



SPACE-BASED POSITIONING
NAVIGATION & TIMING
NATIONAL ADVISORY BOARD

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

Thirteenth Meeting

June 3-4, 2014

The Omni Shoreham Hotel
2500 Calvert Street
Washington, DC 20008

Bradford W. Parkinson
Acting Chair

James J. Miller
Executive Director

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**SPACE-BASED POSITIONING
NAVIGATION & TIMING**
NATIONAL ADVISORY BOARD

**Thirteenth Meeting Agenda
June 3-4, 2014**

The Omni Shoreham Hotel, Empire Ballroom
2500 Calvert St NW (at Connecticut Ave.)
Washington, DC 20008
Metro: Red Line to Woodley Park/Zoo Metro

Tuesday, June 3, 2014

8:30 – 8:40	BOARD CONVENES <i>Call to Order & Announcements</i>	Mr. James J. Miller, <i>PNT Advisory Board Executive Director, NASA Headquarters</i>
8:40 – 9:10	Opening Remarks & Introductions <i>Remembrance of our PNT Board Chair, Dr. James R. Schlesinger</i>	Dr. Bradford Parkinson, (<i>Acting Chair</i>), Mr. Marty Faga & Gov Jim Geringer – (<i>other members at their discretion</i>)
9:10 – 10:00	Brief Overview: PNT Board Work Plan & Objectives <u>Working Group 1: Assured Availability</u> <ul style="list-style-type: none"> • Protect the Clear and Truthful Reception <ul style="list-style-type: none"> ○ 1.1 Spectrum Allocation Assurance (Spectrum Sub) • Toughen User's Receivers <ul style="list-style-type: none"> ○ 1.2 All GNSS Signal Receivers (International Sub) • Augment or substitute PNT sources <ul style="list-style-type: none"> ○ 1.3 Non-GPS PNT (International Sub) <u>Working Group 2: Affordability of PNT</u> <u>Working Group 3: Economic Value of PNT</u> <ul style="list-style-type: none"> • 3.1 Spectrum Denial – Economic Impact (Spectrum Sub) 	Dr. Bradford Parkinson & WG Team Leads: <ul style="list-style-type: none"> ■ Ms. Ciganer & Mr. Hatch ■ Dr. Betz & Dr. Enge ■ Mr. Higgins & Mr. McGurn ■ Admiral Allen & Dr. Axelrad ■ Gov Geringer
10:00 – 10:30	GPS Modernization Activities & Program Plans <i>System, Signals, and Emerging Services</i>	Lt. Col. Brian Bailey, <i>GPS Deputy Chief Engineer, GPS Directorate, U.S. Air Force</i>
10:30 – 10:45	BREAK	
10:45 – 11:00	Update from National Coordination Office for Space-Based PNT <i>Proposed GPS Economic Assessment Follow On Activities</i>	Mr. Jason Kim, <i>Senior Advisor, National Coordination Office for Space-Based PNT</i>
11:00 – 11:20	U.S. Department of Transportation (DOT) GPS/PNT Update <i>CNAV Activation and Civil Signal Monitoring Plans</i>	Ms. Karen Van Dyke, <i>Director for PNT, DOT OST Research and Technology</i>
11:20 – 11:40	United States GNSS International Engagement <i>Highlights of Bi-laterals and the Multi-Lateral UN ICG</i>	Mr. Kenneth Hodgkins, <i>Director, Office of Space & Advanced Technology, State Department</i>
11:40 – 12:00	GLONASS & Multi-GNSS in the Intl GNSS Service (IGS) <i>The Lessons to be Learned from Service Disruptions</i>	Dr. Gerhard Beutler, <i>PNT Board Member, Astronomical Institute, University of Bern</i>
12:00 – 1:00	LUNCH	
1:00 – 1:30	Strategies for Limiting Civil Interference Effects <i>...And Why Civil Receivers Need to Have Jamming Meters</i>	Mr. Logan Scott, <i>Founder, Logan Scott Communications</i>
1:30 – 2:00	A Proposed European (CEPT) Regulation for RNSS Spectrum <i>Addressing Pseudolites & Indoor Messaging System (IMES)</i>	Dr. Kurt Zimmerman & Mr. Michael Swiek, <i>GPS Innovation Alliance (GPSIA)</i>
2:00 – 2:30	New Technology for PNT Resilience <i>Conquering Hostile Operating Environments</i>	Mr. Nunzio Gambale, <i>CEO, Locata</i>

2:30 – 2:50	Progress Toward Resilient PNT <i>Good News and Bad News</i>	Mr. Dana A. Goward, <i>President & Executive Director, Resilient Nav & Timing Foundation</i>
2:50 – 3:10	Alternative Positioning, Navigation, and Timing (APNT) Update <i>Aviation Solutions for Challenging Scenarios</i>	Ms. Deborah Lawrence, <i>Program Manager for Navigation, Federal Aviation Administration</i>
3:10 – 3:30	Latest on Global eLORAN Infrastructure Evolution <i>GNSS Back Up and Then Some...</i>	Mr. Mitch Narins, <i>Chief Systems Engineer for Navigation, Federal Aviation Administration</i>
3:30 – 3:45	BREAK	
3:45 – 4:00	Implementing GPS/GNSS Tsunami Warning Systems <i>Saving Lives, Infrastructure & Big Bucks Through Proactive Alerts</i>	Dr. Craig Dobson, <i>Program Scientist, Science Mission Directorate (SMD), NASA Headquarters</i>
4:00 – 4:15	GPS/GNSS Search and Rescue (SAR) U.S. & Intl. Developments <i>Emerging Medium Earth Orbit (MEO) SAR Applications</i>	Dr. Lisa Mazzuca, <i>Search & Rescue Mission Manager, NASA</i>
4:15 – 4:30	Demonstrating the Deep Space Atomic Clock (DSAC) <i>Potential Value & Performance Upgrades for Space Platforms</i>	Dr. Todd Ely, <i>Principal Investigator, DSAC, JPL/NASA</i>
4:30	ADJOURNMENT	

Wednesday, June 4, 2014

9:00 – 9:05	BOARD CONVENES <i>Call to Order</i>	Mr. James J. Miller, <i>PNT Advisory Board Executive Director, NASA Headquarters</i>
9:05 – 9:15	Announcements & Agenda <i>Quick Thoughts & Guidance from June 3 Presentations/Discussions</i>	Dr. Bradford Parkinson, (<i>Acting Chair</i>), Mr. Marty Faga & Gov Jim Geringer
9:15 – 9:45	Protecting U.S. Critical Infrastructure from PNT Disruptions <i>Sector Prioritizations & Focus – Electric, Power, Telecom & more</i>	Ms. Sarah Mahmood, <i>Department of Homeland Security (DHS) Science & Technology</i>
9:45 – 10:45	International Member Regional Updates & Perspectives <ul style="list-style-type: none"> ▪ Dr. Gerhard Beutler ▪ Dr. Elizabeth Cannon ▪ Mr. Arve Dimmen ▪ Mr. Matt Higgins ▪ Dr. Hiroshi Nishiguchi ▪ Dr. Rafaat Rashad 	(<i>at member's discretion</i>) <i>Switzerland</i> <i>Canada</i> <i>Norway</i> <i>Australia</i> <i>Japan</i> <i>Egypt</i>
10:45 – 11:00	BREAK	
11:00 – 12:00	PNT Board WG Recommendation Development <u>Working Group 1: Assured Availability</u> <ul style="list-style-type: none"> • <i>Protect</i> the Clear and Truthful Reception <ul style="list-style-type: none"> ○ 1.1 Spectrum Allocation Assurance (Spectrum Sub) • <i>Toughen</i> User's Receivers <ul style="list-style-type: none"> ○ 1.2 All GNSS Signal Receivers (International Sub) • <i>Augment</i> or substitute PNT sources <ul style="list-style-type: none"> ○ 1.3 Non-GPS PNT (International Sub) <u>Working Group 2: Affordability of PNT</u> <u>Working Group 3: Economic Value of PNT</u> 3.1 Spectrum Denial – Economic Impact (Spectrum Sub)	Dr. Bradford Parkinson & WG Team Leads: <ul style="list-style-type: none"> ■ Ms. Ciganer & Mr. Hatch ■ Dr. Betz & Dr. Enge ■ Mr. Higgins & Mr. McGurn ■ Admiral Allen & Dr. Axelrad ■ Gov Geringer
12:00 – 1:00	WORKING LUNCH	
1:00	ADJOURNMENT	

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

The Tuesday, June 3, 2014 session convened at 8:30 a.m.

BOARD CONVENES

*Mr. J.J. Miller, Executive Director, PNT Advisory Board
National Aeronautics and Space Administration (NASA) Headquarters*

Mr. J.J. Miller welcomed all to the 13th meeting of the Positioning, Navigation, and Timing (PNT) Advisory Board. The Board was established in 2007. With this meeting many Board members mark over five years of service, although the biggest change has been the loss of Dr. James R. Schlesinger, founding Chair of the Advisory Board, who passed away on March 27, 2014. Mr. Miller said that while growing up he had watched Dr. Schlesinger on television as Secretary of Energy and Secretary Defense, and thought of him being “very cool and calm.” Working with Dr. Schlesinger had shown this was indeed the case. The Advisory Board will continue the good work Dr. Schlesinger set in motion. It has become “best practices” in providing citizens with a voice in federal PNT policymaking. That both GLONASS and Galileo have established similar bodies supports this statement. Under Dr. Schlesinger’s leadership, the Advisory Board has made a number of recommendations for system improvements that have been implemented, among them its long advocacy for placing laser retro-reflector arrays on Global Positioning System (GPS) satellites was approved in August 2013. Mr. Miller then presented an Institute of Navigation (ION) Award to Dr. Bradford Parkinson, Gen Kirk Lewis and Dr. Scott Pace. Next, Mr. Miller expressed thanks to Maj Gen Martin Whelan and presented a recognition plaque from NASA.

Mr. Miller explained that the Tuesday session would focus on reports from the Advisory Board Work Groups and other pertinent presentations. The goal is to establish a set of recommendations by adjournment. The meeting is held under the Federal Advisory Committee Act (FACA) and, therefore, all comments are on the record; formal minutes will be taken, with meeting minutes and all briefings posted on the www.gps.gov.

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OPENING REMARKS

*Dr. Bradford Parkinson, Acting Chair
PNT Advisory Board*

Dr. Bradford Parkinson said the meeting would pause for a remembrance of Dr. Schlesinger, who was “boots on to the end.” Right up until the final month of his life, Dr. Schlesinger had been as sharp as he’d always known him. Dr. Schlesinger’s government service included being Director of the Central Intelligence Agency, Secretary of Defense under Presidents Nixon and Ford; and the first Secretary of Energy under President Carter. In all these positions, Dr. Schlesinger “set high standards and left his mark.” Dr. Schlesinger also chaired the 1995 national study on “The Global Positioning Systems: Charting the Future.” In 2007, NASA Administrator Michael Griffin appointed him first Chair of the PNT Advisory Board, a position he held until his death. During Dr. Schlesinger’s tenure Advisory Board accomplished the removal of Selective Availability from GPS Block III; persuaded the Department of Defense to modify GPS Block IIR satellites to Block IIR(M); and led opposition to a major threat to GPS spectrum from mobile satellite service terrestrial broadcasts in the adjacent frequency band.

Mr. Martin Faga said he had known Dr. Schlesinger since the 1980s. While Dr. Schlesinger retired from government service at age 50, he spent the remaining 35 years in significant government advisory roles.

Mr. Faga recalled working with Dr. Schlesinger at the MITRE Corporation. At the time, Dr. Schlesinger was skeptical of new technologies. One day, he asked him when the first dynamo was built, information Dr. Schlesinger wanted for a speech. Two minutes later, he returned with the answer. When Dr. Schlesinger queried on his promptness, Mr. Faga said the information came from the Internet. Dr. Schlesinger expressed skepticism about the Internet’s reliability. Mr. Faga said he had used the Internet to secure the information from the National Institute of Standards and Technology (NIST). Pointing to his own computer, Dr. Schlesinger said, “You’d better come here and show me how you did that.” Mr. Faga also noted that at MITRE

Dr. Schlesinger's whereabouts were often unknown. Once, he called Dr. Schlesinger's office only to learn he had left for England. Dr. Schlesinger also resisted obtaining a cell phone. Then, one day, the "broken down" car he drove broke down in "the middle of nowhere." When Dr. Schlesinger returned to his office, he asked, "Where can I get a cell phone?" Finally, few people knew how much Dr. Schlesinger enjoyed his grandchildren, of which, being the father of eight, he had a considerable number. If any family members were visiting, it was "a different Jim" when Mr. Faga went over to the house to pick him up.

Mr. Kirk Lewis said he first worked with Dr. Schlesinger when the Department of Defense (DoD) and Department of Transportation (DOT) were in conflict over the GPS civilian signals. Dr. Bradford Parkinson was appointed to head a review team to determine a technical solution. This did not, however, address the institutional politics aspect. Dr. Schlesinger believed progress came "one brick at a time," and that the next "brick" was getting the L2C and L5 signals into use. This, Dr. Schlesinger said, would be an accomplishment for the nation. However, no one at the Pentagon wished to spend the money required. Dr. John Hamre, then Deputy Secretary of Defense, convened a high-level meeting at which the modifications being sought were discussed. At that meeting, Dr. Hamre said the modifications were risky and costly. The Secretary of the Air Force said he was unwilling to spend the funds. Dr. Schlesinger then suggested withholding judgment until the discussion was completed. Mr. Lewis recalled Dr. Schlesinger commenting that a lesson he had learned from Admiral Hyman Rickover was that "you can always beat the current system with good slides." The critical slide presented current operations, which included two GPS Block IIR satellites both of which were already exceeding expectations. Dr. Schlesinger asked how it could be riskier to modify twelve additional IIRs than to launch them on a new launch vehicle. This settled the argument. Mr. Lewis added that it was Dr. Schlesinger's characteristic continual involvement at critical points that pushed the development forward.

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BRIEF OVERVIEW: PNT ADVISORY BOARD WORK PLAN AND OBJECTIVES

Dr. Bradford Parkinson and the Working Group Team Leaders

Dr. Parkinson opened the discussion by quoting a high-level federal official, who said "GPS is much too vulnerable; so we must replace it with new inertial sensors and chip-scale atomic clocks." Dr. Parkinson believed three actions are needed to address this: (1) protect the clear and truthful signal; (2) toughen user receivers; and (3) augment or substitute PNT sources. Currently no single U.S. or international entity has responsibility for this range of tasks. Therefore, the Advisory Board has to "nibble" at the problem. Dr. Parkinson asked each Working Groups to present a succinct summary of what was pertinent, important and urgent in its area, along with recommendations that had reasonable chance of acceptance.

Working Group 1 -- Assured Availability -- Protect the Clear and Truthful Reception of Radionavigation Signals

1.1) Spectrum Allocation Assurance Overview

Ms. Ann Ciganer, Mr. Ronald Hatch -- Team Leads

Mr. Hatch explained that the group places highest priority on enforcing existing treaties. The GPS Innovation Alliance would be making a presentation on a spectrum interference issue arising from pending regulatory actions of the European Conference of Postal and Telecommunications Administrations (CEPT). Also, a presentation from Mr. Logan Scott would focus on how to limit, detect and locate Global Navigation Satellite System (GNSS) jammers. Finally, Ms. Ciganer would present the working group's recommendations.

Mr. Hatch explained that the "battle" between GNSS and broadband continues. There are substantial differences between the underlying physics. He presented a five-by-five grid in which nine different spectrum risks were individually assessed for likelihood (vertical axis) and severity of consequence (horizontal axis). Of these, the group had focused on Japan's Indoor Messaging System (IMES) and the proposed introduction of in-band pseudolites in the European Union.

Ms. Ciganer's described the working groups three recommendations:

- The first recommendation is to urge GNSS providers to work with existing regulatory bodies to prevent harmful interference. The International Telecommunications Union (ITU) has regulations that define what constitutes harmful interference to the Radio Navigation Satellite Service (RNSS) and the safety-of-life Aeronautical RNSS (ARNSS). Individual member states are organized into regional conferences. These conferences have enforcement powers that enable the ITU to develop the language for such protections.
- The second recommendation is to increase awareness of the importance of this task among those who enforced the regulations. The ITU has mechanisms that allow different groups to liaison with each other. The ITU could develop improved enforcement measures by coordinating cooperation between these groups.
- The third recommendation is that stronger penalties are needed, not merely for jamming but also for the possession of a jamming device. Furthermore, unlicensed import and export of jamming devices should be banned.

Dr. Parkinson commented that technical people might regard the foregoing as mundane. It is extremely important, however, to go through “whatever hoops” are required to assist these organizations in knowing how to strengthen PNT.

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1.2) Toughen Users’ Receivers

Dr. John Betz; Dr. Per Enge -- Team Leads

Dr. Betz began by explaining the difference between “toughen” and “augment.” To toughen is to increase a receiver’s ability to reject or ignore contaminated or invalid inputs. Such inputs include interference, invalid satellite signals, spoofing, and solar flares. The subgroup had an excellent session on the previous day, including a presentation by MITRE on steps being taken in to toughen aviation receivers. The hope is for the multi-constellation aviation Minimum Operational Performance Standards (MOPS) to be completed by 2018. This should help toughen the system. Another excellent presentation was made on GPS’ ability to operate through the recent GLONASS irregular operation ‘event’ on April 1-2, 2014. Finally, the Defense Advanced Research Projects Agency (DARPA) made an initial presentation on PNT technology development, with emphasis on high quality clocks.

Threat models should not be limited to current threats, but also include threats that can be reasonably anticipated. Many people still underestimate the hazards of jamming and, therefore, question whether the investments to counter them are worthwhile. Better threat models are needed, in particular for applications such as aviation where there is a high cost and long time period to introduce upgraded systems. Also, legacy avionics systems can last for decades.

Consumer receivers face two issues: they must be designed for urban and indoor use; and their capabilities are restricted by the costs of the components that increase those capabilities.

In terms of critical infrastructure, GPS is “an invisible ubiquity” to all critical infrastructures. Clarity is lacking as to who is responsible for toughening the critical infrastructure.

Therefore, it is recommended that:

- Better threat models should be developed, including a reasonable extrapolation for the future.
- Regarding consumer products, while new systems bring long-term performance improvements, they also present new problems in the short-term. This could be addressed, in part, through use of multiple sources.
- Increase awareness, among receiver designers, on “bad actors” such as spoofers and jammers. In contrast, there is high level of attention on cyber threats. Most published articles on spoofing and jamming come from non-U.S. sources.
- Export restrictions should be reviewed so U.S. manufacturers have better access to overseas markets.

Dr. Parkinson noted the Advisory Board will review the highlights and recommendations from each group on Wednesday. It was important to be clear to whom these recommendations should go.

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1.3) Augment or Substitute PNT Sources
Mr. Terence McGurn -- Co-Team Lead

Mr. McGurn noted that the highest priority should be to improve service to the user. The user is generally indifferent to the signal source, provided it is available, consistent, timely and economical. One could look at augmentation in terms of GPS, or in terms of augmenting any short-term replacement to GPS. Various augmentation systems, both ground-based and space-based, already exist. Differential systems have made valuable contributions to agriculture, in particular when weather conditions such as heavy rains reduce the time available to sow crops like cotton.

Dr. Parkinson cited a *Wall Street Journal* report that GPS has made it possible to plant 30 percent of the nation's corn crop in just seven days.

Next, Mr. McGurn addressed new global and regional navigation and augmentation systems. The question is if, and how, resources from other GNSS systems may be used. The Russian GLONASS system had a severe problem this year. If the U.S. makes use of other GNSS systems it must do so carefully. In circumstances of restricted visibility, having access to 100 GNSS interoperable satellites is much better than access to only 30 GPS satellites. The Quasi-Zenith Satellite System (QZSS) is well-suited to a country like Japan with densely-located tall buildings. India recently launched the first two of an eventual eight satellites regional navigation satellite system.

Mr. McGurn then discussed candidate non-GNSS –based systems:

- For the fixed user, timing is generally critical. Fiber optics is a viable candidate that, once laid underground, is secure against interference. Fiber optics, however, might not be sufficiently precise for worldwide financial operations.
- More precise clocks are always useful. For the mobile user position and navigation are central criteria. For such users there are three potential augmentation paths: (1) Enhanced Loran (eLoran), which despite setbacks is still an option; (2) inertial systems, which can ‘flywheel’ through a short-term GPS disruptions (although with inertial systems quality is a function of cost); and (3) local systems, such as Locata and pseudolites. Each alternative raises questions. Use of GNSS systems not under U.S. control requires full transparency of operation. Their use requires reliable performance specifications and assured monitoring that the specifications are being met. This leads back to full transparency. Among the non-GNSS alternatives, eLoran provides somewhat reduced performance specifications and requires a more extensive infrastructure. With inertial systems, accuracy is a function of time of operation and quality is a function of cost.

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Working Group 2: Affordability of PNT

Adm. Thad Allen; Dr. Penina Axelrad, co-leads

Adm. Allen explained that the discussion on affordability is not as advanced as that in other areas. The subgroup began by “laying some bricks” on the subject. Affordability is at the intersection of requirements and resources. Moving the discussion forward requires establishing transparency and definitions. Existing guidelines need to be aggregated. The basic requirement is the DoD requirement. Beyond that, one looks at what one could afford. GPS is the PNT system of ‘first-use’ in the United States. Potential GPS affordability concepts include meeting only minimum requirements and reducing per satellite cost, either through dual launch or by eliminating non-GPS-requirements. The cost of user equipment could be reduced by leveraging developments in the civil sector. The costs of control/operations could also be reduced by the greater use of non-military contractors.

Dr. Axelrad noted that attention has been directed toward concepts for civil/commercial GPS affordability. Three areas include:

- Enhance GPS capabilities with space-borne augmentations, either commercial or civil. This offers entrepreneurial opportunities.
- Augment the core GPS constellation, perhaps through extended operation of residual GPS satellites.
- Use augmentation systems, either commercial operations or by leveraging commercial and international monitoring sites.

Dr. Axelrad reiterated that discussions are still in an early stage. The “next steps” the subgroup proposed reflected this. The first is to identify the total cost, operating costs included, of “baseline” GPS. “Baseline” is defined as that system that meets Air Force, National Geospatial-Intelligence Agency, and other intelligence and DoD requirements. Second, figures are needed on total government expenditures on auxiliary augmentation. Third, previous DoD studies on cost reduction need to be reviewed. Fourth, attention should be focused on generating concepts for reducing both required and possible enhanced capabilities.

Adm. Allen added that his subgroup regards this as the 1.0 version and welcomes comments from others.

Dr. Parkinson said that “affordability” is the toughest task. It is difficult to arrive at a starting point definition of what affordability means. One has to first make assumptions and then judge whether the boundary requirements for these assumptions are hard or soft. This is necessary so one can determine how requirements may be traded against each other.

Adm. Allen noted that this leads directly into governance issues. Complicating this, there is no single existing office that can provide answers to all questions that arise.

Dr. Parkinson noted the requirements process is a continuing issue. Questions include: How long does one have to meet a given requirement? What are the consequences of exceeding a requirement? GPS has vastly exceeded the requirements established when the program was launched. Therefore, “messing around with” the requirements process belongs in the “too hard” box. He has long been concerned that when one investigates a given requirement, one cannot readily determine who established it or whether they still regard it as germane.

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Working Group 3: Economic Value of GPS

Gov. James Geringer, Team Lead

Gov. James Geringer explained that the economic subgroup articulated its task as follows: review existing studies; assess the benefits and impacts of Mobile Satellite Services (MSS) band reallocation; request user and manufacturer views on the potential impact of such reallocation, and consider the impact of the timing of any reallocation. The subgroup is expected to complete this work in the next six months. The Department of Commerce (DOC) will also coordinate an interagency team in consultation with the Advisory Board to develop an approach leading to an updated and authoritative GPS economic benefits assessment. The DOC has experience in undertaking such analysis.

Next steps include: (1) draft a statement of work that draws on scoping the contributions of the Advisory Board; and (2) form an interagency team, to be coordinated by the National Coordination Office (NCO), to seek study inputs.

Previous briefings focused on assuring continued GPS availability. Major actions urged by the Advisory Board -- the removal of S/A; the battle against spectrum encroachment -- are also directed at maintaining GPS’ economic value. Now the potential for conflict with CEPT regarding pseudolites, and the continued concern about jamming and spoofing, also pose threats to GPS’ economic value. Behind this discussion is the continuing issue of what impacts would occur should GPS ceased to be available.

There are several assumptions behind this effort: first, the DOC would lead the economic study; second, the study will include public safety and loss of life issues; and, third, interagency participation and cooperation will take place. On spectrum allocation, the subgroup will seek the thoughts of the full Advisory Board, including the existence, interruption, or non-existence of GPS and impacts in the long-term, intermediate-term, and short-term. The longest-term impacts are those that would occur should GPS

have never existed. Assessing short-term impacts will help address various risk issues, including national security. Intermediate-term impacts follow from an interruption lasting months or years, such as the consequences of power station transformers being damaged.

Those familiar with GPS know its benefits are huge, but this knowledge is more intuitive than empirical. Better documentation is needed. GPS benefits are expected to increase. New and more widely used applications are coming into play. New and improved signals will add further benefits. Incorporation of other GNSS systems will increase signal availability. However, people often don't realize that GPS, for example, enables decision-making software that facilitates better decisions by individuals and corporate boardrooms.

Most studies of GPS' economic impact focus on manufacturing and its related workforce. However, GPS' most important economic impact is that it enables things otherwise not possible. In some areas, such as agriculture, the impact is enormous. The main focus of the study, therefore, should be on the economic value of productivity and cost savings derived from GPS use.

No study can produce a precise answer because adequate supporting data does not exist. However, a concerted effort is needed to present as exact a figure as possible. Any resulting statement needs to be phrased simply, repeated often, and provide a story to tell.

In closing, Gov. Geringer noted comments from two international members, Dr. Nishiguchi and Dr. Cannon. Dr. Nishiguchi said one must look beyond the economic questions. How does one place a dollar value on U.S. leadership, or on the Internet, which is dependent on GPS for its clock function? GPS is the world's only common clock. Gov. Geringer asked Dr. Nishiguchi if he had summarized his comments appropriately.

Dr. Nishiguchi said the summary is good.

Dr. Parkinson expressed satisfaction that Dr. Nishiguchi is taking a higher view of this issue.

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GPS MODERNIZATION ACTIVITIES AND PROGRAM PLANS

Lt Col Brian Bailey, GPS Deputy Chief Engineer

GPS Directorate, U.S. Air Force

Dr. Parkinson introduced Maj Gen Martin Whelan, "a true friend" of PNT who after working directly with the Advisory Board for over four years is moving from Colorado to Washington D.C., and his new assignment at the Pentagon.

Maj Gen Whelan expressed satisfaction over his many years interacting with the Advisory Board, and then introduced Lt Col Brian Bailey.

Lt Col Bailey said his report would focus on current GPS modernization programs and the challenges faced, including spectrum issues. Currently 30 satellites are set as "healthy" and five in residual status. GPS-IIF-6 was successfully launched on May 16, 2014. Agreements exist with 57 international customers, and GPS has over two billion users worldwide. GPS remains the world standard, a status continually held since December 1993. The best User Range Error (URE) performance was 46.6 cm on June 8, 2013.

Dr. Parkinson asked if this is a global average for all satellites.

Lt Col Bailey said it was.

Dr. Parkinson commented that this is truly impressive.

Lt Col Bailey added that the URE figure does not include effects from augmentation systems. Further URE improvements can be expected as the Block IIF continues to replace older satellites.

Lt Col Bailey presented a chart showing the continuous increase in signal accuracy since 2001. It should be noted that URE describes the signal in space and, thus, additional errors occur within the user equipment.

The production of GPS Block III satellites has begun. They will carry a fourth civil signal (L1C) and provide a four-fold improvement in URE compared to Block IIF satellites. GPS III will offer increased availability, increased integrity and a 15-year design life -- the longest yet achieved. Continuous broadcasting of L2C and L5 began April 28, 2014. L2C is currently set as "healthy" and L5 (safety-of-life signal) is set as "unhealthy." These settings will remain until further signal verification occurs. GPS III satellites carry three improved Rubidium atomic clocks. Contracts for GPS-III-SV7 and GPS-III-SV8 were awarded March 31, 2014.

Lt Col Bailey then discussed the ground segment. There has been progress in addressing cyber threats. The Next Generation Operational Control System (OCX) Block 1 will support transition from the current Operational Control System (OCS) in 2017.

Spectrum allocation and spectrum sharing issues currently constitute the largest share of concerns the program office is facing. Spectrum use and allocation is the core that enables everything the system does or could do. There is strong international pressure to reallocate, or share, L-Band spectrum for mobile services. The program office is currently supporting the GPS Adjacent Band Capability study by contributing representative receiver hardware for interference modeling scenarios, and providing subject matter experts.

Significant progress is also being made on M-Code and current GPS segments. Work continues with both domestic and international partners to protect the interests of GPS users worldwide.

Dr. Parkinson said M-Code is essential to military users. He and others are anxious for operators to make greater progress in marketing M-Code receivers. M-Code is likely to be the system of use for operational forces in future conflicts.

Ms. Neilan called attention to a backup slide on Adjacent Band Compatibility showing the L-Band sectioned by user. She asked whether Lt Col Bailey has a rough idea where L-Band spectrum could be released.

Lt Col Bailey said the entire band is being reviewed.

Ms. Neilan noted in the slide that a portion of the band is designated as "mobile."

Lt Col Bailey said some bands are currently shared because valuable spectrum is occupied by telemetry. The Secretary of Defense has requested a study on the feasibility of moving it elsewhere in the band.

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UPDATE FROM THE NATIONAL COORDINATION OFFICE FOR SPACE-BASED PNT

Mr. Jason Kim, *Senior Advisor*

National Coordination Office for Space-Based PNT

Mr. Jason Kim briefed on latest developments at the NCO. The PNT Executive Committee (EXCOM) has new co-chairs: Mr. Robert Work, Deputy Secretary of Defense; and Mr. Victor Mendez, Acting Deputy Secretary of Transportation. The March 14, 2014 PNT EXCOM meeting assigned the DOC to lead an interagency team to undertake the next phase of the GPS economic assessment. The Advisory Board's activities to-date in this area is the first phase of this assessment. The objective is to develop a credible and appropriately-sourced document. An appropriate funding source for hiring consultants needs to be identified, and this will require a Statement of Work (SOW). The NCO will also facilitate the interagency team to ensure the report is supported by all parties and can be presented to the public with confidence.

Dr. Parkinson said such a product entails “a long journey,” and asked for the target date for hiring the economist.

Mr. Kim said the hiring would likely come prior to the close of the current fiscal year.

Mr. Kim continued explaining how the previous day’s subgroup discussion focused on special applications of GPS. Some economic data is available in those areas, but no serious study has yet been made on the far more numerous consumer devices that rely on GPS and how they benefit the economy. It is true that one does not buy a smartphone because of GPS, but nonetheless the device requires GPS. For example, Google has issued a statement about the miles and fuel savings associated with crowd-sourcing. This is an example of things not previously studied that would be included in the next phase.

Gov. Geringer asked Mr. Kim to expand on an earlier comment on whether GPS should be classed as part of the critical infrastructure.

Mr. Kim said the Department of Homeland Security (DHS) has done considerable work with the critical infrastructure sectors to make them aware of their GPS vulnerabilities and encourage building backup systems. The economic study will leverage such data from DHS. The 2004 policy statement describes GPS as a critical component of multiple infrastructures, but this is “as far as we could get” regarding the system designation for GPS.

Mr. Crane noted that GPS’ importance is generally recognized. However, most critical infrastructures are privately owned and it may need to submit GPS to the same review process other sectors have undergone to become part of the National Infrastructure Protection Plan (NIPP).

Gov. Geringer said that the mere fact that an economic assessment is being undertaken suggests widespread doubt whether GPS is highly important when competing for spectrum resources. How can the criticality of GPS be assured when it is not designated as critical?

Mr. Kim said that the EXCOM, in part, considers the economic study to be a “pushback” against pressure from the broadband bid to compete for RNSS spectrum. At the same time, public education is needed on how GPS constitutes a “hidden infrastructure.” Great public confusion exists. For example, the NCO has received numerous emails from persons thinking the NCO is a supplier of street addresses and directional information.

Dr. Parkinson said that, unlike many designated critical infrastructures, GPS is a government-provided service. However, as so many critical infrastructures depend on it, he hopes DHS will approach the issue of GPS’s status with an open mind.

Mr. Crane commented that by the same logic one could declare the Interstate highway system a critical infrastructure.

Mr. Kim continued explaining that the NCO is waiting on the appointment of a new director. A new Deputy Director is expected by August. Other developments include: the implications of language in the National Defense Authorization Act for Fiscal Year 2014 that places limits on the construction on U.S. soil of foreign GNSS ground monitoring stations; and the reform of satellite export controls. This reform means that most commercial satellites and related components are relocated from the U.S. munitions list to the DOC control list. This will considerably reduce compliance issues as items on the DOC list are eligible for export-license exemptions to 36 U.S.-friendly nations. This will greatly aid the U.S. space industry.

Dr. Parkinson noted that the best thing done for the development of European atomic-clock industry was the U.S. refusal to export U.S.-built rubidium clocks for Galileo.

Mr. Kim said that another important issue is that of on-going discussions on GPS spectrum.

Mr. Crane brought up the June 20, 2014, FCC-sponsored workshop to discuss GPS and GPS Receiver Standards.

Dr. Parkinson said he hoped to cast a wide net and involve U.S. manufacturers.

Mr. Miller expressed concern about the workshop should the FCC attempt to dictate how future GPS receivers should be built. Thus far, FCC has directed attention to managing spectrum allocation and transmission and, thus, the Advisory Board should be wary of the FCC undertaking design standards for GPS equipment manufacturers.

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U.S. DEPARTMENT OF TRANSPORTATION GPS/PNT UPDATE

Ms. Karen Van Dyke, *Director for PNT*
DOT OST Research and Technology

Ms. Karen Van Dyke noted that her previous affiliation, Research and Innovative Technology Administration, no longer exists and its responsibilities have been moved to the DOT Office of the Secretary of Transportation (OST) under Research and Technology. This organization is responsible for hiring the next NCO director. At this time a Director has been chosen but they are not at liberty to reveal the name. The new appointment is expected within six weeks.

Ms. Van Dyke said her briefing would be on two topics: first, the early implementation of the civil navigation message (CNAV) on the L2C and L5 signals; and, second, current plans for civil signal monitoring. As noted in earlier briefing, L2C and L5 began pre-operational CNAV broadcasting on April 28, 2014, with L2C set as “healthy” and L5 set as “unhealthy.” The latter is a “use at your own risk” designation, that is, it should not be used for safety-of-life or other critical applications. Ms. Van Dyke thanked Maj Gen Martin Whelan and Gen Robert Wheeler for their leadership on the issue.

Initial CNAV testing occurred in June 2013. The process was conducted in a transparent manner and multiple communities were involved. The tests went well but a number of issues were revealed. This underscores the importance of signal monitoring. One concern was that only eight of the fifteen CNAV message types were tested, and another concern was the lack of published performance standards for the two new civil signals. This led to creation of a “CNAV Tiger Team” in December 2013. A Federal Register Notice (FRN) was issued in March 2014, requesting comment. Only six comments were received, which is insufficient to be regarded as representative. No new risks were cited in these comments. The Tiger Team identified the following open items: first, conduct testing of the remaining untested CNAV message types; second, update SPS performance standards; and third, implement signal monitoring capability. Based on the Tiger Team’s briefing, the Executive Steering Group (ESG) co-chairs made the following recommendations: first to set L2C as “healthy” and leave L5 as “unhealthy” until signal monitoring has been completed; second to work to ensure awareness of the L5 signal’s “use at our own risk” status; and third to retain the Tiger Team to monitor progress on CNAV implementation and address issues that may rise.

Mr. Murphy expressed confusion as to why L5 was designated as “unhealthy.” This might prompt the user community to ignore L5. Since all GPS signals are already “use at your own risk,” this additional step seems unnecessary.

Ms. Van Dyke said this is necessary because additional signal integrity monitoring is crucial to safety-of-life applications.

Mr. Murphy expressed concern that the “unhealthy” designation could, for example, limit crowd-sourcing as a test method.

Dr. Parkinson suggested that the Advisory Board could review the matter at its next session and possibly make a recommendation.

Ms. Neilan called attention to a scheduled briefing from Dr. Gerhard Beutler on the multi-GNSS experiment. The experiment is currently tracking L5 and would strongly oppose to turning the signal off since it needs the input.

Ms. Van Dyke noted the international community can still use L5 even if set as “unhealthy.”

Ms. Van Dyke then addressed civil service performance monitoring. There are two types of monitoring as required by the Civil Monitoring Performance Specification (CMPS) document of December 2005 (revised in April 2009). The first is real-time

monitoring that allows GPS operators, and the second is reporting on GPS performance levels vs. stated commitments. A civil signal monitoring trade study was conducted earlier in 2014, and it recommended that: dual implementation of OCX and non-OCX elements be pursued and the U. S. Air Force should remain engaged in integrating non-OCX monitoring into GPS operations.

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UNITED STATES GNSS INTERNATIONAL ENGAGEMENT

Mr. Kenneth Hodgkins, *Director*
Office of Space & Advanced Technology
U.S. State Department

Mr. Kenneth Hodgkins restated U.S. national space policy for PNT, which include: provide civil GPS services, free of direct charges; encourage global compatibility and interoperability with GPS; promote transparency; enable market access to U.S. industry, and support international efforts to mitigate harmful interference. U.S. international engagements include working with other nations to maintain radio frequency and spectral separation between the M-Code and other signals; achieving interoperability with other system; and seeking fair competition in global markets through bilateral and multilateral agreements. As examples of bilateral efforts, Russia's request to locate GLONASS ground monitoring stations on U.S. territory remains under review. Also, on May 19, 2014, there was a US-China bilateral meeting where interoperability, service monitoring, interference detection and other issues were discussed. The joint statement for this bilateral meeting is posted at www.GPS.gov.

Dr. Parkinson asked whether the International Committee for GNSS (ICG) has determined what "transparency" means. Does a mechanism exist to report all faults that occur, as well as a projecting the likelihood of recurrence?

Mr. Hodgkins said there have been discussions for greater transparency in signal specifications and making available to manufacturers. However, the capability Dr. Parkinson describes does not yet exist. Present efforts are directed at creating templates for system operation.

Dr. Parkinson said this is a good first step, but it is only a "paper" solution. One can claim anything they wish regarding performance, but we really need agreements that bind GNSS providers into reporting actual operational defects. Perhaps, the Department of State (DOS) could work toward such an objective.

Mr. Hodgkins said that's a good point.

Ms. Neilan reported that the ICG has established the International GNSS Monitoring and Assessment (IGMA) task force to develop a matrix of parameters that need to be monitored. China, Japan, and the IGS chaired the task force. The IGMA will address the issue of who may be qualified to undertake monitoring.

Dr. Parkinson applauded this, but said he remained persuaded that what is needed is a fault reporting system that includes providing an explanation of what has occurred.

Ms. Neilan added that templates have been created for all GNSS providers. This is an important first step towards better transparency. She also chairs the ICG working group on Reference Frames and Timing Applications. The group has recommended that all GNSS providers align their broadcast ephemeris to the International Terrestrial Reference Frame (ITRF), and it a good sign to see that GNSS providers are moving in this direction.

Mr. Hodgkins noted that the November 2013 ICG-8 meeting in Dubai also created task forces on Interference Detection and Mitigation (IDM) and on GNSS Interoperability. The ICG-9 session will be held in Prague on November 2014, and the ICG-10 will take place in the U.S. in 2015.

Mr. Murphy noted that aviation participation in the IGMA would be helpful.

In summary, Mr. Hodgkins said that U.S. policy is directed at encouraging worldwide GPS use while placing priority on promoting compatibility, interoperability and transparency. GPS and the various augmentation systems provide continually improving services while maintaining backward compatibility for existing users. Policy stability, service transparency, and continuous improvement are keys to success.

Dr. Parkinson said that Mr. Hodgkins' work, in particular efforts to improve transparency, are important. Transparency is a precondition towards placing reliance on GNSS systems one does not control.

Mr. Murphy said, regarding an issue with GLONASS service on April 1-2, 2014, that he never received an official announcement on what had happened or why it had happened.

Mr. Hodgkins responded that GPS' emphasis on openness reflects the culture in which it operates. Hopefully all GNSS providers will eventually adopt this openness.

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GLONASS AND MULTI-GNSS IN THE IGS

Dr. Gerhard Beutler, *PNT Board Member*
Astronomical Institute, University of Bern

Dr. Beutler first provided a brief background on the International GNSS Service (IGS), the Multi-GNSS Experiment, and the IGS Real-time Experiment; and then addressed the GLONASS April 1-2, 2014 event.

On April 1, 2014, about half of the GLONASS permanent ground monitoring receivers entirely collapsed. Essentially, the entire network broke down. Out of the 180 receivers used by the Center for Orbit Determination in Europe (CODE) approximately 60 were severely affected. The event began April 1, 2014, at 9 p.m. UTC and ended April 2 at 7 a.m. UTC. IGS received its "wake-up call" at 9:23 a.m., April 3, when the International Association of Geodesy (IAG) President Chris Rizos emailed to ask: "What do you guys know about this? Have you been fielding any questions from media or users?" An hour later, Tim Springer at the ESA Analysis Center emailed to report that "nobody noticed," as normal IGS processing had not been affected. Positioning errors as large as 200 km were broadcast. IGS GLONASS-based observations on April 2 were reduced by approximately 10 percent.

The IGS post-processing products were virtually unaffected as they are based on a full calendar day's data. Had the incident continued for a full day the impact could be considerable. The rotation of the GLONASS broadcast orbits were roughly one-half a degree about the inertial x-axis. We do not know how this occurred, but it is sizeable by any standard. In a sense, the incident was almost a "non-event," as only about one-third of IGS GLONASS tracking data was absent and the IGS only generates combined GPS-GLONASS products. The failure was traced to a mistaken Broadcast Ephemerides (BE), which likely occurred during a software update at 9 p.m. UTC. While the GLONASS provider identified the problem almost immediately, this was not communicated to GLONASS users. The impact to users depended on the receiver type and firmware release. It is believed the view correction was been achieved not through a "fix," but by switching back to an earlier software release.

There are a number of aspects about this incident that the IGS needs to discuss. While the BE is not needed for IGS post-processing activities, they are vitally important to the IGS Real-Time Service. There are two steps that the IGS could take to address this: the IGS could undertake real-time validation of the BE for all GNSS systems and make these available to the user community, or the IGS may have to reconsider using BE for the Real-Time Experiment. A lesson learned for the IGS is that prior to combining data from multiple systems, the parameters of general interest should be determined using observations from only one system. GNSS-specific problems would, therefore, be more readily identified. The same principle should be observed by receiver software and firmware.

Dr. Parkinson noted that the IGS is in essence performing an integrity function for its users.

Dr. Beutler said that clarity is important. All information needed to perform the integrity function in real-time exist, but much more needs to be done to monitor system performance closer to real-time. For instance, one commercial network never identified the April 1 “incident” because it was not using the BE.

Dr. Parkinson referenced an earlier conversation regarding the GPS L5 safety-of-life civil signal. The IGS could provide valuable information on the integrity of that signal.

Dr. Beutler agreed.

Ms. Neilan observed that all the IGS data is available; much of it in real-time. The difficulty lays in having sufficient human and other resources to make the best use of that data. An upcoming presentation will show that GPS L5 tracking has begun.

Dr. Parkinson asked which IGS receivers are involved.

Ms. Neilan replied that all receivers in the Multi-GNSS Experiment are already monitoring GPS L5.

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STRATEGIES FOR LIMITING INTERFERENCE EFFECTS

Mr. Logan Scott, *Founder*
Logan Scott Communications

Mr. Logan Scott began by raising the issue on how features already built into receivers could help mitigate jamming. For example, cell phones with GPS/GNSS capability could present the message “Jamming Has Been Detected. Jamming is Punishable by a \$100,000 Fine” whenever jamming of sufficient power or duration is detected. In addition, if receiver or jammer moving that could be used to find the jamming source.

Discouraging jamming may be more practical than attempting to prosecute all jamming offenders. The following steps could be taken:

1. Discourage the acquisition of jamming devices.
2. Get jammers turned off.
3. Limit the effective range of jammers.
4. Provide a means to continue operations during a jamming episode.

No “magic bullet” exists. Public understanding remains weak, and many who use jammers are unaware of the problems they’re causing. Perhaps crowdsourcing could be used to inform people that jamming is occurring. We also need to ask ourselves why people engage in jamming. In the civilian environment jamming is usually associated with criminal activity. However, jammers are also used because of the growing concerns about “government tracking” and privacy issues. Addressing these issues would aid efforts to mitigate jamming.

In the civilian environment jammers tend to be mobile. While airports are commonly thought to “attract jammers,” this may not be entire true. For example, a study of jamming near the Portland International Airport determined that jammers were being used by truckers driving past the airport on the way to a shipping dock. During this study, some trucks were followed including a trash hauler whose driver noticed he was being followed and became “visibly angry” but nevertheless continued jamming. A potential explanation is that, because of the \$3000 in costs per ton to dispose chemical waste, jammers would facilitate illegal dumping. Another example is the 2012 jamming event at the Newark Airport. The Federal Bureau of Investigation was informed on August 3, 2012 and the driver was arrested the following day. The speedy arrest was possible because the driver parked his truck and left the jammer turned on. Jamming is at times used to hide employee theft from company-owned vehicles. In this case situation companies could, instead of relying only on GPS tracking of its trucks, eliminate the motivation to use jammers by also adopting a different strategy such having a “red flag” raised whenever communications between the dispatching office and one of its trucks is lost for a certain amount of time.

Maritime shipping is also affected by jammers. The Chief Pilot of the St. Lawrence Seaway Noted that at some points, roads carrying heavy truck traffic run near the seaway and jamming from trucks is sufficient to jam shipboard systems in the Seaway.

Currently laws against jamming are difficult to enforce. While the stated fines are very large, the apprehension and conviction of offenders is unlikely. Therefore, having hefty fines offers little discouragement if laws are not enforced more often.

Another approach could be using “big data” to identify jammers. This may include tracking credit card purchases of jamming devices, Radio-frequency Identification (RFID) highway toll tags, license plate readers, and smart phone applications. If jamming could be readily identified then alerts -- similar to traffic alerts -- could be reported to the public.

Mr. Scott suggested a legislative step. At present, serious charges are filed if a crime involves a firearm. Similarly, criminal activities could be more severely punished if a jammer is used.

Finally, simply as a matter of good policy all civil GNSS receivers should have jamming detection capability.

Dr. Parkinson expressed concern over some FCC officials that still doubt jamming is prevalent. He asked Mr. Scott to briefing his findings to the FCC at the working level.

Mr. Scott assented.

Mr. Crane said the NCO works with people in the enforcement arena. The NCO would welcome seeing Mr. Logan’s findings.

Mr. Miller noted that the FCC was invited to provide a briefing to the Advisory Board. However, the agency is currently undergoing reorganization and opted not to present at this meeting. If Mr. Scott shares his information with the FCC, perhaps it would encourage the FCC to present at the next Advisory Board meeting.

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A PROPOSED EUROPEAN REGULATION FOR RNSS SPECTRUM

Dr. Kirk Zimmerman & Mr. Michael Swiek

GPS Innovation Alliance

Mr. Michael Swiek introduced the topic by explaining there is a new interference threat to the RNSS spectrum from the CEPT WG regulatory proposal in the European Union. The proposal is based on incomplete and flawed studies, and counter studies have been ignored. The regulatory review of the proposal should be completed in mid-2015. The proposal, if approved, would establish a number of bad precedents, including:

1. Allowing unallocated ground radio transmitters into the ARNS/RNSS frequency band.
2. Admitting harmful interferers and potential spoofers into these frequencies.
3. Creating GNSS availability exclusion zones and “no fly” areas.
4. Contravening international standards for protecting GNSS receiver performance.
5. Giving unequal regulatory treatment of communication and navigation.
6. Misstating GPS and Galileo providers’ policy on signal availability.

Dr. Kurt Zimmerman continued the briefing, and explained how the CEPT WG, which represents 48 nations, developed the proposal. CEPT, and the Electronic Communications Committee (ECC), have issued three reports:

- The 1st report creates a framework for indoor GNSS pseudolites.
- The 2nd second report authorizes a regime for indoor GNSS pseudolites in the 1559-1610 MHz band.
- The 3rd report creates a regulatory framework for outdoor pseudolites.

These reports have faced some objections in the European Union (EU), but they've been overruled by the ECC. For example, the third report was adopted over objections from the United Kingdom. The UK stated "no detailed work and analysis of real proposed systems and operational concepts has occurred" and no "analyzed details and specifications for real systems existed." A standard requirement for pseudolites is that their signals must be "designed to prevent interference with other GPS equipment," but the ECC study characterizes this as "highly restrictive" and recommended use of "a much broader definition." A broader definition, however, would require a legislative change in the EU.

The ECC regulatory recommendations are contradictory. For example, ECC Report 183 states that "compatibility between continuously transmitting pseudolites and ARNS would not easily be feasible", and "compatibility between pulse transmitting pseudolites and ARNS is not feasible." The proposers were fully aware of the interference issues, and their best response was to urge establishment of "no fly" zones alerting pilots to potential dangers.

Dr. Parkinson asked if any pending move authorizes pseudolites in the Galileo frequency bands.

Dr. Zimmerman said that when the EU discussions became specific, only the GPS bands were at issue.

Dr. Parkinson said he hoped the reason for this is "something other than" a wish to degrade GPS in Europe.

Dr. Zimmerman said it is unknown who would hold responsibility for these pseudolite networks. While studies refer to a "Pseudolite Network Operator," no definition of this exists in the proposal.

Dr. Zimmerman continued explaining that the proposal contravenes the International Protection Standard for GNSS Receivers. Specifically, it calls for raising the RNSS noise floor from 1 dB to 3 dB. Further, while the study began with indoor applications, it was later expanded to include both indoor and outdoor uses. ECC Report 128 acknowledges that pseudolites operating indoors will "leak" outdoors and, therefore, should not be used near airports. The international GNSS community, after a long study, has rejected in-band pseudolites on the grounds that they create interference out of proportion to benefits offered. While out-of-band pseudolites are generally considered safe, the ECC gave little attention to their use. The ECC report rejects out-of-band operations on the grounds that they entail the cost of an additional receiver front-end and both its accuracy and costs are not currently known.

Dr. Parkinson asked what commercial entity has sufficient "clout" to advance such a proposal.

Dr. Zimmerman said he did not know.

The proposed regulation could undermine GNSS interoperability. The Galileo system was dependent on the GPS-based European Geostationary Navigation Overlay Services (EGNOS) for its integrity. The reports from ECC and the Joint Research Centre (JRC), however, ignored this interdependency. Also, while discussions have focused on pseudolites the final recommendations generally apply to all ground-based transmitters. For instance, ECC Report 168 states that location system operators "may rely on various technologies, including or not pseudolites."

Mr. Swiek noted that it is uncertain what can be done. The European partners are "somewhat hamstrung" because they exist outside the regulatory environment in question. The matter needs to be addressed outside the CEPT, perhaps at the level of the state departments / foreign ministries. The Galileo and GPS communities agree that a high policy level response is needed.

Dr. Parkinson asked if Mr. Swiek and Dr. Zimmerman have contacted the U.S. State Department.

Mr. Swiek said they have shared their concerns with appropriate officials, and that additional discussions will occur.

Ms. Ciganer noted that, based on past experience, when such proposals are presented, many of the affected equities are simply unaware of what is happening. Once they become aware then cross-equity conversations occur.

Dr. Parkinson once again wondered who may be the real source of the proposal, and hoped the objected was not just to create unreliability in GPS by what amounts to authorized jammers.

Mr. Swiek said that when he had apprised the Galileo community of the proposed “no fly zones,” the response was that they’re spending “a ton of money” to free up air travel in Europe and that this proposal undermines their efforts.

Ms. Ciganer asked whether Mr. Swiek and Dr. Zimmerman have spoken to the ITU. The response was that they have not. Ms. Ciganer noted that Mr Ken Hodgkins of the State Department co-chairs the ITU committee on GNSS. The matter could be presented at an ITU working group meeting in July 2014. Further, Mr. Hodgkins has agreed to place the matter in the meeting agenda for the November 2014 ICG plenary.

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NEW TECHNOLOGY FOR PNT RESILIENCE

Mr. Nunzio Gambale, *CEO*

Locata

Mr. Nunzio Gambale briefed on the ‘Locata’ platform; a commercial PNT system that locally replicates all satellite-based functions. The product has been in development over a long time, but finally began production and shipment over the past year. Given an appropriately equipped receiver, Locata provides a seamless navigation solution in places of low GPS/GNSS satellite visibility. Locata “brings a new tool to the industry’s toolbox, with the flexibility of providing navigation from just inside a warehouse all the way to an area of several thousand square kilometers. Locata works in the 2.4 GHz band, the same band as Wi-Fi, thus enabling its use throughout the world. Locata creates a synchronized local network. The key radio technology is called ‘TimeLoc’, which allows to position two Locata units 20 or 30 kilometers apart while achieving synchronization at better than one nanosecond level. This is achieved without use of a high precision clock.

Locata operates in a similar fashion to GPS. They have a similar signal structure, and from a user perspective no difference is perceived between GPS and Locata. The chief difference is that Locata serves local applications. Furthermore Locata provides flexibility as one can add, detract or rearrange transmitters as needed. In consequence, Locata is a moveable GPS “hotspot.” It should be noted, however, that Locata is not a pseudolite.

The first case study of Locata was undertaken with the U.S. Air Force at the White Sands Missile Range. Ten Locata units provided coverage over 1300 square miles. The Air Force added a receiver antenna to an aircraft that made multiple flights across the Locata coverage area. It was determined that Locata delivered accuracies of 6 cm horizontally, and 15 cm vertically, whenever the GPS signals were jammed within the range.

A second case study occurred at the Newmont Boddington Gold Mine in western Australia. The mine is 3000 meters deep, a depth where considerable GNSS coverage is lost because of terrain obstruction. In addition, the April 1, 2014 GLONASS event provided an unexpected test, where Locata continued supporting operations over 13 hours, during which the mine employed 11 drill rigs at a cost of \$1,100 an hour each. Therefore, Locata avoided financial losses of \$137,000 to its operator. The Newmont Boddington Gold Mine recouped its Locata investment in 90 days.

Locata is well suited to function around important settings, such as airports. The Locata signals look, to a properly equipped user, identical to GPS signals. There are six new capabilities that Locata enables:

- First, it can overcome weak signals. With a satellite-based signal “you get what you get,” but Locata “can give you what you need.”
- Second, current GNSS systems cannot guarantee the requisite number of signals at all possible locations; such as, deep mining.

- Third, GNSS is dependent on “the superb clock in the sky.” Locata can deliver nanosecond-level time synchronization without cables or physical links.
- Fourth, GNSS satellites are expensive to monitor, maintain, and modernize. Locata employs “very inexpensive nodes.”
- Fifth, GNSS signal development and deployment can take decades. Locata can evolve in smaller steps as technology developed.
- Sixth, Locata can transmit both public and encrypted signals simultaneously.

The cost and size of Locata should drop sharply over time. In five years, Locata could be incorporated into a GPS unit for a cost of only several dollars. In time, the Locata hardware should be considerably smaller in size than a dime. Likely uses for Locata could include, among others, port automation, structural monitoring, automotive collision avoidance.

Given the limitations in space-based PNT, the world needs both space-based and land-based positioning components. Locata provides this capability.

Gov. Geringer asked what happens if either Locata or GPS drift?

Mr. Gambale responded that the Locata network is currently synchronized to five picoseconds. The system can synchronize to any time setting that is supplied. If all time sources simultaneously cease the system, would still provide positioning.

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PROGRESS TOWARDS RESILIENT PNT

Mr. Dana Goward, *President and Executive Director*
Resilient Navigation and Timing Foundation

Mr. Dana Goward referred to a *Wall Street Journal* commentary that few people realize their dependence on GPS. Paraphrasing the article, shortly after a hypothetical GPS failure, traffic snarled; cell phones ceased to operate; the Internet went down; stock exchanges and banks -- unable to process transactions -- closed; first responder communications drastically declined in efficiency. The hypothetical outage lasted 11 hours resulting in \$40 billion losses to the nation; a massive oil spill in San Francisco Bay, and 35 traffic deaths above normal expectation.

The “good news” is that such event has not happened yet, but the “bad news” is has become a “slim thread” upon which modern civilization is dependant and thousands of attempts are made every day to disrupt its services.

There is growing awareness in Europe of GNSS vulnerability. In April, both he and Dr. Parkinson attended an event in Rotterdam, The Netherlands, where a half-day discussion was devoted to the topic. Soon thereafter, at the European Navigation Conference, numerous papers were presented on GNSS vulnerability and the need for backup. Russia has expanded its Chayka terrestrial system, and Iran has established its own ground-based PNT system.

The United States never executed its 2008 decision to deploy eLoran as a backup system. However, the 2014 National Defense Authorization Act included language directing the Administration to report on efforts to “plan to provide necessary national security capabilities through alternative space, airborne or ground systems.” Also, DHS has been tasked by Congress to halt further dismantling of eLoran infrastructure, although the DHS Secretary has objected to this language claiming it is “a step backward.”

The Resilient Navigation and Timing Foundation undertakes education programs; seeks better laws and stricter enforcement, and advocates deployment of difficult-to-disrupt terrestrial signals. The foundation includes six international members -- Poland, the Netherlands, Norway, Egypt, the United Kingdom and Australia -- and individual members from corporate, technical and

military backgrounds. The Foundation has established good working relationships with DoD and DOC, but not as yet with DHS or the White House.

GPS vulnerability must be continually stressed. For example, a recent mudslide in Washington State killed 40 people despite specialists warning this would happen because a road dug at its base weakened the hill and tree removal had decreased the mountainside's stability. The tragedy is that those with specialized knowledge were unable to inform those who were in a position to take action. The Advisory Board, like those who knew the mudslide was in the offing, had been unable to persuade those making the decisions. The Advisory Board needs to do three things: first, simplify its message to make it more accessible; second, talk directly to policy makers rather than staff members; and third, policy makers must be told in concrete terms how ordinary people would be affected in case of GPS disruption.

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ALTERNATIVE POSITIONING, NAVIGATION AND TIMING (APNT) UPDATE

Ms. Deborah Lawrence, *Program Manager for Navigation
Federal Aviation Administration (FAA)*

Ms. Deborah Lawrence noted that Presidential Policy Directive 21 directs the FAA to determine the role the agency can play in maintaining the nation's critical infrastructure, safety and security in the event of a GPS disruption. The FAA defines disruption as any interference, intentional or not; man-made or not; sophisticated or not. Waiting for the source of a disruption to be identified and eliminated is not sufficient. At present, the FAA relies on legacy systems which do not fully support Radio Navigation (RNAV), Radio Navigation Performance (RNP), or Trajectory-Based Observation (TBO). Today's Air Traffic Control (ATC) systems cannot be scaled up to handle the anticipated traffic volumes. Further, today's PNT legacy systems cannot support many operational improvements associated with NextGen, nor can they meet performance requirements necessary to maintain adequate capacity and efficiency. The aim is to support both existing, and unfolding technologies, now and in the future. Failure to do so will negatively impact the economy and the environment.

The strength of legacy systems such as DDI (acronym for DME/DME/IRU, which means aircraft navigation based on measurements to two DME stations, plus an on-board IRU) and VHF Omni-directional Range (VOR) is their ability to support a signal during a GPS outage. These systems are already in use by 97% of aviation users, so they would not have to change their MOPS to continue operations. Furthermore, no additional rulemaking would be required. This would enable to meet the *minimum* RNAV requirements. There are, however, some drawbacks since regional jetliners generally do not carry the necessary systems, and loss of GNSS might cause an unacceptable rise in pilot and controller workload when reverting to VOR. Further, this would require the retention of additional Secondary Surveillance Radars (SSRs).

The APNT project is an investigation of alternative ways to provide higher precision backup for GNSS-based PNT services. NextGen APNT is intended to allow users to move seamlessly to continued RNAV and RNP operations. APNT development approach includes:

1. Multiple solution sets required by users needs to be identified.
2. Such solution sets must include ground-based infrastructure that transmits non-GNSS signals to avionics.
3. Signals-in-space must support all users, both legacy and emerging.
4. Robustness and resilience is paramount to maintaining safety of operations.

APNT is not itself a landing system. Rather, it guides aircraft to the landing zone. APNT's overall goals are to provide safe landing; avoid significant workload increases; provide strategic modifications of directories and continued dispatching to and from all areas affected. System benefits include: (1) safety is assured as users can maintain 3 nautical mile spacing; (2) money is saved due to reduced fuel burns; (3) passenger inconvenience due to disrupted schedules is minimized; and (4) capacity would be maintained at nation's 30 largest airports, except Hawaii. APNT also has the additional benefit of eliminating some of the current ground infrastructure. The target is to have a decision by 2015, with initial investments in 2016. This would follow robust evaluations of the two technologies under consideration. The FAA, however, faces cost-cutting pressures and the development of the notional system is dependent on adequate funding. Considerable work is required for prototyping and testing. In conclusion, the FAA is aware vulnerability existed, and APNT is an effort beyond that of a simple backup system.

Mr. Murphy noted that Instrument Landing Systems (ILS) had not been mentioned. These are greatly relied upon.

Ms. Lawrence noted that APNT is not intended to land aircraft, but to get them to a safe landing zone where ILS, or some other system, may be used.

Mr. Murphy noted the planned reduction of VORs. Since most VOR are with Distance Measuring Equipment (DMEs) is there also an intention to reduce or replace the latter?

Ms. Lawrence said there is no plan to eliminate any DMEs currently needed to run the system. Instead, rightsizing would occur.

Ms. Neilan said it appears this is a U.S.-only system.

Ms. Lawrence confirmed this.

Ms. Neilan asked about flights originating overseas and landing in the U.S.

Ms. Lawrence said the APNT project has been discussed in various global forums, and an offer to work with other nations has been made.

Mr. Murphy commented he thought the schedule is very aggressive, particularly if the goal is to make a financial commitment in a year. In his view, the international community “needs to be brought along.” At a recent International Civil Aviation Organization (ICAO) meeting, there was some discussion on the needs for APNT, and in-depth discussions with the international community could take several years. Therefore, in his view it is illogical for the FAA to push ahead so rapidly, given the times required by airlines to reequip. Further, airlines would be reluctant to reequip if a system is not going to be used internationally.

Ms. Lawrence noted that three or four “industry days” have been held to secure input. There is no desire to “get ahead of the game,” but at the same time the FAA has an agenda that requires support.

* * *

LATEST ON GLOBAL eLORAN INFRASTRUCTURE EVOLUTION

Mr. Mitch Narins, *Chief Systems Engineer for Navigation*
Federal Aviation Administration

Mr. Mitch Narins reviewed the history of enhanced Loran (eLoran). A 2004 FAA review stated that “*The evaluation shows that modernized Loran systems could satisfy the current (...) requirements in the United States and could be used to mitigate the operational effects of a disruption in GPS services.*” Also, a 2006-2008 including the Independent Assessment Team (IAT) study, directed by Dr. Parkinson characterized eLoran as “*a cost effective backup -- to protect and extend GPS -- for identified critical applications,*” and recommended to complete the eLoran upgrade and commit to operations for at least 20 years. At the time DHS also wrote a letter concurring with this position. However, since then many eLoran stations have been turned off and the U.S. Coast Guard has initiated the removal of broadcast towers, including a 300-foot tower in Alaska.

The following activities are taking place in Europe: in the UK costs are spread across multiple government agencies; in France economic pressures may lead to the closing of eLoran facilities; Denmark’s system is currently financed by France; Norway plans to discontinue operations in 2016; and The Netherlands remains supportive, because of use of foreign systems at the Port of Rotterdam. In addition, Russia continues to expand its network of Chayka stations and is currently discussing with the UK how the Chayka system could be made compatible with eLoran.

In Asia, while China may upgrade its stations, Japan intends to phase them out. North Korea has stated that, “eLoran is the only proven electronic system that can provide such resiliency,” and is upgrading and expanding its eLoran coverage. In addition, on

three occasions -- in 2010, 2011 and 2012 -- North Korea has engaged in high-powered jamming activities; the third one lasting sixteen days and disrupting 256 ships and 1024 aircraft. South Korea has converted three Loran sites to eLoran and is adding three additional sites. Saudi Arabia has upgraded its five sites to eLoran, and is considered requiring ships to be equipped with eLoran as a condition for entering the Red Sea. Finally, India has six Loran stations and is considering a phased expansion of eleven new sites.

In the U.S. eight Loran towers have been removed, leaving 11 remaining towers. In the meantime the UrsaNav Cooperative R&D Agreement calls for using the remaining Coast Guard assets to demonstrate eLoran's timing and frequency capability. Also, the 2014 US Coast Guard (USCG) and Maritime Transportation Act stipulates that, "*The Secretary may enter into cooperative agreements... to develop a positioning, timing and navigation system, including an enhanced LORAN system, to provide redundant capability and timing in the event GPS signals are disrupted.*"

In summary, while the U.S. provided the initial impetus for eLoran it has foregone its development. Other nations are now contributing to further its development. The eLoran system is currently working far better than what was imagined possible in 2004. The U.S. could benefit from taking advantage of what came before, determining how to redeploy a robust U.S. eLoran system, and most importantly making it happen.

Dr. Betz asked what fraction of overseas GNSS receivers includes eLoran capabilities.

Mr. Narin said he did not know. Some companies produce receivers with both GNSS and eLoran, but he does not know the quantities.

Ms. Neilan asked if any eLoran stations operate in the Southern Hemisphere.

Mr. Narins said no.

Following a question on system vulnerabilities, Mr. Narins said that if an interference signal is set up very close to an eLoran antenna, it could "mess things up." That is why very high antennas are preferred. While spoofing eLoran is not impossible, it is extremely difficult.

Dr. Parkinson commented that eLoran remains extremely vulnerable to political interference.

Mr. Murphy asked if the Loran towers were perhaps dismantled for being structurally unsafe.

Mr. Narins said the towers had been standing for many years and the Coast Guard was concerned about maintenance and upkeep costs. An effective effort to reverse this trend would require recapitalizing the system.

Mr. Murphy asked if recapitalization is included in the stated system cost estimate of \$147 million.

Mr. Narins said it doesn't.

Adm. Allen said that the Coast Guard has informed him the remaining eleven towers will be demolished in the next three years.

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IMPLEMENTING GPS/GNSS TSUNAMI WARNING SYSTEMS

Mr. Craig Dobson, *Program Scientist*
Science Mission Directorate, NASA Headquarters

Mr. Craig Dobson noted that in real estate, value reflects “location, location, location.” In disaster warning, the parallel is “timing, timing, timing.” GPS/GNSS provides both. Current systems can take an hour to determine the tsunami hazard posed by an earthquake. The lever of hazard depends on the type of earthquake depends on a number of factors, such as the underlying rock formation. The Richter scale used in seismology is not a reliable indicator of the tsunami hazard.

The Deep-ocean Assessment and Reporting of Tsunamis (DART) Buoy System is positioned at strategic locations throughout the ocean and play a critical role in tsunami forecasting. The buoys require considerable maintenance, but they provide point source data when a wave passes. The data from just two buoys is sufficient to determine the direction of the geologic “slip” and measure the energy released. These determinations can be made in just minutes. In addition, NASA’s Global Differential GPS System (GDGPS) can measure the tectonic in real time, such as the February 27, 2010 earthquake off the coast of Chile. GDGPS-based data enabled the Jet Propulsion Laboratory alert team to predict a moderate-sized tsunami. The Jason-1 and Jason-2 satellites also confirmed the amplitude of the resulting tsunami.

Any threat forecast system needs a high success rate because too many false alarms can create apathy among people. During the March 11, 2011 earthquake in Japan there were 1,200 operating GPS ground stations which could have provided earlier warnings. However, warnings based on geodetic information took 20 minutes to be issued. GPS could have provided a solution in just 2 minutes. Also, because real time data was not available, officials in Japan underestimated the energy of the tsunami and, thus, incorrectly assumed that the existing sea walls would provide sufficient protection.

In addition to positioning information, GPS can also be used to observe the ionosphere. Geologic disturbances cause ionospheric perturbations within 24 minutes. The disturbances can be used to produce a real time image to predict the arrival time and amplitude of the tsunami. Such a real-time operating system is a near-term possibility. Currently there is sufficient network coverage in the northern Pacific. The network could, in the future, be extended through most of the Pacific except for a few deep ocean sectors.

Finally, the Real-Time Earthquake Analysis for Disaster Mitigation (READI) network is a set of 550 GPS stations maintained by UNAVCO/BO, US Geological Survey, UC Berkeley, Scripps Institution of Oceanography, and California Department of Transportation.

The combination of all available stations would provide over 3000 GPS/GNSS stations in Pacific Basin, resulting in a system that would adequately assess the tsunami hazard and save countless lives. The first step towards this goal is for U.S. agencies to lead by example and provide open access to all relevant GPS/GNSS data. Second, existing U.S. GPS/GNSS stations should be evaluated to determine how to increase their overall capability. Finally, the international community should be engaged.

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GPS/GNSS SEARCH AND RESCUE (SAR): US AND INTERNATIONAL DEVELOPMENTS

Dr. Lisa Mazzuca, *Search and Rescue Mission Manager*
NASA Goddard Space Flight Center

Dr. Lisa Mazzuca explained that the SAR program includes the Air Force Combat Command, US Coast Guard, National Oceanic and Atmospheric Administration, and NASA. The SAR program, in turn, works with various international bodies. The program has existed for over 30 years; grown considerably, and is now in need of overhaul. Current plans call for GPS III, from SV9 onward, to carry a hosted payload to support SAR. This is also known as the GPS SAR. Currently fourteen GPS IIF satellites carry the NASA-funded proof-of-concept Distress Alerting Satellite System (DASS), the precursor to GPS SAR. GPS SAR will enable near instantaneous hazard reporting. Similar systems are being implemented by other GNSS constellations, also known as Medium Earth Orbit Search and Rescue (MEOSAR). This will provide high redundancy and accuracy, as well as resilience to ground-based interference.

The “big bang for the buck” is that the international SAR community will use the system for decades to come. Currently there are two initiatives in the works to further improve these capabilities. The first is to create a Return Link Service (RLS) to the 406 MHz beacon that would confirm that a distress signal has been received and help is on the way. The second is to introduce Second Generation Beacons (SGB) to further improve location accuracy.

While GPS SAR is capable of implementing RLS, the current operations concept does not incorporate it. At present if a transmitter has the embedded signal it has to be picked up by a Galileo SAR for a return message to reach the user in distress. The reply message would be transmitted through the French Mission Control Center. If the U.S. were to employ such a system, it will approximately need 80 bits for a Type-1 message on GPS.

SGB is the other “game changer,” which would allow smaller and less expensive beacons. Collaboration with manufacturers could produce the most competitive product. NASA is currently developing prototype beacons, with the goal to locate victims to within 100 meters in less than 30 minutes after a distress beacon is activated. Currently, “we are lucky to be within 5 kilometers.” In SGB prototyping, a 100-meter standard is met in 95 percent of cases

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DEMONSTRATING THE DEEP SPACE ATOMIC CLOCK (DSAC)

Dr. Todd Ely, Principal Investigator, *DSAC*
NASA Jet Propulsion Laboratory

Dr. Todd Ely explained that the purpose of this project is to build an advanced prototype mercury-ion clock for use in deep space. Basing the clock on a mercury atom, instead of a rubidium atom, offers a substantial improvement. The demonstration model, now under construction, should be in orbit by May 2016. With the demonstration model, size is not a high concern. However, future clocks will be smaller and more energy efficient. In addition, the clock would easily satisfy future GPS III URE requirements for clock and ephemeris errors.

The May 2016 launch will initiate a one-year demonstration period. In orbit, the clock will circle the Earth at a fairly steady altitude of 700 kilometers. The clock may last three to five years. Reducing clock size should make it more attractive to the GPS program. The mercury-ion clock will help with efforts to further reduce the URE. This is a promising technology that offers multiple development paths. The clock is also well suited for various autonomous operations. Looking into the future, clocks based on cold Cesium atoms or optical Rubidium are not expected to reach a Technical Readiness Level of 7 (TRL 7) for five to ten years.

Dr. Parkinson noted that the new clock will “really shine” in the ‘10-day URE’ parameter. Compared to rubidium-based technology, it looks awfully good.

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The Tuesday, June 3, 2014 session of the PNT Advisory Board adjourned at 4:40 P.M.

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BOARD CONVENES

*Mr. J.J. Miller, Executive Director, PNT Advisory Board
National Aeronautics and Space Administration (NASA) Headquarters*

Mr. J.J. Miller convened the Wednesday, June 4 session of the PNT Advisory Board at 9:00 a.m.

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ANNOUNCEMENTS AND AGENDA

*Dr. Bradford Parkinson, Acting Chair
Space-Based PNT Advisory Board*

Dr. Bradford Parkinson noted that while the previous day focused on presentations, today would be a work day in which the Advisory Board would determine how the presentations and other information could be framed as recommendations. He also commented how Dr. Schlesinger routinely observed that “nothing is forever.” The current PNT Advisory Board charter expires May 1, 2015. Efforts are underway to secure a new sponsor, but nevertheless the Advisory Board should show considerable work accomplished before that date.

Dr. Parkinson said he had listened to the summaries of the various Advisory Board Working Groups and, as a starting point for today’s discussion, these topics are:

- Securing GPS status as a critical infrastructure sector
- Upcoming FCC workshop on certification and standards
- Workplan for the economic benefits effort
- Licensing of in-band pseudolites in Europe
- Future, if any, of eLoran
- The “unhealthy” flag placed on the GPS L5 safety-if-life signal

Dr. Parkinson noted that the Advisory Board should strive to make no more than three recommendations to the EXCOM. Any recommendations to the EXCOM must be critical and urgent; must be realistically achievable; and must designate responsibility along with a timeline. Once the selection and prioritization is done, the Advisory Board should compose a letter to the EXCOM in order to provide a “heads up” before an in-person presentation.

Adm. Allen, co-lead on the Affordability working group, said that something regarding affordability should be added to the list.

Dr. Parkinson agreed.

Dr. Parkinson added that “narrowing and prioritizing” will come later; for the moment Advisory Board members may give this some thought.

The Advisory Board agreed to proceed in this manner.

* * *

PROTECTING U.S. CRITICAL INFRASTRUCTURE FROM PNT DISRUPTIONS

Ms. Sarah Mahmood

DHS Science & Technology

Ms. Sarah Mahmood explained that DHS regards critical infrastructure as a key focus area. Understanding potential GPS disruptions is a relatively new subject for the DHS Science & Technology office. Last year, DHS established a task force to improve understanding of GPS vulnerability on critical infrastructure. This is the focus of the briefing, although Advisory Board should regard these findings as preliminary.

Recent spoofing attacks have caught the attention of DHS and prompted to seek a better understanding of GPS vulnerabilities. The effort began with a “deep dive” into the electrical and communication sectors. Key questions are: How is GPS being used in these sectors? Why is it being used? What backup capability exists? How vulnerable is the system? A baseline of GPS dependencies was created, threats were mapped, and potential mitigations determined. The intent is also to develop a methodology for use in other sectors.

The electrical sector study looked at electrical use both current and projected over five years. The “deep dive” considered the impact from unintentional threats (e.g. space weather) and intentional threats (e.g. jamming, spoofing and cyber attack). One of the findings was that few parts of the electrical sector have backup capabilities capable of meeting one nanosecond performance standard for more than a few hours.

The communication sector study showed that while particular subsector timing requirements vary, GPS remains the basic source for timing information. The threats faced by the communication sector are similar to those faced by the electrical sector. Cellular networks are the most vulnerable component of this sector.

Potential mitigations included:

- Better antenna placement and orientation. Use of high-gain, directional, multi-band fixed reception antennae.
- Using Multi-GNSS receivers
- Increasing training in the hazards of spoofing
- Implementation of integrated back-up timing
- Implementation of commercially-available standalone anti-jamming devices
- Reduction of the number of GPS receivers needed
- Implementation of nationwide backup timing systems (e.g. eLoran or the PNT Cloud concept)

The ‘deep dive’ effort also included support from the Small Business Innovation Research (SBIR) program. The objective was to select small business to undertake “deep dive” reviews of two sectors, including the energy sector, and develop a set of a low-cost suite of tools for detection, reporting, and localization of signal interference. Four vendors each received \$100,000 for a six month effort. One vendor tested various GPS receivers and determined that all were vulnerable, but many were able to switch over to backup timing. It was also found that equipment vendors do understand the hazards faced by GPS, but are still reluctant to build-in improved capabilities until the user demand increases. Overall, mitigation techniques are well understood, but the implementation is uncertain. Concerted action is unlikely until all the sectors understand GPS vulnerabilities. The SBIR effort came up with the following recommendations:

- Improve user education, particularly on how GPS-based measurements can be faulty.
- Improve the understanding of multi-pronged threats impacts.
- Develop networked timing redundancy to handle GPS disruptions.
- Embed interference and/or spoofing detection capability in receivers used by the critical infrastructure.
- Use built-in sensor interfaces for GPS threat alerting and locating over wide-areas.

Overall, a convincing case has to be made showing that combating GPS vulnerability merits the use even of scarce resources. Furthermore, costs could be lessened if vulnerabilities are addressed through enhancements to existing product lines.

The objective of Phase II of the SBIR program is to develop a scalable and workable prototype system to detect, report, and locate of GPS disruptions. A two-year \$750,000 contract has been awarded to *Contract Navigation*. The initial focus is to use crowdsourcing to locate disruptions. The initial performance metrics are to detect a disruptive effect within 60 minutes and to locate it within 500 meters.

Future efforts may include GPS receiver characterization and testing; industry education; spoofing mitigations; localization capability, and back-up timing capabilities for critical infrastructure sectors.

Dr. Parkinson described the briefing as “a breath of fresh air.”

Dr. Betz seconded Dr. Parkinson’s praise, and asked that since GPS and PNT were not the only threats to critical infrastructure, how are the threats being prioritized?

Ms. Mahmood answered that each critical infrastructure sector had a coordinating council to address the issue of prioritization.

Dr. Betz asked if there is a priority list that the Advisory Board can review.

Ms. Mahmood said she could not answer that question.

Ms. Mahmood was then asked if there is a strategy to implement the proposed fixes. She responded that the problem needs to be approached from both sides. For example, DHS hopes to develop a prototype capable of protecting the electrical grid, but at the same time it is also aware an effort is needed to raise the electrical sector to use this capability. The Federal government does not own the electrical grid infrastructure, but it can provide “a little shove” to the sector.

Gov. Geringer noted the Advisory Board is currently tasked with an economic assessment and, perhaps, DHS could be a partner in the effort. It is surprising to see that industry continues not to perceive GPS as being vulnerable. However if GPS were somehow turned off then all the critical sectors would immediately recognize its vulnerability.

Ms. Mahmood noted that the electrical sector currently does not consider GPS disruption as a major threat. Many believe that ‘smart (GPS) receivers’ would fill any gap caused by interference to GPS signals. However, the study has shown many receivers are not to fill the gap.

Dr. Parkinson said that, in addition to sector models, a national threat model is needed.

Gov. Geringer cautioned that the SBIR Phase II effort on “partnering” could raise concern that the government is trying to harvest a great deal of private information. Therefore, special care must be taken on how this is presented.

Adm. Allen asked Ms. Mahmood who is the client for this effort?

Ms. Mahmood said that at present no client has been identified, but it is hoped the owners and operators of the critical infrastructures will eventually become the client.

Adm. Allen asked who us sponsoring this effort?

Mr. Crane said that an executive steering group within the NCO has met with the EXCOM co-chairs. The latter had asked the NCO to put together a small group to study how to make critical infrastructures more resilient. This group is accountable to the EXCOM.

Ms. Ciganer commended DHS on its “thoughtful approach.” In her conversations with individuals in the critical infrastructure sectors, it is apparent they are aware of the threats, but they’re also focused on other important issues. One of the “key findings” statements on slide #13 of the briefing states that “*Additional receiver testing /*

characterization / certification especially for receivers used within critical infrastructure.” Is this certification process going to engage industry?

Ms. Mahmood said that has not yet been determined.

Ms. Ciganer commented that the GNSS industry had been undertaking testing for 30 years. The innovation cycle is so fast that developing a test specification could end up being at the expense of further innovation. Users do not want this. Therefore, outreach activities need to be undertaken before testing is done so users are made aware of what is at stake.

Dr. Pace asked what DHS hopes new testing will determine that is not already known.

Ms. Mahmood said greater understanding is sought on how a receiver behaves in response to specific jamming and spoofing attacks.

Dr. Pace recommended that the issue be approached by first asking “what is the threat?” and then “how does that threat effect receiver performance?”

Ms. Mahmood agreed.

Mr. Murphy characterized the presentation as “a great briefing,” and asked whether DHS had had the opportunity to present this to Congress.

Ms. Mahmood said it has not, but that does not mean it won’t happen. The intention is to carry the project forward to demonstrate the need, and then take these findings to Congress.

Mr. Faga noted that industry is typically disinclined to believe it may have a problem. For example, the commission on critical infrastructures was created by President Clinton in 1993 and, at the time, a power company was asked how it would respond if a generator were down for three days (Three days is the general limit of fuel power companies store to operate backup systems). The company replied that was not possible. MITRE then showed them how it could be done by a concentrated attack launching one wave cascading upon another. This possibility had not even been considered by the engineers in the power company.

Dr. Parkinson termed this as “an outstanding observation.”

Mr. Miller asked who owns the crowdsourcing data.

Ms. Mahmood said DHS owns the data, but it will be made available as a subscription service. She is open to suggestions on who requires this information.

Ms. Axelrad said one question that has not been addressed is how the critical infrastructure equipment would respond to what a GPS receiver is telling.

Ms. Neilan asked if a schematic will be developed to show how information flows within any given sector.

Ms. Mahmood said that getting the information at any level of specificity is difficult.

Dr. Parkinson said he felt the entire Advisory Board will go on record to support the effort by Ms. Mahmood and DHS. He also thanked Ms. Mahmood for the candor in her answers.

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INTERNATIONAL MEMBERS REGIONAL UPDATES (at member's discretion)

Dr. Parkinson noted that having six international members on the Advisory Board makes it in the world of GNSS systems. Ms. Neilan added that the inclusion of international members reflects Dr. Schlesinger's desire to make the board as representative as possible.

1) Dr. Gerhard Beutler, *Switzerland*

Dr. Beutler began by providing a comparison between the various GNSS systems, including the number of satellites, orbital planes, inclination, and period. He explained that the differences between the various configurations help provide valuable information for space geodesy applications, and therefore it is important that the information from all systems be made available to the IGS. The Multi-GNSS Experiment (MGEX) is currently based on GPS, GLONASS, as well as emerging GNSS systems and signals from various Space-Based Augmentation Systems worldwide. Various types of equipment are being used, which somewhat complicates the tasks analyzing the data collected. MGEX issues an all-in-one multi-GNSS broadcast ephemeris file that is created from the all broadcast information from all the GNSS constellations and regional augmentation systems. These are supplied in their original form, which is convenient to various kinds of scientific applications. All the data collected by the IGS Real-time (IGSRT) GNSS service is also available to the scientific community. This is in line with the IGS policy of open data, open sources, and open standards. There are a number of other programs also contributing to make this possible, including satellite clocks and ephemerides, space weather, interference detection, and monitoring of natural hazards.

Dr. Parkinson asked if the three charts presented under the 'Precise Point Positioning using the IGS RT Service' slide (#23) all analyzed the same data on the same day.

Dr. Beutler said they did.

Dr. Parkinson said the level of consistency is striking.

Mr. McGurn asked if the data interpretation includes the broadcast ephemerides.

Dr. Beutler said calculations are based on the broadcast ephemerides, but differential corrections are also provided.

Mr. McGurn said his primary concern is broadcast ephemeris, because without it, the April 1, 2014 GLONASS event would not have been recorded.

Ms. Neilan called attention to Dr. Beutler's backup slides, #29-30, one of which shows GNSS orbit validations.

Dr. Beutler said that even incomplete systems, such as Galileo, are achieving good results. The IGS Broadcast Performance Assessment will be released soon, and shows GPS as having the best performance.

Dr. Parkinson noted the GPS performance analysis will likely improve when GPS III satellite data is available.

Mr. Hatch asked, regarding orbit comparison to satellite laser ranging measurements, whether a bias still exists as a function of the beta angle of the sun.

Dr. Beutler said this bias has been greatly reduced, but still persists.

2) Mr. Arve Dimmen, *Norway*

Mr. Dimmen first recalled his previous report on plans to construct a geodetic observatory survey operation at Ny-Alesund in Norway at latitude 78°N. Funding is in place and construction on the access road has begun. Also, the control structure and antennas should be in place by fall 2015, telescope testing will begin mid-2016, full operation is expected to commence in mid-2016, and an additional goal of making the facility a "low-manning" operation should be met by 2019.

Second, the Norwegian parliament recently approved funds for the operational phase of Galileo.

Third, a number of activities have taken place at the International Maritime Organization (IMO). The IMO published the Worldwide Radionavigation System (WWRNS), which includes both the GPS and GLONASS. Both the European Union and China will add their systems by 2016. In a few years, global fleets of ships will be able to use either system (although preferably both) whether they are cruising the Norwegian fjords or entering San Francisco Bay. Marine safety requires reliability from all of these systems, and this means having global reference standards. The Advisory Board may wish to state support for this position.

Dr. Parkinson said he took the same position as Mr. Dimmen, and asked if he is also advocating the locating of foreign GNSS ground monitoring systems on U.S. soil.

Mr. Dimmen said reference standards, per se, are less important than achieving the safety levels needed. For example, Norway cannot, by itself, dictate international safety standards to ships travelling through its waters.

3) Dr. Hiroshi Nishiguchi, *Japan*

Dr. Nishiguchi presented a 2013 videotape of a landmark demonstration project at Tanegashima and Yakushima islands in Japan. The videotape shows potential commercial applications of QZSS MICHIBIKI augmentation services. The signals have permitted for achieving higher accuracy, replacing a 10-meter accuracy level with 1-meter. An earlier demonstration included working under limited GNSS availability, such as in mountainous terrain. The system worked in both cases. Tests were also conducted encompassing entire islands, including the coordination of a video game with a tourist guide. Students participating in this test were able to use the system to navigate from one attraction to another attraction. At each stop, digital characters automatically appeared. After the test, students expressed considerable satisfaction with the augmentation system. Another test was the Digital Stamp Rally where participants moved about the island and collected a digital stamp at each stop. The collector of the most stamps won a prize. In summary, the system is expected to contribute significantly to Japan's growth strategy, which include supporting the 2020 Tokyo Olympic Games.

Ms. Neilan called attention to the fact that the project showed young people that GNSS has a much broader range of users than they had imagined.

4) Dr. Rafaat Rashad, *Egypt*

Dr. Rashad provided a risk assessment of PNT vs. PTA (Protect, Toughen, and Augment). GPS service in recent years has been excellent, with 99+ percent reliability and 99.9 percent availability. The development of thousands of applications had enabled average users to take advantage of GPS in many ways. All these combined make PNT highly valuable to users. Unfortunately, PNT is also vulnerable to jamming, and other threats, and therefore must be protected. Experts agree that there are three necessary steps -- protect, toughen and augment. If the costs of PTA exceed the benefit to PNT, then one is building inefficiency into the system. If toughening the system does not result in greater economic benefits, then safety becomes too costly. Efforts to protect, toughen and augment face limited funding resources and time constraints. Time constraints relate both to: (1) the need to act in keeping with the continued system development; and (2) the time required to persuade system users that the various protections are worth the investment. The ideal situation is where the benefit to PNT and the cost of PTA are in balance. This entails the creation of some regulations. However, this could result in a loss of revenue for certain applications. Both quantitative and qualitative assessments are required.

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PNT ADVISORY BOARD WORKING GROUP RECOMMENDATIONS DEVELOPMENT

All Board members

Discussion led by Dr. Bradford Parkinson, Acting Chair

Dr. Bradford Parkinson presented a list of actions that are most important, most urgent and actionable. However important or urgent a matter may be, no recommendation is useful unless it points to a specific action. The list includes:

1. GPS as a critical national infrastructure
2. Upcoming FCC workshop on certification of standards
3. Economic benefits workplan
4. Licensing of in-band pseudolites in Europe
5. eLoran
6. The “unhealthy” flag on L5
7. Assessment of threats to civilian GPS
8. Affordability

Item #1: GPS as a National Critical Infrastructure

Adm. Allen asked what would change if GPS were designated as a critical infrastructure.

Dr. Parkinson said such designation would raise the priority of GPS within DHS and elsewhere.

Adm. Allen noted that DHS believes demand for this step is insufficient among existing sectors. Perhaps structuring some sort of “national loss of PNT” event would prompt interest right up to the White House “situation room.”

Dr. Parkinson welcomed the suggestion, though said he was uncertain on who should implement it.

Item #2: Upcoming FCC Workshop on the Certification of Standards

GPS receiver designers are deeply concerned that this FCC workshop could create a superimposition over how GPS receivers are to be designed.

A Board Member suggested to “poke back” by asking whether the FCC has authority to set standards for civilian receivers. In general, government settings are done only for national security or public safety. The FCC does not, and should not, have the authority to set receiver standards. The situation is similar to the pseudolite issue. Both are attempts to shift the risk from the transmitters to the receivers, with the objective to accommodate greater demand for access to the L-Band. In both cases, the GPS community is losing the responsibility for receiver requirements.

Dr. Parkinson suggested coupling items #2 and #4 since they are both related to regulation and certification.

Mr. Hatch commented that he was involved in the early work of the Wide Area Augmentation System (WAAS); at the time had been very disturbed by some attempts to proscribe/restrict its algorithms since that would have slowed down innovation. Generally, regulations stifle innovation. There could, however, be a role for minimum design constraints directed at fighting jamming and spoofing.

Dr. Parkinson added that the RTCA already exists with the purpose of setting up for receivers used in safety-of-life applications.

Item #3: Economic Benefits Workplan

Gov. Geringer said the Department of Commerce will determine the procurement process and designate a contractor. Interagency cooperation has been assured. The communication and electrical sectors are insufficiently aware of their

GPS vulnerability, and this fact ties in with the Economic Benefits study. Once the economic benefits are recognized, it will support awareness of the importance of GPS.

Dr. Parkinson noted the FCC has also talked in terms of economic benefits.

Gov. Geringer said the FCC should also be asked why it is addressing receiver specifications, which fall outside its proper domain.

Item #4: Pseudolites in Europe

(previously discussed)

Item #5: eLoran

Dr. Parkinson said the Advisory Board has already recommended its support for eLoran, and confirmed this just last year.

Mr. Hatch noted that it is nevertheless important that eLoran remain an EXCOM issue.

Item #6: “Unhealthy” flag on L5

Dr. Parkinson expressed concern over unexpected consequences. Some manufacturers may ignore the “unhealthy” flag, but flagging could also discourage other manufacturers from using L5 even after the flag is removed at a later date.

Mr. Murphy urged the creation of a clear plan on how the flag would be removed, and encourage the EXCOM to promote greater crowdsourcing during testing of CNAV signals.

Item #7: Assessing Threats to Civilian GPS

Dr. Betz said someone should be tasked with assessing future threat models and the creation of defenses. If this task were given to the FAA, the result could impact: (1) GPS’ designation as a critical infrastructure; (2) the fate of eLoran; (3) and many other consequential matters. The recommendation should be reworded as “assessing the evolving threat model.” Three steps would be involved. First, models should be assessed. Second, a determination of possible responses should be made. Third, responsibility for executing those responses should be assigned.

Item #8: Affordability

Adm. Allen said his workgroup wishes to develop cost models and information on where savings could be secured. This work would continue for several meetings. Affordability is tied to the economics benefit study.

Dr. Parkinson suggested the Advisory Board wait to see what develops in this area.

Adm. Allen noted that work to-date does not support a recommendation to the EXCOM.

Other Items

Mr. Murphy said the Protection subgroup has proposed recommending the EXCOM to advocate for legislation supporting greater penalties for deliberate disruption of GPS operation. The matter could be pressed through bilateral and multilateral discussions.

Dr. Parkinson commented that GPS started out “in a very quiet neighborhood” on the spectrum, but since has become crowded. One issue is whether those who allocated frequencies could be made to recognize that a quiet neighborhood for GPS is generally desirable for everyone. The FCC has recently acquired new leadership which appears open to discussion.

Dr. Parkinson noted he’s not aware of a process whereby the various GNSS systems could establish general standards for the GNSS world.

Mr. McGurn noted such a process would not be within the scope of the EXCOM.

Discussion

Dr. Parkinson said that any letter to the EXCOM should list matters which the Advisory Board has no power to act upon but feels they need to be brought up. One example is the Advisory Board’s concern that various government agencies are beginning to use data from other GNSS systems despite the absence of agreed-upon operational protocols.

Dr. Pace commented that such determinations are made through the ICAO. The certification of foreign systems for civilian safety-of-life functions is already being made, and the DOS is pushing for GNSS open standards and interface control documentation.

Dr. Parkinson noted that such efforts did not prevent the April 1-2, 2014, GLONASS event.

Dr. Pace said it is true that GLONASS has not lived up to agreements, but hopefully this problem can be worked through means other than the EXCOM.

Dr. Parkinson said if the EXCOM believes GLONASS is more reliable than it really is, then it is possible it also has unrealistic expectations about other space-based PNT systems.

Dr. Pace suggested to provide the EXCOM with a competitive assessment of existing GNSS systems.

Dr. Parkinson said there is no specific recommendation on the table. Rather, what is being discussed is whether the Advisory Board should make the EXCOM aware of these concerns.

Dr. Enge observed that in the past ‘faults’ typically arrived in two waves: the first one was unintentional errors in human systems; and the second one was attributable to space weather. Now, there is a third wave that comes from “bad actors,” such as spoofers and jammers. Considerable literature is being published on this subject, but very little is coming from the U.S. Therefore, perhaps it is necessary to meet with persons working on PNT threat models in order to see what could be done about these bad actors.

Ms. Neilan said that one problem faced by prospective U.S. researchers is the difficulty to obtaining jamming devices for testing.

Dr. Parkinson offered a “way forward” for assigning priorities. All Board members can cast two votes: a ‘#1 vote’, worth two points, and a ‘#2 vote’, worth one point.

Gov. Geringer asked whether any items should be combined; e.g. critical infrastructure and threat model.

Dr. Parkinson said he doubted whether those are really the same.

Gov. Geringer noted that the word “sector” has an established definition, which GPS currently does not meet.

Dr. Parkinson said the word “sector” can be removed.

Mr. McGurn noted that unless GPS is given sector status, then it is likely no one will think of it as ‘their problem’.

Dr. Parkinson seconded this comment.

Voting followed. Nine votes were cast for Item #1 (Establish GPS as a National Critical Infrastructure).

Dr. Parkinson asked how many '#1 votes' were cast for Item #2 (FCC workshop on certification).

Ms. Neilan noted that the workshop is scheduled in two weeks, which is well before the next EXCOM meeting. While the issue is was not a '#1 vote' to her, the Advisory Board should nevertheless be represented at the workshop.

Mr. Murphy noted that he EXCOM is likely to object to 'rule-making by workshop'.

Dr. Parkinson said the Advisory Board is uncertain of its legal status, but it is very concerned where this FCC action may lead to.

Mr. Crane said he would be representing the NCO at the FCC workshop.

Dr. Pace noted that the workshop will be on webcast.

Dr. Parkinson then asked for votes on Item #4 (Pseudolites in Europe).

Dr. Pace said he thought this is a priority item. The CEPT action has followed a very bad development process but, unlike the FCC workshop which will come and go, the CEPT process has long term repercussions. It is important to advocate that the U.S. work closely with its European Union colleagues.

Dr. Parkinson agreed that the CEPT action is setting up an extremely bad precedent.

Dr. Parkinson asked for votes on Item #5 (eLoran).

Dr. Rafaat asked whether it is really necessary to restate this recommendation.

Dr. Parkinson said the cover letter could simply affirm this as a standing recommendation.

Dr. Parkinson then asked for votes on Item #7 (Assessing the civilian GPS threat model).

Six votes were cast.

Dr. Parkinson noted that Item #8 (Affordability) is a placeholder.

Dr. Parkinson then asked for votes for the additional item on seeking legislation protection of the GPS spectrum.

One vote was cast.

Adm. Allen noted that there are many matters that may require a legislative response, and at some point the Advisory Board may want to develop a prioritized list.

Dr. Parkinson noted that '#1 votes' assigned the highest priority to Item #1 (Establish GPS as a National Critical infrastructure).

A board member pointed out that '#2 votes' had not yet been cast.

A tally of the ‘#2 votes’ added the following: four additional one point votes for Item #1; three votes for the Item #3 (Economic Benefits Workplan); one vote for Item#4; five votes for Item#5; and one vote for Item#5; and one vote for Item#6 (Unhealthy flag on L5).

Dr. Parkinson noted that Item #5 (eLoran) would be a standing recommendation and those who voted for it could recast their ‘#2 vote’. This resulted in four additional votes for Item#7 (Assessing Threats to Civilian GPS) and one vote for the additional item on seeking legislative protection for the RNSS spectrum.

With this completed, Mr. Faga announced that: Item#1 remained the highest priority with 22 votes; Item#3 received three votes; and Item#4 had six votes.

Dr. Betz suggested that the Advisory Board urge the Department of State to pursue Item#4.

Ms. Ciganer said if Item#4 is taken to the EXCOM, it will assure the issue receives a high level of attention.

Dr. Parkinson said his understanding is that the ‘train has left the station’ and it is being driven by people with no knowledge of navigation.

Dr. Betz proposed direct conversations with Mr. Hodgkins and Mr. Turner at the DOS.

The final results of voting were:

Priority #1: Establish GPS as a National Critical Infrastructure

Priority #2: Assessing Threats to Civilian GPS

Priority #3: Pseudolites in Europe

Dr. Parkinson asked the Advisory Board whether it would authorize him to work with Dr. Pace on drafting a letter to the EXCOM, which would be approved by the Advisory Board before it gets sent out.

Mr. Faga said the Advisory Board should seek advice from the NCO on how best to draft the letter.

Mr. Crane said various routes exist for correspondence. The NCO could facilitate any communication to the EXCOM.

Adm. Allen said the letter should state “Here are the actions we wish the EXCOM to take.”

Dr. Parkinson said the NCO would be given a chance to review and comment on the letter, but in his view it should not be part of the process to draft the letter. In his view, comments should be secured from Advisory Board members and the NCO, and then send the letter directly from the PNT Board to the EXCOM.

Mr. Crane noted the NCO is the permanent staff of the EXCOM and, thus, any letter sent to it will reach the EXCOM. The NCO does this regularly.

Adm. Allen said the Advisory Board needs assurances that the letter would be considered and responded to.

Dr. Parkinson asked for any dissenting comments. None were made.

Dr. Parkinson said that in the next several weeks he, working with Dr. Pace, Gov. Geringer and Mr. Faga, would prepare a letter for distribution to the full Advisory Board. He also asked board members to be prompt in submitting comments.

That done, Dr. Parkinson moved for adjournment. This was seconded, and approved.

The 13th meeting the Space-based PNT Advisory Board was adjourned Wednesday, June 4, at 12:04 p.m.

* * *

Appendix A: Space-Based PNT Advisory Board Members

Special Government Employees:

Bradford Parkinson (Acting Chair), Stanford University
Thad Allen, Booz Allen Hamilton
Penina Axelrad, University of Colorado
John Betz, MITRE Corporation
Dean Brenner, Qualcomm
Joseph D. Burns, United Airlines
Per K. Enge, Stanford University
Martin C. Faga, MITRE Corporation
James E. Geringer, Economic and Social Research Institute
Ronald R. Hatch, NavCom Technology, John Deere Corporation
Rajiv Khosla, Colorado State University
Peter Marquez, Planetary Resources
Terence J. McGurn, consultant (retired CIA)
Timothy A. Murphy, The Boeing Company
Ruth Neilan, NASA Jet Propulsion Laboratory
T. Russell Shields, Ygomi LLC

Special Representatives:

Gerhard Beutler, International Association of Geodesy (Switzerland)
Elizabeth Cannon, Canadian Aeronautics and Space Institute (Canada)
Ann Ciganer, U.S. GPS Industry Council
Arve Dimmen, Norwegian Coastal Administration (Norway)
Matt Higgins, International GNSS Society (Australia)
Hiroshi Nishiguchi, Japan GPS Council (Japan)
Rafaaf Rashad, Arab Institute of Navigation (Egypt)

Appendix B: Presentations

GPS Modernization Update/Lt. Col. Brian K. Bailey

Update from the National Coordination Office for Space-Based PNT/Mr. Jason Kim

DOT Positioning, Navigation, and Timing Update: CNAV Activation and Civil Signal Monitoring Plans/Ms. Karen Van Dyke

U.S. GPS International Activities and Engagement/Mr. Ken Hodgkins

Lessons Learned from GLONASS Service Disruptions/Dr. Gerhard Beutler

Strategies for Limiting Civil Interference Effects Inspired by Field Observations/Mr. Logan Scott

Proposed European (CEPT) Regulation Would Allow Harmful Interferers Into an ARNS & RNSS Radiofrequency Band Within Europe/Dr. Kurt Zimmerman & Mr. F. Michael Swiek

Locata: New Technology for PNT Resilience/Mr. Nunzio Gambale

Progress Toward Resilient PNT: Good News and Bad News/Mr. Dana A. Goward

Alternative Positioning, Navigation, and Timing/Ms. Deborah Lawrence

The Global Loran & eLoran Infrastructure Revolution/Mr. Mitch Narins

Tracking Tsunamis with GNSS: Towards an Improved Indo-Pacific Tsunami Early Warning Network/Mr. Craig Dobson & Mr. John LeBrecque

Deep Space Atomic Clock/Todd Ely

Critical Infrastructure Vulnerabilities to GPS Disruptions/Ms. Sarah Mahmood

Multi-GNSS and Real-Time Service in the IGS/Dr. Gerhard Beutler

Video Report: Landmark Demonstration Experiments/Dr. Hiroshi Nishiguchi

Risk Assessment: PNT vs PTA/Dr. Rafaat Rashad

All presentations are posted at GPS.gov

Appendix C: Sign-In List

Tuesday, June 3, 2014

PNT BOARD MEMBERS

Penina Axelrad, University of Colorado
John Betz, MITRE Corporation
Gerhard Beutler, IAG
Elizabeth Cannon
Ann Ciganer, GPSIA
Martin Faga
Raj Khosla
Hiroshi Nishiguchi
Ruth Neilan
Rafaat Rashad, AIN
Per Enge

NASA PERSONNEL

Barbara Adde, NASA
Yoaz Bar-Sever, NASA Jet Propulsion Laboratory
Craig Dobson, NASA
Todd Ely, NASA Jet Propulsion Laboratory
Lisa Mazzuca, NASA
A. J. Oria, NASA/Overlook
Scott Pace, NASA/GWU

OTHER ATTENDEES

Hamza Abduselen [?]/Federal Aviation Administration
John Anton, EAYSS
Brian Bailey, U.S. Air Force
Frank Bayer, EST
Jim Burton, National Coordination Office
Milton Clary, OSTI
Clark Cohen, PNT Holdings
Robert Crane, National Coordination Office
DeeAnn Davis, *Inside GNSS*
Nunzio Gambale, Locata
Steven Grupenhagen, SAF/AQS
Ken Hodgkins, U.S. Department of State
Bruce Jacobs, Pillsbury
Jeff Jones, Federal Aviation Administration
Jason Kim, Department of Commerce
John Kirkemo, U.S. Air Force
Timothy Klein, Department of Transportation
Deborah Lawrence, Federal Aviation Administration
Irv Leveson, Leveson Consulting
Jules McNeff, Overlook

Wes Merrill, National Coordination Office
Chris Mindrich, National Coordination Office
Steve Moran, Raytheon
Tom Powell, Aerospace Corporation
Samuel Roudebush, MITRE Corporation
Logan Scott, LS Consulting
Mike Swiek, GPSIA
Doug Taggart, Overlook
Mike Tucker, LMG
Dave Turner, U.S. Department of State
Karen Van Dyke, Department of Transportation
Ammyanna Williams, Federal Aviation Administration
Kurt Zimmerman, Trimble

Wednesday, June 3, 2014:

PNT BOARD MEMBERS

Gerhard Beutler
Martin Faga
Terence McGurn
Tim Murphy
Ruth Neilan
Hiroshi Nishiguchi
Per Enge

NASA PERSONNEL

Todd Ely, NASA Jet Propulsion Laboratory
Gregory Mann, NASA
Joe Valvano, NASA/ASRC
Stephanie Wan, NASA/Overlook

OTHER ATTENDEES

John Anton
Brian Bailey, U.S. Air Force
Frank Bauer
Jim Burton
Dee Ann Davis, *Inside GNSS*
John Dragseth, Department of Homeland Security
Timothy Klem [?], Department of Transportation
Irv Leverson
Joe Rolli, Exelis
Russell Shields
Sarah Mahmood, Department of Homeland Security

Appendix D: Acronyms and Definitions

ARNSS	Aeronautical RNSS
APNT	Alternative PNT
ATC	Air Traffic Control
BE	Broadcast Ephemerides
CEPT	European Conference of Postal and Telecommunications Administrations
CMPS	Civil Monitoring Performance Specification
CNAV	GPS Civilian Navigation Message
CODE	Center for Orbit Determination in Europe
DARPA	Defense Advanced Research Projects Agency
DART	Deep-ocean Assessment and Reporting of Tsunamis
DASS	Distress Alerting Satellite System
DDI	DME/DME/IRU, which is aircraft navigation based on measurements to two DMEs plus an on-board IRU
DHS	Department of Homeland Security
DOC	Department of Commerce
DoD	Department of Defense
DME	Distance Measuring Equipment
DMI	DME/DME/IRU navigation
DOT	Department of Transportation
DOS	Department of State
DSAC	JPL Deep Space Atomic Clock
ECC	Electronic Communications Committee
EGNOS	European Geostationary Navigation Overlay Services
eLoran	Enhanced Loran
ESG	Executive Steering Group
EU	European Union
EXCOM	PNT Executive Committee
FAA	Federal Aviation Administration
FACA	Federal Advisory Committee Act
FCC	Federal Communications Commission
FRN	Federal Register Notice
Galileo	European GNSS
GDGPS	NASA Global Differential GPS System
GLONASS	Russian GNSS
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IAG	International Association of Geodesy
IAT	Independent Assessment Team
ICAO	International Civil Aviation Organization
ICG	UN International Committee for GNSS
IDM	Interference Detection and Mitigation
IGMA	International GNSS Monitoring and Assessment
IGS	International GNSS Service
IGS RT	IGS Real-time
ILS	Instrument Landing Systems
IMES	Indoor Messaging System (Japan)
IMO	International Maritime Organization
ION	Institute of Navigation
IRU	Inertial Reference Unit
ITRF	International Terrestrial Reference Frame
ITU	International Telecommunications Union
JRC	European Joint Research Center
L1C	GPS 4th civilian signal

L2C	GPS 2nd civilian signal
L5	GPS 3rd civilian signal
M-Code	GPS New Military Signal
MEOSAR	Medium Earth Orbit Search and Rescue
MGEX	Multi-GNSS Experiment
MOPS	Minimum Operational Performance Standards
MSS	Mobile Satellite Services
NASA	National Aeronautics and Space Administration
NCO	National Coordination Office
NextGen	Next Generation
NIPP	National Infrastructure Protection Plan
NIST	National Institute of Standards and Technology
OCS	GPS Operational Control System
OCX	GPS Next Generation Operational Control System
OST	Office of the Secretary of Transportation
PNT	Positioning, Navigation, and Timing
PTA	Protect, Toughen, and Augment
QZSS	Quasi-Zenith Satellite System
R&D	Research and Development
READI	Real-Time Earthquake Analysis for Disaster mitigation
RFID	Radio-frequency Identification
RNAV	Radio Navigation
RNP	Radio Navigation Performance
RNSS	Radio Navigation Satellite Service
RTCA	Formerly the Radio Technical Commission for Aeronautics, now RTCA, Inc.
SAR	Search and Rescue
SBIR	Small Business Innovation Research
SGB	SAR Second Generation Beacons
SOW	Statement of Work
SSR	Secondary Surveillance Radars
SV	Space Vehicle
RLS	SAR Return Link Service
TBO	Trajectory-Based Observation
TRL	Technology Readiness Level
UNAVCO	A non-profit university-governed consortium that facilitates geosciences research and education using geodesy
USCG	U.S. Coast Guard
URE	User Range Error
UTC	Coordinated Universal Time
VHF	Very High Frequency
VOR	WHF Omni-directional Range
WAAS	Wide Area Augmentation System
Wi-Fi	Local Area Wireless Technology
WWRNS	Worldwide Radionavigation System