?	Mr. Martin Harriman, Executive Vice-President, LightSquared
	How much more testing? Handsets? Integrated platforms?	Dr. Javad Ashjaee, CEO, Javad GNSS
	How much more change to the spectrum environment?	Mr. Scott Burgett, Software Engineering Manager, Garmin International
	What is the "end state" LS^2 business plan? Other entrants?	Mr. Mark Sturza, President, 3C Systems Company
	What is an appropriate transition time for GPS users?	
4:50 - 5:00	Afternoon "Wrap-Up" Discussion What else should be examined on November 10?	All PNT Advisory Board Members
5:00	ADJOURNMENT	

Thursday, November 10, 2011

9:00 - 9:05	BOARD CONVENES Call to Order	Mr. James J. Miller, PNT Advisory Board Executive Director, NASA
9:05 - 9:15	Announcements & Agenda Thoughts from November 9 discussions	Dr. James Schlesinger, Chair Dr. Bradford Parkinson, Vice-Chair
9:15 - 10:00	International Member Regional Updates & Responses	

Dr. Gerhard Beutler, Switzerland

Dr. Hiroshi Nishiguchi, Japan

Dr. Rafaat Rashad, Egypt

Mr. Arve Dimmen, Norway

10:00 - 10:15 **BREAK**

10:15 - 12:00 PNT Advisory Board Member "Round Table" Discussion

Finalizing Recommendations for PNT EXCOM Taskings.
Due Date: PNT EXCOM December 14, 2:00 - 4:00

PNT Architecture Assessment: Perform an independent assessment of the way ahead for the National PNT Architecture Implementation Plan.

GPS Commercial Outage Impact Assessment: Using scenarios and available data, conduct an assessment of the impact to U.S. commercial infrastructure of GPS. Evaluate specific role(s) of space-based PNT in the operation of civil/commercial cyber networks.

Non-ICD Compliant Civil/Commercial Receivers: Evaluate the implications of user non-compliance with GPS Interface Control Document (ICD) specifications and potential solutions.

Advisory Board Technical Subcommittee: Establish an Advisory Board subcommittee capable of evaluation and timely feedback on emerging technical issues.
(Actively working LightSquared issues)

All PNT Advisory Board Members

Working Group/Panel Lead Action Plans

Dr. Hermann (or designee)
GPS Sustainment, Availability, & Affordability

Mr. Trimble (or designee)
GPS International Cooperation & Coordination

Dr. Parkinson (or designee)
GPS Interference Detection & Mitigation

12:00 - 1:00 **WORKING LUNCH**

1:00 **ADJOURNMENT**

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Session of Wednesday, November 9, 2011

Call to Order

Mr. James Miller, Executive Director of the PNT Advisory Board

National Aeronautics and Space Administration

Mr. Miller convened the ninth session of the National Space-Based Positioning, Navigation, & Timing (PNT) Advisory Board sponsored by the National Aeronautics and Space Administration (NASA). Miller said he regarded this meeting as a milestone, as the Board's experts have been meeting for five years through two Presidential administrations. Unfortunately for this particular meeting, Advisory Board Chair Dr. James Schlesinger fell ill shortly before the meeting and would be unable to attend.

Mr. Miller reminded members and observers that the Advisory Board consists of independent experts from outside the U.S. government, and iterated that the Board now serves as a model for other nations that operate Global Navigation Satellite Systems (GNSS). This could be seen at the last International Committee on GNSS (ICG) meeting, where Russia announced the formation of a similar industry Board for GLONASS. In this manner, the Global Positioning System (GPS) continues to offer worldwide benefits as a critical infrastructure enabler that requires robust protection from harm.

It was also noted that participating Advisory Board members were appointed by the nine Federal agencies that comprise the PNT Executive Committee (EXCOM), and that all Board members volunteer their time to serve. The Advisory Board is chartered under the Federal Advisory Committee Act (FACA), which means that all comments are for the public record, with formal meeting minutes to be taken and posted online. The main objective of this November Advisory Board meeting is to make recommendations for the forthcoming PNT EXCOM meeting in December 2011.

In Dr. Schlesinger's absence, Dr. Bradford Parkinson, the Board's Vice-chair, would preside.

Dr. Bradford Parkinson, Vice-Chairman

Dr. Parkinson recommended that Gov. Geringer be appointed as Acting Vice-chair. This was moved, seconded, and approved. Dr. Parkinson then read a brief statement from Dr. Schlesinger:

> "The Board has an opportunity to discuss the potential impact of *LightSquared* on GPS and will spend considerable time on the issues of interference and mitigation. In thinking about this, he was reminded of a comment by Aldous Huxley, author of *Brave New World*, who stated that "technological progress has merely provided us with a more efficient means of going backward." However, he [Dr. Schlesinger] does not hold this to be true. Rather, GPS has provided Americans with a better quality of life and had done likewise for others around the globe. He urges the Board be vigilant that the next 'cool killer app' not interfere with this success. It is not the task of the Advisory Board to assess *LightSquared's* business model, but to ensure the continued improvement of citizens' lives. The Board recognizes the value of GPS as a critical infrastructure enabler to safety in aviation, to first responders, in precision agriculture, to homeland security and in other areas. The Board also recognizes the future value of Mobile Satellite Service Networks (MSS). He expressed hope that assessments from neutral sources would be the final arbiter of the issues at hand. By the conclusion of the second day's session, he wanted a cohesive Advisory Board to have taken the actions that would allow the PNT EXCOM to be updated on the key matters the Board needed to bring before that body."

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PNT Executive Committee Update

Mr. Tony Russo, Director
National Coordination Office for Space-Based PNT

The Advisory Board is a key information source for the EXCOM, which had time reserved for the Board at its scheduled meeting of December 14, 2011. In addition, the EXCOM has requested the Advisory Board's views on a list of topics. During the past year interference issues have been the dominant topic for the EXCOM. That emphasis to-date has been on low power jammers being produced in large quantities in China and elsewhere. Efforts are proceeding with the Federal Communications Commission (FCC); Department of Justice (DOJ); Department of Homeland Security (DHS) and other law enforcement agencies. Several online retailers that sold such jammers have been closed down. The Advisory Board's international partners were also engaged in this work.

Dr. Parkinson noted that Mr. Ray Clore of the U.S. Department of State (DOS) would deliver a report on this issue during the morning session. Mr. Russo noted that the Advisory Board would also be considering those interference issues that related to *LightSquared.*

The EXCOM has submitted taskings to the Advisory Board, and the time period for a response is nearing its end. These issues were 'on the table' before the issue of GPS and *LightSquared* arose. The taskings from the EXCOM are:

- *Non-ICD Compliant Receivers:* This reflects GPS receivers not complying with systematic technical baseline requirements, such as Interface Control Documents (ICD) or Interface Specifications (IS). The Department of Defense (DoD) believes that this has led to instances where receivers are malfunctioning unnecessarily when GPS operations are actually working fine. This results in "lost time" as these anomalies are reported and investigated. The Advisory Board has been asked to comment and whether some 'certification process' should be established for GPS receivers; and if so, should the government or some private agency administer it.
- *DoD/DOT PNT Architecture:* The Board is asked to provide comments on how the DoD & Department of Transportation (DOT) *PNT Architecture* recommendations are to be implemented nationally over time. The EXCOM seeks the Board's comments on what impediments might arise in implementing such an architecture and how they might be overcome.
- *Loss of GPS Operations*: GPS faces potential service outages due to sunspot activity, jammers, and other interference sources. The EXCOM seeks the Board's assessment on the possible impact of such outages. Which commercial sectors were most vulnerable to such threats and what could be done to reduce the associated hazards?

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U.S. National Space Policy Update: White House Perspectives on Future PNT Policy Actions

Mr. Chirag Parikh, Director of Space Policy
National Security Council

Mr. Miller announced that Mr. Chirag would not be able to participate but wanted the Advisory Board to consider how solid the current National Security Policy Directive-39 (NSPD-39) remains, and what might need to be done to strengthen the PNT environment. The context for this request is the potential for the current Administration to undertake a new PNT Policy examination.

Dr. Hermann noted that he was not sure how the Board should proceed to capture its views -- was a subgroup appropriate? Mr. Miller noted that the Board had a session scheduled for Thursday to map out how to prepare its recommendations for the EXCOM. He suggested that session would provide an opportunity to see what improvements in the PNT policy arena may be advisable.

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GPS Constellation Update & Modernization Plans

Brig Gen David Thomson
Air Force Space Command

Brig Gen David Thompson, representing Gen William Shelton, said that Col Harold 'Stormy' Martin was to provide an update on the GPS constellation. However he first had a few comments for the Advisory Board:

First, Gen Shelton takes the GPS constellation seriously and not simply in military terms. An unprecedented level of service is being provided. In part, this reflects the circumstance that a great many satellites had outlasted their expected periods of service. Two GPS IIF satellites have been launched and there are ten more ready to go. In addition, the Air Force had created a launch program that could put a GPS satellite into orbit on six months' notice.

Second, the GPS III program is still progressing in a tough fiscal environment. Any program can have technical or budget problems, particularly so at a time when all Federal departments face major budget challenges. Therefore two primary questions needed to be balanced: (1) how to sustain, and; (2) how to economize. The GPS program enjoys credibility throughout the military services, and as budget cuts continue, GPS would nevertheless continue to be a priority due to its cross-cutting nature. The Air Force will continue its robust work as the "stewards of this national treasure".

Third, the Air Force is "deeply involved" in activities related to *LightSquared*.

Progress & Challenges for Legacy and New Systems

Col Harold Martin
Air Force Space Command

This presentation provided an overview of GPS performance, modernization efforts, and recent events. GPS is a critical asset in American society, sometimes when one is not even aware they are using it. For example, it is now used for every day applications such as synchronizing computer networks, and has thus become vital to nearly all segments of society.

There were at present thirty active GPS satellites – including 9 GPS IIAs; 12 GPS IIRs; 7 GPS IIR-Ms and 2 GPS IIFs. The 9 GPS IIA satellites have been in operation for over 15 years, significantly beyond their 7.5 year design life. Four GPS satellites are also in reserve and could be moved into position to replace a failed satellite. GPS has met its civil performance commitments continually since 1993. The national commitment to maintain at least 24 satellites in operation has also been met. The latest GPS IIF-2 satellite was launched on July 16, 2011, and GPS IIF-3 is scheduled for launch in September 2012.

In 2001, the *GPS Standard Positioning Service (SPS) Performance Standard* specified a minimum accuracy of 6 meters (signal in space). In 2008, the performance standard was updated. Since Selective Availability (S/A) was set to zero, the performance of GPS has greatly improved and is now measured with a global average User Range Error (URE) of approximately 0.9 meters. This has been mainly due to improved clocks on the newer GPS satellites.

GPS has undergone a number of modernization efforts, both in satellite design and the command and control system. In the mid-2000s the GPS IIR-M satellites included a capability to broadcast the second civilian signal (L2C), and in 2010 the first GPS II-F satellite included an additional third civilian signal (L5) to support safety-of-life applications such as aviation. GPS III satellites will include a 4th civilian signal (L1C) with increased power, integrity, and service life. The GPS Ground Control Segment (OCS) has moved from using a mainframe system in the 1990's, through an Architecture Evolution Plan (AEP), and towards a Modernized GPS Ground Control Segment (OCX). The AEP system, in place since 2007, allowed using all of the Air Force satellite command and control capabilities. A $1.58 billion OCX contract was awarded on February 10, 2011. At present (as of Nov. 2011) there are 9 GPS satellites broadcasting the L2C civil signal as a blank message, and by 2016 there should be 24 GPS satellites broadcasting L2C.

GPS satellites also currently carry the Nuclear Detonation Detection and Reporting System (NUDET) secondary payload and the Proof-of-Concept Distress Alerting Satellite System (DASS), the latter developed by NASA to provide distress alerts for worldwide Search and Rescue (SAR). Gen Shelton has approved including the operational DASS system on GPS III, which improves the reporting of distress alerts for SAR from up to several hours to near real-time. Final approval for the operational DASS is expected in the summer of 2012. The DASS payloads will be provided by Canada to make this a truly global partnership.

Another GPS secondary payload under development are the Satellite Laser Ranging (SLR) reflectors to enable laser ranging to GPS satellites to provide more precise tracking and improved geodetic references. Col Martin stated he is looking forward to provide the laser ranging capability which will improve precision applications such as earth modeling, mapping, measurement of ocean sea level height, and tectonic crustal movement.

In summary, the current GPS constellation is the largest and most accurate it has ever been. Modernization of the command and control network will improve signal monitoring and new secondary payloads are coming on line that will continue to modernize and improve the performance of GPS.

Gov. Geringer brought up the recent Congressional Budget Office (CBO) discussion about the Air Force having to reduce its capabilities, and asked Col Martin if this reduction could affect both the military *and* civilian side, or just the military side. Col Martin responded that no position had yet been reached and noted that the document in question was a Congressional report rather than a budget decision. Gov. Geringer agreed and added that his understanding was that the CBO report had focused more on the GPS receiver side rather than more advanced satellites. Also, Gov. Geringer said he thought it was central that the additional requirements had been vetted on the GPS III satellites because future GPS satellites carrying fewer improvements would end up costing more and take longer to build.

Brig Gen Thompson said that under the current funding the Air Force was watching the minimum 24-satellite constellation standard and making sure that was maintained above all else. Dr. Hermann commented that at the Advisory Board's previous meeting it had been difficult to make a compelling case for a 30-satellite baseline constellation. Gen Lord noted that the Advisory Board had long favored the larger constellation, but understood that the Air Force would face some very difficult alternatives regarding budget constraints and launch rate.

Gov. Geringer asked whether the 3 targets of GPS interference (military, civil, and commercial) were of equal concern. Gen Thompson responded that the Air Force did not have a specific tasking for civil and commercial interference.

Dr. Parkinson noted that the Advisory Board had advocated a 30-satellite baseline constellation because even though more than 30 satellites are currently in operation, many of these are very old. Col Martin commented that in late November 2011 one of these satellites would be turning 21 years old. If one looked down the road to 2015, Dr. Parkinson said, "things could get, as pilots used to say, squirrelly." Dr. Parkinson placed his priority on maintaining the launch schedule and budgets for the additional satellites.

Mr. DalBello said that while there were 30 satellites in space, they were not currently located where one would want them had a 30-satellite system been planned from the start. Gen Thompson said that a 30-satellite constellation was not being planned and, instead, a 24-satellite array was being closely watched. Gen Thompson also made reference to the "Expanded-24 constellation" which makes better use of satellites currently in orbit, thereby adding 3 GPS satellites over the baseline 24-satellite constellation.

Gen Lord commented that international activities were a central part of Space Policy 2010, and that he believes the new PNT policy should look to aiding providers as well as users.

Dr. Parkinson thanked Col. Martin for his work in "steering forward" efforts related to SLR Reflectors. This, he said, was needed not simply for scientific reasons, since half its sponsors for the SLRs came from the military side as well.

Dr. Hermann asked whether the design of a spacecraft influenced the possibilities of interference. Gen Thompson said this was the case and added that it is doubtless there is a need across the spectrum for more jam-resistant signals.

Ms. Ruth Neilan asked if plans existed to measure the antenna phase centers of GPS satellites and make that data available to users. Gen Thompson said he was unaware of such an effort.

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National PNT Architecture

Karen VanDyke, Director for PNT, Research & Innovative Technology Administration, Department of Transportation

Ms. Karen VanDyke reported on the PNT Architecture effort that had been co-chaired by DoD and DOT in 2006 and included participation from 31 government organizations. Many GPS users are unaware of their dependence and vulnerability. We require a strategic vision for moving forward and overcoming emerging challenges.

This effort identified gaps in PNT capabilities at the national level. For example, users want navigation capabilities, and emergency location information, both outdoors and indoors. This is difficult to provide inside a building. As users continue embracing GPS they also expect higher accuracy, and even special features such as enabling crash avoidance signaling in cars. Further, users may want to get up-to-date highway travel information such as incidents/construction sites and recommended detours. The question thus becomes how to deliver all this information to users. Thus, a user may come to think GPS 'went wrong' because their receiver provided information that a mountain pass was clear when, in fact, it was blocked. It remains up to the individual to understand the limitations of what information GPS actually provides, however most will just come to rely on it more and more.

The biggest capability gap now seems to come from interference sources, such as "cigarette lighter" GPS jammers that can be bought on the Internet. For instance, one year ago interference was noted about once a week coming from a turnpike near the Newark airport in New Jersey. Since that time the interference episodes have increased to several times daily. This shows that one could not necessarily wait to have the interference source identified and mitigated. Instead, there is a definitive need to implement alternatives to PNT to ensure solutions even in challenging environments.

U.S. leadership in global PNT requires a strategy that the U.S. can best achieve through improved efficiency and effectiveness via a 'Greater Denominator System'. This system, as recommended by the architecture study, would include the following vectors: multiple phenomenology; interchangeable solutions; synergy of PNT and communications; and cooperative organizational structures.

The *National PNT Architecture Implementation Plan* includes nineteen recommendations approved by the DoD and DOT in July 2010. The first goal is to assess architecture progress by determining whether capability gaps are being closed faster than others are opening. The second goal is to assist agencies in showing why funding is needed to continue modernization efforts in this budget-constrained environment. The third goal is to promote cross-agency participation so that national problems were not addressed "piecemeal".

Captain Burns asked what penalties could be incurred if a person was caught with an intentional jammer. Ms. Van Dyke said the focus is on the supplier side. Once an individual user was made aware they were violating the law, they were willing to turn in the jammer. The FCC is targeting suppliers with fines of up to $1,000 for the first offense. Ms. Ciganer commented that the principal sources of supply are outside the U.S. in places like China and Europe, and that this issue had been raised among the International Committee on GNSS (ICG) which has set up a workshop on interference mitigation.

Mr. Brenner said he completely supported the approach of going after the supplier, and asked whether the total frequency of jamming events was known. Ms. VanDyke said this is not known and that there is no central location to which jamming episodes are reported at the national level.

Dr. Hermann noted that the EXCOM had tasked the Advisory Board to assess the DoD/DOT *National PNT Architecture Implementation Plan*, although he did not know whether the EXCOM was expecting the assessment to be an implementing function or analytic one.

Mr. Miller noted that in the afternoon session Mr. John Merrill from DHS would address a number of points related to GPS interference as raised by Ms. VanDyke.

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Analysis of Alternatives (AoA) for Future GPS
Architecture Option & Flexibility for Back-ups

Mr. Kirk Lewis, Senior Advisor
Institute for Defense Analysis

This briefing discusses alternatives for future GPS options and backups. When taking the larger view the central task is that of making information available to a GPS receiver looking 10-12 years ahead and attempting to assess the likelihood and impact of various events. What are the challenges? What are the opportunities to mitigate those challenges? Four major aspects of GPS operation need to be considered:

- Maintain current service level and enable improved service
- Consider different orbits, platforms and signal sources
- Remain within context of GPS III program & budget
- Consider impact of cost of launch

GPS satellites operate in Medium Earth Orbit (MEO). However, other orbits and signal sources could be employed. Also, is there a way in which a 24-satellite baseline constellation could supply a 30-satellite baseline constellation capability? The issue becomes the amount of outage that could occur at any given time. One analysis shows that with 24 satellite slots and a 45 degree masking angle, it is impossible to calculate a solution for 2-5 hours during a 24 hour period. If increasing the constellation to 27 slots, then the outage time is reduced to 20-80 minutes a day. For 33 slots the outage is negligible. Therefore, just by relocating 3 spare satellites there is a substantial decrease in outages. There are three factors that are a cause for concern: rate of satellite failure, rate of satellite replenishment, and –most importantly – the program's funding profile. GPS funding has been increasing for a decade, so what are the consequences should the appropriation curve level out?

Dr. Hermann noted that only U.S. (GPS) capabilities are being analyzed and asked if the value of emerging foreign capabilities had been considered as a means to mitigate GPS losses. Mr. Lewis said he was responding to the task as defined by Gen Shelton on the GPS environment in 2030. Therefore, we are assessing how changes in the future environment will affect systems today.

Dr. Parkinson asked Mr. Lewis to comment on the probability of a foreign system being available for U.S. use sometime in the next three or four years. Mr. Lewis said that "commercial users will vote with their pocketbook", but military users will continue to require a minimum level of service that has to be available.

Mr. Lewis presented in-orbit cost figures for each group of GPS satellites:

- GPS IIR $104 million
- GPS IIR(M) $134 million
- GPS IIF $238 million
- GPS III 'A' $350 million

- GPS III 'B' $380 million
- GPS III 'C' $425 million

The largest factor in the increases shown is the rise in launch costs. Alternatives may include:

- A hosted GPS payload, and/or transponder, on Geosynchronous Orbit (GEO) satellites
- Dual launches of MEO satellites. This could include GPS 'Spartan' (with no other payloads) or a GPS 'Limited' (GPS vehicles with less than the full signal set)
- A hosted GPS payload, and/or transponder, on a Low Earth Orbit (LEO) satellite

The most important analysis criterion would be the performance attributes, and followed by technical issues such as integration of payload and payload control. Scheduling issues and constraints related to launch opportunities are also important; and for these a business case would need to be made.

There is real potential for alternative GEO and MEO options should the government decide to examine this route. One GEO satellite provides the coverage of 3 MEO satellites. Future civilian satellites in GEO could broadcast both civil and military signals as well.

Recommendations:

1. Expand capabilities to 30 slots using alternate constellations
2. Develop the GPS-III ' Spartan' satellite, intended for dual launch
3. Continue work on GPS III as planned
4. GPS navigation payloads for hosted rides should be prepared and staged
5. The Federal Aviation Administration (FAA) and NASA should partner on providing improved GEO services

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Alternative Positioning, Navigation & Timing (APNT) Study Update

Mr. Leo Eldridge, Satellite Navigation Manager
Federal Aviation Administration

Mr. Eldridge seconded Mr. Kirk's earlier call for better cooperation and coordination between various agencies, domestic and international. Along these lines, the FAA is planning for new ICDs for Satellite-Based Augmentation Systems (SBAS). The central question is which services are needed should GPS not be available anytime in the future.

When discussing long-range planning associated with the next generation of navigation services, a key question is what timing and other services are needed. One assumption is that the level of air traffic will double. A second assumption is that more precise methods for separating aircraft are needed. Position control will be based on four-dimension considerations. With this added complexity the air controller really becomes the aircraft controller by exception. This presents a paradox, since all these capabilities depend on improved GPS performance, while at the same time operations must continue in the event that GPS service becomes unavailable.

Mr. Eldridge presented two views of aviation pathways near Atlanta. In the first, flight paths are determined using radar vectors. In the second, flight paths are determined by Area Navigation (RNAV), which is enabled to double the traffic since it ensures aircraft fly more precise paths while maintaining the needed separations between them. RNAV is dependent on GPS however. Should there be an unscheduled GPS outage, a means to provide alternative coverage is needed. The price of GPS jammers keeps falling and should GPS service be lost at a major airport, there simply wouldn't be enough time available to track down and fix the problem. Thus, the challenge is to ensure navigation services continue to be met without interruption in many different environments.

There are three backup alternatives:

- *APNT Alternative 1:* More effective use could be made of existing Distance Measuring Equipment (DME). Some of these systems are over fifty years old and many aircraft and pilots have adapted to using DME tools in more complex ways.

- *APNT Alternative 2:* Greater use could be made of Wide Area Multi-Lateration (WAM) as an alternative to secondary radar. Such systems compute aircraft location and send it to the aircraft. This also may leverage the Automatic Dependent Surveillance-Broadcast (ADS-B) functions within the avionics, for which standards are currently under development.

- *APNT Alternative 3:* Pseudolites (PDLs), which would consist of ground stations that emit an additional signal that could be used by an aircraft to determine its own position.

None of these approaches, however, would be as good as GPS. These alternatives compare as follows:

APNT Alternative 1: There were 1,100 DMEs in operation today. To take full advantage of DMEs, both scanning and inertial capabilities are needed. DME coverage at 18,000 feet was fairly good. This would necessitate two steps for implementation: (1) requirement changes are needed because DMEs were not currently authorized to achieve the needed flight path separation performance (fortunately, existing equipment manufacturers claim these specifications could be met); and (2) a P31 feasibility study would still be required for some of this equipment.

APNT Alternative 2: When an airliner replies to transponders at various ranges, the timed pulses involved allows the aircraft to determine its own location. The number of ground stations is approximately 800 (compared to approximately 2,000 stations for DMEs and PDLs). The WAM stations would be independently and precisely located, permitting accurate data to be received by the aircraft. However, while DME requires two points to determine an aircraft's location, WAM requires three.

APNT Alternative 3: Signals are broadcast from multiple ground points rather than from the aircraft. The aircraft calculates its position through a Receiver Autonomous Integrity Monitoring (RAIM)-based integrity solution. This is a new service in addition to using existing GPS equipment.

Options two and three require a common timing reference.

Mr. McGurn asked if these systems would work for international flights. Mr. Eldredge responded that considerable interoperability already exists on the avionics side.

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GPS Time as a Critical Infrastructure Application

Dr. Robert A. Nelson, President
Satellite Engineering Research Corporation

Coordinated Universal Time (UTC) began in 1961 with the use of atomic clocks. This time scale is based upon contributions from timing laboratories around the world, coordinated by the International Bureau of Weights and Measures (BIPM), near Paris. UTC is an atomic time scale that is maintained within 0.9 second of Earth rotation time (UT1) through the occasional addition of a leap second. The definition of UTC was adopted in 1972 to facilitate navigation at sea by means of radio time signals, but this motivation has been made obsolete by the subsequent development of GPS. Over the past forty years, there has been a rapid increase in technologies that are very time sensitive. The present definition of UTC with leap seconds holds problems for many types of modern infrastructure – such as safety of life systems for aircraft navigation and control, communications systems, financial networks, and electrical power grids. These rather require a uniform time without discontinuous steps. Therefore, a recommendation has been made by the International Telecommunication Union to eliminate leap seconds from UTC. This will be voted upon at the group's January 2012 meeting in Geneva.

The Earth's rotation is constantly slowing down. One basis for determining this is data from ancient solar eclipses, such as the one recorded in Babylon in 136 BC. For the calculated path of the eclipse to pass through Babylon, an eastward shift correction of 48 degrees, or about three hours of time, is required. The Earth's slowing is inexorable. Due to the historical circumstances of its definition, the atomically-defined second is equal to a second defined by the length of the day in 1820, and since 1820 the length of the day has increased by 2.5 milliseconds. This difference accumulates to nearly one second over the course of 365 days in a year, which is compensated by the addition of a leap second. However, in recent years there have been random changes that have temporarily eliminated the need for the leap second. No leap seconds have been added since 2008. If the leap second were dropped permanently, then the difference between uniform atomic time and Earth rotation time would not exceed two minutes over the next century. This would be imperceptible to the average person. For those who need a measure of the Earth rotation angle, such as for pointing telescopes and for tracking satellites, the International Earth Rotation and Reference System Service (IERS) provides a difference between UT1 and UTC with a precision of about 10 microseconds in real time. This is five orders of magnitude better than the maximum difference of 0.9 second currently used.

Dr. Nelson said he wished to leave the group with a thought. Relativistic considerations are essential not only to GPS but to all other highly precise uses of time. In consequence, corrections must be made for the velocity of the clock and the surrounding gravitational potential. For example, with GPS satellite clocks, there is a drift with respect to ground clocks of 38.6 microseconds each day, which is enormous, and is compensated by a frequency offset of the clocks prior to launch. Dr. Nelson then addressed the question of time transfers in the solar system, such as between clocks on Mars and an Earth. Obviously clocks on the two planets would not operate synchronously with each other. To compare the two clocks, it would be necessary to perform relativistic corrections on the order of ten milliseconds. In addition, mathematical adjustments need to be made to the readings of clocks onboard any satellites heading for Mars. Dr. Nelson added he recently published a paper in the journal *Metrologia* that discusses these principles and chaired a drafting group at a recent International Telecommunication Union - Radiocommunication sector (ITU-R) meeting in Geneva that prepared a proposed Recommendation on this subject.

In summary, progress in clocks has yielded instruments of great precision. Scales based on astronomical time have been replaced by scales based on atomic time. Atomic clocks continue to be reduced in size and power, such as a mercury ion clock he described that is under development at the NASA Jet Propulsion Laboratory (JPL) that is suited for future use on spacecraft. There has also been progress in the development of so-called chip-scale atomic clocks, which are clocks with modest size and power requirements but are not miniature devices despite their name.

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In adjourning for lunch, Gov. Geringer noted that the annual NASA ethics briefing would be given during the meal.

Mr. Miller announced that the presentation to be made by Brandon Wells of DHS had been rescheduled for Thursday's session.

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U.S./International Initiatives & Partnership Opportunities

Mr. Ray Clore, Senior Advisor for GNSS Issues
Department of State

Recently there have been changes to the 2004 U.S. National Space Policy, including a specific statement that: (1) foreign PNT services may be used to augment and strengthen the resilience of GPS. This could be achieved through encouraging compatibility and interoperability with other GNSS systems; and (2) a commitment has been included to "support international activities to detect and mitigate harmful interference." Eventually there may be so many satellites in space that the U.S. could make productive use of them for additional redundancy.

Bilateral Activities:

- The U.S.-EU GPS- Galileo Cooperation Agreement, which has been in effect since 2004, was finally ratified by the European Union parliament on October 26, 2011. There has been very good cooperation and consultation with Europe including, for example, the discussion of GPS-Galileo issues in June 2011 in Brussels, Belgium; on-going/planned operator-to-operator coordination meetings to focus on GPS III, Wide Area Augmentation System (WAAS) and European Geostationary Navigation Overlay Service (EGNOS); and an October 2011 video conference that included discussion of *LightSquared*'s potential impact on GNSS.
- The U.S. and Japan have had very close cooperation on GNSS issues including: the role of Quasi-Zenith Satellite System (QZSS); an effort to establish a method to focus alerts down to an area approximately 100 meters across; and co-sponsoring a workshop on GPS interference.
- While no "broad agreement" exists with Russia, several working groups were still active. The U.S. continues to encourage the Russians to adopt Code Division Multiple Access (CDMA) signals. A U.S.-Russia joint statement reaffirming the intention to continue cooperation was signed in September 2011.
- U.S. activities with China included operator-to-operator coordination sessions on GPS and COMPASS in September 2010.
- The 3rd U.S.-India Joint Working Group on civil space cooperation convened in July 2011.

Multilateral Activities:

- The International Committee on GNSS (ICG) continues to focus on assisting developing countries realize the advantages and full potential of GNSS services. Outcomes from the sixth ICG session include endorsement of the ICG Multi-GNSS Experiment and the creation of a subgroup for monitoring and assessment. Templates have been

completed and placed on the ICG website. U.S. participation at the session included a systems update, a presentation on GNSS use in disaster management, and an update on the FAA and use of GNSS. These presentations demonstrate that the U.S. is keeping its word in regard to GNSS. A U.S. recommendation for GNSS service providers to develop respective Space Service Volumes (SSVs), similar to that approved for GPS, was also approved.

- The Asia-Pacific Economic Cooperation (APEC) GNSS Implementation Team, established in 2000, is working to bring the benefits of GNSS to all economies. Four project proposals are currently in development. The U.S. is developing a regulatory roadmap for performance-based aviation navigation; Japan is working on a multi-GNSS constellation; Thailand is working on a RAIM prediction system; and South Korea is working on opportunities for space-based augmentation systems.

The Department of State (DOS) bases its work on guidance derived from U.S. national space policy. The general intentions are to promote GPS use through multilateral cooperation that further enhances compatibility and interoperability, and through promotion of other systems augmenting GPS signals, such as the Japan Quasi Zenith Satellite System (QZSS). The U.S. continues to support transparency in all GNSS activities.

Mr. Terence McGurn reported having been told that China would issue their Interface Control Documents (ICD) by November 2011. Mr. Clore said his most recent information was that publication should occur within several weeks.

Ms. Ruth Neilan noted that she served as chair of the ICG reference group on timing. She further stated that the Chinese had attended the sixth ICG meeting, and that they were hoping to have an ICD released prior to the start of their February 2012 testing.

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Update of U.S. Interference Detection & Mitigation Plan

John Merrill, PNT Program Lead
Department of Homeland Security (DHS)

DHS had developed Patriot Watch, a system with three major aspects: (1) protect the nation's 18 critical infrastructure and key resource sectors; (2) pursue a System-of-Systems approach characterized by open architecture and a multi-phased/multi-layered approach, and; (3) provide near real-time situational awareness of PNT interference events. Patriot Watch will monitor data collection, and then process that data to provide analysis and evaluation of the dynamic environment.

DHS has also taken steps regarding GPS jamming equipment including: (1) working with the FCC to monitor sales of jamming devices; (2) educating law enforcement and customs officials on the danger of jamming, and; (3) conducting discussions on the possibility of using U.S. fiber optic networks to undertake time dissemination (this possibility is made easier by the fact that most the fiber optic capability is owned by a limited number of carriers).

Dr. Bradford Parkinson noted that some highway tollbooths have the capacity to record and recover the license plates of vehicles passing through, and suggested this technology could perhaps be used to identify vehicles carrying jamming devices. Mr. Merrill said this possibility was being actively worked and tested.

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Panel Discussion: *LightSquared* Compatibility with GPS

EDITORIAL NOTE FROM PNT BOARD EXECUTIVE DIRECTOR, James Miller: A number of Advisory Board members recused themselves from this discussion based on consultation and discussion with NASA Office of General Counsel during the annual ethics briefing. While the intent of the Panel was to continue the transparent, balanced discussions begun at the June meeting regarding the national policy question of GPS (Radio Navigation Satellite Service) and LightSquared (Mobile Satellite Service) co-existence, a number of press reports indicated that a legal strategy would be pursued if a technical solution could not be found. The following Board members thereby formally recused themselves to avoid the potential appearance of a conflict-of-interest on any particular matter: Parkinson, Burns, Hatch, Lord, Murphy, and Ciganer. Also for the record, Brenner recused since the June meeting, and Parkinson was not present on June 10 when the Board recommendation that the Federal Communications Commission (FCC) find other, more compatible spectrum was formulated.

Gov. Geringer introduced the Panel Discussion, led by Mr. Tom Stansell of *Stansell Consulting*. Speakers included Dr. Javad Ashajee of *Javad GNSS*, Mr. Scott Burgett of *Garmin International*, Mr. Jim Kirkland of *Trimble*, Mr. Martin Harriman from *LightSquared*, and Mr. Mark Sturza of *3C Systems*.

Mr. Stansell framed the discussion as follows, "Is it proper to convert an MSS space band into a terrestrial broadcast environment?" If the answer is "yes," then a problem for GPS users will be created where there currently is none. The FCC has asked that people from both sides of the argument work together towards resolution. If an interference problem is introduced, then the question becomes who is affected? Thousands of applications and millions of users already exist, and technical tests clearly show that there is an interference problem with modifying the MSS band. So then the problem evolves into "can the interference be mitigated"? If so, how long will it take? What will it cost? Who would pay?

1) LightSquared Can Complement GPS

Dr. Javad Ashajee
CEO, Javad GNSS

PNT devices are commonly thought of as containing only three elements (position, navigation, and time). However, there is also a fourth component: communications. GPS is an example. On a typical circuit board, one side contains the GNSS features, while the other contains the communications device. In general, PNT businesses have lacked a good and readily available communications partner.

This briefing focuses on use of the "lower ten" channel within the MSS band, and also explores the "shields" that may be implemented in receivers to protect GPS users from harmful interference. The nominal signal received power from *LightSquared* is -10 dBm, while GPS military/commercial power is -133 dBm; and GPS encrypted P-Code power is -143 dBm. Thus, it would appear that the proposed *LightSquared* power is 20 trillion times stronger than GPS. However, *LightSquared* engineers have noted the power is typically -40 dBm, rarely is over -30 dBm, and would "absolutely never" get as high as -10 dBm. The root of the problem is that GPS signals are wide open and there are no "fences" in place.

Four kinds of tests can be done to analyze the effectiveness of proposed filters, or "fences", to protect GPS.

- The first is component analysis and simulation. As an analogy, it is like looking at a person and saying they look healthy.
- The second was a sine wave in-circuit measurement, which is analogous to performing an electrocardiogram on a person.
- The third is anechoic chamber system test. This is similar to a stress test on a treadmill.
- The fourth is the "ultimate test", which is not unlike a test given to a gymnast who is capable to making more strenuous moves.

When these tests are carried out with proposed filters, "the entire GPS signal is preserved." In terms of the GPS L1 signal, the baseline measurement of the error is less than the thickness of a standard business card (better than 0.2 millimeters), and for the GPS L2 signal the error is 0.1 millimeter.

The proposed filter provides a "solid wall" between GPS and the *LightSquared* signal with minimal performance degradation. Every filter of course, has a limit to the amount of power it can tolerate. However today's filters still allow for full operations with 10 dBm of headroom. In addition, even if 44,000 *LightSquared* transmitters were directed at a single satellite they would create a signal power of only -58.5 dBm.

A technology development road-map was presented, and indicated a "*LightSquared* Protected" receiver would be available in November 2011, while a "*LightSquared*-Compensated" system would be introduced in March 2012. "*LightSquared*-Integrated", the ultimate goal, combines the first two and adds the communications model, to be available June 2012.

2) Garmin: PNT National Advisory Board Panel Discussion LightSquared

Scott Burgett
Software Engineering Manager, Garmin International

This briefing offers the perspective of general location navigation and certified aviation operations, both of which are quite different from the high-precision market. *Garmin* is very supportive of broadband, but does not wish to see it go forward at the expense of GPS. Garmin has been a consistent participant in the entire Technical Working Group (TWG), and has participated in testing such as the Nevada Sky Tests.

At the close of the TWG testing process, there was a claim that 99% of the installed user base and cellular devices would be free from harmful interference. Burgett does not agree with this assertion since only 29 of the many thousands of deployed devices were tested, and furthermore, the 99% claim is based on harmful signal degradation of 6 dB rather than the standard of 1 dB. Also, the propagation model used, while well suited for a communications link analysis, is not suitable for an interference analysis. Finally, the 99% claim assumes only the "lower 10" would be in use, which at this time, is far from decided. The vast majority of devices tested failed miserably at the "upper 10" channel. There is also a major jamming issue with the installed base using only the "lower 10" channel.

Another complexity is that integrated aviation devices cannot be simply 'retrofit', but rather need to be replaced entirely. This requires FAA approval, design steps, and installation. This is expensive. The time required to retrofit the aviation fleet is in the range of ten to fifteen years, and in most applications consumers customarily purchase GPS devices believing they have a life expectancy of 8-10 years.

In terms of a "way forward", it is very difficult to design products that are compatible with *LightSquared* when the pertinent technical "end-state" information is not readily available. The "upper ten" MSS channel has proven to be totally incompatible with GPS, however the FCC conditional authorization for *LightSquared* to use that channel is still open.

3) Trimble: PNT National Advisory Board Panel Discussion LightSquared

James Kirkland
Vice President and General Counsel, Trimble Navigation

The issue of proposed mitigations needs to be placed in the context of what is the problem we are trying to solve. This varies with the type of GPS receiver being considered. A GPS receiver in one's car is a small integrated unit. It cannot be broken apart and put back together. A precision receiver, on the other hand, is a physically larger device that is more forgiving of retrofit options. The mitigation proposed earlier in the panel discussion presents a possible solution at the specific precision receiver end of the market.

Much had been said about filters. Precision receivers were designed to use the GPS signals and the MSS power band. When one speaks of filtering, a key consideration is where the filter "drops" on the frequency spectrum. Precision receivers did not previously filter signals in the MSS band because those satellite signals were offered money by *LightSquared*. If implementing the proposed mitigation dramatically improves the interference rejection, why wasn't this offered earlier? The reason is that precision receiver manufacturers had contracts which required them to receive the entire band. Manufacturers could design filters that will greatly improve their performance, but is this "good enough"? This is the question that the FCC and others are putting to the test.

Another critical unresolved issue was cost. Any solution involved retrofitting or outright replacement could range in the "tens of thousands" of dollars based on receiver type. Who will pay this? The industry position is that *LightSquared*, as the new entrant to the field, should pay the cost. This ensures that the full economic costs of the system are borne by the entrant. Merely replacing the commercial receivers currently in use is a multi-billion dollar undertaking.

4) LightSquared

Martin Harriman
Executive Vice President, LightSquared

Mr. Harriman suggested that the conversation be moved away from GPS for a moment. What is *LightSquared* about? Why build it? The company is attempting to build the world's first integrated satellite/terrestrial seamless network. Once completed, it will boost productivity coast-to-coast. The share of U.S. homes with broadband service had increased from 64 to 70 percent. Still, the U.S. is still ranked 20th in the world in broadband usage, behind Estonia, Belgium, Iceland and Malta. The U.S. was falling behind in a key technology; a technology he believed was peculiarly important to small business.

LightSquared is a satellite operator that had launched in 2010 the world's most sophisticated satellite. The company had chosen to adopt the business model of being wholesalers. They believed this was the best way to proceed. The company's goal is to be the best network operator in the world, and sell that capacity to new players. *LightSquared* will enable wireless competition across a range of industries. It will enable a plethora of people who wished to do business in a new way. At present there were 300,000 *LightSquared* satellite customers.

LightSquared is working hard to establish at what power levels it could operate – and then implement those power levels. It will then make a commitment that those power levels would never be exceeded. The current plan showed 23 MHz of separation between *LightSquared* and GPS activity.

The number of groups in conversations with *LightSquared* is encouraging. They are working with multiple filter makers. *LightSquared* is actively engaged with three of the nation's top five GPS precision manufacturers. In summary, *LightSquared's* network design and wholesale model will "create superior RF connectivity at significantly lower cost." Through *LightSquared's* satellite coverage and high speed terrestrial coverage, then the "missing link" that GPS had lacked could be provided.

Questions and Answers:

Dr. Ashajee was asked if he had done any work to evaluate the MSS and GPS filters that have been developed by other companies. Dr. Ashajee said he had not, but would be pleased to do so.

Dr. Hermann asked if attention was being paid to manufacturers of MSS devices. He noted that for the record *Trimble* had purchased *Omnistar* which operates on an open licensing model. Trimble allows people with a receiver to use that code, without royalty.

Mr. Kirkland noted that the approach described by Dr. Ashajee was not necessarily a solution for precision receivers. It still needs to be shown that those receivers will operate properly. So long as there is an "upper 10" on the table, it is a potential problem for GPS users. A surveyor investing $30,000 in equipment is unlikely to want to trade it out. Moreover, changeover in aviation fleets can take decades.

Mr. Harriman was asked if *LightSquared* would formally relinquish any claim to the "upper ten" on the bandwidth. He acknowledged that the "upper ten" might create a more difficult spectrum. He noted that his company had paid over $100 million to have access to that spectrum. Therefore, they were unwilling to let go of it unless it was certain that the interference problems could not be solved.

Dr. Ashajee was asked if he planned to retrofit existing receivers with the new solution he had presented that day. Dr. Ashajee said everything current shipped by his company was either *LightSquared*-compatible or eligible for a free retrofit. Currently installed systems could be retrofitted for $300 to $800. Mr. Harriman added that the possible federal government expense for retrofitting was approximately $50 million and that his company had offered that amount. Mr. Kirkland said he had seen estimates that were much higher. Mr. Harriman said the matter was on the table.

Gov. Geringer said he did not wish to give the impression that Dr. Ashjee's solution was the only one possible. The question requires the technical folks to "sit together and resolve it."

Mr. Stansell asked what is the actual expected cost of a filter? Figures quoted ranged from five cents to $500. Mr. Stansell said the key question is whether one was replacing a circuit board or a filter. Filters are only one component of what may need to be replaced.

A comment was made that U. S. airlines operate thousands of GPS receivers, and these are precision units that would need to be replaced and certificated at a cost in the hundreds of millions of dollars.

Mr. Harriman said he thought that is a misrepresentation. There are receiver standards in aviation, and they must conform to those standards. *LightSquared* is working very hard with the FCC to see how this can be worked out. Clearly, he believed the challenge could be met. This was not a problem contemplated when these standards were promulgated.

Mr. Kirkland replied it is not just the cost of a simple technical fix because he also had to go through certification processes to make sure all performance standards continue to be met. He noted that if you swap out a receiver, you have to go through involved procedures. The military has detailed testing protocols to make sure the weapons systems will perform as intended, and this is why we hear about big numbers in terms of cost since we have lots of aircraft and lots of military systems that are affected.

Mr. Stansell asked if international allocations for augmentations in the MSS band were already allowed, would narrowing the signal for *LightSquared* – say, in the U.S. - impact international users and sales of receivers? Even if the technology were available, there may not be international acceptance into moving the downloaded signal into the upper part of the MSS band.

Mr. Harriman said he did not think that would be the case. If one wished to use the same receiver worldwide, but that receiver were filtered so that some of the L-Band cannot be sent in the U.S., and yet that service is provided in that spectrum segment in Europe, then it could become an issue. This would require having separate U.S.-certified receivers and European-certified receivers. This is one of the issues that need solving once the filtering issue is agreed upon.

Mr. Stansell asked Mr. Burgett how many *Garmin* products were now in use in the United States. Mr. Burgett replied that 70-80 million devices are deployed worldwide, though he did not know what the U.S. share was.

Mr. Stansell presented a question related to precision agriculture. If filtering devices were a solution, what would it cost to retrofit agricultural equipment that farmers have been using with success for the past decade? What downtime would be involved? Who would pay the associated costs and downtime? What would be the overall impact on the nation's agricultural productivity?

Mr. Kirkland said the retrofit cost Dr. Ashajee had quoted of $300 to $800 per unit for a precision receiver was a starting point. Each manufacturer had to design and implement its own retrofit option. Costs would vary from manufacturer to manufacturer.

Mr. Stansell said he believed testing related to *LightSquared* would continue beyond the current November 2011 deadline. Has *LightSquared* asked the FCC to extend its milestones?

Mr. Harriman said the first phase of testing was complete. Discussions were currently in progress on starting the second phase and hoped they would proceed as quickly as possible. *LightSquared* will be undertaking some pre-testing during the week of Thanksgiving to ensure that the testing was ready to proceed; in doing this it bears the burden of proof. He welcomed participation by others who may have devices they wished to test. *LightSquared's* contracts with Sprint, while calling for a later start than hoped, should prompt things to move more rapidly once in progress.

Mr. Burgett said he had attended the testing at White Sands and believes an excellent job was performed by all. Work was proceeding night and day to process the data, and he was looking forward to seeing the results.

Mr. Stansell asked how a technical solution would be retrofitted into military equipment, and at what costs? His own experience was that the military is unwilling to settle for simulated tests, and instead, requires live tests of any design changes. Brig Gen Thompson said this is generally the case because a great deal is at stake.

Mr. Stansell, in closing the panel, said he believed we have learned about a clever solution to a problem with a range of products. What had not been addressed is "the elephant in the room" – the costs and time delays involved. The time and cost framework for undertaking retrofits may not be fully resolved in the near-term. In any case, he has never seen as much energy and dedication as the GPS community and *LightSquared* are devoting to this effort.

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Seeking a Solution to *LightSquared* Interference

Mr. Kirk Lewis, Senior Advisor
Institute for Defense Analysis

Mr. Kirk Lewis presented an "abbreviated history" of *LightSquared.* In 2003, the FCC first authorized an undertaking with a limited number of base stations and comparatively low allowable power levels. In 2005, reconsideration of that Order removed all limits on the permissible number of base stations, raised the allowable power to 1.5 kW; and promised "in very strong terms" no stand-alone terrestrial service. In 2010 the "Harbinger Order" gave *LightSquared* Ancillary Terrestrial Component (ATC) authority and permission to increase the base station power to 15kW. The "triggering event" was the conditional waiver granted by the FCC in 2011, which waived the requirement on *LightSquared* of operating dual-mode handsets. Right around this time, he added, *LightSquared* proposed up to 40,000 transmitters, each of which could be 15 kW. All these changes effectively enable a shift in the business plan from a satellite-based service with a limited terrestrial-based component into a service that is predominantly terrestrial-based in terms of number of users and communications traffic.

While much has been accomplished in initial testing, there are several large segments that remain to be effectively tested. This testing had been undertaken by DoD, other agencies, manufacturers and various user groups. The test results for the first phase, as reported in June 2011, states that many military, precision-civil, public safety, and aviation receivers are severely affected even at lower power levels.

There are a number of options available to mitigate this interference. The simplest approach is to rescind the waiver the FCC had granted *LightSquared*. Another approach is to move *LightSquared* to another band on the frequency. A third option is to assist *LightSquared* in finding a solution that does not interfere with GPS. The general consensus among the GPS community is that the full impact of *LightSquared* is yet to be determined. Much work remains to be done in the precision-user and other areas.

Another issue is the technical solutions and their affordability. For example, retrofitting is not a practical option for smaller receivers, while the validation/certification process for other equipment involves a lengthy amount of time. As an analogy, when a few years ago a decision was made to phase out the GPS L1/L2 codeless signal, it was decided to allow twelve years for its

implementation. This is not an unreasonable timeline when one was dealing with large numbers of precision receivers worldwide that rely on GPS L1/L2 codeless tracking. He noted that neither GPS nor MSS were standing still. Both, he said, were becoming progressively more embedded in our national economic and security environments.

Gov. Geringer termed the presentation excellent. He added that he thought it unfortunate that the *LightSquared* panel had chosen not to attend, as all but one participant from *LightSquared panel* had left the meeting by this point.

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Receiver Certification: Making the GNSS Environment Hostile to Jammers & Spoofers

Mr. Logan Scott
LS Consulting

Mr. Logan Scott identified three major elements of the "civil protective triad":

- The first element is "receiver certification," which maintains situational awareness in regards to jamming and false information. This drives the general allocation information.
- The second element is the "jamming devices," which are becoming ubiquitous. In Taiwan, 117 jamming events occurred daily on average.
- The third element is "receiver situational awareness". By this we mean that there is an education problem among the GPS applications R&D community because an effective threat response also requires an understanding of the threat. Twenty years ago everyone working in this field had military experience, whereas today most designers lacked this experience and do not consider jamming and related concerns as something they needed to factor in. Mr. Scott reviewed two incidents: in Mesa, Arizona (1) in 2001 a Gulf Stream II lost GPS contact and the flight control system turned 35 degrees in the direction of other traffic, and; (2) in 2008, a maritime receiver was ''spoofed" by a jammer and reported a speed of over 100 knots.

Mr. Scott then addressed the topic of intelligent receivers. These have the capacity to measure numerous jammer parameters. Such receivers report interference to users in less time than would be required to de-bug systems. Second, they avoid the transmission of hazardous information. Finally, intelligent receivers can maintain files on specific jammers and their activities.

While most receivers in use have the basic tools to undertake these checks, they are not doing so. Thus, we need a "receiver certification program" that could be easily used by a non-expert – for example, a local county sheriff who must purchase some GPS capabilities. Why would a manufacturer want to include anti-spoofing capabilities in the receivers it is marketing? The reason is that doing so offers a competitive advantage.

Mr. McGurn said both he and Mr. Scott had served together on a panel on how GPS supports critical infrastructure. One finding was that often if something went wrong in the critical infrastructure, it did so in the first few minutes of operation. This leads to a belief that most of the situation is caused at the receiver end. Also, they had defined "jamming scenarios" as distinct from "spoofing scenarios". In the Mesa, Arizona incident described earlier, a jamming incident had been treated as a spoofing incident. This shows that the focus should be placed on situational awareness at the receiving end.

Mr. Scott asked whether it would be appropriate for the Advisory Board to support efforts by manufacturers to include situational awareness in receiver design, and also, some means of testing that showed that given receivers had met a standard.

Dr. Parkinson said many matters advanced by Mr. Scott had been well-known for some time, but not acted upon. An illustrative example of this approach could be how in the early years of electric wiring in homes, many were burnt down due to faulty electrical wiring, leading to the establishment of an "Underwriters Laboratory" which enabled manufactures to say that their products had met an independent safety test. If Mr. Scott is advocating a similar approach, Dr. Parkinson would strongly endorse it.

Mr. Kirk said this might be an excellent task for the GPS Industry Council to undertake, as doing so would not require government oversight.

Dr. Hermann said the outcome would be that a piece of equipment would be certified – by consensus – as having met a standard. Several testing labs already exist.

Gov. Geringer asked whether people preferred voluntary or mandatory. Mr. McGurn responded that creating a "certification process" should suffice in motivating manufacturers to meet such standards.

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The Wednesday, November 9 session of the PNT Advisory Board adjourned at 5 p.m.

Session of Thursday, November 10, 2011

Call to Order

Dr. Parkinson called the session to order, and announced he was recusing himself from any discussion relating to *LightSquared*. He also noted that Joe Burns, Tim Murphy, Lance Lord, Ron Hatch, Dean Brenner and Ann Ciganer would be recusing themselves. This recusal may be temporary, as NASA General Counsel was reviewing the statement that it was the sum and variety of outlooks expressed by Advisory Board members that prevented conflicts of interest from occurring. Dr. Parkinson noted that some of those recusing themselves were identified with the *LightSquared* proposal through their companies' interests, while some remained in opposition to expected *LightSquared* interference to GPS.

Gov. Geringer suggested that the recusal be limited to the potential question of interference with GPS caused by *LightSquared*, rather than the broader issue of interference generally.

Dr. Parkinson termed this an excellent suggestion. Dr. Parkinson then restated the tasks assigned to the Advisory Board by the EXCOM, which include:

- PNT Architecture Assessment: Perform an independent assessment of the way ahead for the *National PNT Architecture Implementation Plan*.

- GPS Commercial Outage Impact Assessment: Using scenarios and available data, conduct an assessment of the impact to U.S. commercial infrastructure of GPS. Evaluate specific role(s) of space-based PNT in the operation of civil/commercial cyber networks.

- Non-ICD Compliant Civil/Commercial Receivers: Evaluate the implications of user non-compliance with GPS Interface Control Document (ICD) specifications and potential solutions.

- Advisory Board Technical Subcommittee: Establish an Advisory Board subcommittee capable of evaluation and timely feedback on emerging issues.

After some discussions the Advisory Board members were assigned to four working groups, and a "lead" assigned to each group. The objective for each group is to review the tasks at hand, and if consensus isn't reached, the Advisory Board may need to work off-line and provide a briefing at the next meeting.

James Miller noted that Mr. Brandon Wales was on hand to give the Homeland Security presentation that had been scheduled for the previous day. He thanked Mr. Wales for his patience.

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Risks to U.S. Critical Infrastructure from GPS Disruptions

Mr. Brandon Wales, Director of Homeland Infrastructure Threat & Risk Analysis Center
Department of Homeland Security

Mr. Brandon Wales noted that in the previous year the EXCOM had requested his office to undertake a comprehensive national risk assessment related to GPS disruptions. That report was nearing completion as the National Risk Estimate (NRE). The NRE is modeled along the lines of other efforts in the intelligence community. The main task is to develop a product line that provides authoritative and coordinated risk-informed assessments of key national security issues. This includes two assessments:

- The first such assessment is on trends in global supply chain risks. The study has been used in driving the national strategy of global supply train to be forthcoming from the White House.

- The second assessment was on GPS security, which involved working with both users and equipment manufacturers. This process includes several phases: the first phase is to review risks in various scenarios; and the second phase evaluates "alternative futures" with emphasis on risks that may affect GPS, to include formal input from the Air Force.

Dr. Parkinson noted that Mr. Wales' charter was directed on the use of GPS in the U.S., whereas the broader international PNT community is trying to develop a single interoperable signal (GPS L1C, Galileo Open Service, etc.). Does the DHS study plan to include GNSS constellations and/or include foreign countries?

Mr. Wales said this issue was touched upon and will be addressed in future work. Applications that currently rely on GPS could in the future expand to also use other systems, including international systems and non space-based tools.

Dr. Parkinson said that without official approval, other systems would likely not be certified and would not be used in aviation or other applications attempting to determine what track a train is on.

Mr. Wales noted that the report had not dealt in detail with mitigations, but it did look at how to increase the robustness of domestic symptoms. A corollary report looks at how potential disruptions might be addressed.

Mr. McGurn noted he had taken part in some of those discussions. While the sentiment is that it would be beneficial to incorporate foreign systems, there is a lot of work that needs to be done to ensure availability and reliability. GPS has undergone a rigorous review, and this is yet to happen with other systems, i.e. GLONASS, which has had some major failures. Very frank discussions are needed on this issue.

Mr. Wales identified four critical infrastructures that are studied in the NRE:

- Communications
- Emergency Services
- Energy
- Transportation Systems

Early on, banking and finance had been included in the study, however following various discussions with those in the field, the topic had been omitted. Some efforts have been made to determine whether those users are overly dependent on GPS. For instance, the time in some of the clocks used in finance applications is derived from GPS time.

Mr. Hatch noted that precision agriculture should be included because it is an area heavily reliant on GPS and precision GPS.

Mr. Wales noted that a considerably broader realm of activities is dependent on GPS, but that the NRE study focuses on a select number of sectors.

Mr. Brenner asked if the federal government has an estimate on the number of GPS devices in service. Mr. Wales said it did not.

Mr. Wales then identified the highlights of the NRE report:

- Critical U.S. infrastructure is increasingly at risk from growing dependency on GPS. GPS could be called a "shadow utility," since it is embedded across platforms and systems.
- GPS is increasingly integrated because it is accurate, available, reliable, and provided at "no cost". Despite this, awareness of the role played by GPS is limited. It was difficult to find people within the various infrastructures that really understand how GPS is embedded in their operations. Sometimes it took 20-30 telephone calls in a given segment to locate an individual well-versed on the subject. GPS generally faced three types of disruptions:
    - Those that occur due to natural events, such as sunspots or space weather
    - Those that occur due to bandwidth crowding from other radio signals
    - Disruptions caused by intentional interference – such as jamming or spoofing
- Reporting of GPS outages is generally poor. Often they are unknown to the receiver. Jamming disruptions are more common than spoofing disruptions, but the latter are likely to be more serious. Mitigating interference with GPS remains a challenge. Also, manual skill levels commonly decline in activities that are strongly dependent on GPS.

Key uncertainties regarding GPS' future include:

- The extent to which GPS applications are layered into sector operations
- The vulnerability of GPS to intended or unintended disruptions
- The extent to which disruptions can be identified and mitigated
- The accuracy, integrity and continuity of alternative PNT systems

The NRE report should be completed in late December 2011 and, pending review, it should be released in January 2012.

Mr. McGurn noted he has attended several workshops in this study, and commented that Mr. Richard Moore has provided great guidance in these meetings. As mentioned earlier, the determination of interference due to jammers is more likely than that due to spoofers. There are relatively few jamming instances for which even anecdotal data exists. There are even cases in which interference had been the fault of the receiver. Efforts should be made to build better receivers with higher integrity of operation. When one is either jammed or spoofed, much of the damage was done in the first few seconds or minutes and, thus, the early line of defense is the receiver itself.

Dr. Parkinson said he had reviewed the list of 18 critical infrastructures. The key is to determine the extent to which each infrastructure depends on GPS. For example, agriculture is desperately reliant on GPS and, in consequence, farmers are much more knowledgeable about technical matters than one might imagine. Anecdotally, his own second cousin, a farmer in England, has a very sophisticated understanding of the pertinent technologies.

Mr. McGurn noted that the use of GPS in aviation and farming is quite different.

Dr. Parkinson suggested that Mr. Wales review the list of critical infrastructures to make sure the right choices were made; Mr. Wales said this was a good point and added that there had been a number of reasons for including supply chain (logistics) and manufacturing. Also, it was difficult determining the level of dependence on GPS in a given sector because few people have a good understanding of how GPS affects them.

Dr. Parkinson called Mr. Wales' attention to the process that had been used by the Air Force when it was engaged in phasing out the GPS L1/L2 codeless application, where it hired someone who spent time investigating the likely affects on various groups. The average farmer is likely to neither hear the call for information, nor drive to Washington D.C. to lobby on behalf of GPS-based precision agriculture.

Mr. Wales said the report had also looked at the possible impact of a powerful transmitter on GPS operations including the possibility of wide-scale signal disruption.

* * *

GPS Civil/Commercial Receivers: Compliance and Certification

Mr. Tom Powell, Aerospace Corp
(Substituting for Mr. Jules McNeff)

Mr. Powell noted said he would review the tasking received from the Advisory Board, present relevant GPS compliance documents and GPS performance overview, and discuss the notional certification content and process options.

He began the presentation by asking the following questions -- Are the ICD processes sufficient for the task of certifying receivers? Should some formal approach be established? If so, should this task be undertaken by the government, by some third party, or by the manufacturers themselves? The pertinent tasking statement is "to evaluate the implications of non-compliance with GPS ICD specification and potential solutions." When an anomaly is investigated, it generally shows that one or another aspect of the ICD has not been complied with.

One question, he said, was whether the ICDs are sufficient. If not, what sort of certification process is required, and who would play what roles within the process – the government, a third-party or the manufacturers themselves? The GPS ICDs have been replaced by the term GPS Interface Specification (IS).

There are three key documents for the GPS signals in space (L1/L2, L5, and L1C) and there is also a public body known as the Interface Control Working Group (ICWG), which meets to address potential discrepancies and review changes to these documents. These documents are:

- *IS-GPS-200*: Defines the requirements related to the interface between the space segment of the Global Positioning System and the navigation user segment of the GPS for radio frequency link 1 (L1) and link 2 (L2). Versions of the document prior to Revision D were designated as ICDs instead of ISs.
- *IS-GPS-705*: Defines the requirements related to the interface between the space segment of the Global Positioning System and the navigation user segment of the GPS for radio frequency link 5 (L5).
- *IS-GPS-800*: Defines the characteristics of a signal transmitted from GPS satellites to navigation receivers on radio frequency link 1 (L1). While there are multiple signals broadcast within the frequency band of L1, this Interface Specification defines only the signal denoted L1 Civil (L1C).

In addition, the *Performance Standards* specify the levels of technical performance that users can expect from GPS and related systems. All these documents are available at the National Coordination Office (NCO) website (www.gps.gov). The *Performance Standards* are important to the discussion on *LightSquared*. A performance standard is not a receiver standard. Indeed, this statement is explicitly made in the definition of the performance standard. The performance standards are "not intended to impose" any criteria on receiver design. Rather, they provide a definition of the signal-in-space performance of SPS; establish minimum GPS constellation performance standards; and assume notional receiver designs.

Mr. Faga noted it is his understanding that none of these documents defined how a receiver was to be constructed. Mr. Powell said this was indeed the case -- the document defines the signal in space that is available to be received, so the design of the receiver follows from this.

Mr. Powell added that many elements of GPS receivers operation need to be considered when thinking of compliance. These include reception of signal, modulation, how the elements are computed, the applications to be used, and other items.

In relation to the *LightSquared* debate, when the topic of GPS receivers is discussed one needs to bear in mind that most GPS receivers are deeply embedded into a platform. Only when an end-to-end review is done, is it then possible to know if the receiver is affected. In some cases a receiver may continue to track satellites but the platform's performance can still be adversely affected without the end-user being aware. This is the reason why it is not generally possible to change the receivers' operating characteristics by "swapping out" a given component.

Notional receiver certification categories include:

- Technical certification: Compliance with the relevant specification.
- Performance certification: Making sure that the receiver output is compliant with the performance requirements.
- Security certification: Necessary in the case of military systems.

Several issues need to be considered. First there is the question of the scope of certification. Does a consensus exist on what elements needed to be certified between the manufacturers and the receiver? Many models of receivers exist. Should the government – or a government-sanctioned body – take on the task of certification? Is an industry conducted approach preferable, as in the Underwriters Laboratory (UL) operation? Could self-enforcement be utilized, with individual manufacturers informing the government that they have to subject their receivers to all manner of tests and passed them? The general question is whether such a certification process is needed, and if so, who would run it?

Mr. Faga observed that if a given receiver is to be used in a critical situation, one would want some process to determine whether performance specifications are met. The individual designer will design to the specific specifications. Once someone has designed to their own standards, one needs a way to say the product has been certified beyond the standards of those who designed it. What most designers want is clarity as to what tests their products are expected to pass.

Tom Powell noted that consideration is being given to what are called "test vectors." These are a sequence of tests that could be applied. The question was who applies these tests and who declares that you have passed.

Ms. Ciganer noted that the first civilian GPS receiver was introduced in 1981. Since that time, manufacturers have conducted extensive internal testing to make sure standards are met. A conservative estimation is that there are now over one billion receivers worldwide. There have been three recent incidents, two of them civilian. The two civilian incidents would not have been found by testing. In any case tremendous progress had occurred in the IS process, including a great increase of information readily available to the public.

Mr. DalBello said that an issue much larger than certification is the question of whether receivers are being built to the government standard. According to a *LightSquared* document, "GPS manufacturers have been ignoring the government performance standards". The fact is however, that the government has not issued receiver standards; rather, the government defines the technical standards by which GPS will operate. What the government does is to supply information so the receiver manufacturers design the receiver that is suitable for their application.

Mr. Brenner noted that this issue has nothing to do with cell phones, which have their own standards and their own tests of receiver receptivity.

Gov. Geringer reiterated that the "standard" mentioned by *LightSquared* is not a receiver standard. He asked whether the group needs to call formal acknowledgement to this statement that a possible receiver design is not a standard.

Dr. Hermann said he did not see any strength in the case for imposing government standards. A voluntary standards process should be encouraged that permits manufacturers and users to establish best practices.

Mr. DalBello said that what is needed is a process that certifies that a receiver meet certain standards.

Ms. Ciganer said this is an "apples and oranges" comparison. As noted earlier, testing would not have prevented the two incidents discussed. Certification of critical applications is understood and needed. Certification, however, tends to retard the innovation rate. She was very reluctant to see a competitive advantage flowing to others over what appeared to her to be merely a "paper issue."

Mr. Hatch said he would be very leery to see government-imposed certifications on commercial applications.

Mr. DalBello asked whether the Advisory Board should address this question.

Dr. Parkinson suggested that a recommendation be pulled together, and if there was also a "minority report", so be it.

Dr. Hermann asked if there was a single advocate at the table in favor of government imposed standards.

Dr. Parkinson said that when speaking about standards, we need to be very clear what kind of standards these are, whether design standards, performance standards, or other standards. This question should be left to the subgroup.

An audience member said it might be useful for those present to know commercial receivers are broadly used by operational military forces. Many uniformed personnel prefer their commercial equipment over the heavy, expensive, and complicated military equipment.

Ms. Ciganer stressed that it is important that the current U.S. innovation rate continue to remain competitive.

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International Member Reports

1) From GPS-only to multi-GNSS: getting ready … an update

Dr. Gerhard Beutler
Switzerland

Dr. Gerhard Beutler reported on: the GPS, GLONASS and Galileo systems; the International GNSS Service (IGS); the Global Multi-GNSS Analysis; and SLR for the various GNSS systems.

In terms of performance, GLONASS has the highest inclination, which is an advantage in obtaining positioning for the Arctic and Antarctic regions. GPS, on the other hand, provides the same ground track for each day of operation and, thus, any portion of the Earth not tracked in a given day would not be tracked at all. For over 20 years the IGS has performed daily analyses of GNSS satellite ground tracks. This is one of the advantages in tracking multiple GNSS systems. Since 2008, analyses show a 1.2 cm improvement for GPS and a 1.7 cm improvement for GLONASS.

The IGS M-GEX experiment will conduct global multi-GNSS signal tracking, with emphasis on the newly-available GNSS signals, such as the modernized GPS, GLONASS, Galileo, Compass signals, as well as QZSS and other regional navigation satellite systems and augmentations. The primary purpose of the experiment is to collect, and make publicly available, observational data. It is not a trivial task to combine data from multi-GNSS systems, so once this experiment is completed a more definitive plan of the analysis will follow and eventually lead to a Multi-GNSS pilot project. Completion of this experiment is expected in late 2012.

The objective of the Global Multi-GNSS Analysis will be to determine the satellite orbits; length of day; calibration, and many other items. This data will be derived from tracking GNSS receivers, acting either individually or in concert with other systems. The number of multi-GNSS receiving stations has increased from approximately forty at the beginning of 2008, to eighty by the end of that year; after that point it has remained stable.

The Galileo Science Advisory Committee (GSAC) has recommended improvements to the scientific applications and Galileo and the European Geostationary Navigation Overlay Service (EGNOS), and is continuing to update the Galileo Science Opportunity Document (GSOD). Also, the *3rd International Colloquium on 'Science and Fundamental Aspects of the Galileo Program'* has taken place, an event which drew over one hundred participants who addressed earth science, physics and metrology.

The SLR reflectors on GNSS satellites provide an independent means of ascertaining their position, which is very important. All GLONASS, Galileo and GIOVE-A and –B satellites currently have SLR reflectors, whereas only one (of two) operational GPS-IIA satellite with an SLR reflector remains in the active constellation.

2) Toward Materialization of QZSS

Dr. Hiroshi Nishiguchi
Japan

The in-orbit configuration of the first QZSS satellite, named *Michibiki*, is now complete. In addition, the Japanese cabinet has made two "jumps" regarding the future. The cabinet decisions of September 30, 2011, are first directed at basic thoughts on the promotion of full-fledged QZSS operation, and second, implementation of a strategic architecture for space exploration and utilization. QZSS is also to contribute to national security by: enhancing the competitive edge of Japanese industry; improving the functioning of industrial and administrative functioning; upgrading Japan's international presence; strengthening Japan's alliance with the U.S.; and raising the nation's capacity to respond to natural disasters.

The short and long term plans for QZSS are: (1) to complement and augment the critical infrastructure of space-based PNT in the 21st century; (2) in the short term, deploy four QZSS satellites in the early stage, and; (3) in the long term, add even more GEO satellites.

It is important that the Japanese government take a lead role in governance of the QZSS operation. The Cabinet could be charged with securing the necessary budget for the QZSS constellation, revising the pertinent law as necessary and – based on the successful operation of *Michibiki* – providing cooperation between the public and private sectors.

3) Remarks from Dr. Rashad, Egypt

Dr. Rafaat Rashad noted that a number of conferences have taken place in the U.S., Japan, Korea and elsewhere to address the problem of jamming and interference, both intentional and inadvertent. While technical solutions are likely to be found, significant questions will remain; namely, how long will a solution take, what will it cost, and who will pay? The members of the GNSS community and the Advisory Board stand equidistant between the manufacturers and the customers. That is, the Board has been protecting the interests of transportation, aviation, safety-of-life and other matters, but not engaging directly the GPS equipment manufacturers and the communications industry. It is inevitable that standards continue to be developed and updated.

4) Remarks from Mr. Dimmen, Norway

At present, the performance standards for GNSS receivers within the International Maritime Organization (IMO) are fragmented. A goal should be set to evolve existing systems into a single performance standard for maritime radionavigation receivers. This is critical as traffic at sea continues to increase. In addition, new routes are opening such as the northern sea route – which passes at a latitude higher than the Asiatic land mass, typically between Rotterdam (Netherlands) and Yokohama (Japan) – now offers potential large savings in travel time. Thus far in 2011, there have been 17 ships have taken this route, including one of 120,000 tons.

Dr. Parkinson asked if there had been any adversarial challenges passing through waters that Russia might consider considered territorial.

Mr. Dimmen called attention to one photograph, which showed a Russian ice breaker ready to lend assistance. The challenges are, so far, navigational in nature. He urged those interested in the topic to read an article, "Breaking the Ice: Navigation in the Arctic," written by Advisory Board member Dr. Per Enge and others, which discusses the Arctic extension of SBAS, the use of LEO satellites to broadcast information; and how multi-constellation GNSS could be used to improve vertical performance.

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Advisory Board Discussion:

Dr. Parkinson explained that the purpose of the Advisory Board subcommittees is to develop preliminary ideas. Each will spend approximately thirty minutes to provide ideas with the understanding they would not constitute the final word on the subject. These might either indicate answers to questions posed by the EXCOM, or questions of urgency to Board members. In response to a point raised by Mr. McGurn, he invited the designated group leaders to invite non-board members to participate at their discretion. Advisory Board members are free to serve on more than one task force, with the caveat that each group had thirty minutes to develop and present its preliminary thoughts. Dr. Parkinson reaffirmed his recusal from the *LightSquared* discussion, however he would still report on the results of any work done by the subcommittees as appropriate to ensure the work was coordinated and completed.

Subcommittee 1: Standards for GPS and Non-ICD Compliance

Mr. Terence McGurn briefed on the discussions of this subcommittee. In his view these two topics are quite different, and suggested that the issue of GPS standards be treated separately. Dr. Parkinson agreed.

Mr. McGurn added that the issue of GPS standards requires a sponsor, and in his view, DHS could be the appropriate sponsor. This is based on Mr. Scott's paper on the subject presented the previous day. This paper has really been the first time the subject was thoroughly discussed. Dr. Parkinson asked whether the Board should issue a statement on whether or not there should be GPS receiver standards. Mr. McGurn said Mr. Scott would be better prepared to answer this.

Dr. Parkinson, seeking clarification, asked whether the case has been made that there are no formal standards for GPS receivers. Mr. McGurn said there are none, public or private. Mr. DalBello agreed there are no formal receiver standards, other than the fact that performance standards in space influenced how receivers were designed. Designs will vary, he added, depending on the purpose of the receiver. Dr. Parkinson asked if any of this should be recorded as a statement from the Board. Dr. Hermann said he did not see the intent of documenting this.

The point, Dr. Parkinson said, is to correct inaccurate information placed into the public record by *LightSquared* on receiver standards. There are two different issues. One is the assertion made by *LightSquared* that "there exists a standard for receiver design, but this standard was being commonly ignored by manufacturers." The second statement should be that no such U.S. standard existed.

Mr. Brenner noted that the group also had before it the proposal from Mr. Scott that some type of 'Underwriters' Laboratory' approach be adopted for vetting receiver standards. In terms of the assertion by *LightSquared* that manufacturers have been ignoring government design procedures; this is simply not the case. The pertinent document clearly states it is not a receiver design directive.

Dr. Parkinson said that if the Board has established that no design standard for receivers existed, then the Advisory Board is free to confirm that fact for the public record. He noted that the 'Underwriters' Laboratory' issue is a longer-term one. This drew the comment that the *LightSquared* task force would address the first-named issue. Mr. McGurn said the group would progress its thoughts on this issue for presentation at the next Advisory Board meeting. Mr. DalBello said he would be happy to work on the "non-ICD compliant issue" as a contributor in this effort.

Subcommittee 2: PNT Architecture Implementation

Dr. Robert Hermann said he and Gen Lord are concerned that the discussion does not appear connected to anyone who might actually be charged with implementing the results of the discussion. Rather, this appears to be mostly an analytic effort to describe certain ideas as important and to identify the existence of certain tasks. This process has involved the separate efforts of thirty-one agencies and departments that were in theory working together to compose a list of possible recommendations. The subcommittee believes it does not have enough knowledge on the subject to undertake a substantive review. Nonetheless, it seemed clear that the effort was taking place from "the bottom-up", and that any outcome depended on some statement being mutually agreeable to each of the thirty-one agencies involved. It is not clear this activity is connected to the EXCOM in any way that would encourage the EXCOM to commit to its outcomes, if any. The people who were engaged in the effort do not seem connected to people who had either resources or money to mandate its implementation beyond their own limited departmental sphere of influence.

Gen Lord commented he was aware of a parallel exercise proceeding at Space and Missile Command; a second analysis of alternatives being undertaken at DoD; and a third supplemental effort being carried forth by the FAA. These activities not only proceeded in parallel, but also along lines similar to the effort in which he and Dr. Parkinson are also engaged. It is difficult to comment on these efforts unless we know the relationships between all these various pieces. What bothers him the most is that all the decision makers are going to be thrown into day-to-day arguments

about how to get $500 billion removed from the defense budget without any useful outside guidance as to priorities and with every program a potential offset for every other. There is no group connected to an overall architecture and someone ought to stand up and assert some leadership.

Dr. Hermann asked if there was any reason why the Advisory Board could not publicly make such a statement.

Gen Lord said he does not know what range of dialogue the EXCOM would entertain.

Dr. Hermann said that the existing PNT architecture effort consisted of a group of distributed individuals who are not committed to adopting the outcome of their own discussions. This is no way to run a railroad; nor is it any way to develop a national PNT architecture. The EXCOM is perhaps a body of well-meaning and competent people, but it is not the government structure to actually make hard choices and to know what the trade-offs were.

Dr. Parkinson said the first rule of war is being violated; that is, there is no unity of command.

Dr. Hermann noted that when he was invited to serve the Advisory Board, he observed that this was a weakness – but signed up anyway. The EXCOM needs more teeth. It needs to be analytical in the broad sense, not just on technical questions -- but also on the national and international consequences of their actions. The EXCOM should say: "This is the architecture program we would support" and do so in way that has lasting influence.

Mr. Hall said what is being discussed is putting someone in charge. That might require a different venue. If the Advisory Board concludes that the current method of operating does not appear to respond to fast-rising issues, then another method may be required. The National Security Council is considering issuing a new policy at PNT, and would seek the Board's input at some time. What is being discussed was putting somebody in charge of the issue, and it is doubtful the post "Czar for GPS" will be created.

Dr. Parkinson suggested that Dr. Hermann write up his thoughts, and added the group might be "wasting its powder" on this issue.

Subcommittee 3: Commercial Effects of GPS Outages

Mr. Ron Hatch said this subcommittee included experts in aviation and agriculture, though not in financial and cyber security.

One of the most important issues regarding the effect of GPS outages is their duration – be they seconds, minutes, days or months:

- Short term outages might be, for instance, the consequence of a solar flare. Capt. Burns pointed out that the issue of outages due to solar flares is essential to aviation routes over the poles.

- If there is an outage lasting several days, the impact becomes significant. This could include, for example, a brief drop of the number of operational GPS satellites below 24. In this case, users would need to revert to their previous ways of operating.

- An outage of a few months would have a huge national and international impact. This could, potentially, be precipitated by a massive solar event that permanently disables multiple satellites. It is unfortunate that eLoran is not available as a back-up system.

A comment was made that George Mason University annually holds a seminar, "A Day Without Space," and good material might become available from that institution on this as an issue worthy of greater societal situational awareness.

Dr. Parkinson commented that most are all aware that things could get bad -- the more specific question should therefore be, is it possible to get credible financial estimates of the impacts?

Mr. Murphy said he has data on the costs of operating aviation in a degraded mode.

Dr. Parkinson asked whether there was some way of using available data plus anecdotes to address the questions of costs at the group's next meeting?

Dr. Hermann said that when one has a GPS outage, one needs to identify the problem. For example, if there is a total electrical outage one faces a variety of problems. If there is a cyber threat then there are many more possibilities as to its origin.

What is needed, Dr. Parkinson commented, is information on the probability of certain disruptive events and the cost of such events.

Mr. Hall said he believes DHS has a fairly robust process. It might be fruitful for the Board to review the list of sixteen vital infrastructures and provide comments on those that need to be included. His belief is that agriculture, banking and finance should be added.

Dr. Parkinson said the group needs to cast a wider net; perhaps the matter could be addressed in an interim meeting group before the next Advisory Board meeting.

Subcommittee 4: GPS and LightSquared

Dr. Parkinson announced that he was recusing himself from this discussion, and leaving the room to make that recusal clear. In addition, five Advisory Board members, Ann Ciganer, Tim Murphy, Ron Hatch, Joe Burns and Dean Brenner also left at this time. This was done, Mr. Miller commented, to ensure against any appearance of conflict-of -interest.

Gov. Geringer said he believed Advisory Board members are well informed on the issue. Among other things, he noted that Mr. Miller, in his capacity as Executive Director, had sent Board members near-daily press releases, newspaper articles, editorials and other material. Gov. Geringer stated that his subcommittee had expressed unanimous support for the August 13, 2011 letter from the Advisory Board, which restated the main points of the letter sent to the EXCOM in June 2011.

The current November meeting included an updated panel discussion on technical issues regarding GPS and *LightSquared* coexistence. In this discussion, LightSquared did not take use of the "upper 10" channel in the MSS band off the table, and it included only one proposed, proprietary solution which has not been independently validated. In holding this open panel discussion, the Advisory Board has gone above and beyond in attempting to be fair, balanced, and transparent to all parties in an open forum. He felt the lack of completeness in testing, viable solutions, and "who pays" needed to be noted.

Gov. Geringer stated that the Advisory Board does not feel it to be within its purview to find a solution for *LightSquared* that does not conflict with GPS. This is not an issue limited to *LightSquared.* Rather, it is the Board's task to ensure the service levels of GPS users are not harmed. The Advisory Board should therefore direct its future attention to any terrestrial or space-based jamming or spoofing activity.

Part of the issues that still require the group's engagement are the effort of several manufacturers that are working to find a technical solution. None had as yet been independently verified. Also, attention has yet to be paid to the new GNSS signals and military signals. The Advisory Board also has to work with its international members, whom are particularly concerned that this matter is being treated as a US-centric issue, and that it overlooks and understates the role the U.S. plays worldwide and the reliance the world puts on GPS.

Dr. Beutler's briefing pointed out how the interleaving of the various GNSS systems is of great importance. This was more pertinent by *LightSquared's* stated intention to expand its network. Further, as of November 2011, we don't know the end-state to for *LightSquared*. The corporation's Chairman has said he would not negotiate in public whether sale of the high band would be pursued. Gov. Geringer said it is his own belief that *LightSquared* plans to await the best possible commercial offer before proceeding. The lack of definition of the end-state trumps any conditional approval that the FCC granted. There is no transition plan; no one in a position to propose one; no one to say who would be affected, and no one to say who would pay. The Advisory Board's main guidance is the well articulated Air Force presentation from the previous day. The Air Force stated that its stewardship of the GPS system reflected the belief that the system was vital to international security, economic growth and public safety. He wished to reaffirm the "international" aspects of this statement.

Where do we go from here? There is a strong sense in the international community that the U.S. has allowed the matter to get too far. The U.S. needs to demonstrate respectability and reliability. The general international view is that the U.S. should simply have dismissed *LightSquared* issue as frivolous. The U.S. status in the world is diminished simply by allowing this to proceed. Gov. Geringer added that he believed some of these issues should be itemized for the EXCOM. There is strong support for the letter the Advisory Board had sent in June 2011. His own view is that the FCC needs some "backbone." He said he wished to be clear: the FCC may be feeling bold in achieving broadband, but that body should be aware that there were many other great ways in which that could achieved. GPS has national

security impact, an economic impact, and a safety-of-life impact that goes well beyond anything offered by the admirable goal of broadband. Gov. Geringer asked if any members of the work group had anything to add.

Mr. Hall noted that the arguments advanced the previous day had been technical ones. Whether *LightSquared* should go forward on technical grounds belies the fact that this is a national and international security and public safety issue. Given that GPS is inherently vital to public safety and national security; this is an area in which caution needs to be exercised. The argument advanced by *LightSquared* regarding a "performance standard" that, in fact, actually is not a "receiver standard" shows how even technical issues can become confused. Care needs to be taken in this political debate while bearing in mind the important national security and public safety concerns.

Mr. Russo noted that the assignment of tasks to the Advisory Board occurred prior to *LightSquared*. There is, therefore, no "*LightSquared* task". These are macro issues, in general. The EXCOM has responsibility for military, commercial and civilian users. The EXCOM could, therefore, address military issues. He did not, however, regard this as the most productive use of the EXCOM's time, as other groups are already charged with acting in this area. His "advice to the advisors" is that they supply additional detail as to what the impact might be on the commercial users.

Mr. DalBello said he believed the wrong question is being addressed. First, he said, the Advisory Board has stressed the importance of GPS. Then it suggested the simplest solution was to move *LightSquared* to a different frequency and the response was to do nothing. The group needs to go to the EXCOM to say that views have been put on the table and that a technical solution could perhaps be possible. It then needs to ask the following issues. Are these designs workable? What costs are entailed? What public benefits might be weighed against those costs? We need to raise these questions because the FCC is unlikely to be satisfied until we work our way down this list. There is little point in making additional statements as to the importance of GPS.

Gov. Geringer noted that the tasking from EXCOM, which includes discussing *LightSquared* interference, was dropped onto the Advisory Board's lap. The question is where do we go from here?

Dr. Hermann said he would be comfortable in reviewing whatever Gov. Geringer subsequently wrote. He also believed the question of how one works through this was pertinent. He was concerned that an EXCOM that represented the whole country may not be equipped to undertake this task in its current mode of operations. It seemed to him that the EXCOM was the body to task the matter out.

Gov. Geringer said that having taken "our shot" at assessing the mater as a technical issue, the Advisory Board has completed this task. The FCC had the power to grant or not grant certain things.

Dr. Hermann said he believed the Advisory Board had sufficient responsibility that it could give broad advice to the EXCOM as to the nature of the problem and what needed to be resolved.

Mr. Hall said that it was a key point to have the end-state specified so that complete testing could be undertaken.

Mr. DalBello said the FCC has effectively placed the *LightSquared* process on hold.

Dr. Hermann noted that if the President and/or the Secretary of Defense believed national security is an issue, they can override a decision of the FCC.

Gov. Geringer noted that there is no clarity as to how large a system *LightSquared* intended to build or what share of the possible bandwidth it might eventually use. Until the Advisory Board knows what the end-state is, it would be in no position to give advice.

Mr. Hall suggested that the Advisory Board adopt the approach of moving forward until it found the end state; then, it could begin to answer questions.

Mr. McGurn said one way to examine the matter is looking across the bandwidth. The answer is that the "upper 10" is "a non-starter." If someone comes up with a filter that could allow them to use that, there would still be time needed for the military and the aviation to find the budget for refitting. This could take several decades. On the "lower-10", *LightSquared* claims to have a solution. This still needs to be tested, and the same refit would still be needed even if the tests proved successful. There would be delays in any circumstance. It is a major problem for a corporation to engage in such a course when the financial return are still decades away.

Dr. Hermann moved that Gov. Geringer write-up the thoughts he had expressed.

Ms. Neilan stated her full support for what Gov. Geringer is drafting. She noted that during the breakout session it was clear that the international participants were "absolutely aghast" that a threat such as *LightSquared* was even being considered.

Mr. Rashad commented that the Advisory Board's recommendation of September 3 was based on the information that was available then. The new information provided at the current meeting indicated that there is, at best, only a partial solution to the *LightSquared* issue.

Closing:

In closing, Gov. Geringer commented that in the public health domain, the best approach is prevention. He hoped the group would act now and not wait for an emergency.

Mr. Miller suggested the possibility of holding the group's next session in the second or third week of May, 2012. The next EXCOM session is likely to be held sometime in Dec. 2011 or Jan. 2012.

The Thursday, November 10 session of the PNT Advisory Board adjourned at 12:20 p.m.

* * *

Appendix A: National PNT Advisory Board Membership

Special Government Employees:

- James R. Schlesinger (Chair), MITRE and Barclays Capital
- Bradford Parkinson (Vice Chair), Stanford University
- Dean Brenner, Qualcomm
- Joseph D. Burns, United Airlines
- Ann Ciganer, U.S. GPS Industry Council
- Richard DalBello, Intelsat General
- Per K. Enge, Stanford University
- Martin C. Faga, Former President & CEO, MITRE
- James E. Geringer, ESRI
- Keith R. Hall, Booz-Allen Hamilton
- Ronald R. Hatch, NavCom Technology, John Deere
- Robert J. Hermann, Global Technology Partners, LLC
- Rajiv Kholsa, Colorado State University
- Lance Lord, Commander, Air Force Space Command
- Peter Marquez, Orbital
- James P. McCarthy, U. S. Air Force Academy
- Terence J. McGurn, private consultant (retired CIA)
- Timothy A. Murphy, The Boeing Company
- Ruth Neilan, Jet Propulsion Laboratory
- Charles R. Trimble, Chairman, U.S. GPS Industry Council

International Representatives:

- Gerhard Beutler, International Association of Geodesy (Switzerland)
- Arve Dimmen, Norwegian Coastal Administration (Norway)
- Hiroshi Nishiguchi, Japan GPS Council (Japan)
- Rafaat M. Rashad, Arab Institute of Navigation (Egypt)

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Appendix B: Presentations

- U.S. International Diplomatic Initiatives and Opportunities on GNSS Issues – Ray E. Clore
- Alternative Positioning, Navigation & Timing (APNT) Study Update – Leo Eldridge
- Considerations for Constellation Sustainment – Kirk Lewis
- "Seeking a Solution to *LightSquared* Interference" – Kirk Lewis
- GPS Status and Modernization – Colonel Harold Martin

- GPS Civil/Commercial Receivers: Compliance & Certification – Jules NcNeff
- 'Patriot Watch' – Vigilance Safeguarding America – John Merrill
- GPS Time as Critical Infrastructure Application: Robust Time Dissemination & Chip Scale Atomic Clocks – Dr. Robert A. Nelson
- Activities and Current Policy Issues – Tony Russo
- Receiver Certification: Making the GNSS Environment Hostile to Jammers & Spoofers – Logan Scott
- National PNT Architecture Goals & Evolution – Karen VanDyke
- National Risk Estimate: Risks to United States Critical Infrastructure from Global Positioning Systems Disruptions – Brandon Wales

Presentations are posted at http://www.pnt.gov/advisory/

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Appendix C: Attendees

Wednesday, November 9, 2011

NASA participants:

- J. J Miller — NASA
- Barbara Adde — NA SA
- Alicia Anderson — NASA
- Josh Buck — NASA
- A. J. Oria — NASA/Overlook
- Calvin Ramos — NASA
- Victor Sparrow — NASA
- Kathleen Spear — NASA
- Robert Spence — NASA
- Stephanie Wan — NASA
- Thomas von Peak — NASA
- Larry Young — NASA Jet Propulsion Laboratory

Others:

- Ken Alexander — National Coordination Office
- Javad Ashajee — Javad GNSS
- Nedda Ashajee
- Nema Ashajee
- Mitra Ashajee
- Mark Bernstein — Meeting reporter
- Rachel Bernstein — Space News
- John Betz — Mitre Corporation
- Michael Bergman — Department of Homeland Security
- Frank Boulben — LightSquared
- Michelle Braca — LightSquared
- Miriam Braun — LightSquared
- Dwayne Brodie — LightSquared
- Scott Burgett — Garmin
- John Cabala — Federal Aviation Administration
- Michael Canice — LightSquared
- Richard Canning — LightSquared
- Dominck Cante — LightSquared
- Gilbert Carmichael — LightSquared
- Regina Cates — CSG
- Jay Chavhar — Freedom Technologies
- Marc Cheves — American Surveyor Magazine

• John Cheneyep	U. S. Air Force
• Ray Clore	U.S. Department of State
• Clark Cohen	Coherent Navigation
• Robert Crane	National Coordination Office
• John Croft	Flight International Magazine
• Tess Cruz	LightSquared
• Charlie Daniels	Overlook Systems
• Gemma Davey	LightSquared
• Dee Ann Davis	Inside GNSS
• Seb DeLiso	Department of Defense Joint Staff
• Stephen Dye	LightSquared
• Anita Eisenstadt	National Coordination Office
• Leo Eldredge	Federal Aviation Administration
• Richard Engelman	Sprint/Nextel
• Robert Erickson	SMC
• Wes Epton	Ernst & Young
• Dan Federick	LightSquared
• Robert Fuchs	LightSquared
• James Gigrich	
• Mark Golarzewski	LightSquared
• Kisti Grant	BNP Media
• David Hamilton	LightSquared
• Rick Hamilton	U.S. Coast Guard
• Tom Hammond	House Science Space Technology Committee
• Eric Harrington	LightSquared
• Byran Hartin	LightSquared
• Robert Hassin	National Coordination Office
• Chris Hegarty	MITRE Corporation
• Adeline Hinderer	European Union
• Cabral Hobson	LightSquared
• Brent Hughes	LightSquared
• Sai Kalyanaraman	Rockwell-Collins
• Behzad Kamgar	ONR
• Jamie Kax	LightSquared
• Sue Keith	LightSquared
• Jason Kim	Department of Commerce
• Paul Kirby	TR Daily
• Jim Kirkland	Trimble
• David Logsdon	SEC
• John Fischer	Orolia
• Ron Hatch	Deere Corporation
• Tom Hammond	House Science, Space and Technology Committee
• Richard Keegan	Deere Corporation
• Patrick Kerry	Javad GNSS
• Matt Kotman	Ernest & Young
• Penny Kozalos	LightSquared
• Nicholas Khun	Knighthead
• Dale Leibach	GPS Coalition
• Kirk Lewis	Institute for Defense Analysis
• Andrew Logan,	Government Executive
• Frank Lorga	Federal Aviation Administration
• Katie Lorish	CGA
• Curtis Lu	LightSquared
• Stephen Malys	NGA
• Harold Martin	United States Air Force
• Etman Mathewa	NCGA
• Marcus McKinley	LightSquared
• Melvin McNamara	LightSquared

• Jules McNeff	Overlook Systems
• John Meckley	LightSquared
• Chris Melus	LightSquared
• Harriet Meresie-Norton	LightSquared
• John Merrill	Department of Homeland Security
• Michele Millsaps	LightSquared
• Mahmoud Mizra	LightSquared
• Ed Morais	ITT
• Steve Moran	Raytheon
• Navio Mufti	LightSquared
• Brian Raymond	National Association Manufacturers
• Robert Nelson	SERC
• Chris Ogilvie	LightSquared
• Masoud Olfat	LightSquared
• David Olsen	Federal Aviation Administration
• Scott Pace	George Washington University
• Richard Park	OSD/Space & Intel
• Tom Powell	Aerospace
• Edward Powers	USNO
• Brian Ramsey	Mitre Corporation
• Milo Robinson	National Coordination Office
• Robert A. Rosenberg	EPS
• Tara Rudra	European Union
• Tony Russo	National Coordination Office
• Joseph Sapp	A3Z-50
• Andrew Scheffer	OCP
• Amy Schortz	NSJ
• Les Schroeppel	SAIC
• Logan Scott	LS Consulting
• Raj Sengupta	LightSquared
• Faezeh Shahbandeh	FCPS
• Todd Shields	Bloomberg News
• Ann Swanson	Dow Lohne
• Michael Shaw	Lockheed Martin
• Hank Skalski	U.S. Department of Transportation
• Larry Skorski	USG
• James Slater	self
• Lisa Snow	Department of Defense
• Jeff Snyder	LightSquared
• Tom Stansell	self
• Mark Strouse	J. P. Morgan
• Mark Stunza	3 C Systems
• Doug Taggart	Overlook Systems
• Shannon Tedit	LightSquared
• Gary Thomas	United States Coast Guard
• David Thompson	Air Force Space Command
• Jonathan Turner	LightSquared
• Vanesa Vacanti	LightSquared
• Nicholas Vanderberghe	LightSquared
• Karen Van Dyke	Department of Transportation
• Felix Wai	Credit Suisse
• Brandon Wales	Department of Homeland Security
• Gary Walker	
• Maureen Walker	U.S. Department of State
• Kenneth Ward	Federal Aviation Administration
• Tim Warren	Communications Daily
• Chris Weasler	
• Chari Wiggins	J Group

- Steve Wilson — Deere Corporation
- Y. Yamamoto — Translator for Mr. Nishiguchi
- Janet Young — Inmarsat

Thursday, November 10, 2011

NASA participants:

- James J. Miller — PNT Advisory Board executive secretary
- A. J. Oria — NASA/Overlook
- Stephanie Wan — NASA

Others:

- John Betz — Mitre Corporation
- Dean Brenner
- Charlie Daniels — Overlook Systems
- John Fischer — Orolia
- Harold Martin — U.S. Air Force
- Mitch Narins — Federal Aviation Administration
- David Olson — Federal Aviation Administration
- Richard Park — Department of Defense
- Milo Robinson — National Coordination Office
- Robert Rosenberg — GPS/IRT
- Logan Scott — LS Consulting
- Hank Skalski — Department of Transportation
- James Slater — self
- Tom Stansell
- Gary Thomas — United States Coast Guard
- Karen Van Dyke — Department of Defense
- Janet Young — Inmarsat

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Appendix D: Acronyms and Definitions

ADS-B	Automatic Dependent Surveillance-Broadcast
AEP	Architecture Evolution Plan
APNT	Alternative PNT
AoA	Analysis of Alternatives
APEC	Asia-Pacific Economic Cooperation
BIPM	International Bureau of Weights and Measures
C/No	carrier-to-noise ratio
CBO	Congressional Budget Office
CDMA	Code Division Multiple Access
cm	centimeter
COMPASS	Chinese Global Navigation Satellite System
DASS	Distress Alerting Satellite System
dB	decibel
dBW	decibels relative to one Watt
DHS	Department of Homeland Security
DME	Distance Measuring Equipment
DoD	Department of Defense
DOJ	Department of Justice
DOS	Department of State
DOT	Department of Transportation
EGNOS	European Geostationary Navigation Overlay Service
eLORAN	Enhanced LOng RAnge Navigation
EU	European Union

EXCOM	National Space-Based PNT Executive Committee
FAA	Federal Aviation Administration
FACA	Federal Advisory Committee Act
FCC	Federal Communications Commission
Galileo	European Union Global Navigation Satellite System
GBAS	Ground-based Augmentation System
GEO	Geosynchronous Orbit
GGOS	Global Geodetic Observing System
GLONASS	Russian Global Navigation Satellite System
GNSS	Global Navigation Satellite System/s
GSAC	Galileo Science Advisory Committee
GSOD	Galileo Science Opportunity Document
GPS	Global Positioning System
GPS III	GPS Block III
ICD	Interface Control Document (referred to as Interface Specifications, or 'IS', by the GPS Directorate)
ICG	International Committee on GNSS
ICWG	Interface Control Working Group
IERS	International Earth Rotation and reference system Service
IGS	International GNSS System
IIF	GPS Block IIF
IIIB, IIIC	GPS Increments 'B' and 'C'
IMO	International Maritime Organization
IRT	Independent Review Team
IS	Interface Specifications
ITU-R	International Telecommunication Union Radiocommunication Sector
JPL	NASA Jet Propulsion Laboratory
kW	kilowatt
L-Band	radio frequencies between 1 and 2 Gigahertz
L1C	GPS 4th Civilian Signal
L2C	GPS 2nd Civilian Signal
L5	GPS 3rd Civilian Signal
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
MHz	Megahertz
mm	millimeter
MSS	Mobile Satellite Service Networks
NASA	National Aeronautics and Space Administration
NRE	National Risk Estimate
NCO	National Coordination Office for Space-Based PNT
NexGen	Next Generation Air Transportation System
NPEF	National Space-Based PNT Systems Engineering Forum
NSPD-39	National Security Policy Directive #39
NUDET	Nuclear Detonation Detection and Reporting system
GAO	Government Accountability Office
GEO	Geosynchronous Equatorial Orbit
GNSS	Global Navigation Satellite System/s
GPS	Global Positioning System
OCS	GPS Ground Control Segment
OCX	GPS Modernized Ground Control Segment
PNT	Positioning, Navigation, and Timing
QZSS	Japan's Quasi-Zenith Satellite System
PDL	Pseudolite/s
PNT	Positioning, Navigation, and Timing
RAIM	Receiver Autonomous Integrity Monitoring
RNAV	Area Navigation
RNSS	Regional Navigation Satellite Systems
S/A	Selective Availability
SAR	Search and Rescue
SBAS	Satellite-Based Augmentation System
SLR	Satellite Laser Ranging
SPS	GPS Standard Positioning Service
TWG	Technical Working Group

UT1	Earth Rotation Time
UTC	Coordinated Universal Time
WAAS	Wide Area Augmentation System
WAM	Wide Area Multi-Lateration