SPACE-BASED POSITIONING NAVIGATION & TIMING

NATIONAL ADVISORY BOARD

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

Eighth Meeting

June 9-10, 2011

Sheraton Crystal City Hotel – Crystal V & VI
1800 Jefferson Davis Highway
Arlington, Virginia 22202

Meeting Minutes

James R. Schlesinger
Chair

James J. Miller
Executive Director

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Eighth Meeting Agenda
June 9-10, 2011

Sheraton Crystal City Hotel – Crystal V & VI
Metro Blue/Yellow Line to Crystal City
1800 Jefferson Davis Highway
Arlington, Virginia 22202

Thursday, June 9, 2011

9:00 – 9:10	**BOARD CONVENES** *Call to Order*	Mr. James Miller, *PNT Advisory Board Executive Director, NASA*
9:10 – 9:30	Introductions, Announcements, & Agenda *Goals for the 8th Meeting - What We Want to Accomplish*	Dr. James Schlesinger, *Chair* Dr. Bradford Parkinson, *Vice-Chair*
9:30 – 9:50	Update from PNT Executive Committee *Taskings & Expectations for PNT Advisory Board*	Mr. Tony Russo, *Director, National Coordination Office for Space-Based PNT*
9:50 – 10:15	GPS Constellation Update & Modernization Plans *Planning to Meet Current & Future Requirements*	Col. Harold "Stormy" Martin, *PNT Chief, Air Force Space Command*
10:15 – 10:30	U.S. National Space Policy Developments *White House Perspective on Future PNT Policy Activities*	Mr. Chirag Parikh, *Director, Space Policy, National Security Council*
10:30 – 10:45	**Welcoming Remarks from the NASA Administrator**	**Mr. Charles Bolden, *NASA Administrator***
10:45 – 11:00	**BREAK and Group Photo**	
11:00 – 11:25	National PNT Architecture Implementation Plan *Progress & Plans for Building Synergies*	Ms. Karen Van Dyke, *Acting Director, PNT, DOT - Research & Innovative Tech. Admin.*
11:25 – 11:50	U.S. Interference Detection & Mitigation Plan *Patriot Watch & Critical Infrastructure Protection*	Mr. Michael Bergman, *PNT Programs, Department of Homeland Security*
11:50 – 12:00	Announcements & Morning Discussion "Wrap-Up"	All PNT Advisory Board Members
12:00 – 1:00	**LUNCH**	
	Panel Discussion - LightSquared Compatibility with GPS	
1:00 – 1:20	Initial Results of National PNT Engineering Forum (NPEF) Testing & Analysis of *LightSquared* Effects on GPS	Mr. Deane Bunce, *NPEF Co-Chair, Federal Aviation Administration (FAA)*
1:20 – 1:40	Initial Results of RTCA Testing & Analysis of *LightSquared* Effects on GPS	Mr. Robert Frazier, *Spectrum Planning and International Office, FAA*
1:40 – 2:00	GPS Industry Perspective on *LightSquared* Plans	Mr. Jim Kirkland, *Vice President and General Counsel, Trimble Navigation*
2:00 – 2:20	*LightSquared* Plans, Strategies, & Next Steps to Provide Services that Co-Exist with GPS	Mr. Jeff Carlisle, *Exec. VP for Regulatory Affairs & Public Policy, LightSquared*
2:20 – 3:00	***Panel Discussion – All Speakers Open Mic for Q&A***	All PNT Advisory Board Members

(Day 1 Continued)

3:00 – 3:15	**BREAK**	
3:15 – 3:35	U.S. International Initiatives and Opportunities: *Latest Bilateral & Multilateral Developments*	Mr. Ray Clore, *Senior Advisor, Advanced Technologies, Department of State*
3:35 – 4:10	International Member Regional Updates • Dr. Gerhard Beutler • Dr. Hiroshi Nishiguchi • Dr. Rafaat Rashad • Mr. Arve Dimmen	(*at member's discretion*) *Switzerland* *Japan* *Egypt* *Norway*
4:10 – 4:30	Ny Alesund: Norway's High Arctic Contribution to the Advancement of Global Positioning, Navigation & Timing	Mr. Per Erik Opseth, *Director of the Geodetic Institute, Norwegian Mapping Authority*
4:30 – 4:50	GRASP: Spaceborne Co-location and Cross Calibration for Improved GNSS Interoperability	Dr. Yoaz Bar-Sever, *GPS Project Manager, Jet Propulsion Laboratory*
4:50 – 5:00	Afternoon "Wrap-Up" Discussion *What else should be examined on June 10?*	All PNT Advisory Board Members
5:00	**ADJOURNMENT**	

Friday, June 10, 2011

9:00 – 9:05	**BOARD CONVENES** *Call to Order*	Mr. James Miller, *PNT Advisory Board Executive Director, NASA*
9:05 – 9:15	Announcements & Agenda *Thoughts from June 9 discussions*	Dr. James Schlesinger, *Chair* Dr. Bradford Parkinson, *Vice-Chair*
9:15 - 10:15	Working Group/Panel Lead 20 Minute Plan Updates • *GPS Interference Detection & Mitigation* • *GPS Sustainment, Availability, & Affordability* • *GPS International Cooperation & Coordination*	 Dr. Parkinson (*or designee*) Dr. Hermann (*or designee*) Mr. Trimble (*or designee*)
10:15 – 10:30	**BREAK**	
10:30 – 12:00	PNT Advisory Board Member "Round Table" Discussion *Feedback, Strategy & Prioritization to Complete Taskings* **Non-ICD Compliant Civil/Commercial Receivers** Evaluate the implications of user non-compliance with GPS Interface Control Document (ICD) specifications and potential solutions. **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. **Advisory Board Technical Subcommittee** Establish an Advisory Board subcommittee capable of evaluation and timely feedback on emerging technical issues.	All PNT Advisory Board Members
12:00 – 1:00	**WORKING LUNCH**	
1:00	**ADJOURNMENT**	

Table of Contents

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Session of Thursday June 9, 2011

Opening Remarks

Mr. James Miller, Executive Director

Mr. James Miller convened the 8th meeting of the National Space-Based Positioning, Navigation & Timing (PNT) Advisory Board and noted that this was a public session, and that any comments made would be put on the public record with formal minutes posted online. All presentations would also be posted on the www.pnt.gov government website within seven days, and the official meeting minutes within ninety days.

The PNT Advisory Board emerged from the 2004 Presidential Policy on National Space-Based PNT, and the Advisory Board has been operating since 2007, fully sponsored by NASA on behalf of the PNT Executive Committee (EXCOM). The Board works closely with those government agencies engaged in managing and planning for the future operations of the Global Positioning System (GPS) constellation and its augmentations, and already supports Federal cost-savings efforts such as advocating for "dual-launch" of GPS satellites, while ending outdated and expensive constraints such as GPS Selective Availability (S/A) dithering.

Mr. Miller thanked Board members who provided their expertise to the Federal government entirely without compensation and on their own time. He then welcomed seven new members, each whom had been nominated by one of the PNT EXCOM departments, and appointed by NASA Administrator Charles Bolden. Mr. Miller noted that the group would receive a visit from Administrator Bolden later that morning.

Mr. Miller noted that the EXCOM had assigned specific taskings to the PNT Board for discussion, along with whatever other independent matters the Board wished to pursue. He noted that National Coordination Office (NCO) Director Mr. Anthony Russo would provide a more detailed presentation on expectations shortly, and that the intent was to have initial findings ready to present at the next EXCOM, tentatively scheduled circa November 2011.

Dr. James Schlesinger, Chairman

The Board has to date been a helpful influence on EXCOM issues under consideration and he wishes this to continue. The selection of new members reflects a conscious decision to expand the range of the Board's expertise to include precision agriculture, communications, transportation, and policy and information technologies, along with a new international representative from Egypt. In sum, the new members joining us are:

- Mr. Dean Brenner is Vice President, Government Affairs, for Qualcomm, the world's largest manufacturer of chips for cell phones, and the inventor of 3G and 4G technologies. With respect to GPS, he noted that Qualcomm had early on developed the technology that allowed identifying the location from which 911 cell phone calls are made.
- Mr. Richard DalBello is Vice President for Legal and Government Affairs of Intelsat, the world's largest operator of satellite services, and is currently deeply engaged with the United States government on satellite communications for troops in the Middle East. He noted that in the 1990s he worked at the Office of Science and Technology Policy (OSTP) when early important decisions on GPS were being made.
- Mr. James Geringer is Director of Policy and Public Sector Strategies of the Environmental Systems Research Institute in Cheyenne, Wyoming, which provides geographic information to 120 nations. He has a background in mechanical engineering; worked on the unmanned space program; was engaged in production agriculture and served two terms as governor of Wyoming.
- Mr. Ronald Hatch is Director of Navigation Systems Engineering and Principal and co-founder of NavCom Technology, Inc., a wholly owned subsidiary of John Deere. He noted that GPS was used for virtually everything on the farm; his own specialty was high accuracy of operations.
- Dr. Rajiv Khosla is the Colorado State University Monfort Professor and current president of the International Society of Precision Agriculture, with members in 44 countries. His organization aims to raise the productivity, profitability and sustainability of agricultural production.
- Mr. Peter Marquez is Vice President of Strategy and Planning for Orbital Sciences, which builds both launchers and satellites. Prior to joining Orbital, he worked as White House Director for Space Policy. He entered government service in 2002 at the Department of Defense, where he worked in the Office of the Under Secretary

of Defense for Policy, eventually rising to the position of Director of Special Programs, in which capacity he oversaw all DoD Special Access Programs.

- Dr. Refaat Rashad, representative of Egypt, has been President of the Arab Institute of Navigation since 2001; is a master mariner; has been a professor at the University of King Abdul Aziz, and head of the post graduate department in the Arab Academy of Science and Technology and Maritime Transport.

Dr. Schlesinger noted that Capt. Richard Smith had to resign from the Board for health reasons, however he expects new members to make important contributions just as original members always had. He reviewed the agenda, calling attention to the issue of expected radio frequency interference (RFI) to GPS from a company called *LightSquared* and their proposed new use of Mobile Satellite Service (MSS) spectrum for terrestrial broadband network operations. He noted that he and Dr. Parkinson had participated in the last EXCOM meeting in May 2011, where *LightSquared* had been a principal topic. General William Shelton, Commander, Air Force Space Command, was unable to attend that EXCOM meeting; however he did send Brig Gen Robert D. Rego in his place.

Brig Gen Rego noted that upon assuming command in January 2011, Gen Shelton established three "#1" priorities. The first, he said, was to support the joint fight; the second was to operationalize and normalize cyberspace capabilities; and the third was "get our arms around" acquisition aspects. One aspect of this is the feasibility of dual launch of navigation satellites. Finally, he said, the "elephant in the room" was *LightSquared*, where the Air Force was playing a key role in assessing possible impacts on the military.

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Space-Based PNT Update on Executive Committee Activities

Tony J. Russo, Director
National Coordination Office

In 1983 President Reagan – following the downing of a Korean airliner in Soviet airspace -- declared GPS would be available to international civilian users free of charge. In 2004 President Bush created the U.S. Policy on Space-Based PNT. Earlier management of GPS/PNT issues at the national level had not been optimal in the past because it had occurred only at the Assistant Secretary level; matters improved greatly when authority moved to the Deputy Secretary level with a formal EXCOM, with an independent Board, to coordinate activities and plans with the White House. Mr. Russo described the organizational structure of space-based PNT, adding as a personal goal the strengthening of communications between the Board and government decision makers.

Mr. Russo presented the latest on U.S. Space-Based Policy, stressing the need to provide uninterrupted availability of service in an increasingly demanding environment. Mr. Russo also presented President Obama's Space Policy of June 2010, which added language about the need to work with foreign systems to improve American capabilities and, also, to expand international activities to detect, mitigate and improve resiliency to interference. Mr. Russo noted the broad range of GPS applications – from precision agriculture to timing in banking – and said it was important not to optimize outcomes for one sector at the expense of another. Mr. Russo identified the topics of EXCOM focus: the number one issue is interference, intentional or not, to the GPS system. The Board, he said, would hear about $30 jammers built solely to jam GPS signals. In presenting EXCOM's taskings to the Board, he noted that each had been endorsed by all nine federal departments of EXCOM. These are:

- International cooperation; most recently, progress made in negotiations with the Chinese and coordination with the COMPASS system
- GPS Program Office Update; in particular, on the response to Government Accountability Office (GAO) concerns; GPS IIF status; GPS IIIA status
- Interagency Forum for Operational Requirements (IFOR) processes; this is a continuing consideration
- Broadband Impacts on GPS; Mr. Russo noted that the EXCOM meeting of November 5, 2010 had determined that no adverse impact on GPS should occur as broadband goals are sought
- Implications of President Obama's Space Policy to national and international activities

Mr. Russo said the previous EXCOM meeting had been largely devoted to the *LightSquared* issue. On January 1, 2011, the EXCOM became aware of its potential impact to operations relying on GPS. The May 2011 EXCOM meeting reviewed the interim results of the technical working group set up by FCC. He wished to thank *LightSquared* for accepting government participation in its review, a step which was not legally required. He believed the process to date has been cordial and collegial; further, he said, *LightSquared* had supplied the government with technical assistance. Three main next steps were identified: first, to formally engage the FCC Chairman and provide for a public comment period; second, to engage White House processes; and third, to continue data sharing and work on mitigation options with *LightSquared.*

Dr. Schlesinger, as a point of clarification for international representatives, noted that the FCC was a body of the U.S. Congress, and was therefore independent of the Executive Branch. In consequence, the EXCOM could not direct the FCC which, in turn, could not direct the EXCOM, though generally a good working relationship existed.

Mr. Russo presented the EXCOM's taskings for the Advisory Board:

- First, there is a problem with many commercial GPS receivers being only "partially" compliant with the GPS Interface Specifications (IS); that is, because these receivers were not built to meet formal military system specifications, they often require multiple software updates to process upgraded constellation messages.
- Second, PNT Architecture; the EXCOM seeks the Board's input on this.
- Third, GPS Outage Assessment: what consequences would follow for commercial users from GPS outages? How, for example, would a ten-hour GPS outage affect cell phones; the Internet; the financial community, etc? He believed only part of the problem was visible to those inside government; the Board was being looked to provide a broader perspective.
- Fourth, Role of PNT in Cyber Networks: he noted anecdotal information that GPS would be used to link machine-to-machine interfacing, but the EXCOM lacked deep understanding of this. A related question: how would GPS disruption affect cyber networks?
- Fifth – was a question as to what extent PNT Board members could serve as a technical resource team or subgroup where the EXCOM could secure immediate technical information when needed.

He noted that the EXCOM was anticipating the next meeting in November 2011, and hoped to hear from the Board prior to then on these taskings.

Discussion:

Dr. Schlesinger reported hearing that the penalty for possessing an illegal jamming device was confiscation of the jammer, which he thought was trivial.

Mr. Russo said, actually, fines of up to $11,000 could be issued. The problem was that prosecution could occur only when someone was apprehended illegally using a jammer; possession did not itself constitute a crime. Given this prosecutorial difficulty, seizing the jammer was often simpler. The need, he said, was a statute making mere possession a crime. Other countries had increased penalties – in Australia, fines of $100,000 could be invoked. He noted that the Federal Communications Commission (FCC) had gone after several Internet sites threatening $11,000 fines. This had worked short-term; most reentered business weeks later under a different web address. Still, he thought it important that the FCC was prepared to address the issue. He believed public education was needed about the hazards of jamming: for example, an employee using a company car might acquire a jamming device so his employer could not track his whereabouts. Such persons were generally unaware they were doing anything wrong or illegal or were disrupting communications for others.

Gov. Geringer asked the jammer range. Mr. Russo said many were only effective for 50 to 100 feet.

Dr. Parkinson noted that at the level of one Watt, the disruption occurred over line of sight from the jammer.

Mr. Brenner noted that cellular systems had similar problems with people interfering with cell phone calls; to an extent, he added, the FCC had gone after the producers. The users may not know the systems are illegal, but the manufacturers do.

Mr. Russo said he believed acting against producers was the correct step: as a consequence of the recommendations of this Board and others, two manufacturers have been prosecuted. However, most manufacturers were overseas; he also noted efforts with customs officials to impound them on arrival.

Gen. McCarthy asked how practical it was to find interference.

Mr. Russo said that when a low-power jammer was employed, it was very difficult to locate: one incident involving an individual with a $30 jammer took several months and perhaps $100,000 to resolve. At present, he said, the reality was that only fairly limited steps that could be taken in regards to jammers of less than 1.0 milliwatt. In technical terms, he said, it was fairly easy to locate jammers of one Watts or over; the limit was one of resources to locate, track down and prosecute.

Mr. McGurn said the television show, "60 Minutes," had presented a segment on high frequency stock market trading -- transactions took place mini-seconds apart. He regarded as "scary" the havoc that would occur if something happened to the timing delay. There was a further problem with noncompliant receivers: when a receiver failed, how did it behave? That is, did it give a constant reading? Did it assume a continuing constant speed?

Mr. Russo said the EXCOM had considered the matter and believed the risks were substantial. He added the Department of Homeland Security (DHS) had undertaken a study of who was impacted by GPS downtime. The EXCOM had initiated a comprehensive risk assessment that included people from the banking community. A report was expected later this year.

Gov. Geringer asked if the Board's tasking included looking inside cyber networks. Mr. Russo responded that it did.

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GPS Constellation Update & Modernization Plans: Planning to Meet Current & Future Requirements

Col Harold "Stormy" Martin, PNT Chief
Air Force Space Command

Col Harold Martin said he would present a status report on the GPS constellation; discuss recent events, and present plans for modernization. Col Martin described GPS as a critical asset -- vital to international security; economic growth, and public safety. The intention was to maintain the system as available, reliable, accurate and free of charge. He described the constellation as very robust, noting that the global GPS civil service performance commitment has been continuously met since December 1993. He noted the first of a new block of satellites, the IIF, was launched in May 2010 and the next launch set for July 2, 2011. He noted that existing residual satellites could be brought into service if needed. Col Martin reported continued improvement in system accuracy; present accuracy was 0.8 meters, which exceeded the performance standard. Col Martin noted, on system modernization: GPS was now in the II-F era, which he characterized as adding IIR-M capability, the third civil signal (L5), and a longer twelve-year satellite design life. He noted most existing satellites greatly exceeded their 7.5 year design life.

Dr. Parkinson asked when should we expect full capabilities for L2C?

Col Martin responded that nine satellites currently had this capability; however, the current GPS command and control system lacks the capability to put the civil navigation message on the L2C signal That capability has been moved to the GPS Modernized Ground Control System (OCX), due to come into operation in 2015.

Dr. Parkinson said he believed Launch, Anomaly, and Disposal Operations (LADO) had demonstrated the capacity to accelerate this process; could this be used?

Col Martin said LADO was primarily used to correct launch errors. The system purchased by the Air Force lacked the capability to control those signals; the contracts in force did not allow for this capability, but alternatives were under consideration. He observed that it was a difficult time to secure funds for GPS improvements.

At this point, Dr. Schlesinger halted Col Martin's presentation to introduce the NASA Administrator Charles Bolden.

> NASA Administrator Bolden thanked those present for their contributions to advancing the nation's capabilities in positioning, navigation and timing. PNT, he said, was very important to NASA as it sought to explore other worlds and to understand our own world better. Improvements in navigation – the Chinese invention of the compass; the European invention of the sextant – has greatly extended the range of trade and contributed to economic growth. NASA was both a contributor and a benefactor of PNT technology. He noted his own personal education in GPS came when he navigated "our tangle of highways." Most people are unaware of the role GPS played in Automated Teller Machines (ATMs) and cell phones; in satellites that assist in weather predictions; in allowing the Space Shuttle to map the surface of Earth in eleven days; and in permitting accurate measurement of the deformation of the recent earthquake in Japan. PNT technologies need to advance at a rate that will match our needs for security and for improved knowledge. It is a great compliment to GPS that other nations were developing similar systems, and he urged coordination with those systems. Not many years ago airplanes might fly into mountains of which their pilots were unaware; now, anyone on earth can know their position within a few meters. GPS would be playing a key role in the Next Generation Air Traffic Control system (NextGen), the forthcoming aviation navigation system. For this and other reasons, NASA is proud to support the activities of the PNT Advisory Board.
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> Gen McCarthy made reference to the previous evening's visit to the Goddard geodetic facility. He was deeply impressed, he said, by the high scientific competence of the NASA employees; whatever fiscal challenges may occur he hoped this level of technical expertise could be maintained.
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> Administrator Bolden said it had been a failing to allow the nation's civil servants to be cast as incompetent and uncaring: he was pleased Board members had seen the quality of those engaged in NASA. Similar standards were maintained at all NASA facilities. He was concerned that, given budget restrictions,

government might "take a break" from investing in high quality technical expertise, on the faulty assumption that such individuals would be readily available five or ten year hence.

Mr. Faga noted that when cutbacks had been required at the MITRE Corporation, the effort was made to determine which capabilities were vital to operations and which could be maintained elsewhere.

Administrator Bolden said NASA was reviewing infrastructure, but doing so with the view that infrastructure was not simply physical structures, but the key capabilities the agency required. As downsizing occurred, the question of what was uniquely valuable must be kept uppermost.

Administrator Bolden described NextGen as a critical undertaking: it will allow aircraft to communicate with each other in real-time without increasing pilot activity, which will allow more efficient operations. This will in turn save fuel and decrease airport delays. GPS is a critical component of Neaten. Capt. Burns said commercial airlines had a vested interest in NextGen; there was concern about the weakness of the GPS signal and interference with that signal. He questioned whether airlines would invest without having certainty the system would function. Administrator Bolden noted that United, Southwest and other U.S. carriers had worked on such matters as constant climb following take-off and constant descent. The fuel savings were on the order of $5 billion. If, he said, his organization received one-tenth that amount, it would equal NASA's $500 million aeronautics budget. He appreciated the willingness of the commercial carriers to work with NASA.

Dr. Schlesinger asked about relations with Congress. He thought it probable that Congress was largely unaware of the importance of GPS to various civilian agencies; in consequence, it "handed the bill to the Air Force."

Administrator Bolden acknowledged that his administration had a "rocky first two years" on Capitol Hill, due to lack of effective communication. Today, he said, "we talk to them as much as we can." He noted that NASA had an increasing number of champions on the Hill.

(At this point, the meeting recessed to allow Board members to be photographed with Administrator Bolden. Following his break, Col Martin resumed his presentation.)

Col Martin presented the Architecture Evolution Plan (AEP), established in 2007 when a modern distributed information system replaced mainframes. This had increased capacity for monitoring GPS signals and increased worldwide command capability. Since the system was established, he noted, great benefits have been and continue to be added for the warfighter. He then described the OCX, which would control a more capable GPS constellation and monitor all GPS signals. A $1.5B contract was awarded in February 2010 and the Preliminary Design Review (PDR) set for June 2011. Col Martin described the modernized GPS civilian signals L2C and L5, and the future L1C civil signal for GPS III. With the L5 in place, 20 GPS satellites will have more robust safety-of-life capabilities by 2018. If, as has been largely the case thus far, satellites exceeded their design lifetime, the result will be a very large constellation.

Col Martin then discussed *GPS Expandable 24* (*E24*), a new capability for worldwide users that optimizes GPS assets to improve operational effectiveness for global users and terrain challenged environments. It increases the number of satellites overhead for better availability and coverage and would, in particular, aid the warrior operating in the canyon environment of Afghanistan. In closing, Col Martin said GPS accuracy was the best ever and best in the world. The commitment remained to keep GPS the "gold standard" of GNSS worldwide.

Dr. Schlesinger queried whether improvement had occurred in coordination of satellite control segments.

Col Martin said it had been: he noted the first GPS III launch was set for 2014; NextGen was slated for 2015. A system coming on-line in 2013 would assure the ability to control the satellite; the control issue, he added, was one in which the Air Force has been actively engaged.

Mr. Geringer asked Col Martin to characterize Air Force commitment to meeting those targets.

Col Martin said it was "keenly in the eye" of Space Command that undertakings not backslide.

Gen McCarthy asked about budget status.

Col Martin said that the *E24* was "bought and paid for." Some financial advantage had accrued from individual satellites exceeding their design life. He added that "for the most part," GPS-III was bought and paid for.

Gov. Geringer said GLONASS, the Russian Global Navigation Satellite System, was becoming a more accurate system; this international coordination was pleasing. Did *E24* affect such coordination?

Gen McCarthy said *E24* was independent of international partners.

Mr. Russo commented that while Space Policy now permits the U.S. to meet requirements using other nation's satellites, such systems had to demonstrate they could meet GPS accuracy performance requirements. The vision for the future was that some requirements would be met by GPS and a combination of "some other systems."

Dr. Parkinson said the Board strongly championed interoperability and interchangeability; other systems, however, were "a very long way from being certified." He believed GLONASS was some years away from achieving an accuracy that would add user value.

Dr. Schlesinger commented that, historically, GLONASS had not demonstrated consistency.

Ms. Neilan noted the Board has twice recommended retro-reflectors be added to the GPS satellites; what was Col Martin's view on the matter? Col Martin noted that non-military GPS requirements had to secure funding; it now appeared retro-reflector funding would be forthcoming for the GPS III-B and III-C.

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White House Perspective on Future PNT Policy Developments

Chirag Parikh, Director, Space Policy
National Security Council

Mr. Chirag Parikh said he would focus on Presidential PNT policy. One function of the National Security Council was to ensure that Presidential space policy was followed. With the exception of the manned space flight program, GPS was the most visible national achievement in space. His office was reviewing three sector specific aspects of polices enunciated by the Bush administration: space transportation; commercial and remote sensing, and space-based PNT. The review of space-based PNT would come in the November-December time frame, giving the EXCOM and Board appropriate time to identify policy issues that need addressing. It had been seven years since the Bush policy was issued; it was time for an update.

Mr. Parikh assured the Board that *LightSquared* was a highly important issue; developments in that area were being followed. Communication with PNT and others had been constant; response from industry had been considerable; Congressional discussion was being tracked. Mr. Parikh noted that in May 2011, he and colleagues from the Office of Management and Budget (OMB) and OSTP hosted a meeting that drew very high attendance. The session was beneficial for both the White House staffers and to the speakers, who were able to exchange various views on the topic. The EXCOM meeting immediately thereafter focused on *LightSquared.* At that meeting, the Deputy Secretary for Defense requested that a formal interagency process led by the White House be established on this issue. The pertinent FCC waiver stated no commercial use was to be made of *LightSquared* until testing was complete. He anticipates initial results from the technical working group within ten days, and hopes the FCC will provide sufficient time for due diligence to be undertaken on this report.

Mr. Parikh noted that efforts were underway for ideas, mitigation systems, etc., so that GPS benefits could be maintained without losing anything in Broadband or 4G. It is time to move from expressing concerns to finding answers; some answers will be more painful than others.

Mr. McGurn asked what had happened to *eLoran*.

Mr. Parikh responded "we know that it went away." He deferred the "why" question to Mr. Russo.

Mr. Russo noted that while EXCOM had endorsed *eLoran*, it had no funds to pay for it. This required seeking funds from individual departments, which commonly responded that their own backup needs were accounted for. The problem was the failure to lay the groundwork and present the evidence that *eLoran* was needed not as a department preference but as national infrastructure supported by policy.

Dr. Parkinson said *eLoran* was "clearly a very viable back-up system." Furthermore, its existence would discourage sabotage: as *eLoran* could not be easily jammed, it lowered the value of jamming GPS.

Dr. Schlesinger said that particular attention should be paid to OMB's role, as they were "the perpetrator."

Dr. Per Enge asked if a 'Plan B' existed for *LightSquared* if the whole idea proved to be bad.

Mr. Parikh said the question was: what are the alternatives? As yet, he said, a sufficient grasp of the technical issues did not exist.

Dr. Schlesinger said it was not simply a technical issue; he suggested that Congress, which had considerable authority over the FCC, might be "induced" to help on this issue.

Mr. Hatch said John Deere had announced it could not operate with *LightSquared* adjacent to the GPS band. The augmentation systems being used operated across the entire band; they did so because assurances had been given the entire band was available. With *LightSquared*, 100,000 GPS receivers would be put out of service. Tests run on the lower portion of the band, he reported, still caused a full lock on the system.

Mr. Parikh said the economic value cited by Mr. Hatch for GPS was paralleled by the economic value OMB cited for broadband. He noted that the technical studies were beginning to come in.

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National PNT Architecture Implementation Plan: Progress & Plans for Building Synergies

Karen Van Dyke, Acting Director, PNT
DOT – Research & Innovative Technical Administration

Ms. Van Dyke noted that Board comment was being sought on implementation of the PNT architecture. A 2025 time frame had been chosen for identifying issues facing GPS as it allowed sufficient time to address issues. GPS does not work "everywhere, all the time." There are challenges such as environments that were physically or electromagnetically impeded; high accuracy with integrity; timely notification of misleading information; accurate geospatial information, and PNT modeling and simulation capabilities. *LightSquared* had not been part of the architecture effort.

In constrained environments -- underground; urban canyons, etc. – satellites are not visible down to the ground. This often conflicted with the expectations of users, who expected their GPS systems to operate in underground garages.

Electromagnetically-impeded environments – intentional or not -- had been an issue for DOT for at least a decade. Small jammers were a big issue; they were increasingly common. Effects could also be traced to increased solar activity or to malicious or terrorist-inspired jamming. Malicious jamming could be very difficult to locate and stop; e.g., jammers could be attached to transit buses, and then turned on and off.

High accuracy is needed for proper function and safety; higher accuracy would allow for higher rail and road capacity and improved safety. Drivers required 10 cm accuracy; railroads required 1 m accuracy. The development of greater accuracy carries a parallel need for greater integrity. Accuracy was crucial to precision agriculture; otherwise, an unmanned vehicle could be driven meters off course.

Regarding safety-of-life applications, timely notification was crucial if PNT information was degraded. This was also a continuing issue for aviation, which requires very rapid notification of misleading information.

In geospatial information problems are, generally, database errors rather than GPS errors. One concern is that some truckers used "off the shelf" GPS systems that did not list truck routes or report current highway construction.

Improvements are needed in modeling and simulation used to demonstrate GPS-related capacities. Unless reliability can be demonstrated to the end user, acquisition is unlikely. Further, if incorporating the use of an atomic clock, the importance and difficulty of modeling and simulation increases.

The PNT architecture is the product of 30 government agencies, led by the departments of Transportation and Defense. The effort was intended both to identify and resolve problems and to find ways in which system effectiveness could be increased; the latter followed in part from the tight fiscal situation.

Ms. Van Dyke then presented the National PNT Architecture 'Recommendation Tree'. She believes the rest of the world is looking to the United States for solutions. The architecture was a framework for evaluating potential solutions; the "greater common denominator" approach would be used to create solutions that met the broadest range of user needs. This would be approached collectively, rather than by having each department address its own concerns.

Noting that GPS was the cornerstone of the national PNT system, Ms. Van Dyke asked: If we are seeking 10 cm accuracy, what do we do when GPS is disrupted? She discussed the desire to develop interchangeable solutions, which she said had been urged

by Dr. Parkinson. She noted potential involvement of foreign GNSS systems and, also, that GPS may be a victim of its own success: it was difficult to sell people on a backup system when GPS worked so well. The question was: how did the community work collectively to address this challenge?

After recommendations had been identified, an implementation plan was established listing the near-term tasks; this plan had been signed off on by the DOT and DoD last year and released to all departments and agencies. As a general statement, Ms. Van Dyke read a quotation from the most recent issue of the *Institute of Navigation Newsletter*:

> *"I am of the opinion that we do understand the problem and we know where the answers lie. Unfortunately, it appears we are unwilling to bear the cost of confronting these issues head-on. Instead, we seem to paper over the risks, and to continue to presume upon the benevolence of Mother Nature and the forbearance of our adversaries."*

PNT is "at a pivotal point." Credit is now being taken for things that were decided in the past; while there was a road map for the future, it was very difficult to get funding for anything new. Ms. Van Dyke closed by stating the Board's tasking relative to architecture development: the Board is asked to undertake an assessment of what could be done to ensure successful implementation; to identify organization, functional or technical issues that might impede implementation; to suggest how the likelihood or impact of such impediments might be reduced.

Mr. Geringer made reference to a slide that identified inaccuracies stemming from stale data. He believed information systems required a thorough review. To date, he said, the emphasis had been on signal accuracy; however, accuracy was compromised if the information system receiving the signal was faulty. Hardware and software structures appeared to be separated: he saw great potential in increased accuracy, but that potential would be realized only if data was properly assessed.

Dr. Parkinson said the military had been looking at effects-based results; this, he added, was only for the military. He was aware of no federal undertaking to improve results on the civilian side. He believed Gov. Geringer's point was well taken.

Ms. Van Dyke agreed this was a challenge; in effect, she said, commercial users decided this for themselves. A much closer relationship could be developed on what the user needed.

Mr. P. Marquez asked how the 'National' PNT Architecture effort was initiated.

Ms. Van Dyke deferred to audience member Mr. Jules McNeff, DoD OSD contractor.

Mr. McNeff said the architecture had grown out of a Defense Science Board (DSB) task force on the future of GPS conducted in 2004. Dr. Schlesinger had co-chaired that effort. One recommendation had been that an overall architecture be created to look beyond GPS to national PNT. That recommendation was carried over to fall 2005, when it was briefed to Mr. Gordon England, then Deputy Secretary of Defense. It was coincident with the first meeting of the EXCOM, held in 2006. EXCOM broached the idea that the architecture should extend beyond DoD on a multiagency basis. In early 2006, DoD and DOT had signed off on a Terms of Reference. These terms led to the original architecture efforts that developed the 19 recommendations that flowed into the implementation plan.

Mr. Marquez said it appeared the Board's tasking was to "hold people's feet to the fire."

Ms. Van Dyke said, in effect, this was true. She urged the Board to weigh in on actions it thought cost effective or otherwise beneficial.

Mr. McGurn noted that even if the White House told a Secretary to do something, it did not necessarily get done. He noted that some issues straddled two or more departments; how was the Board to force them to work together.

Ms. Van Dyke said this point was well taken. She noted that it was easy for a given agency to step back from a problem in hopes that someone else would tackle it. The question was: who is prepared to "raise their hand" and take responsibility.

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Initial Results of National PNT Engineering Forum: Testing and Analysis of LightSquared Effects on GPS

Deane Bunce, Co-chair
National PNT Systems Engineering Forum (NPEF)

Mr. Deane Bunce said he serves as co-chair of the National PNT Engineering Forum (NPEF) and would report on work completed by May 31, 2011; a redacted version was pending. The study is a collaborative effort of the DoD, GPS Directorate, Air Force Space Command and various civilian agencies and administrations. The NPEF's charge was "to perform an assessment of *LightSquared* Terrestrial Broadband System Effects on GPS Receivers & GPS-dependent Applications." This assessment, based on the anticipated *LightSquared* deployment, was to be coordinated with other entities, including *LightSquared*, to assess potential mitigations for GPS users. Mr. Bunce presented the GPS bandwidth "before" and "after" the introduction of *LightSquared.* This bandwidth had previously provided no interference issues for GPS; *LightSquared* would greatly change that. A solid test approach was needed. Working primarily with testing experts at DoD, the effort had closely replicated the actual equipment to be used. He identified three test methods: laboratory conducted emissions; anechoic chamber; and live sky with a single Air Traffic Control (ATC) station. The first, he said, provided the most solid and controlled data that was developed. It emulated *LightSquared* signals using shaped noise for 5 MHz and 10 MHz bandwidths, each centered on "high band" and "low band" levels. Due to time constraints the NPEF had tested only a subset of aviation receivers. Each test combined a given power level and a given stand-off distance from the receiver to determine the impact of a single ATC station. Results varied widely as aircraft manufacturers do not produce identical filtering:

- All receivers adversely affected by Phase 0, 1, 2 signals to varying degrees (> 30 dB range in Phase 0 power for 1-dB C/No degradation)
- 5 and 10 MHz Low signals caused minimal effects on the limited set of receivers that were tested
- Conducted 1 dB C/No degradation and loss of tracking tests for seven receivers related to FAA infrastructure and aviation
- Space-Based Augmentation System (SBAS) word error rate tests were conducted for two aviation receivers

Dr. Parkinson asked what maximum *'LightSquared'* tower power level had been used. Mr. Bunce said levels up to the 15 kW maximum allowable had been tested. Mr. Bunce said NPEF also undertook error rate testing and accuracy degradation. The error rate testing showed that basically all receivers failed at a 1dB level.

Mr. Bunce reported chamber and live sky testing conducted in New Mexico in April. Invitations had gone out to anyone who wished to bring a receiver to the test site. He offered several caveats: not all GPS receivers were tested; the testing was done on a single ACT, not an aggregated group. The 32 chamber tests produced nearly identical results -- a loss of GPS solution. No device could get through "stepped up" power without losing GPS service.

Mr. Bunce presented results from live sky testing: police cruisers lost reception whenever they were within 600 feet of the *LightSquared* tower; police headquarters lost the capability to track cruisers. Ambulances lost reception at 1,000 feet from the tower; further, ambulances reported they were moving when they were actually stationery. Finally, the General Motors *On-Star* GPS-based service was lost on most vehicles.

Mr. Bunce presented information on satellite tracking loss traceable to a single *LightSquared* ATC. He presented data on the anticipated density of *LightSquared* towers in dense urban, suburban, and rural environments. Based on this, he modeled the aggregate effect on aircraft reception. Mr. Bunce presented mapping of four areas nationally where aircraft would be affected by *LightSquared* transmissions; the map showed areas of 1 dB degradation.

Dr. Parkinson noted the 40,000 towers might be built: what percentage of this did the four sites represent?

Mr. Bunce said six percent. He then reported that simulations of an aircraft at 500 feet in the Washington, D.C. area showed no positioning output was being received by the aircraft. This finding had been based on two different receivers; virtually the entire Washington D.C. area was affected.

Of possible mitigations, the simplest is to relocate *LightSquared* to a different frequency band. Second GPS receivers could be equipped with "accept/reject" filters relative to *LightSquared* transmissions. This would be costly and time consuming – seven years or longer would be required to produce, build, certify and install redesigned receivers; further, the filters would reduce performance. Third, *LightSquared* antenna patterns and exclusion zones could be modified; this would require additional base stations that would add to aggregate interference. Fourth, *LightSquared* implementation could be limited to the lower end of MSS L-band; although this may compromise its ability to operate nationally. Fifth, the transmitting power of *LightSquared* base stations could be reduced; however this would require more base stations to meet the same coverage plans.

The key NPEF finding is that all GPS receivers would be impacted by the *LightSquared* network. Simulated deployment of the anticipated 40,000 base stations suggested loss of GPS function at stand-off distances ranging from several kilometers to outer space. Other findings include:

- Out-of-band emissions due to close proximity appeared to be satisfactory;
- No universal mitigation approach has been identified;
- NPEF recommended that the FCC waiver of January 26, 2011 allowing terrestrial-only ATC operation be rescinded;
- The Federal government should conduct further tests on the system's operational, economic and safety aspects.

Based on test results, the FCC should revisit and readdress the effects of the 2003-2010 ATC authorizations within the MSS L-Band. He closed by outlining additional testing he believes is necessary.

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Initial Results of RTCA Testing & Analysis of *LightSquared* Effects on GPS

Mr. Robert Frazier
Spectrum Planning and International Office
Federal Aviation Authority

Mr. Robert Frazier explained that RTCA Inc. (RTCA) is a private, non-profit organization that developed consensus-based recommendations in surveillance, communications, navigation and air traffic management issues. RTCA functions as a federal advisory committee whose recommendations were used by the FAA as a basis for policy, program and regulatory decisions. Mr. Frazier also said he was an FAA employee; however, he was giving this report as co-chair of the RTCA study group. The general tasking was to determine how aviation receivers would perform in various scenarios. This particular study used a source path receiver model previously employed by RTCA to evaluate interference. GPS receiver model parameters and scenarios details were then aggregated with the projected number of *LightSquared* base stations. *LightSquared* has been very helpful and cooperative throughout the process.

The study request arrived March 17, 2011 and the report delivered on June 5, 2011. The analytic process utilized is the classic source-path-receiver method: Radio Frequency Interference (RFI) source parameters; the propagation path parameters – including distance, direction, altitude and free-space or other. The receiver parameters were those used in previous RTCA technical reports on GPS interference. Mr. Frazier then listed four analysis scenarios: low altitude flight; final approach; airport surface (taxiing); and high altitude (5.49 km) flight. In all scenarios but final approach, the GPS receiver was required to track and acquire; that is, make a "cold start" acquisition. Mr. Frazier provided the vertical antenna pattern used in the model – this is important because at times the aircraft was above the ATC tower and at other times it was below.

Mr. Frazier then presented a generic metropolitan deployment plan for ATC base stations; the metro zone tower spacing of 2.2 kilometers became more dispersed as one moved from the urban core. He noted that no towers could be placed in the immediate vicinity of an airport itself. Dr. Parkinson said the previous speaker suggested a peak density of one tower per 400-800 meters. This discrepancy was explained by the fact that 2.2 kilometers was the urban zone; while 400-800 meters was the "dense urban zone." Mr. Frazier then laid this generic deployment ATC tower plan over six metropolitan areas: Boston, New York, Philadelphia, Washington D.C., Richmond and Pittsburgh. Responding to a question, he said this was a density mapping, not an interference mapping. The aircraft GPS receiver antenna elevation patterns are the same as those used by RTCA for fifteen years, and which were accepted by the aviation community. He also defined the GPS Receiver Minimum Operational Performance Standards (MOPS) RFI Susceptibility, a curve used to determine if interference had occurred.

Mr. Frazier then detailed the results. If *LightSquared* operated at 1552.7 MHz, the resulting interference exceeded the GPS threshold by a large amount in all cases. He reported that the effects of unwanted emission were very low; such "third order effects" needed to be included, he said, because they can become significant in the aggregate. Mr. Frazier then discussed aggregate RFI results. If *LightSquared* operated at a 1552.7 MHz mean aggregate RFI, this exceeded the MOPS limit by 42.7 to 55.8 dB – an "enormous amount." He noted that MOPS was a minimum receiver requirement; while many receivers exceeded it, none were required to. This circumstance, he said, could be expected to lead to a complete loss of GPS service. Even at the rural density, aggregate RFI exceeded MOPS by 24 dB. The study had lacked the time to determine "worst case" altitudes, which may be worse that the 5.5 km used in the study.

As a possible mitigation, base stations operating below -30 dBW at a frequency of 1555 MHz should in principle not present problems to GPS systems. At Dr. Parkinson's request, Mr. Frazier said the -30 dBW equaled about one milliwatt power. As ATC frequency decreases, power could be increased without affecting GPS performance.

Mr. Hatch expressed a concern: for GPS, it was the "top" of the power, not the minimum, which was of interest. It appears the propagation model is optimized for "getting the data across" rather than for "what causes interference for GPS."

Mr. Frazier said what RTCA had done was to use a model commonly used by the cell phone industry – "for communications,"

Mr. Hatch interjected – for propagation.

Mr. Frazier said he understood Mr. Hatch was suggesting that interference levels could be higher.

Mr. Hatch agreed and Mr. Frazier affirmed the statement.

Mr. Frazier presented the RTCA study conclusions:

- A single-city base station deployment would render GPS-based operations below 2,000 feet unavailable.
- The high altitude U.S. East Coast scenario suggested that GPS-based operations will be unavailable over a whole region any normal aircraft day.
- Base station operation was compatible with aviation GPS operations only if it was at the lower 5 MHz channel at the lower band end.
- Base station operation at lower 10 MHz channel was compatible with GPS signal tracking but not signal acquisition.

Dr. Parkinson asked whether all points within the geographic model had been run; Mr. Frazier said no study of impact at high altitude had been made; he added that a safety margin was applied to the 5 and 10 MHz calculations.

Mr. Frazier presented RTCA recommendations:

- From an aviation standpoint, LightSquared upper channel operation should not be allowed.
- Further study was recommended to determine more carefully a refined terrestrial base station power v. frequency limit.

The full report is available at: www.rtca.org/onlinecart/all +products.cfm.

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GPS Industry Perspective on *LightSquared* Plans

Jim Kirkland, Vice President & General Counsel
Trimble Navigation

Trimble Navigation is a founding member of the coalition to *Save Our GPS*, which includes representatives from construction, energy, agriculture, transportation and other sectors. Mr. Trimble said he believes the preceding presentations show overwhelming evidence that *LightSquared* would interfere with GPS. This comes as no surprise to individuals who understood GPS operations and the pertinent bandwidth. When *LightSquared* had in November 2010 presented a proposal to establish a freestanding terrestrial network as its primary service, it turned upside down what the FCC had originally permitted. Such terrestrial use had always been ancillary (i.e. for use as a back-up to satellite-based operations). The FCC had permitted ancillary service because such space-based systems were compatible with GPS operations. Reading the relevant FCC documents makes it clear what the FCC saw coming: a ubiquitous terrestrial broadband service, which the FCC would not permit. An FCC statement in 2003 states:

> "*We will authorize MSS-ATC subject to the conditions that the added terrestrial component remains ancillary to the principal service… We do not intend, nor will we permit, the terrestrial operation to become a freestanding service.*"

A second "bedrock requirement" was that ATC operate on a non-interference basis. In January 2011, FCC conditionally approved *LightSquared* but stated the service would not be activated if it caused interference. Mr. Kirkland believes it would cause devastating interference. No workable accommodation exists, so another spectrum should be found for *LightSquared* operation. More broadband and more spectrum for broadband wireless should be available; however, this simply did not work at the band at the lower end of the spectrum where satellites are operated. The FCC has failed to seriously confront the interference issue; it was a plain problem in physics: one cannot operate a high-powered system next to GPS. Over time many people had paid "good money" to create a system that offers accuracy measured in centimeters; a myriad of devices have been designed to receive the MSS signal; and these receivers must receive a signal anywhere on the band.

Dr. Schlesinger said the FCC Chairman recently stated that last year's waiver was not the trigger that gave *LightSquared* access to the spectrum adjacent to GPS. The FCC Chairman asserted that *LightSquared's* predecessor gained access to that band in 1995 and authority to provide a terrestrial service in 2004. He added that the FCC Chairman "took a shot" at the GPS community; stating: "It should be no surprise to anyone involved that the company was planning to operate a major terrestrial network in the spectrum adjacent to the GPS." The FCC Chairman stated that the GPS industry actively participated in the relevant proceedings as early as July 2009.

Mr. Kirkland responded that until the FCC waived the integrated service requirement in January 2011, the clear record was that any service in the MSS band had to be ancillary to a mobile satellite service and integrated with that service. So long as *LightSquared* operated a satellite-based service, its need to protect its own assets would cause it to avoid creating interference; that, in turn, would meet the protection needs of GPS. *LightSquared* did not say that it would build 40,000 towers, thereby ensuring that no one in 90 percent of the country could receive its satellite service. The FCC chairman's statements on non-interference were inappropriate, as they assume an outcome for tests not yet completed. The prospect is that *LightSquared* in practice ceases to be a satellite service and transforms into a terrestrial service. The company has stated its terrestrial network would be "tens of thousands" of times larger than its space-based system; he quoted a company official as hoping the space-based service would be like a gym membership – everybody paid for it; hardly anyone used it.

Dr. Schlesinger noted the FCC Chairman maintains that the GPS Industry Council had filed a letter saying the interference question was resolved. He sought Mr. Kirkland's comment.

The industry letter, Mr. Kirkland clarified, referred only to out-of-band emissions.

Dr. Schlesinger quoted the *LightSquared* Chief Executive Officer: "Unfortunately, the development of this new network is being frustrated by interests who are trying to close the door to innovation behind them."

Mr. Kirkland noted the GPS industry's 30-year record of innovation. To define the issue as GPS v. *LightSquared,* is "major bootstrapping." The uncertainty caused by the hasty and ill-considered action of the FCC will slow the development of precision agriculture, construction and other fields. Regarding mitigation, even if it were possible why should it's cost be imposed on such an innovative sector of the economy?

Ms. Neilan termed Mr. Kirkland's presentation as a very good summary and asked whether this was potentially an issue with other countries?

Mr. Kirkland said aviation automatically made it an international issue. Given the speed with which the matter was moving, he added, many people had not yet had the chance to express their concerns.

Dr. Schlesinger asked Mr. Kirkland to send a full-copy of the 11-page report to the Board.

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***LightSquared* Plans, Strategies and Next Step: Provide Services that Co-Exist with GPS**

Mr. Jeff Carlisle, Executive Vice President
Regulatory Affairs and Public Policy
LightSquared

Mr. Jeff Carlisle noted that considerable data is arriving from a mix of testing groups. He would address the question of what *LightSquared* was doing; how it had been authorized; and what were its next steps (he noted that he brought with him Mr. Rich Lee, *Greenwood Consulting*, who could respond to more technical questions). The *LightSquared* network requires an investment of $14 billion over eight years. This is in addition to the $1 billion already invested in two satellites; the first was launched in November 2010 and already handled its first call the previous week. *LightSquared* will continue to support an environment of dual mode devices – satellite and terrestrial –and at least one early model can be plugged into a computer, permitting instant satellite access should terrestrial access be interrupted, a capability that is unprecedented. *LightSquared* does not intend a direct retail presence; rather it will sell through retailers, which he thought a sensible approach given wireless industry consolidation. Something has been lost in the discussion of *LightSquared's* proposed system; namely, that it is built on 15 years of providing services to a range of users. *LightSquared* has a history of significant technical advancements and, for example, it is the only mobile satellite provider offering push-to-talk function. *LightSquared* has coordinated spectrum issues with five different governmental organizations and developed considerable understanding on how to avoid interference. We are committed to providing competitive broadband services that in no way reduce the capabilities of GPS, which we regard as a critical infrastructure in the United States. *LightSquared* can co-exist with GPS.

Responding to Mr. Kirkland, he said he believed the relevant core question was what *LightSquared* was licensed to do and when was it licensed. The definition of 'ancillary' is important, specifically what it means to the FCC. That, he said, was on the public record. The technical specifications were not determined in a waiver procedure in the past few months, but occurred between 2001 and 2005 -- a four-year proceeding which included initial rules; an authorization issued to *LightSquared's* predecessor and, finally a reconsideration of those rules that engaged dozens of parties; producing thousands of pages that led to the creation of the 2005 FCC rules. The rules adopted by the FCC in 2003 permitted establishing approximately 10,000 base stations. This follows on a two-year rule making procedure that engaged the GPS Industry Council and many others. It has not been a "state secret"

that *LightSquared* was adjacent to the L-Band. In 2002 *LightSquared's* predecessor had already entered into an agreement to limit its out-of-band emissions. In 2005, the FCC issued a reconsideration of its rules, with two important consequences: first, it removed the limit on the number of base stations; second, it established a power level of 32 dBW, the power *LightSquared* was deploying today. That, Mr. Carlisle said, is what the FCC says about the definition of an "ancillary" system; additionally, the FCC ruled that in dual mode receiving devices, the device need not have to contact the satellite first.

Mr. Dimmen asked if all receivers still needed to be space capable.

Mr. Carlisle said the dual mode was not a requirement; only a "safe harbor." An integrated service is being provided and the user is charged a single rate for both, whether they are used or not. Integrated does not need to mean "technical integration"; it can also mean "financially integrated".

Dr. Parkinson asked if Mr. Carlisle believed that had been understood by GPS users.

Mr. Carlisle responded that these were the statements made publicly at the time.

Dr. Parkinson then asked whether Mr. Carlisle believed the FCC actually explained the ramifications of what you think of as ancillary? Engineers do not always read the fine print as thoroughly as lawyers. Has the FCC made any effort to "reach out" to users to explain the decision they had made.

Mr. Carlisle said that's "a different issue." There is a great deal of "FCC language" that the average person might not understand. The points of discussion are the requirements for an integrated service: dual mode is not the only way in which one could meet the criterion. Up until November 2010 *LightSquared* was meeting the integrated service requirement through the dual mode device; in November 2010, it sought to change that requirement. He asked Dr. Parkinson if that explanation helped.

Dr. Parkinson said it did so to an extent, but he still "did not understand" how all this could have happened without the matter being explored in detail with the GPS user community.

Mr. Carlisle said the FCC had, in fact, not shared *LightSquared's* interpretation, although it still issued the waiver "to allow us to move forward."

Dr. Parkinson said this implied that the FCC "did not understand its own language".

Mr. Carlisle said that as *LightSquared* would be retailing through dealers, the customers would be paying the same price whether they used both systems or not; the FCC held that the sale of ground-only devices would be a violation of its 2003 rule. In 2009 *LightSquared* sought a modification in its authorization that would allow it to increase its power to 15 kW, and this was granted in March 2010. The U.S. GPS Industry Council participated in this review. No subsequent challenge was filed to that power increase until September 2010 when the GPS Industry Council first raised an issue. This date fell two months prior to the FCC decision that Dr. Parkinson found objectionable.

Dr. Parkinson responded that while the GPS Industry Council was a great organization, it did not represent all GPS users; *LightSquared* had the tactical advantage of being a single entity; GPS users do not have a "single authority," indeed, he doubted all users had yet been contacted on the issue.

Mr. Carlisle said that the public process was important and that the entities with the most concern had had the opportunity to present those concerns. Given that the standards had been on the record for six years, he did not believe there was cause for complaint.

Dr. Parkinson responded that he saw a difference between the issuance of regulations and some effort to contact the people who will be affected by them; he criticized the FCC for not actively undertaking an effort to bring the matter to user attention. He noted that the analysis could have been done any time in the past five years.

Mr. Carlisle agreed that was the case.

Dr. Schlesinger asked if the FCC was required to publish in the Federal Register.

Mr. Carlisle said it was, with the requirement of a public comment period.

Gen McCarthy requested more information on the testing processes ordered by the FCC in January 2011.

Mr. Carlisle said *LightSquared* had volunteered to take part in the process. Following upon a further point of Gen McCarthy, Mr. Carlisle said there had been criticism that the review commission should have made a final decision; he noted that while the

testing process had been ratified, the final results were not yet known. The technical group consists of 35 engineers from various entities; he was one co-chair; Charles Trimble was the other. Everything is being done by consensus; seven subgroups with over 100 engineers are engaging; and the report would be published on June 15.

Mr. Hatch asked what the difference was between this test and others of which the Board had heard.

Mr. Carlisle said the NPEF test was FCC-authorized; the others were not. The integrated service waiver does not change the power, number, or location of any prospective base stations that may be deployed; further, the 32 dBW and 40,000 stations do not change as a result of the waiver. If *LightSquared* were to "walk away" from the waiver tomorrow the interference issues would still need to be resolved.

Mr. DalBello said that if every user set was required to be dual mode, then every user could be tuned to the satellites. In that case *LightSquared's* own self-interference would determine how it handled interference generally.

Mr. Carlisle said that was not the case, as everything started terrestrial. The satellite had a limited capacity which is reached at some point; the vast majority of people will be within the range of the ground based service.

Mr. DalBello commented that the space-based service was something like a "gym membership – everybody pays, but hardly anybody goes."

Mr. Faga said the satellite service appeared secondary.

Mr. Carlisle said they would continue to use dual mode devices; if those devices are outside the ground network, at some point the satellite capacity is exhausted. Users will be charged one price; at any given time, maybe only five of one hundred will be using the space-based. That was what the "gym membership" analogy pointed to. Most people will be within reach of the ground-based system. The suggestion that the space-based system is a "fig leaf" was false and unfair; *LightSquared*, has already spent $1.2 billion on its satellites and intended to make full use of them.

Dr. Parkinson noted that the group was touching on the meaning of "ancillary", where in this case the meaning "ancillary" has changed from the satellite having ancillary ground-based service to a ground-based service with ancillary satellite service. He did not understand how the GPS industry could have been so naïve five years ago so as not to have understood this switch.

Mr. Carlisle asked whether 10,000 stations – as opposed to 40,000 – would have been ancillary. According to the FCC, he said, it was.

Dr. Parkinson responded that while Mr. Carlisle claims it was "no secret" it's apparent this was not known or understood. The decision is, in his view, flawed because the FCC did not direct the inquiry.

Mr. Carlisle said the FCC process was based on incoming information; if FCC was told GPS could be protected, then that was what was in the report.

Dr. Parkinson contended the fact that the FCC published something in the Federal Register did not mean that GPS users had in any effective way been informed.

Mr. Hatch commented, "We're having the wrong argument here, we're engineers arguing with a lawyer." The issue is that dual terrestrial-space for *LightSquared* enables to price the system to the ground but, in turn, the adjacent space band is being affected.

Mr. Carlisle said the first point was correct, as any other model for broadband delivery was bankrupt, but insisted that the space portion was not subsidizing the terrestrial portion since the cost of the satellites could only be recovered if it was fed by the general revenue stream. He agreed that the characteristics of the adjacent band are critical and that *LightSquared* wanted to operate without causing interference. GPS use, however, should not in itself block other authorized services in the L-band such *LightSquared's*. If a debate was needed on the question of whether GPS needed a protective band adjacent to it, that debate should have occurred in 2005. However, it has never been *LightSquared's* position that solutions existed only on the GPS receiver side. Also, the further one gets from the edge of the bandwidth the lesser the problems created and, for instance, other things that could be looked at included the transmitting power and the distribution system. In addition, an effort should be made to identify what GPS-based services would be affected during *LightSquared's* two to three-year build-out period. In any case we have not taken any solution "off-the-table."

Dr. Parkinson questioned the time feasibility of such approaches, and stated that "the time constant for my aviation friends is 15-18 years." Aviation has invested $18 to $23 billion in GPS and its augmentations compared to the $1 billion investment by *LightSquared*. In addition, estimated productivity savings in using GPS for aviation range between 10 to 30 billion each year. There is a potential for the a "destructive" collision course between GPS and *LightSquared*. What can be done to avoid this?

Mr. Carlisle said both sides needed to work together. He noted that much of this discussion started as a regulatory litigation in September 2010. He urged that people be "honest" about what share of their universe would actually be affected and how quickly that share of the problem could be resolved.

Mr. Marquez said all this can be discussed, but there seemed to be an expectation that the engineers will come in and solve the problem. The one thing that is clear is that any solution must follow the laws of physics.

Mr. Carlisle disagreed, saying there are various ways to mitigate and that he did not think there would be interference under some of the alternatives that have been proposed. A variety of ways exist – from technical to financial – to achieve mitigation. *LightSquared* urges to begin this conversation.

Gov. Geringer said Mr. Carlisle had done an admirable job of presenting matters as though this was a regulatory hearing but we're still faced with a common sense decision that ultimately derives in a Hobson's choice: "Do you want broadband or do you want GPS"? It is necessary to reflect from an enterprise risk management basis and it would be better not to choose the least-worst choice. It is difficult to understand why Mr. Carlisle is so insistent rather than engaging. The first rule in any situation is to do no harm. This situation reminded Gov. Geringer about when the Governor of New Mexico had a case where the state had signed a contract to sell water to El Paso for a period of time, but when the time passed there was a court ruling that New Mexico could not cease selling that water because El Paso had become dependent on it. The rationale for this decision was based on common sense rather than legalisms. He urged Ms. Carlisle to consider more fully the interests of the general public.

Mr. Carlisle responded that he believes the common sense approach is to establish the technical working group so there is agreed-upon data.

A member in the audience argued that it appeared that *LightSquared* position was that the costs to the GPS community to mitigate the effects of broadband service should be borne by that community and, if this was objectionable, it should have been raised sooner.

Mr. Carlisle commented that how an issue arises and how it is resolved are not the same thing; it doesn't matter how it happened – "we have to go on from here."

Dr. Parkinson asked whether the *LightSquared* plan was public.

Mr. Carlisle said it was posted on the company website.

A member of the audience asked if *LightSquared* was prepared to put money on the table to solve the problems for the most critical users.

Mr. Carlisle said the company had already done so and was open to discussing more. The company wanted a full discussion with the GPS community on how to solve the problem for the most effected and critical users.

Captain Burns said aviation, specifically NextGen, is critically dependent on GPS. The industry has eight to ten years to replace a system at a cost of $100,000 per aircraft. The GPS system provides enormous fuel savings; time savings; safety of life – "how can we give any of this away?"

Mr. Carlisle said he believed the RTCA report suggested a lower band might accommodate aviation.

Dr. Khosla asked whether mitigation plans could ensure that precision agriculture would not be adversely affected. Precision agriculture is already having a positive $20 to $30 billion annual impact on the economy. He noted that currently one billion people worldwide were undernourished, and that traditional productivity growth in agriculture was 1.4 percent a year, whereas to adequately feed the nine billion people by 2050 as projected will require that this be increased to 3.0 percent. Agriculture is becoming ready to make use of precision agriculture devices now, and the United States is the leader in this field as other countries were just getting started and looking to the U.S. for long term solutions.

Mr. Carlisle said there was no debate of the importance of precision to agriculture and other applications such as construction.

Dr. Parkinson commented that what to some people might seem like peripheral uses –- agriculture; construction; safety of life -- are fundamental to the U.S. productivity.

Mr. McGurn wondered about the FCC process: did it engage technical people who would look at a situation and say, for the common good, they should look at something a little harder? How does the technical and the political interplay?

Mr. Carlisle said that, broadly, the FCC is driven by "other than politics." However, it was an appointed body. The record in this case is thousands of pages long. When the FCC makes rulings it creates investment expectations because the legal process has been completed. While it was possible to petition the FCC to change its mind, that was unlikely.

Mr. McGurn said it appears that the FCC was looking at business interests rather than at the consumers.

* * *

U.S. International Initiatives and Opportunities: Latest Bilateral and Multilateral Developments

Ray Clore, Senior Advisor
Advanced Technologies
Department of State

Mr. Ray Clore said he would highlight GNSS initiatives and opportunities. The opening statement of U.S. Space Policy on GNSS remained unchanged: "Maintain leadership in the service, provision and use of GNSS." Also unchanged are the commitments to free service (all other national systems were imitating this) and technical transparency. Since 2004 one statement had been added: "Foreign GNSS services may be used to augment and strengthen the resiliency of GPS." He said he saw no conflict between this statement and the commitment to maintain leadership.

Dr. Schlesinger commented – and Mr. Clore agreed – the U.S. had sovereign national security requirements that went beyond resiliency.

Mr. Clore described the world's existing and planned GNSS systems and satellite-based augmentation systems. The Russian GLONASS has currently 23 operational satellites and 5 are planned for next year. Galileo still plans for an 18-satellite constellation by 2014, but he believes that 2018 or 2019 is more likely.

Dr. Schlesinger raised an issue on whether GLONASS, because of its "rather spotty record", would reach 30 operational satellites.

Mr. Clore said that Mr. Putin and Mr. Medvedev appeared to "be in the saddle" and if they decided they wanted this system it would likely be built.

Mr. Clore identified three major international GNSS objectives: ensure compatibility; achieve interoperability (there has been some progress for this objective); and promote fair competition, an objective that is sometimes forgotten. These objectives are pursued by the U.S. through both bilateral and multilateral efforts.

- U.S.-China: The State Department had made attempts to initiate civil space-based discussions; this will be pursued at the pending Vienna conference. The Chinese are not necessarily in favor of large bilateral exchanges, but they're open to discussing matters "on the fringes".
- U.S.-Japan: There has been excellent cooperation, including the agreement for QZSS monitoring stations on Hawaii and Guam and, also, an upcoming two-day workshop on monitoring.
- U.S.-India: While India's representatives have not shown to recent meetings the State Department has been reengaging them. The U.S. industry has good opportunities in India. A civil space workshop would be held in Bangalore in July later this year.
- U.S.-Australia: There was a bilateral meeting in 2010. For geographic reasons, Australia was an extremely important signal monitoring location. The Australians wish to discuss various matters; one of which is -- given that the Indian Ocean was the most sensible place to de-orbit a satellite – that Australia is at risk of de-orbiting overshoot.
- U.S-Russian Federation: A meeting on GLONASS use has taken a back seat. Working groups meet occasionally to discuss compatibility and interoperability. The Russians have mandated that dual GLONASS/GPS receivers should be attached to vehicles flying over Russian airspace; this creates an opportunity for U.S. companies. Mr. Clore's current understanding is that there are three Russian companies selling identical GLONASS receivers made in the same Chinese factory. A Board member asked if Russia was part of the L1C discussion, and Mr. Clore replied that the Russians had made some "desultory comments" about L1C but he had never heard them say they accepted LIC. There have been suggestions of a 25% tax on GPS-only receivers sold in Russia.
- U.S.-European Union: The U.S.-EU GPS Galileo Agreement of 2004 has been a "long slog," but all European Union (EU) member states have now ratified it. Final approval from the European Parliament is due in a few months. The EU is now seeking a high-level meeting with the U.S. but we don't know what topics they want to discuss. This may be clarified at an upcoming meeting in Brussels, Belgium. It is that global L1C operation could come more rapidly if the U.S. pursues it cooperatively with Europe.

- Multilateral: The International Committee on GNSS (ICG) provides the framework that allows providers to encourage transparency and support countries that wish to develop GNSS capabilities and use; in this latter area progress was slow. The Asia-Pacific Economic Cooperation (APEC) GNSS Implementation Team promotes implementation of regional GNSS augmentation systems to enhance inter-modal transportation, specifically in the Asia-Pacific region. Eight-five persons attended the group's 14th meeting in Seattle last year, and the 15th meeting this year will be in Brisbane, Australia.

In summary, the major themes of U.S. space-based PNT policy are to ensure that the GPS constellation remains a reliable foundation for all civil users; that the U.S. pursues bilateral and multilateral cooperation on satellite navigation issues; that progress continue on compatibility and basic interoperability; and that the U.S. remains open to ways in which non-U.S. space-based PNT services could augment and strengthen GPS.

Dr. Parkinson urged that outreach efforts be made with China; in particular, to gain more detail on both performance and operation specifications. The Chinese, he said, have been cordial but not forthcoming. They wish manufacturers to embrace the Chinese Global Navigation Satellite System (COMPASS), but absent clarity on COMPASS receiver specifications they are unlikely to attract U.S. and international business. Further, it is only by publishing their specifications that they will receive needed feedback on their suitability.

Mr. Miller noted, relative to *LightSquared*, that systems operating higher in the L-band would be less affected. One could argue that *LightSquared* could give other national systems a competitive advantage.

Mr. McGurn asked if the Russians still intended to deploy a public signal that would be closer to *LightSquared*. Mr. Clore replied that the intention stood, though overlay problems with the Chinese remained.

Mr. Dimmen asked what actions are underway to extend augmentation systems in the far northern hemisphere. Mr. Clore said this is being worked through the International Civil Aviation Organization (ICAO).

* * *

Ny Alesund: Norway's High Arctic Contribution to the Advancement of Global Positioning, Navigation and Timing

Knut Arne Gjetsen
Deputy Director of the Geodetic Institute
Norwegian Mapping Authority

Per Erik Opseth
Director, Geodetic Institute
Norwegian Mapping Authority

Mr. Gjetsen welcomed the opportunity to present information on the *Ny Alesund* Geodetic Observatory. The Norwegian Mapping Authority is part of the Ministry of the Environment, and its mission includes measuring environmental changes. *Ny Alesund* is the northernmost research facility in the world and it is intended to develop it as a world leading site of arctic climate and environmental research. He introduced Mr. Opseth.

Mr. Per Erik Opseth explained how the Earth is in constant motion; e.g. Norway has moved 30 cm to the northeast in the past 20 years; further, Norway is rising as the post-glacial rebound continues 10,000 years after the retreat of glacial ice. Because of this motion the Earth is best measured accurately from space. Environmental studies require the establishment of very precise reference and geodetic frames. The importance of geodesy is usually underrated, perhaps because geodesists are usually not gifted at explaining their work in accessible terms to the general public. Norway is contributing to space-based geodesy in two ways: first, the *Ny Alesund* observatory; second, a software package called *GEOSAT* which the Norwegian defense research institute has been developing for over 25 years. Mr. Opseth highlighted the variation in sea level calculations as derived from satellites operating in different orbits: near the equator, data was nearly identical; as one moved to the poles, a difference of 1.5 cm occurred. He noted no data existed north or south of 66 degrees, the turnaround point for satellites. As, he believed, climate change was first recognizable in the Polar Regions, monitoring those areas was a high priority. *GEOSAT* is partly up and running. Its goal is to monitor the sea level height and ocean currents, but questions relating to the shape, and gravity field, of the Earth remain to be resolved. Satellites such as the NASA Gravity Recovery and Climate Experiment (GRACE) are currently addressing the gravity issue. Based on this data it has been possible to make gravitational calculations. The benefit of the new and planned European satellites is that they measure what happens above 66 degree latitude. The *Ny Alesund* observatory is located at 79 degrees north. Combining the data from all these sites will also enable scientists to derive conclusions about ocean currents. Modern geodesy is becoming dependent on satellites and, also, large numbers of science users worldwide require the accurate reference frames being derived through modern geodesy. Norway is also modernizing its facilities to enable Very Long Baseline Interferometry (VLBI) and establishing a station for satellite laser ranging. Without *Ny Alesund*, the accuracy of Earth

Orientation Parameters (EOP) would probably be reduced by 20 to 30 percent. In addition, *Ny Alesund* will be connected by a 200 km long fiber-optic cable, at a cost of $14 million and targeted for completion in 2013.

Gov. Geringer referenced the need for a global observing system, and noted that the U.S. Government has not assigned a lead agency on this: does the Board have any tasking that would help it follow through on things like what Norway was doing?

Dr. Beutler explained that many current activities are performed under the aegis of the International Association of Geodesy (IAG) in which the U.S. is a strong participant. International bodies are the appropriate venue.

Ms. Ruth Neilan commented that she had visited the Norwegian site in 1990 while it was being built.

An audience member agreed with Dr. Beutler's comment that an international effort was required. A major effort is needed to modernize the networks to meet modern requirements. For example, U.S. antennas at its stations are three to four times older than those in Norway. Ny Alesund is an extremely important station. Also, NASA has begun developing a prototype integrated observatory and would share this expertise with other nations. Currently, NASA provided about 40 percent of the world's global geodetic observing stations, and work is shared with "sister agencies" in Japan, Europe, Eurasia, Australia and elsewhere that are also contributing to this system.

Mr. Miller said he believed there is a synergy between the current tasking regarding PNT architecture and the enabling techniques just discussed.

Dr. Parkinson agreed; the Board is authorized to make statements of support and endorsement. He strongly urged a continuation of modernization at NASA facilities and suggested that the two geodesists on the committee word a statement to such effect.

Dr. Schlesinger said there were advantages to making occasional recommendations that are not accompanied by requests for funds.

Mr. Brenner said that the public/private partnerships he saw the previous day at the NASA Goddard Space Flight Center was the most impressive he had ever seen.

The Thursday, June 9, 2011 session of the PNT Advisory Board adjourned at 5:20 p.m.

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Session of Thursday June 9, 2011

The session of Friday, June 10, 2011 convened at 9 a.m.

Opening Remarks

Mr. James Miller, Executive Director, noted that the day's agenda would be altered to account for the previous day's extended discussion on *Lightsquared* and GPS. He noted that the previous day's session had drawn representatives of the national press and expressed interest as to what they would report on.

Dr. Schlesinger welcomed Board member Robert Hermann, absent the previous day, and introduced the next speaker Mr. Michael Bergman of the U.S. Department of Homeland Security.

* * *

GPS Interference, Detection and Mitigation

Michael Bergman
PNT Programs, Department of Homeland Security

Mr. Michael Bergman noted that he was substituting for Mr. John Merrill, and would discuss DHS Interference, Detection & Mitigation (IDM), the Patriot Watch concept, and back-ups to GPS-based timing.

DHS IDM governance is an almost verbatim restatement from NSPD-39. Key points include to: coordinate domestic capabilities to identify, analyze, locate and mitigate sources of interference to GPS and its augmentations; develop and maintain capabilities, procedures and techniques; and routinely exercise civil contingency responses to ensure continuity of operations if GPS is disrupted or denied; and collect, analyze, store and disseminate interference reports from all sources, thus enabling appropriate notification, investigation and enforcement.

The Patriot Watch is a "system-of-systems" that incorporates open architecture and a multi-phased approach for situational awareness. It's design includes government and commercial hardware and software, and provides persistent monitoring for situational awareness, thereby allowing a timely response to anomalies. There is also a need for a system independent of GPS -- the Central Data Repository, which is a text-based system for reporting 'PNT incidents'. It is based on the FAA Spectrum Engineering Tracking System (SETS) to which agencies, such as NASA, also have access.

A domestic timing back-up, independent from GPS, takes the back-up signal straight from the master clock and disseminates time using the existing national ground communications infrastructure. Several tests have been done: one in a clean environment and another in a jammed environment. Results show excellent time transfer. Current plans included a long-haul test.

Dr. Hermann asked whether this was a funded program and or an idea looking for funding; Mr. Bergman responded that, to his knowledge, there was an existing agreement with the commercial industry.

In summary, Mr. Bergman said, Patriot Watch is a systematic layered approach with open architecture; the PNT Incident Portal is nearly complete pending final testing, and planning is in process for a long-haul ground communications test.

Discussion:

Mr. McGurn noted that over time considerable effort has gone into creating facilities, but not as much effort had been directed to the 'sensors' themselves.

Mr. Bergman suggested raising this issue with Mr. Merrill.

Mr. McGurn said this appears to be a "one-size-fits-all" approach on interference which, he thought, is inappropriate since broadband detection and spoofing require quite different responses.

Gov. Geringer asked what the central depository has yielded. Mr. Bergman responded that data collection enables identification of patterns and the ready sharing of information between agencies. Additionally, a *listserv* provided information to high priority members, so this is also a notification system.

Mr. Marquez asked whether the sensor responses are automatic or requires individuals watching monitors. Mr. Bergman said it is the former.

Mr. McGurn said considerable work has been done in this area, but DHS did not yet seem to have integrated these efforts. He noted, as an example, Mr. Phil Ward who has developed a simple "jam meter" that identifies anything over the ambient noise barrier as "bad stuff."

* * *

GRASP: Spaceborne Co-Location and Cross Calibration for Improved GNSS Interoperability

Ruth Neilan
Vice Chair; Global Geodetic Observing System

The Geodetic Reference Antenna in Space (GRASP) is a proposed new space mission to enhance GNSS, particularly our capability to measure sea and ice level height changes. High precision GNSS is the primary technique for gathering information on how the earth is changing. The mission would also improve the accuracy of orbit and clock states. An accurate terrestrial frame reference system is essential for positioning on the surface of earth. Space missions such as JASON, Ice Cloud and land Elevation Satellite (ICeSAT) and GRACE have improved our understanding of changes in sea and ice levels. In addition, GRACE has supplied important data on changes in the gravity field.

Many techniques go into determining terrestrial frame reference, including optical laser ranging, GNSS radiometric signals, gravity field models, etc., but there is no one method that directly connects the data from these varied sources. One of the reasons for the importance of including laser retro-reflectors on GPS III satellite is to enable the comparison of co-located radiometric and optical measurements.

The issue of whether sea level change is accelerating is a difficult one; currently the sea level rise ranges between from 1.2 to 1.6 mm annually but measurement accuracy within 0.1 mm/yr is needed in order to address this question. Dr. Hermann asked why a higher level of accuracy was needed, and Ms. Neilan responded that if a signal was changing on the order of 1.0 to 3.0 mm per year, with that change varying worldwide, then one needs to understand the reference frame to within one order of magnitude better, that is, 0.1 mm annually.

Ms. Neilan discussed how biases in the positioning GPS satellite antennas create problems since these variations, when received by the ground network, add errors to the system. GRASP is a small satellite, about the "size of a briefcase," carrying a GPS antenna and a French transponder system. A small satellite operating at Low Earth Orbit would provide a better understanding of what, if any, biases exists between these measurements. Mission life is two to three years. While using GRASP to solve the sea level problem was important, it would also improve GNSS interoperability by establishing a common reference.

In summary the improvements GRASP will provide include:

- Serve as a flying geodetic super-site, thus realizing the terrestrial reference frame with 1 mm accuracy and 0.1 mm annual stability as specified by the Global Geodetic Observing System (GGOS);
- Improved measurement of sea level changes; complement data being collected by Jason-2/3 and GRACE Follow–On (GRACE FO); and
- Enhance the global geodetic infrastructure through improved inter-technique ties.

The final release of an Announcement of Opportunity (AO) would come next week; mission budget was $150 million; and proposals are due in three months. The mission carried the geodetic community's endorsement; all data will be publicly available.

Discussion:

Gen McCarthy asked if GRASP would lead to improved navigational accuracy from the user perspective. Ms. Neilan said that IGS work on orbit determination improvement has not been brought into the GPS navigational message. This is done by NGA who used both IGS, and their own data, to improve the orbit data for the GPS satellites.

Regarding the ice mass, Gen. McCarthy asked whether this reflects microscopic changes in geodesy or the altimetry. Ms. Neilan said both; the GRACE mission is very sensitive to changes in ice mass.

Dr. Hermann asked at what point in sea level measurement one stops averaging; for instance, he lacks a 'feel' for how the sea level ten miles east of Boston is determined. Ms. Neilan said the first changes in sea level are measured by tide gauges around the world, with daily readings written down by hand. Nowadays these changes were recorded hourly. A long-term record is now needed since the science community wants continuous measurements.

Dr. Hermann said he did not understand why currently available data is insufficient. If there is an inherent variable of 0.1 mm then how is an answer ever to be achieved? Dr. Beutler responded that the main issue is the separation of different impacts since there are multiple error sources which are not well understood, and the GRASP mission will try to eliminate that.
Mr. McGurn added that the orbital model was constantly changing; therefore, work needed to be done continuously.

Dr. Schlesinger asked what this effort will yield beyond "satisfying our curiosity?" Ms. Neilan responded that sea level change is a fundamental issue facing society, and is particularly urgent in coastal urban areas. Dr. Schlesinger noted that sea levels have been rising since the end of the Little Ice Age and, in any case, what could be done about it "other than gurgle." Ms. Neilan said many scientists believed sea level rise was accelerating; if this could be demonstrated, it may be possible to do something about it.

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International Member Reports

Dr. Gerhard Beutler
Astronomical Institute, University of Bern, Switzerland

Dr. Gerhard Beutler commented on the GNSS satellite status: GPS currently has 31 operational satellites in six planes; GLONASS has 23 satellites in three planes; and Galileo has GIOVE-A, GIOVE-B in orbit and four In-Orbit Validation (IOV) satellites are planned for this year. There is only one GPS laser-reflector equipped satellite remaining in operations while all other GNSS systems will carry such reflectors on all space vehicles. GLONASS is closer to full operational status, and while the Russians have progressed in extending satellite lifetime it's still much less than that of GPS satellites.

Dr. Beutler also presented information of the cumulative ground tracking of these three systems. GLONASS has higher elevation and is better suited for high latitude readings. However, in terms of Positional Dilution of Precision (DOP) GPS offers the best performance. The number of combined GPS/GLONASS receivers in the IGS network has increased from approximately ten in 1999 up to over 140, which is one of the reasons why GLONASS currently cannot deliver accuracies comparable to GPS back in 2000. The rapid growth in the number of combined GPS/GLONASS receivers is a matter of consequence. In a real-time environment – such as IGS – one strives to make continued progress both in the number of monitoring stations and analysis tools and, also, performance data is available for previous years and improved results can be retroactively calculated: this provides an important advance.

On the subject of high accuracy clocks in space, Dr. Beutler noted a quote he made in 1984: *"… the best way of modeling the clocks is: define a statistical model of clock performances using available information on clock offset, drift, and jitter. This leads to a simple stochastic differential equation … for the clock synchronization error as a function of time."*

At the time he had not acted on this view because clocks were not sufficiently accurate. Today the situation was different and clock prediction has become easier. At present orbit errors were becoming the limiting factor on predictions, and tools such as laser retro-reflectors on GNSS constellations and Low Earth Orbit (LEO) satellites enable the validation of satellite orbits and providing an absolute measurement between an earth-bounded observer and the satellites. Thus, it is important that future GPS satellite be equipped with laser retro-reflectors.

Dr. Hiroshi Nishiguchi
Secretary General, Japan GPS Council, Japan

Dr. Nishiguchi expressed his heartfelt gratitude to the international community for its abundant help to Japan following the great natural disasters on March 11, 2011, including the U.S. assistance named "TOMODACHI (Friendship) Operations" provided both by the U.S. military, public, and private sectors. These included not only human and material contributions, but also advisory services relating to the accidents at the affected nuclear power plant. U.S. actions deeply impressed the Japanese people and reminded them what "True Alliance" between these two nations meant. Therefore, he extended his special appreciation to the person who mentioned "TOMODACHI Operations" the previous day.

This disaster has accelerated proper recognition of the Quasi Zenith Satellite System (QZSS) implementation in Japan. The Japanese people have come to recognize the necessity to expedite the implementation of "Space-based National Geo-spatial Data Infrastructure" and the importance of effective GNSS utilization. The Secretariat of Space Strategy Headquarters was now hurrying to work out the basic architecture plans for realization of QZSS; a full-fledged system that could also include search and rescue and public regulated services.

The magnitude of the March 11 earthquake has disturbed the earth's cluster deep underneath the Japanese Islands; reportedly, the cluster slid up to 5.3 meters to the east. This sudden slide came after several hundred years of bit-by-bit movement to the west. GPS has enabled measurement of these crustal movements precisely and in real-time. The GPS-based Frame of Reference Network implemented in the late 1980s is working properly. GPS is, indeed, the gold standard for the world.

QZSS utilization has been successfully demonstrated. Many applications are expected to follow including, among other applications, precision farming, robotic construction machine control, Search and Rescue (SAR), precise tsunami monitoring, and effective personal navigation in urban canyons.

The Japan GPS Council is looking forward to continue its efforts to advance GNSS utilization policy in Japan.

Dr. Refaat M. Rashad
Arab Institute of Navigation, Egypt

Ancient Egypt possessed two of the Seven Wonders of the World – the Great Pyramid in Giza and the Pharos in Alexandria, a lighthouse built in 325 B.C. In addition, well over 5,000 years ago Egyptians laid down the basis for the development of Astronomy and Geodesy. Egyptian representatives are currently engaged in international GNSS conferences and venues, and are working towards expanding the use of GNSS; Egypt hopes to bring something new to the international communities. The United States has provided excellent leadership in this area, which is demonstrated by the proven 24x7 performance, and reliability of GPS. Other GNSS systems being developed by other nations will raise the total effectiveness of the system. During the past year Egypt has established groups in Cairo and Alexandria to monitor and augment GPS signals over this region. GPS is an essential tool for providing safety-of-life functions, which apply in all settings – land, sea, transportation and including police and ambulance, and organizations such as the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO) will be placing more emphasis in these areas.

Mr. Arve Dimmen
Director, Division for Maritime Safety
Norwegian Coastal Administration, Norway

Mr. Dimmen presented a photograph of the foreign ministers of Norway and Russia signing an Arctic Sea demarcation treaty between them that follows forty years of negotiations. This treaty is leading to increased activity in that area, and over the summer of 2011 the Norwegian government plans to undertake seismic exploration in the portion of the Arctic Sea now established as Norwegian.

In May 2011 Norway established a Galileo ground station with satellite uplink capability; this station will be ready to communicate with the first Galileo IOV satellite scheduled for launch later this year. However, the coverage provided by Galileo augmentation systems still needs improvement. Tests are scheduled to be undertaken soon in Europe, which offers an excellent opportunity for multi-national efforts.

Further discussion is needed on developing effective back-ups to GNSS. There is increased awareness of the importance of back-up to maritime navigation. GPS signal loss is critical because most shipboard systems are interlinked; GPS loss can lead to failure of radar and other systems, a circumstance which is worrying. Also, commercial vessels generally do not have a "graceful degradation design" compared to comparable military systems. The solution, however, should not be trying to revive past navigation techniques.

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Reports from the PNT Advisory Board Working Groups

Subgroup #1: GPS Interference Detection & Mitigation

Subgroup #1 reported that it had that morning circulated a paragraph which, if approved by the Board, would be transmitted by Dr. Schlesinger, Chairman, to the EXCOM with all possible speed. Gov. Geringer was credited with having "put in late hours" to refine the wording. The proposed statement in its entirety is,

"Recommendations to the Positioning, Navigation, and Timing Executive Committee Regarding LightSquared

Background:

At the June 9, 2011, meeting of the Positioning, Navigation, and Timing (PNT) Advisory Board briefings were received regarding the LightSquared broadband initiative.

These briefings, from the U.S. Government, independent researchers, and LightSquared, described interference issues between the proposed LightSquared terrestrial broadband system and the Global Positioning System (GPS).

Recommendation:

The PNT Advisory Board recommends the EXCOM should file formal comments with the FCC regarding the interference issues.

Based upon information and test results provided to the PNT Advisory Board at the meeting of June 8-10, 2011, the provision of GPS services cannot be assured if the LightSquared proposal for satellite and terrestrial broadband provision using the MSS L-Band receives final approval.

The only reasonable and viable option to continue ubiquitous availability of GPS and the provision of a new 4G wireless broadband capability would be for the FCC to assign an alternate frequency spectrum to LightSquared that has little or no probability of affecting the delivery or utilization of GPS services.

Rationale:

The PNT Advisory Board believes there are no technical solutions to the interference produced by LightSquared's terrestrial segment.

LightSquared's system will jam the GPS signal within the United States. This will affect all users of GPS including these critical sectors: aviation, the financial infrastructure, emergency services, precision agriculture, construction, railroads, general navigation (automobiles and watercraft), the power grid, and some satellites.

The negative economic, national security and foreign policy impacts of this deliberate signal fratricide significantly outweigh any possible benefit derived from the operation of LightSquared in the MSS L-Band frequencies.

The Advisory Board believes that the expansion of broadband services within the United States is in the national interest. The Advisory Board does not believe that broadband services should come at the detriment of an established piece of global critical infrastructure.

The Advisory Board believes that the FCC, the Executive Branch, and Congress have been presented with a false choice between LightSquared and GPS. The Advisory Board believes that both systems can peacefully coexist with LightSquared moved to a different portion of the spectrum- away from the MSS L-Band".

Gen McCarthy moved the recommendation be adopted; the motion was seconded.

Dr. Schlesinger invited discussion.

Dr. Hermann said the Board should make its views known in a public forum.

Dr. Schlesinger said he would report the recommendation to the EXCOM.

Dr. Hermann said the Board had been constituted as a select body expected to render expert judgment and counsel; that being so, this action was appropriate.

Dr. Schlesinger asked if any prohibition applied.

Dr. Hermann said Board members were precluded from individual lobbying of the EXCOM; the action was a collective recommendation from the Board to the EXCOM, which was the Board's formal client.

Mr. Brenner said that, in keeping with Federal ethics rules, he was recusing himself from discussion and vote.

Dr. Schlesinger asked whether the recommendation was "a little on the mild side." He wished a statement stronger, such as if *LightSquared* went forward, then GPS service "cannot be assured."

Gen McCarthy said the Board did not need to prove that damage would ensue; the burden of proof lay on the party proposing the change.

Mr. DalBello suggested broadening the statement from GPS to GNSS generally; *LightSquared* might be harmful to U.S. relations with international agencies. Mr. Faga expressed agreement.

Mr. Marquez offered an amendment to add to the sentence ending "affecting the delivery of GPS services" the phrase "and GNSS services generally." He believed repercussions would be international.

Dr. Schlesinger expressed hesitancy, saying the Board reported exclusively to EXCOM, which dealt specifically with GPS. He suggested a less direct phrase, "GPS and other international signals," might be preferable.

Dr. Hermann said that overstated the restraint required of the Board. *LightSquared* would not merely affect GPS in the U.S.; it would reduce the effectiveness of all PNT systems – it would interfere with the efforts to exploit the capabilities of multiple systems, efforts from which all portions of society would benefit.

Dr. Schlesinger noted, unhappily, that some within the DoD had suggested that the GPS system be reduced below 24 satellites to save money, with compensatory exploitation of other nations' systems.

Dr. Hermann noted that national security was not the only consideration; farmers benefitted from being able to use multiple systems in their operations. The Board, he believed, was obligated to be concerned with space-based PNT issues at large.

Mr. McGurn said it may be useful to clarify what the Board was trying to protect.

Dr. Hermann said the subject was *LightSquared* interference with the radio frequency band that carried GPS. His disagreement with Dr. Schlesinger was that the latter wished to exclude discussion of systems not within minimal military requirements. The user will find value in the multiplicity of signals; soon thereafter, he added, the military would also find such value. Further, he wished to avoid entering the bandwidth used by China unless it was clearly essential. Additionally, *LightSquared* will affect U.S.-based users of Galileo because of the band in which it would operate.

Mr. Marquez's amendment was seconded.

Audience member Robert Rosenberg said the national security issue was clear. Suppose, he said, that he as a Galileo or COMPASS sponsor discovered that a new U.S. operation would prevent them from operating in the United States; it was logical that, in response, GPS use in Europe or elsewhere would be restricted. That very rapidly would become a military issue. Further, there were national security implications if it became clear that the U.S., relative to PNT, did not keep its word.

Ms. Neilan termed it appropriate to add GNSS; the most recent national space policy, she noted, spoke of U.S. leadership not just in GPS, but also in GNSS.

Dr. Beutler, referencing discussion of the appropriateness of the word "assured," said he believed "assured" was preferable.

Dr. Schlesinger restated his view that he regarded such wording as weak.

Dr. Hermann said he thought it was very strong: U.S. Space Policy for PNT said service was to be "assured." Saying it would not be was "a 100 percent statement."

Dr. Schlesinger noted "mitigation devices" remained to be discussed; however, he added, "those of us who are mathematicians" knew the universe of mitigation devices was "a null set."

Mr. Marquez said that inverting the first and second sentences might strengthen the statement. No support for this was voiced.

Dr. Schlesinger said he believed there was a consensus that paragraph two, as written, strengthened paragraph one.

The recommendation was put to a vote. All members were in favor, with one recused.

Subgroup #2: GPS Sustainment, Availability, & Affordability

Dr. Hermann noted that Subgroup #2 was assigned to look at architecture, sustainability and portability; the group included Board members Burns, Faga, Murphy and Trimble, with Dr. Parkinson as honorary member. They had met February 19, 2011. He had learned something about how much an advisory group could accomplish when it lacked adequate staffing level; considerable investigation had been foregone on matters due to the lack of detailed cost and program information. Some tasks, could appropriately be assigned to the "wise and judicious" members of the Board; however, if analytic and technical resolution was required, his group "lacked the bandwidth" to tackle them. He thanked Capt. Murphy for providing aviation information.

Subgroup #2 has chosen to address the question of a 30-satellite GPS baseline constellation. He noted Dr. Parkinson's comprehensive presentation of the military importance of 30 satellites as a baseline; and added that while the DoD remains lukewarm to this proposal there may be other constituencies that may need a larger constellation. Another issue that needs discussion is what it means for GPS to continue to be the "gold standard." Finally, the subgroup has been working on developing a statement to emphasize the importance of international cooperation. However, additional topics such as governance, back-up systems, electronic warfare and survivability cannot be addressed at this time due to the limitations in resources available.

Dr. Hermann said there may be already an argument in the current U.S. Space policy that could support a larger than 24-satellite baseline constellation, namely,

> *"In creating and sustaining the GPS system the U.S. has provided an important global infrastructure for its own military purposes; with augmentation, its domestic air traffic management purposes; and many other civil and commercial uses. It has pledged to provide access to this system to all users, foreign and domestic, without charge. It has been a world-changing achievement. In 2010 the President established a new Space Policy for Space Based PNT which continues these commitments. Current plans, programs and activities position the U.S. to satisfy these commitments."*

While the U.S. Space Policy in itself does not specify the number of satellites, a larger than 24-satellite constellation is already supporting the U.S. commitment to support civil and commercial users (with approximately 30 GPS satellites already in operation). The subgroup has looked into non-military constituencies that might require the larger constellation.

Dr. Schlesinger commented he never understood the military's lack of interest in a 30-satellite constellation.

Dr. Hermann noted that given U.S. operations in Afghanistan, which is characterized by severe masking angles, now was the likeliest time to successfully make an argument to the military for a 30-satellite baseline constellation.

The subgroup has looked at aviation and agriculture as areas that might most benefit from a 30-satellite array. Dr. Hermann said that contrary to his expectations, additional numbers of GNSS satellites in Medium Earth Orbit (MEO) satellites would eliminate the need for ground- or space-based augmentation systems; the integrity issues in the certification process would continue to require an augmentation system. The cost of additional satellites would exceed any savings in augmentation systems.

Dr. Schlesinger commented that the FAA's position was that three regional navigation satellite systems like the Wide Area Augmentation System (WAAS), distributed globally, would obviate the need for more than 24 satellites.
Dr. Hermann responded that while this was the conclusion of a study from the MITRE Corporation, it was not clear whether this is also the FAA's formal position. The issue the subgroup is trying to address is whether a sufficiently robust system would permit doing away with augmentation systems and their conclusion is that it is not.

Gen McCarthy said that the term "augmentation system" may be a misnomer when applied to a variety of systems (in addition to GPS) and, thus, airlines would insist on keeping such systems for "back-up" in the case of GPS failure even though a GPS augmentation will not work if GPS isn't working. Within aviation language, what the group is referring to as "back-up systems" actually includes primary navigation systems as when used while landing in bad weather. Thus, in this instance, GPS has become the back-up. Dr. Hermann did not dispute this, but observed that many in the field looked to an aviation future in where satellite-based systems are the primary source for navigation.

Mr. Murphy disagreed with the statement that few significant benefits followed from a 30-satellite baseline system. While this may be true for WAAS, there are still Ground-based Augmentation Systems (GBAS) that would benefit greatly. GBAS systems are in the evolutionary path for NextGen. The MITRE study mentioned earlier did not include GBAS in its trade-space.

Dr. Hermann speculated whether there is a good business case to justify funding six additional GPS satellites in the baseline constellation. Mr. Murphy said the business case for a 30-satellite baseline constellation is based on providing integrity when augmentations are part of the equation. Mr. Marquez commented that he believed integrity requires an off-board, non-GPS signal, thus the integrity requirement is not necessarily dependent on the number of satellites. Dr. Hermann conceded the point.

Dr. Schlesinger commented that when stating a 30-satellite baseline does not provide material advantages, this is generally assumed to imply we're asking for additional funding for GPS. If, however, dual-satellite launches are implemented – as the Board has been advising – the financial picture changes considerably. Focusing only on a cost of $350 million per additional satellite, instead of looking at the larger picture, "prices us out of the market".

Dr. Hermann said his subgroup has reviewed the concept put forward by Dr. Parkinson for a 'lighter' and less expensive satellite dedicated to PNT. However, it is doubtful the prospect of cheaper GPS satellites would greatly influence the military. In fact, if the decision to build more of these 'lighter' satellites were his to make he's not really sure whether he could support it. Reducing costs per satellite by 25% does not necessarily mean these saving will be reinvested in GPS.

On the subject of aviation, Dr. Hermann said Subgroup #2 concluded that an assured level of 24 satellites and a space-based Geosynchronous Orbit (GEO) augmentation is the most practical architecture for aviation purposes. Thus he didn't find aviation to be a compelling argument for 30-satellite baseline constellation.

Agriculture is also a major user of space-based PNT. Mr. Hatch being part of the subgroup has provided us with a lot of useful information in terms of cost estimates. The estimated current annual U.S. savings from precision agricultural are in the $15-20 billion range, with additional savings in Europe and elsewhere. Efficiency improvements of five to fifteen percent are the norm. The market for PNT equipment for agriculture is approximately $2 billion. Also, while it may appear that agriculture is adequately supported by a 24-satellite baseline, there are applications which benefit from being in line-of-sight with six satellites but we do not have cost figures on their incremental value to efficiency.

The subgroup's general judgment on reducing GPS cost is that less costly architectures and configurations might exist that would enable equivalent or better performance, but his subgroup lacked the time and resources to investigate these beyond a broad conceptual level. Approaches considered included use of simpler, GPS–dedicated satellites; or operating at an altitude different to MEO.

Dr. Schlesinger noted that the Air Force had told the Department of Energy the mass of GPS satellites could not be further increased; this, he said, had implications on the non-PNT NUDET (Nuclear Detonation Detection and Reporting system) payload. Lockheed-Martin has established that dual–launch is feasible and, in fact, the Russians launch their satellites in "threes". In addition, Congress has sought information on the "mini-GPS" satellites so we should consider this point as "work in progress."

Dr. Hermann then addressed what is meant by the "gold standard." Referencing the 2010 National Space Policy, he noted as key, the statement that the United States must maintain its leadership in the service, provision, and use of GNSS; and that to this end the U.S. would: provide continuous worldwide access; pursue compatibility and interoperability with foreign systems; maintain the constellation to satisfy civil and national security needs; and invest in domestic capabilities and support international efforts to detect, mitigate and increase resiliency to harmful GPS interference.

Dr. Hermann added that over the next decade we may end up seeing as many as 90 GNSS satellites in operation. If done properly, this expansion will give global users "a whole lot of satellites for all applications". And, as nations gained more confidence in each other's competence, the overall number of GNSS satellites could thereafter be decreased as trust and true interoperability converged.

Dr. Schlesinger cautioned that this point is overstated because GNSS satellites may be used for military purposes. Dr. Hermann responded that if the U.S. avoids relying on other GNSS systems, then other nations might decide not to rely on us as well.

Dr. Schlesinger, relative to maintaining the "gold standard," said this reminded him of the remark of a British diplomat who kept saying "the world is crying out for U.S. leadership," while at the same time nearly everyone else complains about "how arrogant we are."

Dr. Schlesinger asked, in terms of other nations operating a baseline constellation of 30 or more satellites, what does this mean for remaining the "gold standard" and the 24-satellite baseline for GPS?

Dr. Hermann responded that the primary point is that GPS is in operation and has proven to be dependable, thus it's the "anchor tenant in the mall." It is possible, however, there could be a politically-inspired "race" over GNSS satellite numbers but it is difficult to make the case.

Dr. Schlesinger said U.S. Space Policy was written well before others got into the game. Dr. Hermann said he doubted a 35-satellite Chinese system "challenges our notion of ourselves."

Mr. McGurn highlighted the transparency of the GPS system as established by policy and, also, that other systems have not performed as reliably in safety-of- life situations. Mr. McGurn asked whether adopting a six-layer system had been considered by the subgroup.

Dr. Hermann responded that the subgroup had not discussed this; however, previous reviews had concluded that 6 x 4 (six orbital planes, 4 slots per plain) was a suitable solution for a 24-satellite baseline constellation, although 3 x 10 option may be preferable for a 30-satellite baseline.

Mr. Marquez said that the number of satellites is a false measure of "gold standard" -- what matters is the performance standard, reliability, transparency, and other criteria. Dr. Herrmann said he believed a clearer definition is needed for what 'performance standards' means and, he has not seen progress of late.

Dr. Enge commented that much of the aviation cost analysis is driven by promises on future capabilities; could such promises be strengthened? Dr. Hermann quoted Capt. Joseph Burns that airlines will invest only in systems that are actually operating, so it is unlikely promises alone can change the procurement patterns for aviation.

Subgroup #3: GPS International Cooperation & Coordination

Ms. Ruth Neilan noted that the Board should make formal recognition of the Norwegian accomplishment reported earlier, and proposed the following statement:

> *"The Board recognizes the important activities of the Norwegian Mapping Authority's (StatensKartwerk) Geodetic Division in support of global geodesy for Earth observations and global change. The Board encourages and commends their plans to implement the collocation of high precision geodetic techniques, VLBI, Satellite Laser Ranging (SLR) and including multi-GNSS, at their Svalbard station in Ny Alesund for these purposes. The Board also heard NASA's view of a coordinated approach in the framework of the GGOS to improve and modernize the global infrastructure with international partners for additional collocated stations".*

Dr. Schlesinger asked if there were any objections to adopting the resolution. None were raised; the statement was adopted.

Ms. Neilan said that considerable cooperative work is proceeding through the International GNSS System (ICG). She chairs a very interesting group on geodetic references and timing; the group is truly international, combining technical experts with systems providers from various countries. This group has developed a template to be used to secure basic information from all the world's GNSS systems.

The IGS has also been working on the Asian/Pacific region for a multi-national GNSS campaign. This effort is being led by Japan, and its space agency recently announced purchase of sixty GNSS receiver tracking sets. A call for proposed location sites has also been issued.

Ms. Neilan advocated to promote GPS use by the various national mapping agencies which, in turn, promotes consistency and compliance in mapping, and also open access of shared data. Her IGS group has been working with FIG (International Federation of Surveyors), which includes nearly every major mapping organization. The aim is to create stronger working relationships and to promote data sharing.

Ms. Neilan noted publication of an excellent study in Australia on the benefits supplied by GPS to precise mining, agriculture and construction, and a "staggering" value in term of financial benefits.

* * *

Final Remarks

Several Board members expressed thanks to NASA for the visit to GSFC for the very informative tour, and particularly for the opportunity to see the geodetic installation there including a new VLBI antennae, and the "real-time" view of two SLR instruments ranging to a GLONASS satellite. NASA deserves praise for establishing a true public-private-academic partnership, as it was apparent that GSFC draws on resources and talents from all three sources.

Dr. Schlesinger, referencing his earlier exchange with Dr. Hermann, said he had neglected to ask Mr. Robert Rosenberg about the Independent Review Team's (IRT) position on a 30–satellite GPS baseline.

Mr. Rosenberg responded from the audience that two or three years ago the IRT had presented availability studies to U.S. Air Force Space Command (AFSPC), and that he had recommended that Gen Kehler declare a formal need for a 30-slot GPS constellation. Gen Kehler declined to do so, but asked the IRT to undertake a formal study of alternate constellation structures that would provide the same level of availability and quality of service. A study was conducted using quantitative analysis, incorporating availability; accuracy; bounded inaccuracy; and integrity. A set of alternatives was defined, including *Spartan* which had been advocated earlier by Dr. Parkinson. The *Spartan* alternative includes satellites at GEO in addition to MEO. Attention was also paid to developing a completely independent package from the current GPS payload. These alternatives were presented to Gen Shelton, whose team is now reviewing them. This review however, needs to be understood within the context of potential significant budget reductions within DoD and other government agencies.

Dr. Schlesinger asked if the IRT no longer advocated for 30 satellites; Mr. Rosenberg said "we are an advocate of answering the question posed to us."

Mr. Miller brought the session to a close, thanking all for their participation. He noted that work remained, and requested that the three subgroups continue pursuing their tasks in between meetings. He noted that NASA could provide hosting for any subgroup as needed.

Dr. Hermann noted that the Board had been assigned four additional tasks; how were these to be assigned? Dr. Schlesinger responded that there was not time to do so at the present.

Mr. Miller said the minutes of the meeting would be sent out for review; pertinent news clippings would be sent, along with photos from Goddard. The wish, he said, was that Dr. Schlesinger and Dr. Parkinson would brief the EXCOM at its November meeting on any progress made. Mr. Miller advised anticipating the next PNT Advisory Board meeting prior to the next EXCOM meeting in November.

Dr. Schlesinger adjourned the eighth meeting of the PNT Advisory Board at 12:26 p.m.

* * *

Appendix A: National PNT Advisory Board Membership

U.S. Board Members:

- James R. Schlesinger (Chair), MITRE and Barclays Capital
- Bradford Parkinson (Vice Chair), Stanford University
- Dean Brenner, Qualcomm
- Joseph D. Burns, United Airlines
- 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 - Intelligent Systems Group Torrance
- Rajiv Khosla, Colorado State University
- 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

International Representatives:

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

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Appendix B: Attendees

- Barbara Adde NASA
- Ken Alexander Federal Aviation Administration/National Coordination Office
- Dr. Yoaz Bar-SeverNASA Jet Propulsion Laboratory
- Turner Brinton Space News
- Roy Clore U.S. Department of State
- Mike Cohen MITRE
- Robert Crane Department of Homeland Security/National Coordination Office
- Charlie Daniels Overlook Systems
- Dee Ann Davis Inside GNSS
- Seb Deliso Joint Staff
- Kris Ekdahl Akin Gump
- Chris Espinoza Department of Homeland Security, Science and Technology Support
- John Fisher Spectracom Corporation
- Kate Fraser GAMA
- Robert Frazier FAA Spectrum Engineering
- Robert Gessin NCD
- Knut Arne Gjetsen Norwegian Mapping Authority
- Phil Goldstein Fierce Wireless
- Scott Grantham OSD
- Tone Hertzberg Ministry of the Environment, Norway
- Larry Hothem USG/DOI
- Jason Kim Department of Commerce
- Paul Kirby TR Daily
- Jim Kirkland Trimble Navigation
- Oddgeir Kristiansen Norwegian Mapping Authority
- Dr. John LaBrecque NASA HQ
- Roland Lejeune MITRE

- Kirk Lewis — Institute for Defense Analysis
- N. V. Laningham — U.S. Department of State
- Chopo Ma — NASA GSFC
- Catherine Majauskas — Federal Aviation Administration
- Stephen Malys — National Geospatial-Intelligence Agency
- Harold Martin — United States Air Force
- Jules McNeff — OASD(NII)OSTI
- Amy Mehlman — Consultant
- James. J. Mille — NASA, PNT Advisory Board Executive Director
- Steve Moran — Raytheon
- Ed Morris — ITT GS
- Dave Olsen — Federal Aviation Administration
- Dr. A.J. Oria — NASA / Overlook Systems Technologies, Inc.
- Ron Peck S — ELEX System Integration
- Milo Robinson — National Coordination Office
- Tony Russo — National Coordination Office
- Les Schroeppel — SAIC/Federal Aviation Administration
- Any Schutz — Wall Street Journal
- Todd Shields — Bloomberg News
- Hank Skalski — Department of Transportation/RITA
- Karen Van Dyke — Department of Transportation/RITA
- Stephanie Wan — NASA/ARTES
- Graham Warwick — Aviation Week
- Frank Weiss — NASA Jet Propulsion Laboratory

(Four additional signatures were not legible)

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Appendix C: Presentations

Space-Based PNT: Update on Executive Committee Activities
Anthony J. Russo, director
National Coordination Office

GPS Status and Modernization
Col. Harold "Stormy" Martin
PNT Command Lead AFSPC A3P

National PNT Architecture
Karen Van Dyke
DOT RITA

GPS Interference, Detection and Mitigation
Michael Bergman
PNT Programs
Department of Homeland Security

LightSquared Effects on GPS: Test and Analysis Results
Dean Bunce, co-chair
National PNT Systems Engineering Forum (NPEF)

LightSquared ATCt RFI Assessment
Federal Aviation Administration

U.S. International Diplomatic Initiatives and Opportunities on GNSS Issues
Ray E. Clore
Senior Advisor on GNSS
Office of Space and Advanced Technology, Department of State

International Members

G. Beutler
Astronomical Institute, University of Bern
Switzerland
Member: IAG Executive Committee; IGS Governing Board

Dr. Hiroshi Nishiguchi
Secretary General, Japan GPS Council
Japan

Dr. Refaat M. Rashad
Arab Institute of Navigation,
Egypt

Arve Dimmen
Director, Maritime Safety
Norwegian Coastal Administration
Norway

Ny-Alesund: Norway's High Arctic Contribution to the Advancement of Global Positioning, Navigation & Timing

Knut Arne Gjetsen, Deputy General Director
Norwegian Mapping Authority

Per Erik Opseth, Director, Geodetic Institute
Norwegian Mapping Authority

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Appendix D: Acronyms and Definitions

3G, 4G	Third and Fourth Generation of cellular communications)
AEP	Architecture Evolution Plan
ATC	Air Traffic Control
ATM	Automated Teller Machine
AO	Announcement of Opportunity
APEC	Asia-Pacific Economic Cooperation
C/No	carrier-to-noise ratio
cm	centimeter
COMPASS	Chinese Global Navigation Satellite System
dB	decibel
dBW	decibels relative to one Watt
DHS	Department of Homeland Security
DoD	Department of Defense
DOT	Department of Transportation
E24	GPS Expandable 24 Constellation
eLoran	Enhanced LOng RAnge Navigation
EOP	Earth Orientation Parameters
EU	European Union
EXCOM	National Space-Based PNT Executive Committee
FAA	Federal Aviation Administration
FIG	International Federation of Surveyors
FCC	Federal Communications Commission
Galileo	European Union Global Navigation Satellite System
GBAS	Ground-based Augmentation System
GEO	Geosynchronous Orbit
GEOSAT	Norwegian software package for space geodesy
GGOS	Global Geodetic Observing System
GLONASS	Russian Global Navigation Satellite System
GRACE	Gravity Recovery and Climate Experiment
GSFC	NASA Goddard Space Flight Center
GPS III	GPS Block III
IAG	International Association of Geodesy
ICAO	International Civil Aviation Organization
ICD	Interface Control Document (referred to as Interface Specifications, or 'IS', by the GPS Directorate)
ICeSAT	Ice Cloud and land Elevation Satellite
ICG	International Committee on GNSS
IDM	Interference, Detection, and Mitigation
IGS	International GNSS System
IIF	GPS Block IIF
IIIB, IIIC	GPS Increments 'B' and 'C'
IMO	International Maritime Organization
IOV	In-Orbit Validation
IRT	Independent Review Team
IS	Interface Specifications
JASON	NASA Oceanography mission to monitor global ocean circulation
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
LADO	Launch, Anomaly, and Disposal Operations
MEO	Medium Earth Orbit
MHz	Megahertz
mm	millimeter
MOPS	Minimum Operational Performance Standard
MSS	Mobile Satellite Service
NASA	National Aeronautics and Space Administration
NCO	National Space-based PNT Coordination Office
NextGen	Next Generation Air Traffic Control
NPEF	National PNT Engineering Forum

NUDET	Nuclear Detonation Detection and Reporting system
GAO	Government Accountability Office
GNSS	Global Navigation Satellite System/s
GRACE	Gravity Recovery and Climate Experiment
GRACE FO	GRACE Follow-On
GRASP	Geodetic Reference Antenna in Space
GPS	Global Positioning System
OCX	GPS Modernized Ground Control System
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
QZSS	Japan's Quasi-Zenith Satellite System
PDOP	Position Dilution of Precision
PNT	Positioning, Navigation, and Timing
PDR	Preliminary Design Review
RFI	Radio Frequency Interference
RTCA	RTCA, Inc. (formerly Radio Technical Commission for Aeronautics)
S/A	Selective Availability
SAR	Search and Rescue
SBAS	Space-Based Augmentation System
SETS	Spectrum Engineering Tracking System
SLR	Satellite Laser Ranging
VLBI	Very Long Baseline Interferometry

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