SPACE-BASED POSITIONING
NAVIGATION & TIMING
NATIONAL ADVISORY BOARD

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

Fourteenth Meeting

December 10-11, 2014

*The Omni Shoreham Hotel*
2500 Calvert St NW
Washington, DC 20008

**Bradford W. Parkinson**
**Acting Chair**

**James J. Miller**
**Executive Director**

SPACE-BASED POSITIONING NAVIGATION & TIMING

NATIONAL ADVISORY BOARD

# Fourteenth Meeting Agenda
# December 10-11, 2014

The Omni Shoreham Hotel, Hampton Ballroom
2500 Calvert Street, NW (at Connecticut Avenue)
Washington, DC 20008
*Metro: Red Line to Woodley Park – Zoo/Adams Morgan*

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## Wednesday, December 10, 2014

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| **9:00** – 9:05 | **BOARD CONVENES**<br>*Call to Order & Announcements* | Mr. James J. Miller, *PNT Advisory Board Executive Director, NASA Headquarters* |
| 9:05 – 9:20 | Opening Remarks & Introductions<br>*Proposed Meeting Goals & Objectives from PNT Steering Group* | Dr. Bradford Parkinson *(Acting Chair),* Gov. Jim Geringer & Mr. Marty Faga |
| 9:20 – 10:00 | Concise Recap on PNT Board Recommendations & Work Plan<br>• GPS as Critical Infrastructure<br>• GPS Threat Assessment<br>• Commercial Pseudolite Operations in RNSS Bands<br>• GPS Back-Up (eLoran & other options)<br>• GPS Economic Assessment (Phase II) | Dr. Bradford Parkinson & Working Group Team Leads |
| | **Working Group-1: Assured Availability**<br>• ***Protect*** the Clear and Truthful Reception<br>1.1 Spectrum Allocation Assurance (Spectrum Subgroup)<br>• ***Toughen*** Users' Receivers<br>1.2 All GNSS Signal Receivers (International Subgroup)<br>• ***Augment*** or Substitute PNT Sources<br>1.3 Non-GPS PNT (International Subgroup) | <br><br>• Ms. Ann Ciganer & Mr. Ron Hatch<br><br>• Dr. John Betz & Dr. Per Enge<br><br>• Mr. Matt Higgins & Mr. Terry McGurn |
| | **Working Group-2: Economic Value of PNT**<br>2.1 Spectrum Denial – Economic Impact (Spectrum Subgroup) | <br>• Gov. Jim Geringer |
| 10:00 – 10:45 | GPS Modernization Activities & Program Plan Update<br>*Satellites, Ground Segment, Emerging Capabilities & Services* | Col William T. "Bill" Cooley, *Director, GPS Directorate, U.S. Air Force* |
| **10:45** – 11:00 | **BREAK** | |
| 11:00 – 11:30 | National Coordination Office Update<br>*PNT EXCOM Interagency Focus, Priorities, & Expectations* | Mr. Harold "Stormy" Martin, *Director, National Coordination Office for Space-Based PNT* |
| 11:30 – 12:00 | International Cooperation and the United Nations International Committee on GNSS | Mr. Kenneth Hodgkins, *Director, Office of Space & Advanced Technology, State Department* |
| **12:00** – 1:00 | **LUNCH –** *Annual Ethics Training for Special Gov't Employees* | |
| 1:00 – 1:30 | U.S. Department of Transportation GPS/PNT Update<br>*Adjacent L-Band Compatibility & GPS Signal Monitoring* | Ms. Karen Van Dyke, *Director for PNT, DOT Office of the Secretary, Research and Technology* |
| 1:30 – 2:15 | Radio Regulator Spectrum Management Perspectives & Priorities<br>*Emerging Trends in Spectrum Efficient Technologies* | Ms. Paige Atkins, *Acting Assoc. Administrator, Spectrum Management, NTIA* & Mr. Ron Repasi, *Deputy Chief, Engineering and Technology, FCC* |

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| 2:15 – 2:45 | Toughening GPS Receivers against Interference<br>*Ensuring Signal Reception in Spectrally Busy Environments* | Dr. Gary McGraw, *Fellow & Engineering Manager, Advanced Technology Center, Rockwell Collins* |
| 2:45 – 3:15 | A Comprehensive Quantitative Economic Assessment of GPS<br>*Establishing Scope, Duration, Expectations, & Deliverables* | Dr. Irving Leveson, *Founder, Leveson Consulting* |
| **3:15** – 3:30 | **BREAK** | |
| 3:30 – 4:00 | Role of GPS & Precision Timing in the Financial Services Sector<br>*Some Key Industry Timekeeping Requirements and Applications* | Mr. Andrew Bach, *Chief Architect for Financial Services, Juniper Networks* |
| 4:00 – 4:30 | Terrestrial GPS Augmentation with a Metropolitan Beacon System<br>*Some Evolving Solutions using Multiple Radio Bands* | Dr. Frank Van Graas, *Professor, Ohio University* & Mr. Subbu Meiyappan, *Co-Founder, NextNav* |
| 4:30 – 5:00 | Complementing GPS/GNSS with Micro-PNT Techniques<br>*Advancing Autonomy in Challenging Environments* | Dr. Robert Lutwak, *Program Manager, Defense Advanced Research Projects Agency (DARPA)* |
| **5:00** | **ADJOURNMENT** | |

## Thursday, December 11, 2014

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| **9:00** – 9:05 | **BOARD CONVENES**<br>*Call to Order* | Mr. James J. Miller, *PNT Advisory Board Executive Director, NASA Headquarters* |
| 9:05 – 9:15 | Announcements & Agenda<br>*Quick Thoughts & Feedback from Dec. 10 Discussions* | Dr. Bradford Parkinson (*Acting Chair),*<br>Gov. Jim Geringer & Mr. Marty Faga |
| 9:15 – 9:45 | Intelligent Transportation System Evolution<br>*GPS/GNSS Role in Emerging Vehicle Fleet and Highway Infrastructure* | Mr. Brian P. Cronin, P.E.<br>*Team Leader, ITS Research, Intelligent Transportation Systems Joint Program Office (JPO)* |
| 9:45 - 10:30 | International Member Regional Updates & Perspectives<br>• Dr. Gerhard Beutler<br>• Mr. Arve Dimmen<br>• Mr. Matt Higgins<br>• Dr. Refaat Rashad | (*at members' discretion*)<br>*Switzerland*<br>*Norway*<br>*Australia*<br>*Egypt* |
| 10:45 – 12:00 | PNT Board WG Reports & Recommendations to PNT EXCOM | |
| | **Working Group-1: Assured Availability**<br>• ***Protect*** the Clear and Truthful Reception<br>1.1 Spectrum Allocation Assurance (Spectrum Subgroup)<br>• ***Toughen*** Users' Receivers<br>1.2 All GNSS Signal Receivers (International Subgroup)<br>• ***Augment*** or Substitute PNT Sources<br>1.3 Non-GPS PNT (International Subgroup) | Dr. Bradford Parkinson & WG Team Leads:<br><br>• Ms. Ann Ciganer & Mr. Ron Hatch<br><br>• Dr. John Betz & Dr. Per Enge<br><br>• Mr. Matt Higgins & Mr. Terry McGurn |
| | **Working Group-2: Economic Value of PNT**<br>2.1 Spectrum Denial – Economic Impact (Spectrum Subgroup) | • Gov. Jim Geringer |
| | **Proposed Issue Areas to be Worked:**<br>• Anti-Spoofing Authentication Codes<br>• "Toughening" Techniques for Commercial Receivers<br>• FCC Licensing of non-U.S. GNSS Services<br>• Criteria for U.S. use of other GNSS systems<br>• Strategies for International Engagement | |
| 12:00 – 1:00 | **WORKING LUNCH** | |
| **1:00** | **ADJOURNMENT** | |

**Table of Contents**

**NATIONAL SPACE-BASED POSITIONING, NAVIGATION & TIMING (PNT) ADVISORY BOARD**
*The session of Wednesday, December 10, 2014 convened at 9 a.m.*

**Board Convenes**
*Mr. James J. Miller*
*PNT Advisory Board Executive Director, NASA Headquarters*

Mr. Miller welcomed the participants to the 14th meeting of the National Space-based Positioning, Navigation & Timing (PNT) Advisory Board. Since its inception in 2007, the Board has achieved a fuller representation among interested parties and tackled challenging issues both in the U.S. and overseas. The Federal Advisory Committee Act (FACA) requires the Board to have a balance of perspectives. Recent additions of expertise include the areas of precise agriculture and transportation. Board members are appointed by the NASA Administrator. The Board must avoid both the fact and appearance of conflict of interest. The intention is to direct discussions to high national policy matters instead of specific provider's matters. He noted that if any member feels they face a potential conflict of interest, then they should recuse themselves and consider themselves a member of the audience while that item remains under discussion. Mr. Miller expressed special thanks to Gen L. Kirk Lewis and Dr. Scott Pace, and recognized the presence of Gen Steven Denker (HQ, Air Force Space Command), Mr. John Stenbit (former Assistant Secretary of Defense), and Col William Cooley (GPS Directorate). All presentations are posted at www.gps.gov within 24 hours; and formal meeting minutes within 90 days. Also, Dr. Bradford Parkinson, as acting chair, is empowered to make changes to the agenda. Mr. Miller also stressed that this session's main task is to finalize recommendations to be presented to the Dec. 15, 2014 meeting of the National Space-Based PNT Executive Committee (EXCOM).

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**Opening Remarks and Introductions**
*Dr. Bradford Parkinson, Acting Chair*
*Gov. Jim Geringer & Mr. Marty Faga*

Dr. Parkinson noted that Dr. Hiroshi Nishiguchi -- who, representing Japan, has attended every Board session – is unable to attend. Also, Gen Lewis and Dr. Pace are serving as technical advisors to the Board.

Dr. Parkinson restated the Board's major accomplishments to-date. The Board's primary objective remains to ensure PNT capability to all users. Currently there is no other operational equivalent to the Global Positioning System (GPS). GPS is the backbone for global PNT services and is provided without charge to the public, services which the public has come to take for granted. GPS signals transmitted from space are inherently weak. Therefore, action is needed to *Protect, Toughen, and Augment* (PTA) these signals. To this effect the Board has established a number of working groups (WGs) that will report on the status of their work, major issues faced; and possible recommendations including their urgency and likelihood of being accepted.

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**Concise Recap on PNT Board Recommendations & Work Plan**
*Dr. Bradford Parkinson, Acting Chair*

Dr. Parkinson reviewed the recommendations made by the Board on August 29, 2014 (see Appendix E for the signed letter), namely,

- First, GPS is – and should be designated – a critical national infrastructure. It should be noted that 14 of the 16 currently identified critical infrastructures are highly dependent on GPS.)
- Second, there is a continuing need for a formal national threat model of hazards faced by GPS. Ms. Karen Van Dyke, Director of PNT, Department of Transportation (DOT), previously wrote a national assessment for PNT that should now be updated and include a focus on steps for both users and providers to take.
- Third, in relation to prospective licensing in Europe of pseudolites in the GPS frequency band, it is important that such signals not be authorized. In attempting to protect their own national systems, some nations are unknowingly acting in a way that could threaten free trade.
- Fourth, as the Board has frequently expressed, attention needs to be called to GPS' fragility. A backup system is a high order need. The Board holds the view that the optimal backup is Enhanced Loran (eLoran). It is regrettable that existing Loran stations are being dismantled. However, currently there is some reexamination of this issue at Federal level.
- Fifth, the Board is now in the second phase of its study on the economic impact of GPS. Phase one identified $65 billion annually in economic benefits to selected commercial areas. Dr. Parkinson sought further comments from Gov. Jim Geringer, the economic study coordinator.

Gov. Geringer noted that the undertaking is an interagency effort. Many organizations represented in the PNT EXCOM have economic experts of their own, who will be engaged. The study is becoming more focused on the value that Global Navigation Satellite Systems (GNSS), which include GPS, are providing to the civil economy and less focused on the economic consequences of the GNSS signals not being available.

Ms. Neilan asked whether the assessment embraces international aspects.

Gov. Geringer said that while no focus is made on international matters, in practice there are no national boundaries to GPS services. GPS is an added value to logistics worldwide. While one can focus on U.S. sectors, one cannot not "cordon off" the advantages of GPS to the world.

Ms. Neilan noted that at the 9th meeting of the International Committee on GNSS (ICG) a recommendation was made that other countries establish bodies similar to the Board. Such bodies could also be urged to undertake their own economic assessments.

Gov. Geringer welcomed information from all interested parties.

Mr. Miller noted that phase two of the economic study is intentionally divided into two sections. The first, now in need of completion, is to identify GPS' benefits to the United States, thereby answering the immediate question posed by the PNT EXCOM. The second phase extends this to studies of international markets.

Mr. Stenbit reported that Galileo, the European GNSS, has undertaken considerable work in this area.

Dr. Parkinson noted that several Australian studies have focused on the value of GPS.

Mr. Higgins noted that since many U.S. corporations operate internationally, the benefits they accrue from GPS are also international.

Dr. Parkinson presented a chart outlining the 'Way Forward' for the Board, namely,

- Continue the economic assessment
- Remain ready to assist on developing a national threat model
- Proceed on *Protect, Toughen, and Augment* activities applicable to all users and including anti-spoofing and other measures
- Emphasize system backup and track action on eLoran, should it be the accepted backup
- Track Federal Communications Commission (FCC) licensing of non-GPS use of receivers in the United States and explore the state of the art in the toughening of commercially-available receivers

Finally, Dr. Parkinson noted that international engagement efforts included participation at the recent ICG meeting in Prague, Czech Republic, and plans to attend the upcoming ICG 10th meeting in Boulder, Colorado in November 2015.

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**Reports from the PNTAB Working Groups**

***Working Group 1: Assured Availability: Protect; Toughen; Augment***
*Working Group 1.1: Protect Clear and Truthful Reception*
*Ms. Ann Ciganer; Mr. Ron Hatch*

Mr. Hatch said he would describe the issue and Ms. Ciganer would address what was being done about it. The issue is that the European Union has approved adopting recommendation 11(08) permitting use of pseudolites (which are, effective, ground-based GNSS satellites) to obtain local performance improvements. Insufficient attention has been paid to such unintended consequences as the elimination or degradation of signals to non-protected GPS receivers. In effect, 'licensed interferers' with the GPS signal will be created. Currently, the recommendation is circulating for approval among the 48 nations that were members of the European Conference of Postal and Telecommunications Authorities (CEPT). The European Technical Standards Institute (ETSI), composed of private subject matter experts, has recommended approval of the proposal to the CEPT. Along with that approval, ETSI recommends adoption of "no fly" zones; stated that all license holders should monitor the correct functioning of the pseudolites, and stated that Radio Navigation Satellite Service (RNSS) system operators should supply the required pseudorandom noise (PRN) codes under the local administration of each national authority.

Ms. Ciganer took over from Mr. Hatch, and explained that progress occurred during discussions with various groups in the U.S., Europe, and Japan and with systems suppliers. As per longstanding international policy, any proposed ground transmitting system must first prove its operation does not cause interference with the GPS band. The pending action would reverse the burden of proof and establish precedent for a directly contrary policy. Interestingly, several European pseudolite manufacturers have announced they would not build devices that would operate in the bandwidth reserved for RNSS activity. Working Group 1 has two recommendations: (1) the Board should recommend to the EXCOM that it work cooperatively with the CEPT to achieve the withdrawal or amendment of Recommendation 11(08); and (2) raise with the CEPT the point about this proposal not distinguish between indoor and outdoor use of pseudolites and, also, the fact that the technical reports behind the European recommendation do acknowledge that indoor pseudolites could cause significant interference with GNSS signals, including signals near airports. The admission that this threat has not been competently studied provides further grounds for urging the withdrawal of Recommendation 11(08).

Dr. Parkinson noted that the Board's list of recommendations includes a "placeholder" on this subject and, thus, a new recommendation may not be necessary. The Board could instead request that current status be clarified.

Ms. Ciganer requested that any statement from the Board use full names rather than acronyms.

Dr. Parkinson agreed, and added that references to "indoor" operation are extremely "fuzzy" in technical terms.

Ms. Ruth Neilan noted that a significant shift is occurring in the paradigm, and studies undertaken to date have not adequately addressed this shift.

Ms. Ciganer presented an additional proposed recommendation to the EXCOM to urge enactment of legislation to prevent proliferation of GNSS jammers, and to increase penalties for unauthorized use of such jammers within the U.S. Furthermore, the import, export, or transit of such unlicensed devices should be banned. These steps, would require involvement from the FCC, the Department of Commerce (DOC), and the Department of State (DOS).

***Working Group 1.2: Toughen Users' Receivers***
*Dr. John Betz; Dr. Per Enge*

Dr. Enge explained that the term "toughen" refers to the ability of satellite navigation receivers to reject or operate through contaminated or invalid inputs. The term refers broadly to the capabilities of all satellite navigation receivers. In the previous day (December 8, 2014) a session was held with representatives of the financial, agricultural, and telecommunications industries, as well as a leading receiver manufacturer. At this session the question was asked on how "toughen" would affect each sector and what each sector could do about it. Attention focused on the fixed site/time transfer aspect and absolute time applications. Today users have a common need for an accuracy of 1 millisecond. In the event of a GPS failure, that standard could be met by "fallback" to atomic clocks. This substitution would occur "gracefully" – that is, without notable disturbance. However, time and accuracy requirements are expected to sharply increase due to regulations and liability concerns, particularly in the financial world. Timing requirements of one microsecond rather than one millisecond may be needed. Sufficient time exists to make the needed improvements, provided efforts begin promptly. Working Group 2 has three recommendations: (1) the National Coordination Office (NCO) should initiate an effort to document and disseminate broadly a "best practices" approach for toughening GNSS; and (2) the Department of Defense (DoD) and DOS should aid this effort by determining whether and, if so, in what ways, existing International Traffic in Arms Regulations (ITAR) requirements prevent U.S. manufacturers from employing established toughening techniques; and (3) The Federal Aviation Administration (FAA) should be requested to consider use of Schnorr signatures (a digital signature produced by the Schnorr signature algorithm, used in cryptography) for GPS Space-based Augmentation System (SBAS) authentication. The pertinent question is how one can best authenticate data in order to mitigate the effects of spoofing. Schnorr fits the current message length and is generally considered unbreakable at least through 2030.

***Working Group 1.3: Augment or Substitute PNT Sources***
*Mr. Matt Higgins; Mr. Terry McGurn*

Mr. Higgins reported on the previous day's working session. The session began with a "robust discussion" of the status of international GNSS systems and the criteria the U.S. should use to determine whether a system can be trusted. Non-GNSS discussions focused on the future, if any, of eLoran. Another discussion topic was that of international concerns.

Mr. McGurn added that for fixed users the critical concern is timing; positioning and navigation are of lesser importance. The reverse is generally the case for mobile users. He also expressed misgivings on GLONASS', the Russian GNSS, ability to meet the highest PNT criteria, including GLONASS messaging. GLONASS data, however, has for many years been used in surveying and geodesy.

Dr. Parkinson asked why using GLONASS data in surveying and geodesy is not impacted by concerns regarding GLONASS performance.

Mr. Higgins responded by noting that Mr. McGurn was talking about stand-alone signal accuracy. In practice, most surveyors rely on GLONASS data collected by the International GNSS Service (IGS).

Mr. McGurn referred to the April 2014 GLONASS incident users relying solely on GLONASS navigation messages experienced a complete service failure, whereas those generating their own orbital information (e.g. using IGS data) would have been unaware of this incident.

Mr. McGurn continued explaining that safety-of-life applications are of particular concern. This has the ICG to undertake continuous independent monitoring of all GNSS systems since an individual system is likely to experience an outage at some time or another. System users should have prompt access to information about outages and the steps needed to accommodate it. This further underscores the need for transparency.

Mr. Higgins was asked what criteria would establish that a GNSS system is acceptable. He replied that given the variety of sector specific requirements, it is difficult to make a broadly applicable recommendation. The ICG is working to develop an international GNSS monitoring assessment activity. A unified system is preferable to systems developed by individual GNSS providers. Perhaps the work currently being undertaken by the ICG could be extended into other areas of monitoring concerns. In summary, the Board needs to be aware of the quality of other systems and the assessment standards such systems employ. However, it should not duplicate existing ICG efforts. In his view, more work is required before a formal recommendation can be made.

The discussion then moved to non-GNSS systems, such as Inertial Navigation Systems (INS) and eLoran. The Board articulated its concerns about eLoran in its August 29, 2014 letter. At the request of the EXCOM, a working group was established to review options for Complementary PNT (CPNT).

Dr. Parkinson, commenting on Australian aviation monitoring, said he assumes some type of "time to alarm" mechanism is being employed. The FCC has concerns about this. The question is not how quickly integrity can be established, but how quickly a given aircraft can be informed.

Mr. Higgins said the current Australian system lacks such capability.

Dr. Parkinson said that in systems used for "safety of life," providing "time to alarm" is just as necessary as establishing integrity. The international aviation community has been encouraged to move towards tying "integrity" and "time to alarm" into a common system. However, this hasn't been properly addressed as of yet.

Mr. Higgins said robustness is improved through use of multiple systems, provided each individual system operates correctly.

Ms. Ruth Neilan asked whether Australia has already published its new space policy.

Mr. Higgins said it has.

Ms. Neilan suggested that "time to alarm" is something that could be included in ICG monitoring activities as they these continue to develop.

Mr. Higgins turned discussion to the previous day's second topic: international engagement. There are three main players: other GNSS system providers; non-provider nations – which have widely varying levels of PNT sophistication – and the various international bodies.

***Working Group 2: Economic Value of PNT***
*Gov. Jim Geringer*

Gov. Geringer noted that people in Science, Technology, Engineering, and Math (STEM) disciplines need to accept that economics does not lend itself to the statistical exactness to which they may be accustomed. Economic analyses are undertaken to calculate value. Such efforts are often viewed as self-serving, because whoever conducts them can assert benefits but omit offsetting costs. Determining the value of GPS is particularly difficult as GPS is often used in combination with other technologies. This makes it difficult to determine the value added by GPS. A report on the economic value of PNT is due for delivery to the EXCOM within four months. Little time is available for original research. Therefore, the working group will look at studies undertaken by Europe for Galileo, and in Australia. GPS is most commonly associated with navigation; the impact that the GPS timing capability has on the financial world is less recognized. The WG will make

an effort to determine if there are practical ways to measure the costs of a GPS outage. Also, the Board will hear a more detailed report on the economic assessment from Dr. Irving Leveson.

Mr. John Stenbit suggested that trying to refine the cost benefit might not be the best way to go. Two general approaches exist. The first is statistical, pursued through optimization of resources. The second focuses on minimizing your optimal regret. The first is characteristic of economists; the second is characteristic of the insurance industry. He suggested that more attention should be paid to the latter.

Dr. Parkinson termed this a fascinating idea as "minimizing optimal regret" is not an approach normally used by economists.

Mr. Stenbit said the DoD has considerable data on how to minimize maximum regret.

Gov. Geringer noted that EXCOM has requested a *number* – that is, what is the value of having GPS as opposed to not having it. That is the charge given to the Board and the question it needs to answer.

Mr. Stenbit commented that, to a good extent, the Board's ability to meet the EXCOM's goal is an inverse function of the EXCOM's ability to find fault with the methodology used.

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**GPS Modernization Activities and Program Plan Update**
Satellites, Ground Segment, Emerging Capabilities & Services
Col William T. ('Bill') Cooley, Director, GPS Directorate, U.S. Air Force

Col Cooley expressed his appreciation for the recommendations that have been forthcoming from the Board. The GPS Directorate (GPS-D) has reflected on such things as the April 2014 GLONASS incident and directed attention to any similar possibility affecting GPS. Hard work is underway to avoid such an occurrence in GPS. Col Cooley presented a slide summarizing current constellation status and noted the continued improvement in system performance. Earlier (GPS IIA) satellites are nearing the end of their service life, and eight satellites are in residual/test status. The oldest satellites still in use have been operating for 24 years, well beyond their original design life of seven years.

Gov. Geringer asked whether, given increasing user expectations, at some point it may be necessary to increase the "baseline" number for GPS satellites.

Col Cooley responded that the DoD service requirements call for 24 satellites operating in six planes with a 95% confidence. In practice, achieving this requires "24 plus three" satellites. Everyone is aware of the desire for greater capability, but the DoD standard is the one he is required to meet.

Col Cooley continued explaining that that Gen John E. Hyten (Commander, Air Force Space Command) has articulated the need for increased system resiliency. Resiliency, is most easily measured by the number of healthy satellites in the constellation, and the GPS-D intends to meet or exceed all set requirements. Also, funding levels are based on existing formal requirements.

Col Cooley asked if Gen Steven Denker cared to add anything.

Gen Denker said his only comment is that focusing on resiliency improves the overall constellation performance.

A question was raised on how this could be "married" to users' expectations for improved performance.

Mr. Stenbit said that while "24 is an interesting number," the reality is that if one is in the deep mountains of Afghanistan, one cannot receive a truly reliable signal. More satellites would produce a better result. What number of satellites is "sufficient" depends on the problem one is trying to solve.

Gov. Geringer asked whether the 24-satellite baseline is still appropriate.

Dr. Parkinson said that because the FAA is "stuck with" the 24-satellite baseline, it is forced to calculate the user range error (URE) of GPS as four meters, even though far greater accuracy is always achieved. This particularly concerns persons designing safety-of-life systems. It is, however, understandable there would be reluctance in the Air Force to raise the baseline to 30 satellites as they are the ones required to provide funding. A continuing tension exists between what the system is providing and what it can "guarantee." Hopefully the URE parameter can be reduced in the future.

Col Cooley said that as a service provider he prefers to "under-promise and over-deliver."

Col Cooley continued explaining that 2014 has been "a banner year" with four successful launches of GPS IIF satellites, and four more "in the pipeline." System performance continues to improve. The Standard Positioning Service (SPS) range error in 2013 of 0.8 meters is the best performance ever; and the Precise Positioning Service (PPS) range error in 2013 of 0.7 meters exceeds the previous best. These figures on range error reflect the aggregated performance of all satellites. Finally, GPS III satellite vehicle (SV) 01 will be ready-for-launch in 2016.

Military GPS User Equipment (MGUE) is another key sector. The next generation of military GPS receivers is now under construction and incorporate M-Code transmissions, which is a statutory requirement to be met by 2017. There is also much ground segment work being done in the area of cyber security. The fourth exercise on GPS III was completed in September 2014, where 72 of 74 requirements were successfully tested. The exercise was a productive risk-reduction effort.

On civil signal modernization, continuous Civilian Navigation (CNAV) message broadcast on the GPS L2C and L5 signals was initiated on April 28, 2014. Uploading of the modernized message begins on the current week. It is anticipated that user range performance will be equal or better than the legacy system.

Dr. Parkinson noted that L2C and L5 have provided six months of consistent operation.

Col Cooley added that at one point the daily uploading was so free of error that, as a scientist, he almost suspected something was amiss in the reporting.

Dr. Parkinson asked if a fully redundant signal has been created.

Col Cooley said it has.

Dr. Parkinson asked if a user could navigate entirely with L2C.

Col Cooley said one could. Currently 15 satellites are currently broadcasting L2C, and the GPS-D is working closely with receiver manufacturers to encourage them to take advantage of this capability.

Col Cooley closed his presentation with a group photo of seven members of the GPS-D. He wished to make clear that the GPS-D is "not some strange organization" but, rather, one with very real people who provide all of its capabilities.

Mr. Miller expressed his thanks on behalf of his NASA colleagues, and noted the addition of laser retro-reflectors on future GPS III satellites as well as advances in the GPS Search and Rescue (SAR) package. Further, he looks forward to additional civil signal monitoring capability. He also suggested that consideration be given to several points: (1) a good example would be set if performance data on GPS IIF were made available; (2) as the schedule of launches of the GPS III satellites is being extended, could this allow for an earlier introduction of laser retro-reflectors or a new Mercury-Ion atomic clock?

Col Cooley said he recognizes the importance of these points. Regarding introduction of the Mercury-Ion clock, if there are opportunities to increase clock performance that is something he'd be clearly interested in.

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**National Coordination Office (NCO) Update**
*PNT EXCOM Interagency Focus, Priorities and Expectations*
*Mr. Harold 'Stormy' Martin, Director*
*National Coordination Office for Space-Based PNT*

Dr. Parkinson noted this was the first meeting at which Mr. Harold 'Stormy' Martin was Director of the NCO, and also thanked him for past efforts on behalf of the Board while on active duty.

Mr. Martin began by restating the pillar of U.S. space-based PNT policy: "The U.S. must maintain its leadership in the service, provision and use of GNSS." The policy entails providing continuous GPS services free of charge worldwide; encouraging compatibility and interoperability with foreign GNSS systems; maintaining a constellation that satisfies civil and national security needs, continuing efforts to detect, mitigate, and increase resiliency to harmful interference.

The EXCOM has responsibilities beyond GPS. Invoking an adage, Mr. Martin said GPS has taken the best, made it better, and continued to improve it over time. The EXCOM is a consensus-based organization -- a body of equals composed of the deputy secretaries of pertinent federal agencies.

The EXCOM's current priorities include: (1) critical infrastructure security and resiliency; (2) enforcement of prohibition on jamming devices; (3) phase two of the economic benefit assessment of GPS, and (4) spectrum protection.

Most PNT-related user infrastructure is privately-owned and, thus, there are limits on what the U.S. government can do in terms of compelling users to implement adequate protection and backups.

The NCO remains engaged with resiliency, jamming, and enforcement related to interference. The variety and strength of the threats to PNT has greatly increased. Some threats are simple and apparently harmless (e.g. a worker may employ a jammer so his employer cannot track his lunch hour movements), however harmless such actions may seem the threat to GPS is very real. The FCC has the responsibility for preventing jamming. For example, in June 2014 it fined a foreign company $35 million for manufacturing jamming devices sold in the U.S.

An interagency effort led by the DOC will work with the Board on the economic benefit study.

On spectrum issues, there is a Presidential Directive that 500 megahertz of spectrum be made available for broadband use. There are a number of private companies persisting to make filings for use of spectrum adjacent to the GPS L1 frequency bands.

Currently the Nationwide Differential GPS (NDGPS) broadcasts GPS differential correction data to 92% of the continental U.S. The United States Coast Guard (USCG) and DOT have issued a joint notice seeking comments on the future of NDGPS. Responses have been reviewed and followed by a site-by-site analysis.

Finally, NCO outreach efforts have included distributing 34,000 "How GPS Works" posters to teachers in STEM areas. Also, currently there is a "Time and Space" exhibit on display at the National Air & Space Museum.

Dr. Parkinson invited comments and questions.

Ms. Neilan asked whether raw NDGPS performance data will be made public.

Mr. Martin said he is uncertain, but will check to see if a repository exists and then inform the Board.

Ms. Neilan asked if National Geodetic Survey (NGS) data has been made public.

Mr. Martin said that NGS collects and archives all data, and also continuously monitored data quality. The data is available online.

Mr. Betz commented that the EXCOM's scope does not appear to include the use of foreign GNSS signals within the U.S.

Mr. Martin said that while national policy focuses on GPS, there are "hooks" in this policy for international activity. Therefore, the EXCOM can engage with such issues, particularly as they relate to the DOS and DOC.

Dr. Parkinson said the Board wishes to gain clearance for the use of foreign GNSS signals in the U.S. The Board's understanding is that such signals cannot, in principle, even be monitored because approval for their use has not been forthcoming from a sufficiently high level. This matter deserves attention and, hopefully, the issue will end up being "just a high level snag."

Dr. Axelrad said authorization is needed so foreign GNSS can strengthen GPS.

Dr. Parkinson said the EXCOM may need to tackle this issue. Further, DOS may need to participate in case some "quid pro quo" with foreign governments is involved.

Gov. Geringer asked why efforts to declare GPS as critical infrastructure have received "pushback."

Mr. Martin responded that DHS recognizes GPS as a critical enabler of multiple critical infrastructures. Each sector has a lead agency with a process for reaching out to its owners/operators 'constituents' and engage with them to understand their reliance on GPS. Such owner/operators are aware of "a mountain of risks" to their systems and, based on this knowledge, make decisions on how to direct resources to reduce the risk. In practice, however, sector members generally focus on preventing the recurrence of problems that have actually occurred. Therefore, since GPS has never failed it is difficult to persuade owner/operators to assign a higher risk level than they already have.

Gov. Geringer said that given the criticality of GPS to so many things, it is puzzling the Board has to undertake its defense.

Mr. Martin agreed. GPS has become the victim of its own "pristine performance" and explaining that GPS is under threat becomes difficult to sell to corporate leadership.

Dr. Parkinson said the key point is that GPS should be given the visibility it deserves and, hopefully, a declaration that GPS is a critical national infrastructure would achieve this goal.

Mr. Martin was also asked whether stronger laws against civil jammers are pending.

Mr. Martin replied that considerable discussion is occurring on the subject. The FCC has stepped up enforcement activities. For example, an individual has recently been fined $32,000. Therefore, it is apparent the FCC is attempting to make maximum use of existing laws.

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**International Cooperation and the United Nations International Committee on GNSS**
*Mr. Kenneth Hodgkins, Director*
*Office of Space & Advanced Technology, State Department*

Mr. Hodgkins said he would brief on steps in bilateral cooperation taken since the Board's June 2014 meeting and activities of the ICG and the GNSS Provider's Forum.

On bilateral cooperation, a compatibility coordination agreement was been reached in July with Galileo-ITU. Technical meetings were held with Japan in September and November to discuss GPS / Wide Area Augmentation System (WAAS) / Quasi-Zenith Satellite System (QZSS) International Telecommunications Union (ITU) compatibility. Also, the U.S.-European Union (EU) working group met in early December to discuss the next generation of civil navigation and timing systems.

On ICG activities, there has been an agreement that providing support on GPS use in developing nations could best be accomplished through the creation of a group focused on this mission. The ICG includes all current GNSS suppliers, individual UN member states (including Italy, Malaysia and the United Arab Emirates), and 21 international organizations and others with an interest in the subject. There are four working groups within the ICG: Compatibility and Interoperability (WG-A); Enhancement of GNSS Services Performance (WG-B); Information Dissemination and Capacity Building (WG-C); and Reference Frames, Timing and Applications (WG-D). The first meeting in 2006 drew 40 participants whereas the latest meeting ($9^{th}$) drew over 200. It is anticipated that the $10^{th}$ ICG will have at least that many in attendance.

The GNSS Provider's Forum, which runs concurrently with the ICG, was established in 2007 with the purpose to sponsor focused discussions on compatibility and interoperability; encourage development of complementary systems; exchange detailed information on systems and service plans; and exchange views on ICG efforts.

At the ICG $9^{th}$ meeting in Prague, Dr. Parkinson gave a presentation on how to "Protect, Toughen, and Augment" PNT and recommended that other GNSS providers establish Boards similar to this Board and include international participation. There were four important outcomes of the ICG session:

- First, the U.S. urges continued "fair market" operations in the GNSS world. This is in response to an increased incidence of individual nations pressing for adoption of specific GNSS technologies. The U.S. remains committed to "technology neutral" performance-based standards.

- Second, the Interference Detection and Mitigation (IDM) Task Force has initiated discussions of GNSS as a critical infrastructure and is reviewing provider laws relative to jamming.

- Third, the Interoperability Task Force and Systems Providers continues to assess feedback from four interoperability session held specifically to gain industry input.

- Fourth, discussions continued on the importance of interoperable space service volume.

The U.S. will host the $10^{th}$ ICG meeting at the University Corporation for Atmospheric Research, a consortium of over 100 colleges and universities that focused on atmospheric research and earth science systems. Sponsors are being sought for social events.

Dr. Parkinson thanked Mr. Hodgkins for his efforts and sought questions and comments.

Gov. Geringer made reference to matters raised by the Board's work groups, including the EU approach to pseudolites and the need to develop independent orbital monitoring. He noted that Mr. Hodgkins had not addressed these matters.

Mr. Hodgkins responded he has not been directly involved with these questions. The question of pseudolites was not raised at the sessions he attended at the 9th ICG meeting. Perhaps it would arise in the context of Galileo-GPS discussions.

Ms. Ciganer said she believes a presentation on the subject was made to ICG WG-A with a core message that continued worldwide trust in the various GNSS systems requires seamless integrity. Therefore, defining a common position on spectrum protection would make a significant contribution to such outcome.

Dr. Parkinson asked how this recommendation was received.

Ms. Neilan responded that this is a complex issue. Once system operators understand they benefit from worldwide protection of the spectrum, then a common position will be achieved. Significant progress has been made. If providers establish and communicate a common position, then a liaison dialogue could be held with the ITU as well as GNSS and regional providers.

Mr. McGurn said he is encouraged by the importance placed at the ICG session on inter-service monitoring. Monitoring is particularly important as efforts continue to integrate a true GNSS system. In reference to a workshop on monitoring scheduled for 2015, and a recommendation that providers' user service centers develop a process for exchanging information, he asked whether Mr. Hodgkins could elaborate.

Mr. Hodgkins said the USCG will address the EU with the question of the user services centers, whereas the monitoring effort should be left to those most interested in moving matters forward. The DOS is trying to work within the ICG to create a "system of systems" consisting of interoperable civil signals. If, however, those civil signals are not globally useful – due to intentional or unintentional interference -- this approach becomes unworkable. Many smaller countries lack the capability to detect and mitigate interference, and work with these countries is only starting to ramp up. The 2015 workshop could be the first step to achieve these goals.

Mr. McGurn said that he's concerned about overseeing the integrity of the providers' reports. Such reports should be transparent on the causes of any problem and corrective actions that need to be undertaken.

Mr. Hodgkins agreed, saying this is why it is so important to "link up" the various service centers so that standardization can occur.

Dr. Parkinson asked Mr. Hodgkins to find out the dates for that session and whether observers would be welcome.

Dr. Beutler said he could not imagine the ICG itself undertaking the task of monitoring the performance of all individual GNSS systems.

Mr. Hodgkins agreed.

Mr. Higgins said he believes the issue of individual GNSS provider nations requiring use of their own systems is of considerable concern. Has the ICG discussed what might be done about this?

Mr. Hodgkins said it has not. However, the subject has been raised as a possible topic for future work. The next step should be to develop a position on what the Providers' Forum could do.

Mr. Higgins said the matter needs to be drawn to the attention of non-provider nations, as they are also affected by this. Further, the Board should consider scheduling a meeting adjacent to the ICG-10.

Dr. Parkinson said this should be seriously considered.

Ms. Neilan noted that at ICG-9 it was apparent that China is very anxious to host a meeting to discuss which parameters should be monitored. As for who has the capability of performing this task, ICG has "lots and lots" of data but not necessarily the capability to examine it critically.

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Mr. Miller noted the lunch break would include the annual ethics briefing for Board members that are Special Government Employees.

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*Afternoon Session:*

**U.S. Department of Transportation (DOT) GPS/PNT Update**
*Adjacent L-Band Compatibility & GPS Signal Monitoring*
*Ms. Karen Van Dyke, Director for PNT*
*DOT Office of the Secretary, Research and Technology*

Mr. Karen Van Dyke explained said that effort to develop spectrum interference criteria began with a letter from the EXCOM co-chairs to the National Telecommunication and Information Administration (NTIA) on January 13, 2012. The letter said that revised standards are needed to support decision-making on commercial use near the GPS bands, and that such standards should not affect existing and evolving uses of space-based PNT. The then DOT Deputy Secretary, John Porcari, wished to act promptly to define spectrum interference. The FAA and DOT's research organizations were charged with developing a plan, which he approved late in 2012. Following some delays while resources were being secured, the implementation of this plan is now moving forward on parallel paths. The FAA is working on GPS adjacent band compatibility for certified avionics and the DOT is addressing GPS adjacent band compatibility for all other receiever categories. This plan, now known as the GPS Adjacent Band Compatibility Assessment, has two main intentions: (1) derive adjacent-band power limits to ensure continued operation of all GPS services and (2) determine similar levels for future GPS receivers using modernized GPS and interoperable GNSS signals.

Dr. Pace asked whether anyone has been charged with reviewing the satellite communications systems that support transportation. These are also a "rare resource" that needs protection and, in his view, the DOT should be concerned with all satellite navigation signals and not just GPS.

Ms. Van Dyke termed this a good point, and added she did not know whether it is being worked as a separate effort.

Dr. Pace noted that perhaps the same questions should be put to all committees involved with satellite communications.

Ms. Van Dyke agreed.

Ms. Van Dyke then presented the tentative schedule for the GPS Adjacent Band Compatibility Assessment Implementation Plan. Its objective includes developing representative receiver masks needed for each area of operation. Outside of aviation there are no receiver masks, so creating them requires considerable effort. Further, the aggregate effect of multiple transmitters on GPS operation needs to be determined.

Dr. Parkinson noted that the interaction scenarios do not seem to include the circumstance of an aircraft on the runway relying on pseudolites. Is scenario being examined?

Ms. Van Dyke said she could not answer that this was specifically being looked at part of the GPS adjacent band effort.

Mr. Tim Murphy said GPS at the gate is a requirement, and an aircraft will not "pushback" from the terminal without it.

Ms. Van Dyke then identified six issues to address:

- Agreement on the definition of harmful interference;
- Achieving a balance between transparency and the fact that some receiver manufacturer design information was proprietary;
- Agreement on adjacent band services;
- Spectrum protection for augmentation services in the MSS Band;
- Spectrum protection for foreign GNSS; and
- Sufficient resources for receiver testing.

Mr. Higgins noted that other GNSS signals are received in the U.S.; is consideration being given to how multi-GNSS testing might be conducted outside the U.S.?

Ms. Van Dyke said that will evolve from development of the test plan. Phase I will primarily look at existing receivers, including GPS/ GLONASS, whereas Phase II will likely all multi-GNSS receivers.

Mr. Higgins said he believed multi-GNSS would provide enormous and immediate advantages.

Responding to an earlier comment from Ms. Van Dyke about needing more resources, Mr. Miller noted that NASA is already investing $10 million in developing a multi-GNSS signal processing capability.

Ms. Van Dyke said that testing all receiver designs is not practical and, instead, a representative set will be defined. She welcomed assistance in identifying such a set.

Ms. Van Dyke presented information on the Civil Signal Monitoring Performance Specifications (CMPS), which includes 193 GPS performance requirements catalogued by the DOT. The CMPS is a GPS Next Generation Operational Control System (OCX) contract reference document, not a requirements document, and therefore efforts are being made to incorporate the CMPS document into OCX Block II documentation.

Ms. Van Dyke then presented the Civil Signal Monitoring Trade Study. The study team presented two recommendations: (1) pursue dual implementation of OCX and non-OCX elements; and (2) engage with the Air Force on integrating non-OCX monitoring into GPS operations. Considerable discussion has occurred on incorporating requirements into OCX. Everyone speaks of this as a hurdle that can be overcome, but how the two will be balanced still needs to be determined.

Dr. Enge commented that signal monitoring could be very relevant to Advanced Receiver Autonomous Integrity Monitoring (ARAIM), which combines multiple constellations. ARAIM could be a very useful crowd system provided because narrower UREs were broadcast. However, if the URE is four meters a system would not be nearly as useful. Could civil monitoring lead to a narrower URE?

Ms. Van Dyke said that question should be directed to Col Cooley.

Col Cooley said his engineering team is currently addressing the matter.

Dr. Enge observed that the present URE floor is 4 meters, whereas the actual performance is closer to 0.6 meters. If the URE were reduced to one meter, or less, the implementation of systems using multiple GNSS signals would become much simpler.

Dr. Parkinson added that users cannot take advantage of actual performance unless that performance is assured, which is why he urges a less conservative URE range.

Col Cooley said that any commitment to a higher performance level would prompt ripples. If one raises expectations then a number of redesigns would be needed.

Dr. Parkinson said he is not suggesting redesigns. The year-in, year-out data already shows sub-meter performance, and simply reducing the URE from two meters to one meter would "open the world in very useful ways."

Mr. Stenbit noted that Col Cooley has to deal with many contractors and subcontractors that would require revised specifications, and the expense could be enormous.

Dr. Axelrad asked if a change in URE specification is actually needed. Could one not simply report actual performance, absent any error range?

Dr. Parkinson said the essence of the problem is that the reported margin of error is four times the actual error.

Col Cooley said a decision to change performance expectations is above his pay grade. If the Board feels this is highly important, then it should make a recommendation to the EXCOM. The performance specification has not been updated since 2008 and one could perhaps argue it is time for a review.

Dr. Betz said an alternative could be to simply report the actual accuracy that occurred. Such report would not conflict with contractor relationships.

Col Cooley said he will refer the matter to AFSPC for further discussion.

Dr. Parkinson said he believes the argument has been won through "the long erosion of the existing position."

Mr. Murphy said it is not clear that even if the DoD changed the performance expectation, the FAA could then readily change its own performance standards. If events led to an active monitoring system anyway, as raised by Dr. Axelrad's, the specification change may be unnecessary.

Dr. Enge said that in the advanced RAIM concept, the real time-to-alarm comes from the residuals test in the avionics. The question is where does the remainder of the integrity burden reside? If the FAA is willing to let that burden go back to the constellation then issue would be much simpler.

Dr. Parkinson commented that this would be a great enabler for multiple-GNSS throughout the world.

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**Radio Regulator Spectrum Management Perspectives & Priorities**
*Emerging Trends in Spectrum Efficient Technologies*

*Ms. Paige Atkins, Acting Associate Administrator*
*Spectrum Management, NTIA*
*&*
*Mr. Ron Repasi, Deputy Chief*
*Engineering and Technology, FCC*

Ms. Atkins explained this presentation would outline NTIA/FCC spectrum management perspectives including the roles, responsibilities, terminology, processes, policy drivers and goals of NTIA and FCC as they relate to spectrum management. She indicated that the two agencies work collaboratively, particularly in response to presidential priorities such as the current desire to provide additional spectrum to commercial wireless broadband. This requires that commercial objectives and national security concerns be balanced. The NTIA and FCC are making decisions based on this broader context and not just on singular capabilities (such as GPS).

Mr. Repasi then explained the difference between the FCC and NTIA authorities and repsonibilites in managing the spectrum. The Communications Act of 1934, created the FCC which authorizes non-federal operations in the spectrum. NTIA authorizes federal operations in the spectrum. NTIA and FCC coordinate on spectrum matters to address federal and non-federal demands for spectrum, respectively. The NTIA falls within the DOC where it provides advice on various telecommunications issues and administrative actions on behalf of the executive branch. Mr. Repasi added that the FCC is not part of the executive branch, but rather is an independent government agency directly responsible to Congress. The Communications Act of 1934 states that non-federal entities must be licensed by the FCC in order to transmit in the radio spectrum.

Dr. Parkinson asked for clarification on how do satellite transmissions "fold in" to this transmission requirement.

Mr. Repasi said satellite transmissions, including foreign GNSS, are coordinated through the International Telecommunication Union. However, FCC permission is required to use those signals within the U.S.

Dr. Parkinson noted that Galileo transmits in a band near GPS, so would it still have to go through the FCC?

Mr. Repasi said all U.S. domestic users need an FCC approval to use any foreign GNSS signal.

Mr. Miller noted that other GNSS systems are newly emerging, so by what process has FCC determined it has the authority to license those transmissions?

Mr. Repasi referred to FCC authority under the Communications Act and commitments under the World Trade Organization (WTO) agreements reached in the late-1990s when various nations were concerned that foreign satellite access to their markets could pose a competitive harm to their domestic satellite systems. Title 47, Code of Federal Regulations (47CFR), Part 25 codifies the requirements for foreign satellite tranmissions in the U.S. Any decisions to permit operations in the U.S. are expected to be in the public interest and approval will be based on harmonized spectrum use, efficient use of the spectrum, promoting new technologies and services, and protection from interference. The NTIA uses similar criteria.

Mr. Repasi then referred back to the presentation and provided additional information on allocations, service rules, frequency assignments, and the FCC rulemaking process. From a spectrum management perspective the FCC allocates spectrum to services, develops service rules for operations in the allocations, and assigns frequencies conditioned on meeting the requirements of the allocaitons and service rules. Spectrum allocation definitions are very important to determine interference protection rights among the services and he explained that if operations don't conform to the the allocation table, they operate on a non-interference basis. The FCC also has an enforcement bureau to ensure compliance with the rules.

Dr. Parkinson noted that GPS satellites share a spectrum band; how does this fit in with the FCC construct?

Mr. Repasi said a variety of spectrum sharing methods allow for multiple access to the RNSS spectrum.

Dr. Enge noted that "interference risk" is defined and measured differently by the navigation and communications communities, because the former only involves one-way transmission. Is this distinction being recognized?

Mr. Repasi said that in assessing risk, the incumbent operators urge the FCC to focus on "worst case" scenarios. That is, the greatest consequence of harmful interference. However, proponents of various new servcies have urged that risk definitions look beyond such "worst case scenarios." Mr. Repasi added that he believes industry is considering exploring a risk informed interference assessment approach to assessing interference likelihood.

Mr. Shields noted that a risk assessment also involves rules and processes to ensure the rules are being followed. How, can one assure that a Wi-Fi device built in Bangladesh and imported to the U.S. is actually following U.S. rules?

Mr. Repasi said the compliance process involves a number of compliance review bodies. A Bangladeshi device has to meet FCC criteria before it can be sold in the U.S.

Mr. Shields asked how that policy would cover a foreign visitor carrying a Wi-Fi device that has not been subject to FCC review.

Mr. Repasi said that, as a practical matter, such problems have been minimized by convergence on common technology. Following FCC adoption of service rules for unlicensed devices, for example, organizations such as the Wi-Fi Alliance develop standands to create economies of scale and global harmonization of equipment. This helps reduce concern about Wi-Fi-based interference from individual transmitters.

Mr. Ron Hatch asked if the FCC has ever certified receivers rather than transmitters.

Mr. Repasi said certain GNSS receivers are certified by the aviation and maritime sectors, and that the FCC accepts their judgment. At this time he could not recall instances of the FCC certifying a receiver.

Mr. McGurn asked, relative to frequency assignments, whether "authorization" and "licensing" are the same thing.

Mr. Repasi said they are not. Authorizations to federal operators come from NTIA. Licenses for non-federal operations come from the FCC. Authorizations and licenses may be limited or conditional such as, for example, with restrictions to a particular area.

Dr. Axelrad asked whether the "input from industry" to which Mr. Repasi referred to includes input from GNSS companies.

Mr. Repasi said it includes input from any public entity, including GNSS companies.

Dr. Parkinson noted that National PNT policy encourages compatibility and interoperability with foreign GNSS services. However, now it appears various foreign signals are not authorized for use in the U.S. When reviewing the spectrum map, there is clearly a fundamental compatibility problem over how these foreign GNSS would be admitted. Who is responsible for sorting this out? For example, one of Mr. Repasi's charts points to major issues because foreign GNSS systems are on the edges of the GPS bands and, in consequence, users in the U.S. are in principle not authorized to "listen" to them.

Mr. Repasi referred to the earlier conversation on the spectrum allocations table and interference rights. The RNSS band is surrounded by a MSS band, but how quiet is it really? Multiple licensees have already been granted use of the band between 1610 and 1660.5 MHz for example. Also, some ships at sea operate today with MSS transmitter antennas located perhaps on the same mast as GPS receiver antennas. The DOT may want to consider addressing the question of what is meant by "adjacency" in its Adjacent Band Compatability efforts and what the GPS-only recievers in the band can tolerate. Also, in his view work is needed on how MSS downlink data channels may impact compatibility of multi-GNSS receivers when signals are at the edges of the band.

Dr. Parkinson acknowledged that this is also an issue. However, the GNSS compatibility issue previously raised still remains.

Mr. Repasi noted that National PNT policy provides direction for using foreign GNSS signals. He quoted the Presidential policy which staties that: "foreign GNSS signals may be used to augment and increase the resiliency of GPS." What "increase the resiliency of GPS" means, however, is not entirely clear. From a technical perspective, you first need to know what the baseline is for GPS resiliency in order to determine whether authorizing foreign GNSS signals would actually increase or decrease GPS resiliency. You would need to know what GPS-only recievers can tolerate first, before being augmented.

Dr. Parkinson said interference is not the main issue but, rather, that at present foreign GNSS signals cannot be used.

Mr. Repasi said such use could come by seeking waivers to FCC rules.

Dr. Parkinson asked who could request such a waiver.

Mr. Repasi said that one way is to follow a process worked out between the FCC and NTIA in 2011 where the request to the FCC would need to come through DOS or NTIA.

Mr. Higgins said it is odd that legal use can be made of the GPS signals in the L1 band, but not other signals in that band. While "no one is going to prosecute us for using an unauthorized signal," if an unauthorized signal were to be jammed then no one is going to act to protect it.

Mr. Hatch said he is aware of one instance of authorization being required to the GLONASS navigation system. However, there is a distinction between the communication and navigation functions.

Mr. Repasi said the FCC does not recognize that distinction. An authorization would be required to operate with GLONASS.

Dr. Parkinson said it is a simple fact that hundreds of thousands of people currently use GLONASS. "That horse has left the barn."

Mr. Repasi said that just because a given receiver has GLONASS capability it does not mean it has been authorized to use that signal in the U.S.

Dr. Parkinson said that combined GPS/GLONASS solutions have been used for years. Allowing such use produces a more robust system.

Mr. Repasi said the system described by Dr. Parkinson may be more robust in performance, but not necessarily in terms of interference rejection and spectrum protection.

Mr. Shields commented that Mr. Repasi's position is "not understood by receiver manufacturers."

Mr. Repasi said the receiver manufacturers regularly follow spectrum rulemakings at the FCC and that they could follow the waiver process for foreign satellites to gain market access to the U.S. If the FCC were to grant a waiver, one question that needs to be addressed is what does that mean from an interference standpoint?

Dr. Parkinson said this sounds like there was a problem without a solution, and invited Mr. Repasi to talk privately with Board members who are concerned by this.

Mr. Miller commented that technology is developing more rapidly than the ability to regulate its use. The concern around the table is that if one pursues a strict licensing regime then adverse effects may follow. Additional guidance is needed from regulators. The "ultimate question" with smartphones, GLONASS and those involved in building multi-receiver systems is that further information is needed so the activity can proceed collaboratively within the requirements.

Mr. Repasi said that, in his view, existing FCC regulations reflect forward thinking. These regulations were adopted many years ago and anticipated requests from foreign satellite providers to access U.S. markets for all types of services. It gives the FCC a basis for deciding the conditions of operation and whether there are foreign operators it should not authorize.

Dr. Parkinson said the navigation community is not properly engaged in these processes and, thus, when public comments are sought the responses tend to come from persons who don't understand the issues.

Dr. Betz commented that he was confused. He understood Mr. Repasi saying that a process exists whereby signals already dropping on the U.S. require authorization to be tracked, and yet it is inferred that within the "receive-only" sector someone is going to complain about this causing interference.

Mr. Repasi said that the process is open to the public and anyone would have the opporuntiy support or object to the proposed receive-only operations. Even though recievers would not cause interference, their inability to reject emissions in adjacent and nearby spectrum could raise objections from adjacent band licensees if they believe that authorizing the recievers will require them to change their transmitter operations.

Dr. Parkinson said he would greatly welcome a meeting where Board members could further explore with Mr. Repasi the issues involved.

Mr. Repasi said he is amenable to such an approach.

Ms. Atkins returned to the podium to address remaining questions on space policy, including the technical studies that form the basis of policy decisions. She also described the parallel process whereby U.S. proposals are developed. The FCC runs a parallel process and that the two groups work to establish common U.S. positions. The U.S. only has one vote at the World Radio Conference (WRC), which meets every four years to consider changes in international regulations and standards. The U.S. is far likelier to gain what it wants if it acts as part of a regional group. Ms. Akins added that she wishes the Board to feel assured that NTIA and FCC believe they've been successful in protecting the GPS spectrum band. The next WRC will be held in 2015. To the best of her knowledge, that meeting's agenda does not touch on in-band or adjacent-band issues. Policies call for protecting PNT while at the same time making possible the development of other spectrum-based capabilities, to include an emphasis on improving interference resistance across the breadth of GPS applications and receivers.

Mr. Repasi added that the common goals of the NTIA and FCC; are to promote harmonized spectrum use; spectrum efficiency, promote technologies and services, and provide for protection against interference. The two previous Administrations have emphasized increasing space based PNT system resiliency and this remains a priority.

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**Role of GPS & Precision Timing in the Financial Services Sector**
*Some Key Industry Timekeeping Requirements and Applications*
*Mr. Andrew Bach, Chief Architect for Financial Services*
*Juniper Networks*

Mr. Bach explained he has spent 25 years in the financial sector focusing on infrastructure and timing solutions. His briefing provides an overview of timing in the financial sector, including but not limited to GPS. It is expected that the timing requirement of the financial sector will be quite different even in as little as three years. Total financial market capitalization is about $55 trillion, nearly four times the size of the U.S. economy. The Depository Trust & Clearing Corporation (DTCC) alone clears $24 quadrillion dollars annually. Worldwide, about two dozen similarly-sized clearing houses exist. Time is an urgent consideration. The New York Stock Exchange clears $15 billion in the first two minutes of trading. In short, the industry handles tremendous amounts of money very rapidly. The first stock ticker was developed in 1867. Since then time demands of the marketplace pushed technology development; e.g. the 1995 introduction of handheld devices. The faster news travels the faster trading occurs. Back in the days when information moved by sea, trading information was measured in months. The telegraph shortened this to minutes. Today, trading is measured in milliseconds. Once news about a particular company becomes public, a new stock price reflecting that news is established within five minutes.

Challenges currently faced by the financial services sector include: improved timing, improved cyber-security, and heuristic-based trading. The latter refers to trading that is driven by information from multiple news services. For instance, trades may be driven by "tweets", where a trader takes new information, 'digests' it using heuristic processing, and makes a trading decision. The goal is to make that decision within several seconds after news arrived. The current system handles approximately two billion messages a second. This circumstance underscores the need for improvements in precise timing. Timing technology goes beyond GPS. Individual firms base their timing on atomic clocks and other devices. This practice makes them "islands unto themselves" as they are not using a time common to others. It is important that all market participants receive simultaneous access to the same information. This would require participants to share a "standard" time. However, two separate organizations using GPS for timing will not have identical time codes, because organizations differ in their internal use of GPS messages. Regulatory agencies also require that financial transactions be time-stamped. When processing over one billion messages a second, much more sensitive clocks are needed to provide external validation of transactions. A specific client's order may be just one of 100 million traveling through the system.

Mr. Bach explained that at his job he has a fiduciary responsibility to demonstrate he has done nothing to delay an order. In consequence, both his clock and that of his competitor's must match. Otherwise, he would not be able to prove that he has not traded ahead of the market. This is why financial regulators require extremely precise time stamps. In his view, future needs will include

- Developing timing accuracy to one microsecond;
- Time stamping each transaction without affecting its message;
- Creating industry-wide "universal" time;
- Developing analytical tools to measure system performance
- Securing the source of the authoritative timing reference

Potential solutions include: (1) transition from Building Integrated Timing System (BITS) to in-band timing distribution; (2) replace Network Time Protocol (NTP) with Precision Time Protocol (PTP); (3) and a secure and stable GPS, augmented by terrestrial-based timing references. In the United Kingdom, the National Physics Laboratory is working with financial customers on a pilot project. In the U.S., the subject is still in the exploration stage.

In summary, because alternatives exist to GPS a failure does not currently mean that the "sky was falling." However, this may no longer be the case in three to five years' time.

Gov. Geringer asked Mr. Bach for his views on the possibility of signal tampering.

Mr. Bach said he does not have a strong opinion on that. Anecdotally, a short time ago a peregrine falcon built a nest on top of a GPS tower and, because it is a protected species, the tower was out of use for three months. It is possible that someone could develop a capability to tamper with signals. Once again, this is not a major concern at present but it could be an issue in three to five years.

Mr. Burns said that for future aviation users of NextGen, GPS signals are a requirement. Therefore, there is a clear need to protect the GPS timing function and meet future standards as Mr. Bach has described.

Mr. Higgins asked whether a higher level of time synchronization in the financial sector would force other markets to follow.

Mr. Bach said that perhaps not initially, but other sectors would find advantageous ways of making use of the technology.

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**Toughening GPS Receivers against Interference**

***Ensuring Signal Reception in Spectrally Busy Environment***

*Dr. Gary McGraw, Fellow and Engineering Manager*
*Advanced Technology Center, Rockwell Collins*

Dr. McGraw said he would brief what the military could contribute to the "toughen" effort. The most effective anti-jamming technology currently available to the military are adaptive antenna arrays. Digital beam forming techniques are especially effective under a heavy jamming environment because they simultaneously direct a beam to a satellite to "gain" information while also nulling the jamming. A 100-watt jammer could deny service to an unprotected receiver at a distance of 100 km. On the other hand, a high capability adaptive array limits such interference to 0.1 km., and a one-watt jammer would have no discernible denial of service. However, adaptive array techniques may be expensive to retrofit. On current platforms the cost is mostly driven by the need to change the antenna and replace the wiring. On new platforms the cost differential is much lower. Work on producing adaptive arrays in quantity is currently proceeding with a Japanese manufacturer. Economies of scale being are likely to reduce the cost further. Digital beam forming is a proven technology and compatible with both high accuracy and high integrity applications. Unit costs are dropping and, in his view, this approach is viable on new platform installations. When used as part of an integrated package installation the cost differential is not significant. This technology could be highly beneficial to multiple critical infrastructures. However, the primary roadblock faced by manufacturers are ITAR restrictions which do not allow to export this technology. Therefore, for the time being its use in civil applications remains. Also, getting users to adopt such enhanced capabilities will be difficult without a compelling economic case or by means of regulatory mandate.

Dr. Parkinson asked whether Dr. McGraw has tried to apply for an ITAR license.

Dr. McGraw said he is not aware whether Rockwell Collins has sought an ITAR license through its foreign military sales division.

Dr. Parkinson added that certain exceptions to ITAR restrictions have been made for the European Union.

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**Terrestrial GPS Augmentation with a Metropolitan Beacon System**

*Dr. Frank Van Graas, professor*
*Ohio University*
*&*

*Mr. Subbu Meiyappan, co-founder*
*NextNav, LLC*

Dr. Van Graas identified the desired characteristics of terrestrial GPS augmentations and Enhanced 911 (E-911) challenges. Indoor operation is crucial and, further, it is important to have something that can be easily integrated into existing receivers. Today the majority of 911 calls come from cell phones (in California in 2007, 55.8 % of 911 calls came from cell phones; by 2013, 72.7 % did). However, current technology only identifies the city block at which the emergency is occurring. The FCC has issued a notice of proposed rulemaking seeking 50-meter horizontal accuracy and 3-meter vertical accuracy. The latter is to identify the floor level in a given building. One way to achieve the horizontal performance is to broadcast GPS-like signals from nearby transmitters. Such operation must avoid the L-Band, but it would be convenient if it occurred within the cell phone bands. In reviewing urban propagation models one realizes that as frequency increases, signal strength declines. We also need to avoid the lower frequency range as receiver integration would be more difficult due to new antenna requirements. The best spectrum "sliver" is the range of 824 to 960 MHz. This avoids the L-Band and falls within cell phone usage range. NextNav currently has spectrum in the 919.75 to 927.5 MHz band that provides coverage of 93 % of the U.S. population including all major U.S. metropolitan areas. A 30-Watt (ERP) transmitter is used, and system characteristics include: dual-redundant transmitters; battery backup; multiple transmission sites, and ties to GPS for the timing function. Timing performance at the user receiver is in the range of 20 to 50 nanoseconds. Developments are also under way that will eliminate dependence on GPS timing by using two-way time transfer between transmitters.

In 2012, the Communications Security, Reliability and Interoperability Council (CSRIC), a FCC advisory committee, sponsored trials in Silicon Valley including both "tall building" and "low building" areas. These experiments were conducted from "cold start," which presents the most difficult case. The horizontal positioning was 50-meter (67%), while vertical positioning was better than 3m (80%) using differential barometric pressure. Later tests showed that after a "cold start," accuracies better than 10-meter can be achieved using a Kalman filter implementation.

Dr. Van Graas then described the performance of NextNav's local system, which is intended for warehouse, campus, or mall-type settings. The current system produces 5-meter accuracy, 68% of the time.

In conclusion, a GPS-like approach makes integration with existing user devices easier; while in an urban environment a cellular-like approach may be used for improved signal penetration.

Gov. Geringer noted that Dr. Van Graas' map shows coverage to 93 percent of the population, whereas uncovered parts are largely rural areas including all of the state of Wyoming, his state. Why is this happening?

Mr. Meiyappan responded that some regions shown as lacking coverage are in areas for which NextNav has not yet obtained licenses.

Dr. Parkinson asked who conducted the tests on NextNav.

Mr. Meiyappan said the results come from a third-party picked by the operators/equipment and chipset providers.

Dr. Parkinson asked how the adjustment is made for variable barometric pressure.

Mr. Meiyappan said each operating station has a highly sensitive barometric pressure measurement that serves as a reference to measure pressure at the site, thereby determining the height.

Dr. Parkinson asked how this works in buildings with pressurized systems.

Dr. Van Graas said that was an initial concern in these studies, but it was later determined that even pressurized buildings are "not that pressurized."

* * *

**Complementing GPS/GNSS with Micro-PNT Techniques**
***Advancing Autonomy in Challenging Environments***
*Dr. Robert Lutwak, Program Manager*
*Defense Advanced Research Projects Agency*

Dr. Lutwak explained that the Defense Advanced Research Projects Agency (DARPA) studies high-risk concepts to determine their feasibility. The agency's mission is to prevent strategic surprises from potential adversaries while, at the same time, give the U.S. an advantage. Dr. Lutwak works in the Microsystems Technology Office, whose work includes basic components that

enable GPS technology. The aim is to provide GPS equivalent signals in degraded environments and, beyond that, to make provision for superior GPS performance.

New systems and programs emerge routinely, and his office looks for ways to use them. Elements of adaptable navigation sensors and systems include GNSS sensors, other relevant sensors, signals of opportunity, inertial sensors, and clocks. The PNT mission of his office can be summarized as "Where and when it is all of the times." The objective is for navigation errors of less than 20 meters and timing errors of less than one millisecond over a period of an hour. At present, this performance criteria can be met in a stationary laboratory, with unlimited power, for about $1 million. DARPA's micro-PNT goal is to meet the criteria within a volume of 10 cubic meters and 1 watt of power. The practicality of this application is limited by cost.

Chip scale atomic clocks can hold a microsecond timing accuracy for approximately three hours under almost any environment. This meets the requirements of most DoD missions and, thus, from the DoD's perspective the clock problem is largely solved at this point. Major performance increases are in the offing to improve MEMS (Micro-Electro-Mechanical Systems), though not immediately available (for a complete listing and description of options under study refer to the briefing, which is available at: http://www.gps.gov/governance/advisory/meetings/2014-12/lutwak.pdf).

Dr. Lutwak finalized by saying that, in his view, in the future atomic gyroscopes could become standard, just as atomic clocks are today. Atomic physics moves much faster in the laboratory than in real world applications. Fundamental component technology is currently too big, or too power hungry, for its employment in the real world.

Dr. Betz said he particularly liked the performance *vs* CSWaP (Cost Size Weight and Power) slide. Regarding positioning accuracy, he noted that Dr. Lutwak had described a Circular Error Probable (CEP) of 10 meters and asked whether there is similar error data for other parameters.

Dr. Lutwak said the problem with so many dimensions and parameters is that it is difficult to determine how to put them all on one chart. His chart, assumes perfect initial accuracy; perfect transfer of coordinates; perfect initial calibration, and having all five other sensors perfect.

Dr. Betz commented that this is, in effect, a perturbation analysis. If one moves for an hour, gravity variations must be taken into account.

Dr. Lutwak said that currently available gravity maps are not sufficiently accurate, but such maps should be available once these systems are "flying around" with GPS.

Dr. Betz noted no data was been supplied regarding the vertical axis. Could Dr. Lutwak provide an estimate?

Dr. Lutwak said he preferred not to attempt to do so "from the hip."

Dr. Parkinson said he was struck by Dr. Lutwak's statement that "this is the impact if everything else is perfect." This is of concern because some people at the Pentagon not familiar with this subject could interpret this as the problem being solved when, in fact, a proper solution requires the "marriage" of multiple items.

Dr. Lutwak agreed. The inertial measurements are just one input into the overall solution. Other aspects are being investigated by different DARPA programs.

Mr. McGurn asked Dr. Lutwak for his views on dominant drift rates in the MEMS gyroscope.

Dr. Lutwak said the answer depends on several things. The dominant term with MEMS is the temperature effect. As temperature changes, the silicon dimensions change and the MEMS unit changes shape. A way to do performance allowance for in-run, temperature changes are needed.

Mr. Shields noted that in automatic driving, positioning is done by combining cameras with an accurate three dimensional map. Has any consideration been given to what camera positioning could achieve in the absence of interfering cloud cover?

Dr. Lutwak said work is being done in that area, and noted that inertial navigation ultimately needs reference to a fixed point.

*The Wednesday, December 10 session adjourned at 5:10 p.m.*

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*The Thursday, December 11 session opened at 9 a.m.*

**Board Convenes: Call to Order**
*Gov. Jim Geringer, Interim Acting Chair*

Gov. Geringer, chairing the session in place of Dr. Parkinson, welcomed everyone to the second day of meetings. He explained that Dr. Parkinson and Mr. Miller were at this time pre-briefing the NASA Associate Administrator on the Dec. 15, 2014 PNT EXCOM. In Mr. Miller's absence, Mr. Gregory Mann from the NASA Office of International and Interagency Relations (OIIR) would be serving as the Designated Federal Officer (DFO).

**Announcements and Agenda**
***Quick Thoughts and Feedback from the Wednesday, December 10 session***
*Gov. Jim Geringer*

Gov. Geringer said the presentation on economic analysis, originally scheduled for Wednesday, would follow the opening discussion. He asked Board members to comment on what had struck them most in the previous day's discussion.

Mr. Hatch said the FCC presentation on use of GLONASS was key. It appeared to say that if GLONASS is not authorized then the FCC will not protect the upper band which, in his view, contradicts the FCC's stated mission.

Mr. Higgins added that, in his view, there is a need to prepare a White Paper on spectrum issues so that existing confusion gets addressed.

Ms. Ciganer said clarification is needed for the entire RNSS waiver issue.

Mr. Higgins noted that a "placeholder" has been created for a recommendation on this matter.

Ms. Neilan noted, relative to GLONASS use, that people sometimes undertake to do things they're not aware that they are not allowed. For instance, the DARPA presentation reported tracking of GLONASS so, in principle, there's another group presumably in non-compliance with the FCC.

Mr. Murphy said that the DOT and FCC presentations gave the impression that national policy on spectrum is becoming functionally "stove piped." The focus should be to protect the MSS communications bands and, in doing so, the navigation functions would also benefit.

Dr. Rashad said that communication between the user community and the FCC is clearly insufficient.

Gov. Geringer said there is no clear basis on which such communication could be established.

Mr. Dimmen, referring to discussion of on future timing requirements in the financial sector, said the New York Stock Exchange may not be as critically dependent on GPS timing as had been thought. He would welcome a parallel presentation from the consumer end in the financial sector; such as, for example, how dependent are Automated Teller Machines on GPS?

Gov. Geringer said that whatever current the financial sector dependence on GPS may be, within three years high precision GPS time stamping will be needed to ensure transparency.

Mr. Higgins said the crucial aspect of timing is that it proceeds from a common universal time.

Gen. Denker said he was very impressed by the collaborative nature of discussions and the assistance from members in the audience.

Gov. Geringer added that Col Cooley made an extraordinary presentation and was very pleased to see how seriously the GPS-Directorate approaches its task.

Mr. McGurn suggested that the Board meet either before or after the 10$^{th}$ International Committee for GNSS on November, 2015, in Boulder, Colorado. Interfacing with that body should prove useful. The question should be formally raised with the ICG and a closer relationship sought.

Gov. Geringer asked who could appropriately coordinate this suggestion.

Ms. Neilan noted she currently coordinates ICG Working Group D. The Dept. of State, and Mr. Miller, would need to be involved.

Gov. Geringer said he will discuss the matter with those persons.

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**A Comprehensive Quantitative Economic Assessment of GPS**
***Establishing Scope, Duration, Expectations and Deliverables***
*Dr. Irving Leveson, Founder*
*Leveson Consulting*

Dr. Irving Leveson said the EXCOM has authorized a study to obtain an updated and authoritative assessment of the economic benefits of GPS. This is not an academic exercise, but an undertaking with many policy implications. Issues such as spectrum sharing and use of eLoran will be influenced by this economic assessment. Discussion on benefits typically tend to be narrow and rigid. One crucial aspect of GPS is that it facilitates social trends, which in turn facilitates many other trends. The key point is that GPS benefits are expansive.

The study's objectives are:

- First, provide an updated, complete and methodologically sound estimate of the economic benefits of GPS to the U.S.
- Second, provide a basis for follow-on analysis and the final report
- Third, present the combined analysis in two parts: a "showcase" report, including examples and stories, designed for the general audience, and a fully analytical report documented with sources and methods.

The NCO will coordinate an interagency effort. He plans to involve economists from as many EXCOM-related agencies as possible, plus the Treasury Department. The Board will be provided periodic briefings.

The intended approach is as follows:

- First, benefits need to be defined. A broader definition is needed beyond "direct dollar benefits." Further benefits include everything from increased productivity; cost and time savings; new product development, and improved management techniques to such things such as increased choice; reduced stress; improved safety, and better environmental management.
- Second, methods need to be addressed. The benefits derived from GPS must be weighed against the availability of alternate approaches or how markets may have compensated for the absence of GPS. Further, it needs to be remembered that because GPS is often a single part of a more complex application, it cannot be credited with the full added value.

Many existing studies lack proper documentation; some present conclusions without going into details on the reasoning behind them; some are dated; and some use a faulty methodology. Two needs – the desire to be complete and the desire to be authoritative – must be balanced. Dr. Levenson encouraged Board members aware of any pertinent study to alert him. The overall goal is to present information that is more current, complete, methodologically solid, and easier to communicate and document. However, due to the limitations of available data, the study can only provide "ballpark" estimates. Nevertheless, the study will significantly improve the understanding of GPS' importance if presented in interesting and understandable ways, repeated often, and used in both specific and broad situations."

The next steps include:

- First, the Board will be briefed by May 2015.
- Second, an Interim Report will be circulated for comment in early July 2015. The deliverables will include a preliminary briefing report to the Board on the value of GPS to the U.S. economy, and an Interim Report that would serve as the core of the "showcase" and full technical reports.

Discussion:

Gov. Geringer said the presentation is compact and succinct. Creating a report both understandable and acceptable is an extraordinary task. Also, "acceptability" will be crucial. Gov. Geringer asked Board members whether they believe the task is adequately defined and results obtainable within the time available.

Dr. Enge commented that the proposed approach seems somewhat "high level and abstract." For example, GPS technology allows motorists to choose the fastest, the shortest, or the most energy efficient route. Using the energy efficient route reduces the emission of greenhouse gases, of which 20 % can be traced to automotive use. Will, for instance, GPS' contribution to a reduction in greenhouse gases be included in the report?

Dr. Leveson hopes so. Pertinent studies exist, but one needs to remember that emissions of greenhouse gases are an international issue.

Dr. Enge said such reduction is also available worldwide.

Dr. Leveson said Dr. Enge's point is well taken. However, because of existing time constraints, some things may need to be left for later study. Provided the report produces "a conservative estimate that is convincingly large," it needs to cover all bases.

Dr. Betz said the military has experienced considerable dollar savings from GPS' contribution to the determination of force structure and operational efficiency. These steps save taxpayer dollars. The report should make reference to this.

Dr. Leveson said that an allusion could be made to this, but it is outside the scope of the charge.

Ms. Ciganer commented on GPS-induced productivity. The three billion worldwide users of PNT drive international innovation. Will these users believe the report reflects their activities?

Dr. Leveson said anecdotes will serve as examples.

Ms. Ciganer asked if Dr. Leveson intends to include information on surveying; specifically, how would this activity be affected if GPS were not available.

Dr. Leveson said there is not sufficient time to develop new data on this subject, but existing information will be incorporated.

Mr. Higgins said several detailed Australian studies are available on infrastructure; particularly on electrical distribution infrastructure, where direct value stems from quicker uptake. Non-economic benefits include reduced stress among farmers because precision agriculture gives them far greater control of their circumstances. Fuel efficiency also means a reduction in the carbon dioxide footprint. Attention should be paid to applications that would be impossible without GPS such as, for example, developments in rail systems made possible by general GPS activity that has prompted reductions in receiver size and cost.

Dr. Leveson said those studies would be included in the report.

Mr. Shields said that by conservative estimates, automotive accidents cost $600 billion annually. Automated driving based on GPS could reduce this by half. Traffic congestion, often caused by accidents, will also be reduced. Accident-related medical costs will also be reduced, thus saving governments and individual persons considerable sums.

Mr. McGurn added that savings also follow from the improved weather forecasting made possible by GPS. The National Oceanographic and Atmospheric Administration (NOAA) has developed statistics on this.

Dr. Leveson welcomed such information.

On a related matter, Ms. Ruth Neilan noted GPS effects of weather modeling; particularly work undertaken by Taiwan.

Gov. Geringer said that, as proposed, the economic study "has far more opportunity than resources." He agreed with Dr. Leveson that the study needs to go beyond GPS-derived benefits and the costs of GPS disruption, to also include things that would not exist without GPS. This could be "documented by inference" rather than by hard numbers.

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**Intelligent Transportation System (ITS) Evolution**
***GPS/GNSS Role in Emerging Vehicle Fleets and Highway Infrastructure***
*Mr. Brian P. Cronin, P.E. Team Leader, ITS Research*
*Intelligent Transportation Systems Joint Program Office*

Mr. Cronin noted how, as an incidental example of GPS use in transportation systems, just this morning he used his smartphone to download the proper departure time of his bus. There are many challenges associated with automotive transportation, including 33,000 traffic deaths and 5.3 million traffic accidents in 2011. On top of this, traffic congestion resulted in approximately 2.9 billion gallons of gasoline wasted at a cost of $121 billion. Mr. Cronin explained he largely works on vehicles connected by communication links, which may include a vehicle being connected to adjacent vehicles, to pedestrian, or to transportation infrastructure. It is anticipated that within five years use of automated vehicles will begin. Every connected vehicle will report its location, direction, and speed ten times per second. Drivers within 300 meters will receive this information. There are a host of applications that benefit from this technology. The most evolved application is vehicle-to-vehicle (V2V) safety. Currently, if a driver follows a truck that is following another automobile, the trailing driver cannot see the lead vehicle. The trailing driver does not know if the lead vehicle suddenly stops until the truck begins to slow down. With V2V trailing driver is immediately informed and the driver's "blind spot" is eliminated since he has information on vehicles in the

adjacent lane. Also, V2V will inform a driver approaching an intersection on "green" whether a vehicle from either side is poised to run the red light.

Gov. Geringer noted that while these examples may seem anecdotal, the average driver is quite capable of supplying a sense of their value.

Ms. Ciganer, added that the most persuasive statements of increases in productivity will come from the end users that report their real-life reasons for using a particular technology.

Mr. Cronin presented an anticipated timeline of "connected vehicle" development. The National Highway Traffic Safety Administration (NHTSA) on Feb. 3, 2014 announced plans for connecting light vehicles. The first priority is collision avoidance warning. The NHTSA is currently working on regulations to require V2V capability on future light vehicles. Tentative rules will be distributed to the automotive market in order to facilitate business decisions on which capabilities will be marketed. Current technology can provide the 0.5 meter accuracy required for relative positioning between vehicles. Relative to privacy concerns, while the vehicle's position, direction, and speed will be broadcast neither the vehicle nor driver are identified.

Gov. Geringer asked whether drivers could end up thinking that V2V may preempt personal control of their vehicle.

Mr. Cronin replied that V2V just supplies warning messages; it does not exert control over how the vehicle will respond to the warning.

Mr. Cronin continued explaining that for V2V to work, a common technological basis is needed so that, for example, a Ford vehicle can talk to Nissan or Volkswagen vehicles. This requires developing security system that transmit accurate data while protecting privacy. Early in 2015 the NHTSA should be making decisions on V2V technology specifications for vehicles over 5-tons in gross weight. The Federal Highway Administration (FHWA), while generally is not a policymaking body, will act as advisor to the states and others. Government bodies are being surveyed as to what particular problems they wish to address. The FHWA will be issuing documents informing governmental bodies of the specifications and cost benefit calculations of any option they may choose to implement. This document, however, is not a requirement but a "toolkit."

Mr. Cronin presented graphics on improving safety at urban intersections. V2V will provide blind spot warnings; lane change warnings; collision warnings; left-turn across traffic path assistance, and many other advantages. For example, a driver growing impatient behind a stopped bus could prompt him to pass by crossing the median. V2V would alert the driver to any unseen incoming traffic.

A year-long pilot study was conducted in Ann Arbor, Michigan involving 2,800 mostly light vehicles. Two applications were used: (1) left-turn assistance; and (2) intersection assistance. These two applications demonstrated by themselves that their resulting savings were sufficient to finance the entire project.

Mr. Cronin also presented a sample deployment concept which will reduce downtown congestion by improving transit reliability, improving pedestrian safety, while at the same time reducing vehicle exhaust. These applications could be implemented either singly or as a package. In summary, the US DOT Intelligent Transportation Systems (ITS) program is, in his view, successfully developing diverse ITS transportation solutions. ITS research is delivering real capabilities and value to states, industry and the public. It is also addressing issues such as enterprise data, interoperability, technical assistance and deployment, and other emerging capabilities. Mr. Cronin finalized by saying that he definitely foresees an evolution of automobiles into a "connected vehicle" world.

Gov. Geringer invited comments and questions.

Dr. Scott Pace asked, relative to driver privacy, whether insurance companies would want access to information that, in turn, could lower the insurance rates of V2V drivers.

Mr. Cronin said in the future V2V capabilities will be required in all vehicles. In the Ann Arbor project, only 60 vehicles were installed with fully integrated systems; the large majority only transmitted the basic safety message.

Dr. Axelrad asked if the Ann Arbor experiment included bad weather situations.

Mr. Cronin said the system operated through a Michigan winter. In terms of potential outages, a brief delay in data reporting would sometimes occur when going through a tunnel or a major underpass.

Mr. Shields said that when Anti-lock Braking System (ABS) was introduced, insurers reduced rates on vehicles equipped with ABS. In practice, they ended up losing money since people with ABS-equipped cars would tend to drive faster in adverse weather, such as when raining, and end up in an accident. Insurers have also done considerable testing on "pay as

you drive" systems. While this is feasible, it is unclear how an insurance company would implement them. If an insurer reduces rates on vehicles equipped with certain technologies, the rates would need to be raised for other vehicles. Drivers will only benefit from reduced rates if the long-term result is a general reduction in accidents.

Mr. Higgins said he has been involved in Australian studies looking at the accuracy levels required and whether GNSS can achieve them. Many systems assume that a SBAS is available, which is something Australia does not have. In his view accuracy requirements for automotive use should be identified and, therefore, should the target be 10 cm then that would place another requirement for additional supporting infrastructure. If the current is 1.5 meters, then a statement should be included that future requirements are likely to be considerably higher.

Dr. Enge questioned whether GPS alone can achieve an accuracy of 10 cm in urban areas and suggested, for example, combining GPS with Doppler measurements to achieve such accuracy.

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**International Member Regional Updates and Perspectives:**
*(Note: During the International Presentations, Dr. Bradford Parkinson, Acting Chair, and Mr. James Miller, Executive Director, returned to the session.)*

*1) Dr. Gerhard Beutler, Switzerland*

Dr. Beutler noted he would be speaking on behalf of the International Association of Geodesy (IAG). He noted that all GNSS constellations, but GPS, operate in three orbital planes. However, because GPS operates in six orbital planes there is considerable added value to the IGS and space geodesy. The IGS was planned in 1989, global and regional test campaigns were performed in 1992, and became an official IAG service in 1994. Initially, the IGS was called the International GPS Service. Ms. Ruth Neilan was among the original leadership group in 1989 and to this date continues in that role.

From a space geodesy perspective a GNSS satellite would ideally be spherical, rather than "winged" with protruding solar panels, in order to minimize the effects of non-gravitational forces (solar radiation pressure, direct, and reflected from the Earth or the Moon). This, of course, would make the satellites quite expensive so, instead, the IGS uses various tools to analyze GNSS orbit data to determine what these forces are. The IGS works on global solutions, including solving for the coordinates of a tracking network, Earth's rotation parameters, like polar motion and the length of day. Differences between GPS and GLONASS, such as the three vs. six plane orbital configuration, facilitate such modeling. Polar motion data derived separately from GPS or GLONASS agrees to a level of a mm, which is quite remarkable. At the summer 2014 IGS workshop in Pasadena, California, it became clear that the empirical modeling needed improvement for GLONASS, while the models worked satisfactorily for GPS. The availability of SLR (Satellite Laser Ranging) measurements to all GLONASS satellites was and is most important to validate new GLONASS orbit models.

The IGS Multi-GNSS Experiment (MGEX) currently engages 114 stations at 95 sites. MGEX not only collects data, but also generates orbital parameters and other information, which is freely available.

Dr. Beutler complimented the previous day's presentation on CNAV. The important aspect of CNAV is that it carriers much more information in the signal that can then be used in follow-on analyses; for example, enabling inter-signal corrections. Currently there are nine stations capable of tracking CNAV. With CNAV discontinuities in orbit analysis have all entirely disappeared, except during uploads. Initial in-orbit comparisons with IGS data showed that CNAV results are worse than the Legacy Navigation (LNAV) results, which is due to the latency of the navigation message. However, this is not as important as the fact that CNAV has eliminated the discontinuities LNAV experiences hourly.

Dr. Beutler proposed to invite the Chair of the IGS MGEX to report "firsthand" on the performance properties of all Global Navigation Satellite Systems considered in the framework of MGEX.

Dr. Enge asked if the difference between LNAV and CNAV is due to the difference in the resolution in the data in the messages.

Dr. Beutler said it is.

Dr. Parkinson noted he has been asked whether the introduction of L2C and its message has made any difference. It would be most helpful if Dr. Beutler were to send a letter to the head of Air Force Space Command (AFSPC) stating that L2C has made a difference. Such a letter coming from IAG would be very useful as, typically, "civilians don't know who they should thank if they were to thank anybody."

Dr. Beutler said he will write such letter if the interest is confirmed.

Dr. Beutler continued reviewing the benefits of CNAV. Among others, it provides a more flexible structure; requires less frequent updating; provides similar signal-in-space error as LNAV, and makes possible a 30 percent reduction in single-point positioning accuracy. Dr. Beutler also provided information on India's GPS and Geo-Augmented Navigation (GAGAN), including its tracking by the IGS and orbit determination using radiometric vs. optical laser measurements.

*(At this point Dr. Parkinson announced that he and Mr. James Miller had been absent in order to brief NASA Associate Administrator Dr. William Gerstenmaier on the future sponsorship of the Advisory Board. Dr. Gerstenmaier expressed strong support of the Board.)*

*2) Mr. Arve Dimmen, Norway*

Mr. Dimmen began by reporting on the latest Galileo launch. Dual launch of GNSS satellites is good so long there is not a launch failure, as has been the case with the latest Galileo launch where two SVs ended up in the wrong orbit. There are on-going efforts to transfer one of those satellites into a better orbit. At this time there are two other Galileo SVs in storage waiting to be transported to the launch in February 2015.

Dr. Parkinson asked if the Galileo Consortium believes it has identified and addressed the launch problem.

Mr. Dimmen said that is the case.

The European Space Agency (ESA) is pursuing the question of whether to approve the European Geostationary Navigation Overlay System (EGNOS) for maritime use. The initial step is to clarify the maritime requirements, and then assess whether EGNOS can meet them.

Dr. Parkinson noted that EGNOS provides both differential corrections and a very rapid time to alarm. Is ESA also looking at these aspects?

Mr. Dimmen said yes, though the integrity aspect is important.

The International Maritime Organization (IMO) has approved BeiDou, China's GNSS, for maritime use, with certain caveats. While BeiDou is approved as part of the worldwide navigation system, the IMO says it was not suitable for harbor entrances, approaches, or other waters characterized by limited freedom of maneuver.

Presently there are nine eLoran stations operating in Europe. Norway will cease operations at the end of 2015 and France will dismantle its stations by 2016, which will leave only two or three eLoran systems in operation.

Dr. Parkinson noted he's learned that a bill has been placed on the President's desk to halt further dismantling of the U.S. eLoran infrastructure. He asked Mr. Dana Goward of the PNT Foundation to elaborate.

Mr. Goward said in April 2014 he testified before the Merchant Marine, Coast Guard and Fisheries Committee in Congress. When discussing the challenges presented to GPS by jamming and spoofing, he told the committee that since 2010 the Board has consistently recommended that a GPS backup system is needed to support of PNT resilience, whether or not such system is eLoran, The matter was also raised relative to the USCG appropriation act that proposes prohibiting the Department of Homeland Security (DHS) from further dismantling of eLoran infrastructure for one year, and that dismantling only be resumed if the DHS Secretary reaches firm conclusion that the system is not needed. In addition, the proposed legislation would allow the DHS Secretary establish a public/private undertaking to provide a GPS backup. Thus, it is possible that eLoran be reconstituted as a non-public entity. The PNT Foundation finds it encouraging that both Congress and the President are looking into PNT resilience. Enhanced Loran is the primary system under consideration.

Dr. Parkinson asked Mr. Dimmen to forward this news to Norwegian officials.

*3) Mr. Matt Higgins, Australia*

Mr. Higgins referred to an older presentation he made to the PNTAB on Australia's national satellite utilization policy which aims to: (1) ensure continuous, cost-effective access to space capabilities; and (2) implementation of infrastructure plans for GPS and earth observation. A Space Community of Interest (SCoI) has been formed to identify essential space-based services and the potential impact of disruption of those services. The SCoI is an expert advisory group to the Critical Infrastructure Advisory Group (CIAG), which consists of sector groups including banking and finance, health, food and grocery, transport, communications, water services, and energy. In terms of whether PNT should be declared a critical U.S. infrastructure, Mr. Higgins is coming to the view that PNT could perhaps be better seen as an infrastructure that undergirds

infrastructures, rather than just an infrastructure by itself. In early 2015 the SCoI will complete a risk matrix for the various sector users. This document may be useful to other governments.

Dr. Parkinson requested a copy when it is available.

Mr. Higgins then outlined developments in aviation, unmanned aerial systems, rail, and maritime areas. Unmanned systems are an area that is developing very rapidly. Currently there are 150 organizations in Australia, many of them engaged in aerial photography, approved for using such systems. Much of the existing rail infrastructure is analog-based and aging, and a digital-based approach offers many possibilities. On the other hand, the Australian Maritime Safety Authority is dependent on GPS to provide vessel tracking, oil spill response, and search and rescue. An area that is very well covered is the Great Barrier Reef, the world's largest single living organism, which President Obama has expressed hope would still be in existence for his grandchildren to see.

Mr. Higgins then addressed the National Positioning Infrastructure. The regional GNSS network is nearly complete with 130 operating stations. There is growing recognition that many applications will need both high accuracy and integrity. GNSS is, perhaps, the only technology that currently produces 10 cm accuracy throughout the Australian Outback. Australia is strongly committed to cooperation with other GNSS systems. Access to multiple GNSS systems provides a defense against vulnerability should any one system not be available. Regarding international cooperation, Mr. Higgins called special attention to a joint statement of the prime ministers of Australia and Japan where both leaders pledge to "strengthen cooperation in the areas of space and Information and Communications Technology (ICT)" and "strengthen cooperation in the promotion of Geospatial Information Project using QZSS."

Mr. Higgins closed by calling attention to the International GNSS (IGNSS) conference to be held in Gold Coast, Queensland, Australia in July 2015.

*4) Dr. Refaat Rashad, Egypt*

Dr. Rashad noted that GPS is the heart of many applications. Often, reference is made to GNSS in broad terms, but in reality, most applications, including over 90% of international transportation and shipping, only use GPS. For example, maritime GPS use covers multiple situations, including: overseas, ports, approach channels, narrow waterways, surveying, bridging, and under water technology. Also, there are many types of maritime users ranging from small fishing boats to large container vessels and cruise liners. GPS is used to track and monitor individual ships. Within the container vessel applications GPS not only tracks ships but also the movement of individual containers. Currently there are approximately 700,000 ships over 100 gross tons in service displacement. These ships must comply with the IMO's Safety of Life at Sea (SOLAS) standards, which mandate onBoard electronic navigation systems. While the IMO does not specify GPS as a required system, GPS is overwhelmingly the system of use. SOLAS ships carry equipment that is dependent on GPS, and without GPS the ship's entire navigation system would cease to work. Maritime user key requirements include: availability, accuracy, reliability, continuity, accessibility and integrity -- all of which are facilitated by GPS free of direct user charges. The maritime sector is key as 92% of world trade is transported by ship. In 2013, this trade equaled 8.7 billion ton miles – "carrying our bread and butter from one place to another." In the U.S. approximately 300 commercial sea and river ports handle more than 2 billion ton miles annually. A key question is whether the maritime sector can withstand GPS jamming or an outage. The answer is no. Experience with alternate systems is insufficient for them to be considered reliable. This brings the discussion back to eLoran. The United Kingdom is taking the initiative in addressing the consequences of GPS failure and need for backup. Poland and South Korea have also taken some steps. Many countries are waiting to see what the U.S. will do. If, eLoran were named as designated backup to GPS, the supporting infrastructure could be readily restored. Enhanced Loran is an advanced system that broadcasts strong, low frequency signals that are resistant to interference. It also meets the maritime sector's requirements: accuracy, availability, reliability, continuity, accessibility and integrity. Both IMO and IALA (International Association of Lighthouse Authorities) recognize eLoran as an independent backup system. While ships have alternate ways to navigate, it would be difficult and not without negative effects.

Mr. McGurn noted that the various on-ship sensor systems are integrated. Generally, one wishes to get synergy from multiple systems. When a problem occurs, however, this synergy can compound the difficulty. He recalled an event where a ship's GPS was intentionally jammed and its systems reported the vessel was sailing across over land across East Anglia in the UK. Therefore, when systems are integrated one must know how integration can affect operations. It is doubtful that "the guy on the bridge" would know how the various systems are tied together.

Dr. Rashad noted that in the maritime world, interference from jamming or spoofing is an issue mainly close to the coastline.

Mr. Khosla asked if some of this information will be included in the economic study.

Dr. Leveson said it would.

Dr. Rashad noted that GPS has made a significant contribution to accuracy in the routing of ships and multiple studies have identified the consequent savings.

Mr. Higgins asked about eLoran accuracy throughout the world.

Dr. Rashad said there is some variability since eLoran does not have a master clock running the entire system. Accuracy depends on the individual eLoran station, each with its own atomic clock.

Dr. Enge said that in harbor entry and harbor applications, eLoran accuracy is typically 8-20 meters. In aviation, eLoran easily meets the requirements for a non-precision approach.

Mr. Higgins pointed out that eLoran cannot replace all GPS functions. The belief that "eLoran will fix everything" is not true.

Dr. Parkinson agreed. The independent review panel that reviewed eLoran did state such caveats in its report. Another benefit in having eLoran is its deterrent value. If an alternative to GPS were readily available then GPS becomes a less attractive target for jamming or other hostile action.

Dr. Enge made reference to the legal phrase, "attractive nuisance," such as a swimming pool without a fence around it. At present, GPS is something of an attractive nuisance without eLoran to serve as 'fence'.

* * *

**PNT Board Working Group Reports & Recommendations to PNT EXCOM**

*Dr. Bradford Parkinson and Working Group Team Leads*

Dr. Parkinson invited the Board members to comment on the presentations given these past two days. In his view the issue of frequency certification stands out, including the potential use of pseudolites in Europe and the FCC's position that GLONASS is not approved for use in the U.S. If an FCC waiver is was required, what is the appropriate agency to seek it? Since NASA's observation networks operate receivers that accept GLONASS signals, perhaps it would be such agency.

Mr. Hatch asked whether each individual receiver manufacturer needs to apply separately for a waiver.

Dr. Parkinson said he does not know.

Ms. Ciganer said the waiver procedure requires information that could only be supplied by the RNSS provider.

Mr. Shields said that a government-to-government request is required, which complicates matters.

Dr. Betz identified two alternatives: either each receiver manufacturer, or the GNSS system provider, apply for a waiver. The latter would relieve individuals of the responsibility to apply. The FCC may be willing to authorize specific signals more readily than entire systems. One easy approach is to specify signals that use the same spectrum the FCC already allows.

Dr. Pace pointed out that in March 2011, the FCC issued a public notice on the process whereby NTIA would forward waiver requests for use of foreign GNSS systems. Therefore, a process for obtaining a waiver already exists and needs to be worked.

Dr. Parkinson requested recommendations on what could move matters along.

Dr. Pace said the Board should encourage the Administration to act promptly on any waiver requests. The U.S. would, of course, be annoyed if other nations try to exclude GPS signals. While, de-facto, the U.S. accepts foreign signals the point-of-law remains.

Mr. Hatch said the FCC waiver means they would "permit" such signal and also require to "protect' it, otherwise the permission would have no real value.

Dr. Parkinson commented that when Mr. Hatch refers to "they" he is, in practice, referring to the broader Federal government.

Mr. Brenner agreed that a "slew" of ambiguities exist. The FCC needs to recognize the reality that millions of devices currently receiving GLONASS and, further, that it is a good thing because it improves coverage. As such it is not clear who should seek the waiver.

Dr. Parkinson said the Board could inform NASA that it would support such a move, but perhaps allies should also be sought among GNSS equipment manufacturers. Would it be practical for the Board asking the NASA Associate Administrator to seek a blanket permission covering all users?

Mr. Shields said this is not a NASA issue, but a DOS issue. Perhaps NASA should urge DOS to get busy seeking resolution of the matter with other countries.

Dr. Parkinson said his preference for action by NASA is that, metaphorically speaking, if he were to have five platoons of infantry but only one is eager to attack, then he would be reluctant to stop that platoon while the other four lag.

Mr. Miller said NASA produces multi-GNSS receivers for which it had customers – the Air Force, NOAA, international partners, and others. Since NASA space-qualifies its own receivers it does face the FCC hurdles described. Things become murky when, for example, NASA works with commercial operators such as SpaceX. SpaceX can either seek approval through NASA, proceed through NTIA, or proceed independently. Mr. David Turner (DOS) has been very active working with NTIA, but cannot yet make a public statement on this issue.

Mr. McGurn restated his earlier point: if the FCC "authorizes" but does not "protect" a signal, of what value is the authorization? Further discussion is needed for us to understand what constitutes "protecting GNSS."

Mr. Hatch said the ambiguity needs to be resolved soon.

Mr. Betz expressed the view that tackling the easiest ones first makes sense. He is not aware whether the NTIA has received any formal request.

Dr. Pace said that if the NTIA has not yet acted on a specific request, the matter lays within the administration to resolve.

Mr. Hatch asked whether the U.S. Congress could simply say navigation receivers are not "earth stations" as used in the 2011 memorandum, thereby rendering the point moot.

Dr. Pace said Congress can do whatever it wants. However, we need to be very careful about involving the legislative branch on an issue that is an administrative regulatory matter. One cannot not know where proceeding down the Congressional path may lead. Longstanding policy has been to treat all providers equally, but nothing would prevent Congress from acting to favor a specific provider.

Ms. Ciganer said she supports NASA proceeding on the matter because completing the RNSS waiver request requires information that can only come from other GNSS system providers.

Mr. Shields expressed reluctance to make any recommendation without a better understanding of what is happening at DOS on this issue. While, obviously, something needs to be done, it is a general rule that dealings with the FCC go through the NTIA.

Dr. Parkinson said his perception is that Mr. Turner, FCC "frequency people", and the NASA "frequency people" are "joined at the hip." It is probable that nothing would go to the NTIA without having been first approved by Mr. Turner.

Mr. Shields suggested wording a statement that receiver manufacturers need this issue resolved and requesting NASA Administration to work toward such a resolution, without specifically requesting the agency to seek a waiver.

Dr. Parkinson asked the Board whether the NASA Administration should be requested to a take the lead in seeking such a resolution.

Mr. Shields thought that would be fine.

Dr. Axelrad raised two questions: First, how can the DOS be authorized to negotiate bilateral agreements if persons within the U.S. are not authorized to use the foreign GNSS signals? Second, if NASA does it, does that mean BeiDou will not be included?

Dr. Parkinson responded that at ICG he noted that, officially, the U.S. is not authorized to receive foreign signals. He guessed that the State Department should try to reach a private resolution on the matter rather than going public with the problem. The difficulty is that there does not appear any action is taking place.

Ms. Neilan said in her view there would be no discomfort with exploring a waiver request.

Dr. Pace said NASA could certainly be helpful; no legislation prevents it from acting. However, he noted that the Board, while sponsored by NASA, it does not report to NASA, but to the EXCOM co-chairs. The FCC's March 2011 statement sets criteria for NTIA to consider. These include to consider whether the waiver is: in the public interest; consistent with agreements on space debris, consistent with U.S. trade agreements, limited to receive-only RNSS but not other augmentation systems, and compatible in the U.S. government table of spectrum applications. Encouraging the process is a good thing. Many countries have laws that impede interoperability. Such laws exist because regulation lags behind actual use. The U.S. could set a good example by addressing the issue and encouraging other countries to resolve matters in a similar way.

Dr. Parkinson suggested that he draft a statement to be reviewed by Ms. Ann Ciganer, Dr. Scott Pace, Mr. Russell Shields, and Mr. Dean Brenner, and then submitted to the Board. He doubts anything can be put forward at the Dec. 15, 2014 EXCOM meeting. Instead, a statement could be made stating that confusion exists.

Mr. Shields said one should never admit to being confused; rather, one should say the problem is important.

Dr. Parkinson said the issue has "threads that run all over the place" – including bilateral agreements, State Department concerns – against the simple fact that many people are already using foreign GNSS. How could the Board most expeditiously move things along? Dr. Parkinson also asked whether, given that NASA is an actual producer of multiple GNSS receiver systems, the NASA Administrator can take the lead in seeking a waiver.

Ms. Van Dyke noted that she believed a coordinated approach is important. For the moment, the most important thing is to call attention to the conflict between policy and reality and urge that this be resolved. Asked for comment, audience member Mr. Steve Grupenhagan (FAF/ASQ) said he believes an interagency approach to DOS is the best option.

Dr. Parkinson asked whether the EXCOM principals could be advised that the Board is bringing the matter forward not as a recommendation, but as a complex issue that needs resolution.

Ms. Van Dyke noted that an EXCOM "pre-briefing" is scheduled for the following day. Perhaps the matter could be raised at that time.

Mr. Miller said he is comfortable with NASA taking the lead in helping with waivers for particular sectors or applications that relate to NASA-specific issues. However, he does not think NASA should take on the general issue of waivers for all parties concerned.

Dr. Pace said he believes a fairly straightforward, if somewhat complex, process exists that can be pursued. He believes the FCC is also waiting on NTIA, which could act on NASA's behalf or on behalf of others, to make a specific proposal. He, too, favors a multiagency approach and asked whether all agencies concerned have supplied the NTIA with everything it needs.

Dr. Parkinson said the Board should not take steps that do not make a positive outcome more likely, and asked the Board members if there is anything else they cared to add before adjournment.

Dr. Betz noted that the "toughen" working group's presentation included three prioritized recommendations that could be taken to the Dec. 15, 2014 EXCOM meeting.

Dr. Parkinson said that, based on this discussion, he would not present recommendations to the Dec. 15, 2014 EXCOM since it has not been covered in the pre-briefing to EXCOM principals. Instead, he will capture all recommendations in draft form, circulate the draft within the Board, and then send the EXCOM a letter summarizing the Board's views.

Ms. Ann Ciganer said a key point is that the U.S. and the European Commission should work cooperatively with the CEPT to withdraw or amend its recommendation 11(08) authorizing use of ground-based pseudolites.

Dr. Parkinson called attention to the paragraph in his submission that addresses this topic.

Mr. Hatch said he feels the FCC statement that they would not "protect" foreign GNSS signals contradicts their stated commitment to augmenting signal resilience.

Dr. Pace said that if he were to assign priorities regarding interference threats to GPS, the pseudolite issue and the Japanese Indoor Messaging System (IMES) are high on the list. As a generalization, it is more important to put a halt to the things that emit than to things that just receive.

Dr. Parkinson agreed, and noted that these are areas where the U.S. is demonstrating good cooperation with international partners.

Dr. Beutler added that he would write the letter to AFSPC that Dr. Parkinson requested earlier on the value of CNAV in L2C.

Ms. Neilan noted that at the Prague ICG meeting there seemed to be some confusion about the real-time network of the IGS, which is headquartered at NASA JPL, and the Global Differential GPS System (GDGPS) run by Dr. Yoaz Bar-Sever at JPL. It is important that people understand that GDGPS is proprietary and one has to pay for it. This is different that the IGS data that is going to be made available to users in real-time.

Mr. Higgins agreed that spectrum should be a very high priority, but also urged the Board not to underestimate the legalities involved. If use of a combined GPS/GLONASS receiver is illegal, in principle it could allow a legal opening to a competitor to present a challenge.

Mr. McGurn stressed that his earlier question is not rhetorical: it is not clear what the FCC means by "authorizing," but not "protecting" a signal. The Board needs to be clear about what is being sought on this question.

* * *

**Closing Comments**

Mr. Miller thanked all for attending. He reported that the morning meeting with the NASA Associate Administrator had been very productive, and pointed toward a renewal of the Advisory Board's charter. However, to be on the safe side, the Board should next meet before expiration of the existing charter in mid-May 2015. He suggested the dates of Tuesday-Thursday, May 12-14, 2015 and requested member's feedback on their availability.

Ms. Neilan noted those dates may conflict with a scheduled meeting she would be attending in China.

Mr. Miller also raised the possibility that the subsequent Board meeting could ride "on the coat tails" of the 10$^{th}$ ICG session in Boulder, Colorado, in early November 2015.

Ms. Neilan noted that the plenary sessions of the ICG are open to interested parties.

Dr. Parkinson expressed his thanks for all in attendance.

*The Thursday, December 11 session of the PNT Advisory Board adjourned at 12:15 pm.*

* * *

**Appendix A: National Space-Based Positioning, Navigation & Timing (PNT) Advisory Board Membership**

Special Government Employees:

Bradford Parkinson (Acting Chair), Stanford University

Thad Allen, Booz Allen Hamilton

Penina Axelrad, University of Colorado

John Betz, MITRE

Dean Brenner, Qualcomm

Joseph D. Burns, Sensurion Aerospace

Per K. Enge, Stanford University

Martin C. Faga, MITRE

James E. Geringer, ESRI

Ronald R. Hatch, consultant to John Deere

Rajiv Khosla, Colorado State University

Peter Marquez, Planetary Resources

Terence J. McGurn, private consultant (retired CIA)

Timothy A. Murphy, The Boeing Company

Ruth Neilan, Jet Propulsion Laboratory

T. Russell Shields, Ygomi

Special Representatives:

Gerhard Beutler, International Association of Geodesy (Switzerland)

Elizabeth Cannon, Canadian Aeronautics and Space Institute (Canada)

Ann Ciganer, GPS Innovation Alliance

Arve Dimmen, Norwegian Coastal Administration (Norway)

Matt Higgins, International GNSS Society (Australia)

Hiroshi Nishiguchi, Japan GPS Council (Japan)

Refaat M. Rashad, Arab Institute of Navigation (Egypt)

Executive Director

James J. Miller, Executive Director

**Appendix B: Presentations**

Space and Missile Systems Center: GPS Update for PNT Advisory Board/Col. William Cooley

Toughening GPS Receivers against Interference/Dr. Gary A. McGraw

International Cooperation and the International Committee on GNSS/Mr. Ken Hodgkins

DOT Positioning, Navigation and Timing Update/Ms. Karen Van Dyke

NTI/FCC Spectrum Management Perspectives/Ms. Paige Atkins and Mr. Ronald Repasi

A Comprehensive Quantitative Economic Assessment of GPS/Dr. Irv Leveson

GPS & Precision Timing's Role in the Financial Sector/Andrew F. Bach

Terrestrial GPS Augmentation with a Metropolitan Beacon System/Dr. Frank van Graas and Subbu Meiyappan

Complementing GPS/GNSS with Micro-PNT Techniques/Dr. Robert Lutwak

Intelligent Transportation System (ITS) Evolution: GPS/GNSS Role in Emerging Vehicle Fleets and Highway Infrastructure/Mr. Brian Conin

Orbit Modeling and Multi-GNSS in the IGS/Dr. Gerhard Beutler

International Member Regional Update: Australia/Mr. Matt Higgins

Maritime Navigation Next-Gen: Back to the Future/Dr. Refaat Rashad

*(All presentations are posted at GPS.gov)*

**Appendix C: Sign-In Sheet**

PNT Space-Based Advisory Board Members:

Gerhard Beutler, International AG
Dean Brenner
Joe Burns, Sensurion Aerospace
John Deere
Stephen Denker, AFSPC
Jim Geringer, ESRI
Ron Hatch
Raj Khosla
Ruth Neilan, NASA Jet Propulsion Laboratory
Brad Parkinson, Stanford University
Refaat Rashad, Arab Institute of Navigation
Russell Shields, Ygomi

Other Attendees:

Barbara Adde, NASA
John Anton, EA4SS
Paige Atkins, National Telecommunications and Information Administration (NTIA)
Jeff Auerbach, U.S. Department of State
Andrew Bach, Juniper
Frank H. Bauer, NASA
Patrick Braker, BAHES
David Buckman, Braxton
William Burns, United States Coast Guard
Jim Burton, National Coordination Office
David Chelmins, NASA
Milton Clary, EA4SS
Clark Cohen, PNT Holdings
William T. Cooley, U.S. Air Force
Brian Cronin, U.S. Department of Transportation
Bob Edmonds, EXEUS
Todd Ely, NASA Jet Propulsion Laboratory
Juan Figueroa, Department of Homeland Security
Blair Fonrille, U.S. Navy
Jacob Freeman, SMC/GP
Jonathan Freeman
Monty Graham, Department of Homeland Security
Dana Goward, PNT Foundation
Steve Grupenhagen, SAF/AQS
Rick Hamilton, United States Coast Guard
Ken Hodgkins, U.S. Department of State
Mark Jacobsom, George Washington University
Bethany Johns, ACSESS
Kristin Jones, EXELIS
Jason Kim, Department of Commerce
Czaplewski Knyostok (?), EUGIN
Kerry Lawson, NASA ASRC
Irv Leveson, Leveson Consulting
L. Kirk Lewis, Institute for Defense Analysis
Robert Ludwak, DARPA
Harold Martin, National Coordination Office
Gary McGraw, Rockwell Collins
Subbu Meiyappan, NextNav
Charlie Meyer, Alcatel-Lucent
Steve Moran, Raytheon

Paul Murray, Federal Communications Commission
Mitch Narins, Federal Aviation Administration
Dave Olsen, Federal Aviation Administration
A.J. Oria, NASA Overlook
Joel Parker, NASA
Tony Parker
Ganesh Pattabiraman (?), NextNav
Jim Slater, self
John Stenbit, self
Victor Sparrow, NASA
Ronald Repasi, Federal Communications Commission
Jim Slater, self
Lori Thompson, Exelis
Karen Van Dyke, Department of Transportation
Frank Van Graas, Ohio University
Stephanie Wan, NASA Overlook

**Appendix D: Acronyms and Definitions**

| | |
|---|---|
| ABC | Anti-lock Braking System |
| AFSPC | Air Force Space Command |
| ARAIM | Advanced Receiver Autonomous Integrity Monitoring |
| BeiDou | China's GNSS |
| BITS | Building Integrated Timing System |
| CEP | Circular Error Probable |
| CEPT | European Conference of Postal and Telecommunications Administrations |
| CIAG | Critical Infrastructure Advisory Group |
| CMPS | Civil Monitoring Performance Specification |
| CNAV | GPS Civilian Navigation Message |
| CPNT | Complementary PNT |
| CSRIC | Communications Security, Reliability and Interoperability Council |
| CSWaP | Cost Size Weight and Power |
| DARPA | Defense Advanced Research Projects Agency |
| DFO | Designated Federal Officer |
| DHS | Department of Homeland Security |
| DOC | Department of Commerce |
| DoD | Department of Defense |
| DOT` | Department of Transportation |
| DOS | Department of State |
| DTCC | Depository Trust & Clearing Corporation |
| E911 | Enhanced 911. A system in the U.S. that links emergency callers with the appropriate public resources. |
| EGNOS | European Geostationary Navigation Overlay Services |
| eLoran | Enhanced Loran |
| ERP | Effective Radiated Power |
| ESA | European Space Agency |
| ETSI | European Technical Standards Institute |
| EU | European Union |
| EXCOM | PNT Executive Committee |
| FAA | Federal Aviation Administration |
| FACA | Federal Advisory Committee Act |
| FCC | Federal Communications Commission |
| FHWA | Federal Highway Administration |
| GAGAN I | ndia's GPS and Geo-Augmented Navigation |
| Galileo | European GNSS |
| GDGPS | NASA Global Differential GPS System |
| GLONASS | Russian GNSS |
| GNSS | Global Navigation Satellite System |
| GPS | Global Positioning System |
| GPS-D | GPS Directorate |
| IALA | International Association of Lighthouse Authorities |
| IAG | International Association of Geodesy |
| ICG | UN International Committee on GNSS |
| ICT | Information and Communications Technology |
| IDM | Interference Detection and Mitigation |
| IGS | International GNSS Service |
| IMES | Indoor Messaging System (Japan) |
| IMO | International Maritime Organization |
| INS | Inertial Navigation Systems |
| ITAR | International Traffic in Arms Regulations |
| ITS | Intelligent Transportation System |
| ITU | International Telecommunications Union |
| L1C | GPS 4th civilian signal |
| L2C | GPS 2nd civilian signal |
| L5 | GPS 3rd civilian signal |
| LNAV | Legacy Navigation |
| M-Code | GPS New Military Signal |
| MEMS | Micro-Electro-Mechanical Systems |
| MGUE | Military GPS User Equipment |
| MSS | Mobile Satellite Services |

| | |
|---|---|
| NASA | National Aeronautics and Space Administration |
| NDGPS | Nationwide Differential GPS |
| NCO | National Coordination Office |
| NextGen | Next Generation Air Traffic Control |
| NGS | National Geodetic Survey |
| NHTSA | National Highway Traffic Safety Administration |
| NOAA | National Oceanographic and Atmospheric Administration |
| NTIA | National Telecommunication and Information Administration |
| NTP | Network Time Protocol |
| OCX | GPS Next Generation Operational Control System |
| OIIR | NASA Office of International and Interagency Relations |
| PNT | Positioning, Navigation, and Timing |
| PPS | GPS Precise Positioning Service |
| PRN | GPS Pseudorandom Noise Code |
| PTA | Protect, Toughen, Augment |
| PTP | Precision Time Protocol |
| QZSS | Quasi-Zenith Satellite System |
| RNSS | Radio Navigation Satellite Service |
| SAR | Search and Rescue |
| SBAS | Space-based Augmentation System |
| SCoI | Space Community of Interest |
| SLR | Satellite Laser Ranging |
| SOLAS | Safety of Life at Sea |
| SPS | GPS Standard Positioning Service |
| STEM | Science, Technology, Engineering, and Math |
| SV | Satellite Vehicle |
| UK | United Kingdom |
| USCG | U.S. Coast Guard |
| URE | User Range Error |
| V2V | Vehicle-to-vehicle |
| WAAS | Wide Area Augmentation System |
| WG | Working Group |
| WTO | World Trade Organization |
| WRC | World Radio Conference |
| Wi-Fi | Local Area Wireless Technology |

**Appendix E: 29 Aug 2014 PNT Advisory Board Letter to the PNT EXCOM**

SPACE-BASED POSITIONING
NAVIGATION & TIMING
NATIONAL ADVISORY BOARD

**August 29, 2014**

The Honorable Robert O. Work
Deputy Secretary of Defense
U.S. Department of Defense
1000 Defense Pentagon
Washington, DC 20301

The Honorable Victor M. Mendez
Deputy Secretary of Transportation
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 20590

**Subject: PNT Advisory Board Recommendations to PNT EXCOM**

Dear Deputy Secretary Work and Deputy Secretary Mendez,

As you know, the Positioning, Navigation, and Timing Advisory Board (PNT AB) is an independent advisory committee, sponsored by the National Aeronautics and Space Administration (NASA) since 2007. It operates under Federal Advisory Committee Act (FACA) rules to provide counsel and recommendations to the National Space-based PNT Executive Committee (PNT EXCOM) per the 2004 PNT Presidential Policy. The PNT AB last met in Washington DC on June 3-4, 2014. Currently we are principally focused on ensuring uninterrupted national access to PNT services, such as those provided by the Global Positioning System (GPS). To help achieve this goal, we have formulated four key recommendations. They support your recognized PNT EXCOM priorities:

1) **Formally Designate GPS as a Critical Infrastructure Sector for the United States**
Virtually every Department of Homeland Security (DHS)-designated critical infrastructure sector is dependent on access to GPS for positioning, timing, or both. Specifically, these PNT services are pervasive elements in 14 of 16 critical U.S. sectors. Preliminary economic studies show a *direct* value of GPS equipment manufacturing of over $30B a year, which may triple to over $90B when also including the *indirect* benefits facilitated by the use of GPS. These impacts, however, are not yet fully understood nor appreciated by the critical infrastructure sectors, thus relegating GPS to a "stealth utility" status, lacking appropriate protections. Serious potential threats to GPS users range from changes in spectrum regulations, to intentional interference, cyber-attacks, spoofing, and even natural atmospheric disturbances. Such threats are credible and rapidly growing. It is therefore essential that resources and attention be focused on addressing such vulnerabilities. In order to achieve this goal, the PNT AB recommends that the DHS advocate and the President designate GPS as a *separate sector of critical infrastructure* and provide national leadership to counter these threats to our economy and security.

2) **Develop a Formal National Threat Model for PNT Applications in Critical Infrastructure**
The Department of Defense (DoD) routinely develops and updates threat models to GPS defense capabilities, and also prioritizes countermeasures to these threats. However, public safety GPS stakeholders, and other critical infrastructure sectors, do not have a validated threat model. We have studied this in some detail and strongly believe that there is a potential for serious national economic and public safety disruption. The PNT AB therefore proposes that the PNT National Coordination Office

(NCO) be tasked and funded to lead the development of a detailed, PNT National Threat Model (PNT NTM) for GPS. This study should include all classes of threats, the probabilities and economic impacts, and outline potential countermeasures. The PNT NTM study should be developed in cooperation with *all* appropriately cleared civil GPS stakeholders, in particular GPS equipment manufacturers and PNT service providers. We believe the PNT NTM will enable federal departments and agencies, state and local governments, and commercial service providers to better understand and prioritize resource allocation for mitigation strategies.

3) **Prevent the Proliferation of Licensed Emitters in GPS Frequency Bands**
Recent regulatory proposals by the European Conference of Postal and Telecommunications Administrations (CEPT) would license certain terrestrial transmitters, or "pseudolites," to operate in the primary GPS band (also known as GPS L1). This frequency band is designated as a Radionavigation Satellite Service (RNSS) and should be very carefully regulated. These transmitters pose a significant interference threat to GPS and other Global Navigation Satellite Systems (GNSS), including Europe's emerging Galileo system. Therefore, the PNT AB recommends that the PNT EXCOM strongly oppose such licenses and that the U.S. Department of State urgently engage the European Signatories under a demarche pursuant to the terms of the 2004 U.S.-E.U. GPS-Galileo Agreement. The U.S. and the European Union should work cooperatively with the European Commission and CEPT, to prevent the authorization and proliferation of harmful devices in GNSS frequency bands.

4) **Establish a Nationwide CONUS Back-Up to GPS with Existing Infrastructure (eLoran)**
In 2006, an Independent Assessment Team (IAT), commissioned by DOT, unanimously recommended: "*Retain eLoran (enhanced Loran) as a primary backup for critical GPS applications.*" After studying the situation, the PNT AB unanimously concurred and made the same recommendation to the PNT EXCOM in 2007. The PNT EXCOM, with participation from all represented Federal departments, also unanimously concurred. Unfortunately, due to competing fiscal priorities, eLoran was cut from the budget in 2009 and its existing infrastructure is being dismantled. The PNT AB believes that existing Loran sites and antennae could provide an affordable path to a National GPS back-up system, and restated its recommendation at the last PNT EXCOM meeting held on March 14, 2014. We believe that the deployment of a national PNT back-up is now even more urgent due to the rapidly evolving threats to GPS-based PNT services. The PNT AB therefore reaffirms its previous recommendation and requests urgent action to preclude further dismantling of existing infrastructure that could be used as a GPS back-up to prevent disruptions to the U.S. economy, public safety, and security.

In closing, we respectfully remind you of the broad expertise represented by our Board. Our Special Government Employees (SGEs) and sector Representatives have been selected by your PNT EXCOM for their balanced and deep expertise. We thank you for the opportunity to serve and make the broad voice of our community heard. With your support, we believe the economic leverage of PNT can continue its enormous contribution to the safety and economy of the U.S. and the world.

Respectfully,

Dr. Bradford Parkinson
Acting Chair, National PNT Advisory Board

cc:
NASA Administrator, Hon. Charles F. Bolden
Deputy Secretary of Homeland Security, Hon. Alejandro Mayorkas
Deputy Secretary of State, Hon. William J. Burns
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