SPACE-BASED POSITIONING
NAVIGATION & TIMING
NATIONAL ADVISORY BOARD

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

Eleventh Meeting

May 7-8, 2013

The Melrose Hotel
2430 Pennsylvania Ave NW
Washington, DC 20037

James R. Schlesinger
Chair

James J. Miller
Executive Director

Agenda

Tuesday, May 7, 2013

9:00 – 9:05	**BOARD CONVENES** *Call to Order*	Mr. James J. Miller, *PNT Advisory Board Executive Director, NASA HQ*
	Introductions, Announcements, & Agenda Items of Interest	Dr. James Schlesinger, *Chair*
9:05 - 9:30	*GPS Economic Assessment: Quantifying Societal Benefits*	Dr. Bradford Parkinson, *Vice-Chair*
9:30 - 9:45	Update from National Coordination Office for Space-Based PNT *Space-Based PNT EXCOM Recent and Emerging Issues*	Dr. Jan Brecht-Clark, *Director, National Coordination Office for Space-Based PNT*
9:45 - 10:10	GPS Modernization Activities: Progress & Challenges *Ensuring Cyber Security and CNAV Capability*	Major General Martin Whelan, *Director of Requirements, Air Force Space Command*
10:10 - 10:20	GPS III Satellite Reflectors For Performance & Interoperability *Air Force/NASA Senior Advisory Group Update*	Dr. John LaBrecque, *Earth Surface & Interior Focus Area, Science Mission Directorate, NASA*
10:20 - 10:40	GPS III Out To 2030: Building For Future User Applications *Operating in a Multi-National, Multi-GNSS Environment*	Mr. Steve Moran, *Director, GPS Mission Solutions, Raytheon Company*
10:40 - 11:00	Future Trends In GPS User Equipment: *Maximizing Productivity*	Mr. Don Jewell, *Defense Editor for GPS World*
11:15 - 11:30	United States Federal Radionavigation Plan *Infrastructure Update: Nationwide Differential GPS*	Ms. Karen Van Dyke, *Director for PNT, DOT Research & Innovative Technology Administration*
11:30 - 11:50	Global Differential GPS Evolution *A Decade of Civil Signal Monitoring With the GDGPS, but Who Needs It?*	Dr. Yoaz Bar-Sever, *Manager, Global Differential GPS System, Jet Propulsion Laboratory*
11:50 - 12:10	International GNSS Service Real-Time Service & Multi-GNSS Experiment, *Enabling Intersystem Monitoring*	Mr. Mark Caissy, *IGS Governing Board Member, Natural Resources, Canada*
12:10	**LUNCH**	
1:00 – 1:25	United States International Activities & Engagement *Collaboration for the Long Term*	Mr. Dave Turner, *Deputy Director, Office of Space & Advanced Technology, State Department*
1:25 - 1:45	Implementing Galileo/GNSS to GPS Time Offset *Moving Further Towards Interoperability Through "Time"*	Mr. Edward Powers, *Division Chief, United States Naval Observatory*
1:45 - 2:10	Ensuring GNSS Service Benefits are Not Disrupted: *Adjacent-Band Interference to Consumer Radio Receivers*	Dr. Thomas Powell, *Principal Director, User Systems, The Aerospace Corporation*
2:10 -	Tech America Interests in Supporting GPS Economic Productivity	Mr. David Logsdon, *Executive*

2:30	*A Day Without Space: If our GPS Enterprise was Compromised, What Impact Would it Have on our Nation's Economy?*	*Director, Space Enterprise Council*
2:30 - 3:15	Recognizing GPS Contributions *Benefit Measurement, Spectrum Policy and Analysis, and Needs for Assessing and Communicating Benefits*	Dr. Irv Leveson, *Founder, Leveson Consulting*
3:15 - 3:30	**BREAK**	
3:30 - 4:00	Nibbles: *Three Essential Attributes for any GNSS - Availability, Affordability, Accuracy*	Dr. Bradford Parkinson, *Vice-Chair*
4:00 - 4:45	Proposed Structure and Deliverables of GPS Economic Assessment *Quantifying Societal Benefits from GPS Applications – Key Sectors & Critical Infrastructure Applications to be Examined*	Dr. Nam D. Pham, *Managing Partner, NDP Consulting Group*
4:45 - 5:00	Afternoon "Wrap-Up" Discussion *Preliminary Feedback & Discussion for Establishing Economic Assessment Work Plan on May 8*	All PNT Advisory Board Members
5:00	**ADJOURNMENT**	

Wednesday, May 8, 2013

9:00 - 9:05	**BOARD CONVENES** *Call to Order*	Mr. James J. Miller, *PNT Advisory Board Executive Director, NASA* Dr. James Schlesinger, *Chair*
9:05 - 9:15	Announcements & Agenda *Some Thoughts and Guidance from May 7 Discussions*	Dr. Bradford Parkinson, *Vice-Chair*
9:15 - 10:00	International Member Regional Updates & Perspectives *(at member's discretion)* • Dr. Gerhard Beutler, *Switzerland* • Dr. Hiroshi Nishiguchi, *Japan* • Dr. Rafaat Rashad, *Egypt* • Mr. Arve Dimmen, *Norway*	
10:00 - 10:15	**BREAK**	
10:15 - 12:00	PNT Advisory Board Member "Round Table" Discussion *Establishing Expectations, Working Structure, Scope, Timeline, Assignments, and Deliverables for National GPS Economic Assessment -- What top level questions need to be answered?* *(1) Quantify Scope of Gov & Industry Investments* *(2) Prioritize User Base Critical Sectors & Applications* *(3) Review Past Economic Analyses & Identify Gaps* *(4) Derive Values from Productivity Gains* *(5) Determine Ops & Cost Impacts of GPS Service Disruptions*	Intro by Governor Jim Geringer, *PNT Board, Environmental Systems Research Institute* Feedback by All PNT Advisory Board Members in coordination with Dr. Nam D. Pham Develop any additional recommendations and findings for presentation to PNT EXCOM
12:00 - 1:00	**WORKING LUNCH**	
1:00	**ADJOURNMENT**	

Table of Contents

Minutes: Mark Bernstein / Zantech IT Services Corporation

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

The session of Tuesday, May 7, 2013 convened at 9 a.m.

Board Convenes: Call to Order
Mr. James J. Miller, Advisory Board Executive Director

Mr. James J. Miller, Executive Director, convened the eleventh session of the NASA Space-Based Positioning, Navigation, & Timing (PNT) Advisory Board. He explained that the Board is sponsored by the National Aeronautics and Space Administration (NASA) on behalf of National PNT Executive Committee. It is held under the rules of the Federal Advisory Committee Act (FACA) and, as such, is open to the public and sessions are on the record. Formal Meeting Minutes are kept and posted on www.gps.gov within 90 days. Mr. Miller expressed his gratitude to Mr. Jason Kim, Department of Commerce and Senior Advisor of the National Coordination Office (NCO) for "keeping the Board up to date." Mr. Kim works under the new NCO Director, Dr. Jan Brecht-Clark. Mr. Miller welcomed Dr. Brecht-Clark and requested presenters to be mindful of their allotted time slots. The Board is comprised of Representatives and Special Government Employees (SGEs), appointed by the NASA Administrator for their subject matter expertise. SGEs, though participating as volunteers, are similar to government employees in that they were subject to federal ethics rules. Should any matter raised to the Advisory Board pose a potential conflict of interest to SGEs they are obliged to recuse themselves from the discussion**.**

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Announcements and Agenda:
Dr. James Schlesinger, Advisory Board Chair

Dr. James Schlesinger, Chair, noted this meeting marks the third renewal of the National Space-based PNT Board. The group faces various challenges. Changing technologies and their integration with the Global Positioning System (GPS) provide a great opportunity to increase service strength. Adherence to old concepts could slow progress. Selective Availability, for example, impeded progress for years. One of the briefings to be presented at this meeting describes how changing technology may improve GPS user devices in 2020-2030. The Advisory Board has a clear charter to proceed on those changes as it believes is advisable.

Dr. Schlesinger welcomed the Advisory Board members, in particular the international representatives who traveled considerable distances. He introduced Major General Martin Whelan, who is representing General William Shelton, Commander, Air Force Space Command (AFSPC). Dr. Schlesinger noted with regret that long-term members Gen Lance Lord (ret.), Gen James McCarthy (ret.), Mr. Charlie Trimble, Mr. Keith Hall, and Dr. Robert Hermann are leaving the Board and six new members will replace them. Dr. Schlesinger commented on the widespread concern over federal sequestration which, it appears, will not affect current GPS service. The Air Force is continuing to meet its commitment to the user community in both performance and availability. Given there are additional satellites in orbit that can be called into service, and that recent analysis shows that GPS blocks IIA, IIR, and IIR(M) satellites should last two years longer than previous projections, GPS should remain the signal of use for years ahead. He is confident that the Department of Defense (DoD) and the Air Force will maintain the current level of service.

Dr. Schlesinger noted that Mr. Miller had organized a complete and robust schedule. The anticipated federal statement on spectrum management will prompt new challenges for GPS, and three issues the board should focus on include:

1. The Board has commissioned a broad study by economists to determine the economic value of GPS.
2. Enormous pressure exists to reduce the DoD and the Air Force budgets; is there anything the Board might recommend to assure GPS is sustained?
3. How vulnerable is GPS and what can be done to reduce any vulnerability? Dr. Schlesinger invited Dr. Bradford Parkinson, the Advisory Board Vice-chair, to elaborate on this last point.

Dr. Parkinson elaborated with information that the Federal Aviation Administration (FAA) and DoD are currently examining potential vulnerabilities in GPS service access. This is important because it is alarming how some misinformed persons within the federal government are talking about GPS in ways that suggest it may not be essential. In fact, just last week, a senior government official expressed shock that GPS is so vulnerable that it should be replaced. Therefore, it is clear that there is a need to assess GPS' vulnerabilities; address them, and assure the user community that GPS is and will continue to be available. The three central attributes of GPS service are: availability, affordability, and accuracy. Availability requires appropriate satellite geometry and "clear and truthful" reception of signals. Various threats to GPS services exist, including both natural and man-made interference; the latter in turn being either intentional or unintentional interference (which includes signals crossing into the

GPS bandwidth). Responses to intentional interference should include *pre-action* and *deterrence*. Pre-action is deterrence that precedes interference, and prevention is the shutting down of jamming devices. For example, in Australia possession of a prohibited jamming advice is punishable by prison and a fine. Dr. Parkinson added that, in addition to *pre-action* and *deterrence*, there is a third option – *detection*- which is significantly underutilized. A fourth option would be to create robust Global Navigation Satellite System (GNSS) devices that can receive multiple signals so if one is interfered with then operations can proceed with other signals. This fourth option could include backup systems, such as the Enhanced Loran (eLoran), and/or modernizing Distance Measuring Equipment (DMEs). Dr. Parkinson presented a chart showing how progressive steps could reduce the range of a GPS jammer. These steps include the addition of inertial aiding and digital beam-forming antenna in GPS receivers. If combined, these steps would nearly eliminate the area being jammed and greatly reduce the vulnerability of GPS.

Dr. Robert Hermann asked whether these solutions present new and extraordinary management responsibilities. Dr. Parkinson replied that the pre-actions and reactions involved structures that do not presently exist within the federal government. Users and equipment manufacturers are free to implement whichever equipment they view as appropriate. They could, however, decide on this implementation based on the likelihood of interference weighted against the potential consequences of this interference.

Dr. Hermann asked if someone has attempted jamming in the military context, does the authority exist to "go after" the jammer? Dr. Parkinson replied yes.

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National Space-Based PNT Executive Committee Recent and Emerging Issues
Dr. Jan Brecht-Clark, Director
National Coordination Office

Dr. Jan Brecht-Clark said she would speak briefly on matters currently under discussion within the NCO and which would be brought forth to the National Space-Based PNT Executive Committee (EXCOM) meeting on June 11, 2013.

The Critical Infrastructure Resiliency (CIR) "scoping group" grew out of the Fall 2012 EXCOM discussion on GPS interference, identification, detection, and mitigation. The EXCOM requested "more granularity" on system threats and directed the NCO to define the problem and outline a plan of action. The Department of Homeland Security (DHS) is a key partner in this effort as it relates to Presidential Policy Directive 21 (PPD 21) and Executive Order 13636, calling for increased critical cyber-security infrastructure. DHS has offered to make its own critical infrastructure protection framework available. This effort reaches out to both public and private sectors to discuss vulnerability and related factors to ensure that people are educated as to what this means. The Assistant Secretary level PNT Executive Steering Group (ESG) has approved the approach, with DHS taking the lead, on condition that the NCO form two task forces: one to monitor progress in resiliency and look at outreach and education; and the other to look at technology alternatives and how to raise awareness of these in the user community.

Dr. Hermann asked how extensive the analytic work as been in the technology and risk areas.

Dr. Brecht-Clark said it is fairly sophisticated in the assessment of risk areas. Meetings are held with industry representatives to examine the resources and vulnerabilities of each sector – energy, communications, GPS, water, emergency services, etc. The next step is to consider what users could do to anticipate disruptions. The key unknown is what backups the user community is employing in applications such as, for example, banking. It is important to inform the user community of risks and to learn what they are undertaking as protection.

Mr. Marquez asked who holds responsibility for implementing PPD 21.

Dr. Brecht-Clark said it is DHS's responsibility. The NCO is establishing an interagency task force for obtaining information and to provide support. Rob Cramer, an NCO staff member until DHS took control in this area, is leading this effort.

A member of the audience added that Ms. Caitlin Durkovich, Assistant Secretary of Infrastructure Protection, is working with an integrated task force on both PPD 21 and the Executive Guidelines. This activity is focusing primarily on the sixteen sectors identified as key national infrastructure. Work is underway to incorporate PNT into each of the individual sixteen sector plans. The update of PPD 21 will focus on transportation, communications, and information technology; the three sectors believed to be most dependent on GPS. The review of each sector will also consider the role of GPS as an enabler.

Dr. Brecht-Clark continued with the briefing and explained how each individual sector now includes GPS as a topic as a result of discussions on vulnerabilities.

Mr. Robert Cramer, in the audience, said the Executive Order places considerable emphasis on cybersecurity. His group will introduce anything that shows how GPS contributes to system resiliency. Overall the effort is an enhancement over what had originally been intended.

Dr. Hermann congratulated those engaged in the effort, and asked if GPS itself could be declared a critical infrastructure since it supports so many key areas.

Dr. Brecht-Clark stated that the National Infrastructure Protection (NIP) plan does not currently identify GPS in itself as a separate infrastructure, but it does permeate every part of the infrastructure.

Dr. Parkinson added that the cumulative evidence from the sectors suggested GPS has become critical in itself. Raising GPS to a higher level would serve both the community and the nation.

Dr. Brecht-Clark said that acknowledging GPS as a cross-sector dependency would allow efforts to begin more rapidly on the assessment of all 16 sectors. As of yet, however, full information is not available on how each sector uses GPS. Dr. Parkinson agreed.

Dr. Schlesinger asked how the current relationship between DHS and National Security Agency (NSA) could be characterized.

Dr. Brecht-Clark said she did not know.

Dr. Schlesinger suggested that the NSA is likely to be inclined to "turf protection." Since most of the government's cyber-security assets rest with NSA the Board needs to make sure that DHS is taking full advantage of NSA's capabilities in this area.

Dr. Brecht-Clark presented the slide: "GPS Outreach: Raising Public Awareness," and noted that the pending change of the NCO website from pnt.gov to gps.gov should make it easier to find. In terms of public awareness additional activities include: the recently-opened "Time and Navigation" exhibit at the Smithsonian; the distribution of 20,000 "How GPS Works" posters to STEM educators; the NCO's newsletter for Congressional staffers, and the NCO's participation at international conferences. Despite budget cuts, every effort is being made to maintain support for public outreach.

Dr. Schlesinger noted that "we have a bully pulpit" in the White House. A word from the President on the value of GPS would also be very effective as outreach.

Dr. Brecht-Clark moved on to discuss the United Kingdom (UK) L1C patent issue. The UK has identified 41 patent issues worldwide. Early agreement has been reached with the UK on the need to withdraw these patents. Thus far, 38 of 41 have been withdrawn. Three patents remain in Canada, China, and India but action is proceeding to remove them. The U.S. and UK have issued a statement supporting continued open operations for PNT.

In terms of radio spectrum, the general context is that the 2012 Presidential Directive regarding 500 MHz of spectrum is to be made available for broadband over the next ten years. The 1755-1850 MHz frequency band is currently under review by National Telecommunications and Information Administration (NTIA) for potential wireless broadband operators. The NTIA is also beginning to study standards for GPS receivers. In terms of *LightSquared*, it no longer intends to provide broadband service in the frequency band adjacent to GPS L1. Spectrum protection issues for GPS continue to draw national level attention.

Dr. Schlesinger asked whether the change in the chairmanship of the Federal Communications Commission (FCC) would alter this process. Dr. Brecht-Clark said she did not as yet know.

Dr. Brecht-Clark added that the PNT EXCOM has requested additional "granularity" on the threats and vulnerabilities related to GPS and a classified briefing will be held at the June 11, 2013 PNT EXCOM session. The PNT EXCOM will also be briefed on the CIR effort and the National Advanced Spectrum & Communications Test Network (NASCTN), a test center for spectrum issues which is an outgrowth of the challenges presented by *LightSquared*.

Dr. Hermann asked who will establish and operate NASCTN. Dr. Brecht-Clark said it would be run by DoD in combination with NTIA, and will be based in Colorado.

Dr. Parkinson asked if the GPS community is going to have a "strong representation" at that body. Dr. Brecht-Clark said it would since this body is a direct outgrowth from the PNT ESG, which will seek regular updates on the activity. This body could also be used by commercial entities to determine early on whether their proposals are viable.

Dr. Parkinson commented that after having reviewed the proposed staffing, it appears that "PNT people" are a bit thin on the ground. Dr. Brecht-Clark said the undertaking is endorsed by Terry Takei, assistant Secretary of Defense for Networks and Information Integration and the DoD Chief Information Officer (CIO).

Dr. Brecht-Clark added she hoped to give the PNT EXCOM an update on GPS economic impact study, and the FAA will provide an update on the status of civil funding of GPS.

Dr. Schlesinger asked how the matter of civil funding is progressing. Civil funding is often referenced as the "pot of gold that would be reached at the end of the rainbow," but so far no great sums had been forthcoming.

Dr. Brecht-Clark acknowledged a shortfall in civil funding. The military has been forthright in saying that due to sequestration it would not be able to absorb the shortfall, and on the civilian side there is little specificity on what is being paid. If there is no identifiable negative impact to civilian users on the withdrawing of funds then it is difficult to get those agencies to pay.

Dr. Schlesinger commented that Congress, which with sequestration "sits there with a bloody dagger in its hand," should have greater sympathy for civil funding. The recently-appointed Treasury Secretary Mr. Jack Lew was the Office of Management and Budget (OMB) director during the Clinton years and he was the one, working with DoD, that set up a special arrangement to protect the DoD from additional costs for supporting civilian requirements. He could be helpful now. OMB must be made aware of such past efforts to protect funding.

Dr. Brecht-Clark said civil funding will remain a critical budget item over the next few years.

Dr. Hermann asked if he correctly understood the statement that the failure to be forthcoming with civil funding would not have an impact on the prospective funder. Dr. Brecht-Clark replied there is no specific activity that has been slowed down or withdrawn. The funding package for GPS did not separate out what is being paid for by whom, and what would get cancelled if civil funding was not forthcoming.

Gen Whelan said his office is now working to develop a more definitive basis for charges related to GPS operation. Dr. Schlesinger suggested that if coverage were reduced at Washington Reagan Airport – "through which members of Congress fly every week" – perhaps Congress might become more attentive.

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GPS Modernization Activities: Progress and Challenges
Maj Gen Martin Whelan, Director of Requirements
Air Force Space Command

Maj Gen Whelan explained that his briefing would focus on the Civilian Navigation Message (CNAV) signal testing, cyber vulnerability and – at Dr. Schlesinger's request – on GPS program aspects.

CNAV testing is scheduled to begin in June 2013. While CNAV testing has been part of the GPS Modernized Operational Control System (OCX) development effort, specific testing of the message on the L2C and L5 civilian signals has not yet been conducted. The June 2013 tests are the first being conducted as part of OCX development. Testing should not cause any disruption of normal GPS satellite operations nor impact the signal set.

Dr. Schlesinger asked why not simply turn the signal on in June? Gen Whelan answered that the signal has been turned on but not yet populated with message sets. This test series will use an off-line tool to build the message sets. The current system does not allow for simple automation. The test objective is to allow civilian users to participate in the L2C and L5 signal effort. Currently, efforts are underway to clarify the test objectives. The entire GPS constellation will be involved, with exception of the GPS-IIF-4 which will be undergoing early orbit checkout during these tests.

Dr. Parkinson asked Gen Whelan whether he's had an active dialog with civil users on changes "coming down the pike." Gen Whelan responded that the Program Office has. There are on-going efforts to make sure everyone is aware of the test series. Broader awareness adds to the value of feedback from equipment manufacturers. The first round of testing is currently scheduled for June 15-29, 2013. The signal will be populated from the ground for up to ten satellites. Uploads will occur every day. The two prime objectives are: first, to make sure interface specifications are met; and, second, to facilitate the dialogue with GPS receiver manufacturers. Once test results are available Gen Shelton, AFSPC Commander, will determine whether to continue populating the message or continue the test series.

Dr. Parkinson commended Gen Shelton, Gen Whelan, and all those involved in this undertaking. This activity has required quite a bit of additional work but it is a good example of "forward-leaning" that makes good sense.

The GPS OCX ground segment is scheduled to come online in 2016, and will be capable of fully supporting CNA. AFSPC is highly confident that GPS will continue to meet or exceed its worldwide civil and military PNT commitments.

Dr. Schlesinger asked whether this "PNT commitment" constitutes 24 satellites, plus three in reserve. Gen Whelan responded that it does, although sequestration is likely to strain efforts to maintain a 32-satellite constellation in operation. Dr. Schlesinger noted that the Chinese are currently aiming for a 36-satellite system.

Gen Whelan continued explaining that the President's FY14 budget supports all current programs. Regarding FY15 at this time some work has not yet been submitted so AFSPC is not yet in a position to predict the resolution. Also, Gen Shelton has requested additional reviews take place this summer due to concerns raised by the Independent Review Team (IRT). Boeing has delivered the 4th IIF satellite scheduled for launch later this month.

Dr. Hermann, referring to an earlier comment by Dr. Parkinson regarding concerns on perceived GPS vulnerability and some comments that the system might not be worth maintaining, asked what accountability or responsibility does Gen Whelan's office have for providing GPS services.

Gen Whelan responded that AFSPC's role is to provide GPS services and work with the military on code-based equipment and, also, while AFSPC does not provide equipment for civil users, it does work with the same manufacturers that create the equipment used by the civilian community.

Dr. Hermann agreed, but added that he believed support to civilian users should go beyond providing the signal in space just as AFSPC is engaged in making sure the system solution is completed all the way through DoD user equipment. There are issues on availability that go beyond providing the signal, which may include augmentations and other technologies.

Gen Whelan responded that it was probable "things would become more constrained" as the budget tightened; however, full engagement with the civil user community remains a priority.

Gen Whelan characterized cyber vulnerability as a broad concern. The GPS system itself is continually monitored from the surface. As an analogy, when exposed to the environment ferrous materials will rust. Similar things may happen to software systems because of changes in the environment. Review and regular maintenance is performed akin to what you do to remove rust. Military users are required to undertake annual training to improve their understanding of threats to the system and response to those threats. While we cannot discuss specific system vulnerabilities in a public forum, we can assure those present that processes are in place for identifying and responding to vulnerabilities.

Dr. Schlesinger asked whether the DoD addressed the question of prospective obsolescence of GPS for military users adequately. Gen Whelan replied that as far as assuring the accuracy of the signal in the war fighting context (weapons delivery on a target with minimal collateral damage), his office is focused on both the vulnerability of the system and the vulnerability of the spectrum.

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GPS III Satellite Reflectors for Performance and Interoperability
Dr. John LaBrecque
Lead Earth Surface and Interior Focus Area
Science Mission Directorate, NASA

Dr. John LaBrecque began by reminding everyone that the issue of placing Laser Retro-reflector Arrays (LRAs) on GPS has been going on for many years, but this time around he was very pleased to report major progress over the past year. Following an 18 month multiagency Mitigation Study, which included AFSPC, NASA, and U.S. Strategic Command (USSTRATCOM), an agreement has been reached on the plan for the installation of LRAs on GPS III starting with SV-9, scheduled for launch in the 2019 timeframe. A complementary, and independent study, was also conducted by the Aerospace Corporation. This agreement is documented in a Memorandum of Understanding (MOU) for signature by CDR USSTRATCOM, AFSPC/CC and the NASA Administrator. As of the time of this meeting Gen Shelton has already signed the document. AFSPC deserves praise for organizing and supporting this effort, which also included excellent coordination between participating agencies.
Dr. LaBrecque termed this effort a substantial undertaking whose conclusion was that "cooperative laser ranging can co-exist with GPS III hardware." The LRA is currently being developed and an excellent location for the LRAs on the GPS III satellite nadir deck had been identified. The LRA will meet or exceed GPS standards and will exceed by almost 50 percent the performance of the LRAs on GLONASS, Galileo and Compass/Beidou. This design extends GPS ranging capabilities to low elevation angles. The necessary funding for testing, procurement and integration has been identified. Dr. LaBrecque said he has

communicated to the PNT EXCOM his appreciation of the Advisory Board's careful and sustained support. Good support had also been received from other agencies and the NASA Human Exploration and Operations Mission Directory (HEOMD), in particular Mr. James J. Miller.

Ms. Neilan asked whether there is a possibility of also placing LRAs on GPS-III SVs 1 through 8? Gen Whelan responded that as far as an earlier introduction of LRA is concerned, this would involve engineering costs for which there is no budget, nevertheless the International Laser Ranging Service (ILRS) community is satisfied with the plan for implementing LRAs on GPS-III SV-9 and thereafter. Dr. Gerhard Beutler added that he considers this a major step forward and is very pleased by results of the hard fight made for this.

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GPS III Out to 2030: Building for Future User Applications
Mr. Steve Moran
Director, GPS Mission Solutions
Raytheon Company

Mr. Steve Moran explained that his briefing would discuss the implications of operating in a multi-GNSS environment between now and 2030. The current status of GNSS is quite different from what had been predicted earlier. Currently there are approximately 80 GNSS satellites in operation, and this number could easily pass 100 by mid-decade. In addition to the satellites there is also a large ground infrastructure of GNSS monitoring stations, and this component will become increasingly important to users. The following key assumptions can be made:

1. Globally ubiquitous high quality signals will be available to users free of charge. The average user will be indifferent to the source of the signal.
2. The cost of sustaining and modernizing GNSSs will continue to increase. At present, a cost of $200 million per satellite for GPS III is being approached, if not exceeded. This will pressure provider nations to reconsider what quantity of independent satellites is required to meet national sovereignty concerns.
3. Cyber attacks will become more frequent. Currently this issue is not receiving sufficient attention. GPS is taking cyber-security seriously but it is doubtful other systems are. In addition to becoming more frequent, cyber attacks will become more sophisticated and successful. Some GNSS systems may not survive.

PNT science and technology will remain a rapidly advancing field, and even will accelerate. The problem is that since current systems were free of direct user charges then no economic advantage is accrued to potential operators offering alternatives to current GNSS. This lack of economic advantage could in 20 to 100 years end up with space-based PNT being replaced.

Dr. Schlesinger asked whether Mr. Moran meant replaced or supplemented. Mr. Moran responded it was the former because eventually physics will develop the capability of determining positioning just as accurately as GPS.

Gen McCarthy asked what is the basis for this prediction. Mr. Moran said it assumes continued developments in small-scale navigation systems; chip-scale atomic clocks; small space networks, and related technologies.

Gen McCarthy asked what is the timeframe for that to happen. Mr. Moran responded it leads back to the circumstance that so long as GNSS services are free to the user, there is no economic incentive for investment in better, or less expensive, systems.

Dr. Hermann noted that while "free is hard to beat" from the perspective of governments, these systems are hardly free. And, this being the case, would the technological trends Mr. Moran discussed push governments to create different architectures? Mr. Moran said that some countries have already done so.

Dr. Hermann asked who. Mr. Moran replied that India and Japan have decided they do not need a global system and, thus, a Regional Navigation Satellite System (RNSS) would suffice.

Dr. Parkinson interjected that the systems named are not fundamentally different from GNSS. They are regional augmentation systems that still require GNSS satellites for determining position. As of yet there are no alternatives to the existing global approach. All ranging systems rely on microwave signals subject to line-of-sight issues.

Ms. Neilan agreed there may be additional approaches to global systems, but it is doubtful the wider world would move away from a 'federated GNSS' as is being used now.

Mr. Moran commented that he was not making a prediction, but offering a thought about the future.

Mr. Moran continued with his briefing. First, the average user will be indifferent to the source of the signal and, as a result, could become dependent on services that may not be trustworthy. Therefore, further means are needed to assure trustworthiness. Also, safety-of-life users will have issues with integrity assurance, which is knowing when one is not being spoofed.

There are also implications to military users as military GPS equipment becomes more and more similar to the one in use by civilians. If they're receiving signals from multiple GNSS system they'll need to know which signals can be trusted. This will require independent monitoring of foreign GNSS systems to ensure that the correct information reaches the warfighter.

Finally, cost considerations will prompt greater cooperation between nations. In this area, GPS could do more to leverage its current advantage in cyber-security. As Mr. James Doherty of the IRT once said, "trust nothing, use everything, and come up with a solution that meets your needs at the time."

Gen McCarthy expressed concern about the discussion on cyber-security. We can agree that there could be an impact but no one is discussing how to address this impact.

Gov. Geringer asked if the Board could receive a presentation on the topic.

Gen Whelan recommended that any such presentation will include DHS describing their on-going efforts.

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Future Trends in GPS User Equipment
Don Jewell, Defense Editor
GPS World

For over 21 years, *GPS World* has undertaken annual surveys covering 55 equipment manufacturers and well over 500 receiver types. Moreover, within the last decade, feedback from warfighters on what they would like to see in their equipment has also been collected. The current basic design of military equipment is 25 years old. Results from these surveys show that while GPS remains the system of first choice, the standard military unit currently in use does not meet any of the "top ten requirements" in the equipment features warfighters would also like to have. The most common issue raised is what they perceive as a poor interface in the standard military unit, in particular when compared to equipment available to civilian users.

Mr. Jewell showed a civilian GPS receiver built in 1977 by Rockwell-Collins, also a major supplier of GPS receivers to the military, to emphasize this point. The receiver was built for use either on-the-ground or for aviation, weigh 350 pounds, and took two days to install on an aircraft. The 1977 Rockwell-Collins GPS receiver represents "the first and last time" military user equipment offered greater across-the-board features (other than receiver accuracy and security) than commercial equipment.

Mr. Jewell then showed a 1981 Texas Instrument GPS receiver that weighs only 50 pounds including the antennae. In addition to being a smaller receiver this receiver also incorporates antennas, something that is only now being incorporated into military equipment sets.

As a result of this lag in incorporating features available to civilian equipment, many soldiers on the field purchase their own civilian equipment; most commonly, Garmins or iPhones. A Garmin receiver costs $99 and can be worn on the wrist. It was the most popular receiver until 2005 when it was supplanted by the iPhone. The iPhone provides a wealth of capabilities in a unit weighing only four ounces, including 361 navigation applications that are available to users. Also, an iPhone has additional capabilities exceeding the standard military model, including: Assisted GPS SBAS; Three Axis Gyro; Accelerometer; and Pedometer. These allowed users to know their location even when no GPS signal is being received.

Gov. Geringer asked why Mr. Jewell believes the military command structure has tolerated such a situation.

Mr. Jewell responded that he doesn't know, but he has also seen some drafts of directives for military equipment that could bring considerable progress. The issue is that commercially available units are a ubiquitous utility that saves lives in wartime; so many warfighters go out and get them even though doing so violates regulations that are intended to ensure they use more robust GPS military signals instead of more convenient civilian signals. Such convenience includes "one button" applications such as, for example, warfighters in nighttime combat being able to push a single button for the unit to go dark.

Dr. Hermann said that given these statements a large cloud looms over the table. Should the PNT Advisory Board take time to examine this situation?

Gen McCarthy said that an American "GI" does whatever seems necessary under any circumstance.

Dr. Hermann said he admires them and "God help us" if they did not have such instincts. Nonetheless, there are limits to what a soldier in the field should be expected to do.

Dr. Parkinson said that from the military perspective, the problem with iPhones is that, for example, they do not use protected signals. Therefore, their use for targeting is forbidden because using a secure military signal overrides convenience, and rightly so.

Dr. Hermann said he was prepared to raise this issue with the military leadership. There may be procedural reasons for keeping military hardware the way it is, but it misses the point of ensuring warfighters also having the additional features that have been discussed.

Dr. Parkinson said a way is needed to, for example, build a protected "military chip" that could be slipped into civil devices and ensure warfighters get all the best features.

Ms. Ruth Neilan, echoing Dr. Hermann's comments, said that a recent Defense Science Board study does lament the advancement of military equipment, and also reports that mothers of enlisted men are buying the Garmins and iPhones because they want their child to have better situational awareness. Such units may lack secure transmission and robust military GPS signals, but they do supply a great deal else that is useful to those fighting on the field.

Dr. Parkinson said he shares Ms. Neilan's indignation, and one way to approach this issue could be to take a look at procurement practices in the DoD. The difficulty is that once a requirement is in place it is then virtually impossible to get it altered. This is compounded by the fact that at times the source of a particular requirement does not have a name assigned to it and, therefore, we can't go back to reassess its need.

Gen Whelan agreed that the issue is on the requirements and acquisition side.

Dr. Hermann said that someone has to make risk decisions and, in turn, these are then approved by the Joint Chiefs of Staff. Therefore, ultimately the Joint Chiefs of Staff has responsibility for such decisions. At times it appears they stick to these decisions more for internal political reasons than practical considerations.

Dr. Schlesinger said there is always a tendency to follow tradition and, while not wishing to pick on U.S. Navy requirements, an example of this is how in amphibious operations training there is a requirement that ship captains determine their position through traditional navigation devices.

Mr. Jewell commented that, for example, a friend of his had navigated by sextant and star charts to Tokyo, but this shouldn't preclude using something better if it is available.

Mr. Jewell continued with his briefing. The aggregate sales of the most popular PNT devices include: 250 million iPhones; 115 million iPads; 2.2billion downloaded navigational applications; and 100 million Garmin devices. In addition, the Defense Advanced Research Projects Agency (DARPA) has created several dozen smart applications for use with mobile devices. These "apps" are going straight from development to the field, and it is estimated that over 1,000 servicemen in Afghanistan are already use such equipment and applications. For example, one application provides a map that shows safe vs. hazardous areas through which to travel. The application also retains a record of a warfighter's previous movements and issues a warning if too many trips have been taken down a particular route and, thus, made their actions hazardously predictable by the enemy. Mr. Jewell quoted a statement of a serving warfighter who credits a Garmin device with saving lives and that every officer in his unit carries such device.

Of the 8,000 warfighters that have been part of the GPS World survey, every single one has a commercial unit.

Gen McCarthy commented that his son is serving in Afghanistan, his wife is in Hawaii, and every day they have a 10 to 15 minute conversation on Skype. In addition, he's learned from his son that 'Skyping' is common among soldiers to exchange timely information of value to them, but not to the enemy.

Mr. Jewell quoted a May 1, 2013 report from the *Wall Street Journal* that the Pentagon is now embracing Apple and Samsung devices. This is this outstanding news, but it comes ten years too late. Mr. Jewell then presented slides summarizing PNT user equipment trend, current multi-GNSS technology, and a map of the Global Virtual Reference Stations (GVRS) system operated by Trimble and John Deere. Differences between civilian and military equipment include, for example, a Trimble receiver located in Singapore can receive 169 PNT signals while a military receiver sitting next to it would only see a maximum of twenty signals. Furthermore, the Trimble receiver can log the information.

Mr. Jewell then assessed a pending Army release which, in his view, includes both good and bad news. The bad news is that no new signals have been added to existing military equipment, but the good news was that the system is now both a receiver and

transmitter. The latter enables transmitting to separate receivers that have all the additional capabilities warfighters want. This and other advancements show that, in general, the Army is moving ahead. While in his view the military is mistaken in looking for a "one size fits all," there is a way ahead that includes adding networkable devices to existing hardware such as the Precision Lightweight GPS Receiver (PLGR) and Defense Advanced GPS Receiver (DAGR).

On the other hand, the U.S. Marine Corps has decertified use of PLGR, limited the use of DAGR, and approved the purchase of devices from commercial vendors.

The Air Force has fitted 70 percent of its aircraft with networkable and upgradeable PNT devices, and the Navy (which has high networking needs) has placed PNT devices on 60 percent of its fleet.

In conclusion, a future vision for PNT should include multi-GNSS systems; multi-function Commercial-off-the-Shelf (COTS) devices and non-proprietary Operating System (OS); software downloads of applications; and networked devices. Also, to foster innovation it is preferable that the military stop building their own receivers and, instead, set specifications for civilian manufacturers to meet.

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United States Federal Radionavigation Plan
Ms. Karen Van Dyke, Director for PNT
DOT Research & Innovative Technology Administration

Ms. Karen Van Dyke said her briefing would cover both the Federal Radionavigation Plan (FRP) and the Nationwide Differential GPS (NDGPS). The FRP has been produced since 1980. Currently it is a product of the DoD, Department of Transportation (DOT) and DHS, and signed at the Secretary level. The most recent version is dated April 2012. This document places more emphasis on planning for navigation satellite systems. An effort is underway to also include a high-level description of user needs and how they fit with the broader system. The FRP also incorporates a discussion on the National PNT Architecture signed by DoD and DOT. The 2012 document also includes a new section on PNT requirements and their evolution.

DHS and DOT are also working to analyze the future requirements for NDGPS to support investment decisions beyond FY16. NDGPS is a differential GPS system largely used for surface transportation including rail and maritime. Given the advances in 'stand-alone' GPS since differential techniques were first developed, the investment in maintaining NDGPS requires scrutiny. A recommendation from the DoD/DOT National PNT Architectural is that "as GPS modernization of other methods demonstrates new operational capabilities, agencies should transition or divest U.S. GNSS augmentation assets that are unnecessarily redundant to their requirements." The future NDGPS assessment is driven by various factors including the absence of U.S. Coast Guard requirements, the discontinuation of selective availability, and on-going GPS modernization. A Federal Register Notice was posted on April 16, 2013 to seek comment on current and future NDGPS usage. The range of comments requested includes the need to retain the system, the impact if the NDGPS signals are not available, and alternative uses for the existing NDGPS infrastructure. The comment period is open until mid-July 2013. Once comments are assessed, a second Federal Notice will be issued in the fall of 2013 with emphasis to involve those most directly affected.

Dr. Hermann asked what the costs of making desired changes, or the savings from not making them, are.

Ms. Van Dyke said the current DOT budget for NDGPS is $7.6 million, and she estimates the U.S. Coast Guard budget at $15 million for operations and maintenance.

Dr. Enge said this does not seem like a large sum for what is a unique resource. Luckily its spectrum of 300 KHz, along with the 100 KHz allocation for Loran, remains available for potential GPS use. The approach being followed by DOT appears to be thorough. The strength of NDGPS is not just its performance, but also "real estate and tall masts," which could still have their uses as a backup.

Dr. Hermann, "playing the devil's advocate," said he is somewhat skeptical of the requirements process, which at times seems to reflect vested interest. Could the PNT Advisory Board receive an assessment of NDGPS from an independent source?

Dr. Schlesinger said that may not be an appropriate task for the Board since its scope is to focus on specific technical matters.

Ms. Neilan asked whether NDGPS system use has declined over time.

Ms. Van Dyke said, yes, its use has dropped dramatically in particular due to the impact of the Wide Area Augmentation System (WAAS).

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Global Differential GPS System Evolution
Dr. Yoaz Bar-Sever
Manager, Global Differential GPS System
NASA Jet Propulsion Laboratory

Dr. Yoaz Bar-Sever said he would provide an update on the Global Differential GPS System (GDGPS) and its relation to OCX for GPS civil signal monitoring. The GDGPS system has operated since 2000 with 99.999 percent reliability and offering position accuracy within 10 cm. It is supported with funding from industry, DoD, and NASA. The system now runs the largest real-time GNSS global tracking network with over 100 monitoring sites providing information to three redundant operations centers. The key services provided include support to national security and augmentations for high-precision commercial users. The underlying software is called named Real Time GIPSY (RTG). GDGPS is also being used as a test-bed for RTGX, the new GPS OCX orbit determination software currently under development by the Jet Propulsion Laboratory (JPL) for the U.S. Air Force. The development of RTGX is well ahead of schedule. Using GDGPS as a live-data test-bed offers a paradigm shift, compared to past GPS Ground Control software, by offering massive real-world testing well before deployment.

Dr. Parkinson asked if a "time to alarm" specification is included in RTGX.

Dr. Bar-Sever responded that customers expect GPS differential corrections to arrive within six seconds, while the internal expectation is for correction within five seconds.

Dr. Parkinson asked if this means that should a satellite "go bad" the customer would be notified within five to six seconds.

Dr. Bar-Sever responded that if correction ceased to be provided, the user can infer that something is wrong. GDGPS provides information with low latency and it is the user's responsibility to take action based on the information they're receiving.

Dr. Parkinson asked if a "do not use" option exists.

Dr. Bar-Sever said no because that's a policy issue his organization is avoiding. In the FAA's WAAS, the RTG software runs the so-called 'correction processor'. This is a Level D software code responsible for generating corrections and making sure the WAAS system is accurate. The FAA customer separately provides the Level B safety processor that makes the "use" vs. "don't use" decisions.

Mr. Hatch commented that John Deere had also been using the RTG software. Their approach is to stop providing differential corrections when these become too large and, in effect, that's the automatic indicator that a GPS signal should not be used.

Dr. Parkinson commented that this approach is fine provided there is not an issue with the satellite geometry that causes a signal to be properly corrected but for the wrong location.

Dr. Bar-Sever resumed the briefing and described the mission critical applications supported by his organization. These applications include: assisted GPS; precise positioning; integrity monitoring and situational awareness; space weather monitoring, and repeat-path interferometry with Unmanned Air Vehicle Synthetic Aperture Radar (UAV-SAR). In terms of real-time positioning accuracy, the combination of GPS/GLONASS is only slightly better than GPS alone. GPS signals are monitored, on average, with a 25-fold redundancy and a minimum of 10-fold redundancy. GLONASS had been monitored since 2010 with an average eight-fold redundancy. A GLONASS product line is now being offered that parallels that of GPS. GDGPS will continue to evolve in order to support all GNSS signals, including modernized GPS.

Dr. Bar-Sever posed a rhetorical question: who really needs civil signal monitoring? This is an important issue because while many organizations are interested in studying civil signal monitoring (as shown by spending to-date on studies), very few have actually expressed interested in doing it. The FAA has been, for decades, the lone sponsor of GPS civil signal monitoring studies and appears to distrust others also undertaking such work. However at the same time, the cost of civil signal monitoring development within OCX has increased and become difficult to separate from other development costs, resulting in increased overall OCX costs. If we return to the issue of who is interested in civil signal monitoring other than the FAA, NASA's own assets are sufficient to meets its own needs and other potential users have expressed interested in following a path similar to GDGPS. As a result, NASA is hosting an inter-agency meeting on civil signal monitoring. If, indeed, other users desire civil signal monitoring, then it appears more effective that the monitoring be undertaken by civil agencies instead of the approach currently being followed by the military for OCX. In fact, it is possible that over 80% of civil user requirements for the new GPS

signals could be accomplished by GDGPS at very little cost. Some of the most expensive aspects under the current approach are interesting but not really cost-effective nor worth doing.

Dr. Parkinson asked how the proposed group of civil agencies Dr. Bar-Sever is proposing would "plug in" to the problem.

Dr. Bar-Sever responded that the available data is already being studied and, in his view, a range error could be addressed by adding only a few checks.

Dr. Parkinson said he would wish to see a system design and how it would be implemented.

Dr. Bar-Sever agreed that such study is needed.

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International GNSS Service Real-Time Service & Multi-GNSS Experiment, Enabling Intersystem Monitoring
Mr. Mark Caissy
International GNSS Service (IGS) Governing Board Member, Natural Resources, Canada

Mr. Caissy said his briefing would address the IGS Real-Time Service (IGS-RTS), IGS products that support real-time applications, and how the IGS is preparing for future new GNSS signals.

An IGS-RTS pilot project was conducted between 2007 and 2012 with the objective to develop, manage and maintain real-time infrastructure for the IGS. This project has been like a production chain leading all the way to the user. It has also helped us better understand the need for standard formats for data and corrections. In 2009, IGS became a member of Radio Technical Commission for Maritime Services (RTCM), and to-date considerable success has been achieved in developing multiple signal messages. The IGS- RTS was formally launched on April 1, 2013 with the goal to support the scientific community in its GNSS use as well as the public good. Thirty international partners are currently engaged in IGS- RTS. The service contributes to GNSS tracking stations, data centers, analysis centers, combination centers, and analysis coordination. Over 150 ground monitoring stations are currently tracking both GPS and GLONASS. Collectively these stations generate real-time orbits at 3 cm accuracy and clocks at the 250 picosecond (ps) level. The IGS-RTS remains committed to policies of compelling redundancy and open data. The IGS by statute is not allowed to enter into user-level agreements and, therefore, it is a "use at your own risk service." In reality, he said, risk was infinitesimal. Full operational capability should be achieved in late 2013.

IGS-RTS applications include rapid detection and the locating and characterizing of such hazardous events as earthquakes and consequent tsunamis. There has been a strong user response to the April 1, 2013 launching of IGS RTS, including 80 user registrations filed within days and 142 registrations from 38 countries within three weeks. The engineering, consulting and academic communities have all expressed keen interest.

The Multi-GNSS Experiment (MGEX) is preparing us for the integration of multiple GNSS systems. A call for participation was made in 2011. The MGEX Working Group is headed by Mr. Oliver Montenbruck of the German Aerospace Center (DLR). The group's goal is to maintain a continued flow of Multi-GNSS products. Currently there are ten contributing agencies and 66 stations worldwide, including many operating in real-time. The goal is to include all operating GNSS systems and augmentations. MGEX products will include Galileo and QZSS orbits and clocks; four analysis centers to generate these products; decimeter-level accurate orbits; and ready on-line availability. Future efforts include consideration of the biases created by the mix of new signals; recruitment of additional analysis centers; and movement toward a global multi-GNSS monitoring and assessment capability. Challenges remain, including the need to secure added resources; the desire to improve clock tool performance, and the need for further quality control on the data. For example, information on the Galileo GNSS remains insufficient. Others, like the Quasi-Zenith Satellite System (QZSS), have been very forthcoming with information requests.

Gov. Geringer asked whether Mr. Caissy expected Multi-GNSS service to create total interoperability.

Mr. Caissy said the end goal is integration of all GNSS constellations into the day-to-day activity within the IGS.

Gov. Geringer asked if the governance structure is entirely civilian.

Mr. Caissy responded that, yes, it would.

Ms. Neilan noted that the group is undertaking considerable cooperation with the military. An incredible amount of work had been completed in recent years. Over the past four years in particular, engagement with RTCM has created

non-proprietary formats for released data. In January 2013, an agreement was reached on an open standard for equipment manufacturers. Receivers, therefore, will have a common format with openly available orbits and clocks.

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United States International Activities & Engagement: Collaboration for the Long Term
Mr. Dave Turner, Deputy Director
Office of Space & Advanced Technology, Department of State

Mr. David Turner explained that his presentation would be similar to that made April 23, 2013, to the Institute of Navigation Pacific PNT meeting and focus on foundations of U.S. GPS policy and on international cooperation issues. The 2010 Space Policy enhanced the 2004 Space-based PNT Policy. It reemphasizes interoperability and compatibility, while also adding items on the promotion of transparency and enhanced efforts to detect and mitigate interference.

Dr. Schlesinger asked if Mr. Turner still received complaints related to Selective Availability (S/A).

Mr. Turner responded not in some years, although occasionally stories come out that claim the U.S. "once turned something off," which is not true.

Mr. Turner presented the five key points in U.S. GPS policy:

1. Provide civil GPS services, free of direct user charges
2. Encourage global compatibility and interoperability with GPS
3. Promote transparency in civil service provision
4. Enable market access to industry
5. Support international activities to detect and mitigate harmful interference

Mr. Turner also presented several charts on the economic impact of GPS, which he hoped to update with the work currently being conducted by the Board-appointed economists, namely,

- GPS' value to the U.S. economy is between $68 billion $122 billion a year, or between 0.5 and 0.9 of the country's Gross National Product (GNP).
- GPS has produced productivity and cost savings estimated $67.6 billion, particularly in precision agriculture, engineering construction and transportation.
- GPS has produced positive "spillover effects," such as fuel savings, health and safety gains, increased tax revenues, and others.
- More than 3.3 million jobs rely on GPS technology.

This data does not refer only to direct sales of goods and services, but also includes the economic benefits that follow from using GPS technology. GPS technology is of great value to developing nations, as it allows them to "leap frog" earlier infrastructures and still gain the advantages of the Information Age.

Mr. Turner presented a chart of the world's existing and planned GNSS, RNSS, and satellite-based augmentation systems. The U.S. objective regarding these systems is to assure compatibility; achieve interoperability, and to promote fair competition worldwide. Bilateral cooperation has included:

- Discussions with Russia began in 1996, and currently involve the potential of hosting of GLONASS ground monitoring and laser tracking stations on U.S. territory.
- With Japan, discussions began in 1998, beginning with a joint statement from a heads-of-state summit. The highly interoperable nature of QZSS is a result of these discussions.
- With the European Union (EU), a formal executive agreement on GPS and Galileo was signed in 2004 and ratified by the EU in December 2011.
- Discussions with India began in 2007 and are associated with broader civil space discussions.

There are no formal discussions underway with China, but every opportunity is taken to talk with their technical people.

Dr. Schlesinger asked where those discussions hoped go.

Mr. Turner said the hope is that China provides civil user services in a compatible, interoperable and transparent manner.

Dr. Parkinson asked if Mr. Turner believed progress is being made.

Mr. Turner replied that he does. Compatibility has been achieved mostly through hard work by spectrum management people in the Air Force and NTIA. Interoperability should hopefully be achieved over time.
Dr. Parkinson asked if any document exists that binds the Chinese to a particular course.

Mr. Turner said that China has released an Interface Control Document (ICD), but currently he is not in a position to provide a technical analysis. People in the industry would probably argue that this ICD is not sufficient to design and produce adequate the Compass receiver sets.

Mr. Hatch said dealing with China at times is "like pulling teeth," but nevertheless some information is being received.

Multilateral activities include the International Committee for GNSS (ICG). A separate Providers Forum exists for discussions among providers. Many of the matters under discussion by the PNT Advisory Board fall within the area of GNSS service provision, especially multi-GNSS. Efforts have progressively worked through the following list:

1. Providers' Forum
2. Providers Forum System Report
3. Principles of Compatibility, Interoperability, and Transparency
4. Template for Performance Standards (and ICDs), including the *Postulated Performance Standards for Future Services*
5. Service Assurances or Commitments including: (1) *Monitoring of Service Performance*; and (2) *Interference Monitoring*.

What is needed now is to determine how these principles can be put into practice to create parameters for industry-performance standards and ICD. Once this occurs, the next step is to determine how the performance standards of individual systems may work together to create a common operation. Nations operating newer systems were "nervous about what assurances" they are offered. Several weeks ago, the first ever workshop was held on interoperability and included the user community. Feedback was sought from the people who manufacture devices; in particular, how system providers can make it easier for manufacturers to determine interoperability. A separate workshop was also held on the topic of interference. This topic area required great deal more attention around the world.

Mr. Hall commented that Australia is getting serious about interference, and asked whether Mr. Turner is advocating for other nations increase the penalty for interference.

Mr. Turner replied that the term 'advocate' as such is not yet part of their portfolio, but these subjects are indeed discussed.

Gov. Geringer asked how Mr. Turner perceives the governance of the multi-national GNSS activities.

Mr. Turner replied that formal agreements are reached only on a bi-lateral basis, whereas multilateral activities are nonbinding and voluntary. It is probably best they remain this way. The emphasis should be on national responsibility – legal and liability regime; interference; standards, etc.

Ms. Ruth Neilan noted that one of the efforts of the ICG working groups is on the topic of reference frames, timing, and applications. It has been proposed that system providers urge their own experts to become members of this working group. At the most recent meeting in Beijing, China, such experts came and said they were aligning their reference frames to the International Terrestrial Reference Frame (ITRF), which is a good example of how success can be achieved.

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Implementing Galileo / GNSS to GPS Time Offset: Moving Further Towards Interoperability Through "Time"
Mr. Edward Powers, Division Chief, United States Naval Observatory

Mr. Edward Powers said the briefing would discuss some consequences of the bilateral and other discussions in the past decade. The United States Naval Observatory (USNO) keeps the Master Clock for both military and civilian use. The Master Clock includes approximately 100 individual clocks. This leads to the issue of the GPS to GNSS Time Offset and how these can be harmonized. The current reality is that multiple GNSS systems are in various states of operation, as also are augmentation systems and RNSS systems. These multiple systems, however, could be tracked by any given observer to improve PNT availability in areas such as urban canyons. An important step to achieve this is the GPS to Galileo Time Offset (GGTO) in the June 2004 United States and the European Union agreement, which states that, "*The Parties also agree that GPS and GALILEO shall be, to the greatest extent possible, interoperable at the non-military user level… The Parties also agree to transmit the time offsets between GALILEO and GPS system times in the navigation messages of their respective services, as outlined in the document entitled "GPS/GALILEO Time Offset Preliminary Interface Definition."*

> Dr. Parkinson commented that the most desired state among GNSS systems is interchangeability, where any four signals from GNSS systems can provide a PNT answer. This is harder to achieve than interoperability as stated in the 2004 agreement.

Mr. Powers continued explaining that for the navigation user, it is vital that everything be broadcast relative to a time scale. Such scale could be arbitrary so long as it was consistent. All GPS satellites carry atomic clocks which are synchronized to one another and keep GPS time to within 10 nanoseconds (ns) of Universal Time Code (UTC) for over a decade. In the future it is anticipated that receivers tracking multiple GNSS signals will be able to correct errors within the receiver. If a user is in terrain with restricted satellite visibility, only able to one or two signals, and also unable to connect to a network, then it would be possible for the receiver to correct the error using a time error prompt within the navigation message itself. GPS and Galileo have agreed to keep their time scales to within 50 ns of their respective UTCs. However, even this small difference can translate into a positioning error of several meters.

> Dr. Parkinson said that considering the size of the message, he is concerned about time scales used by the various GNSS systems becoming too far apart. The 50-nanosecond agreement for GPS and Galileo is excellent. Does Mr. Powers have any expectation for a similar agreement with GLONASS?
>
> Mr. Powers replied that the USNO has a long record of working with GLONASS. Until a few years ago, GLONASS time varied too much to allow for time scale correction. GLONASS, however, has made great strides in recent years and is now within a factor of three of GPS time. Also, Japan has agreed to harmonize QZSS time directly with GPS time and plans provided by the Chinese show a similar intention for COMPASS/Beidou.

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Ensuring GNSS Service Benefits are Not Disrupted: Adjacent-Band Interference to Consumer Radio Receivers
Dr. Thomas Powell
Principal Director, User Systems
The Aerospace Corporation

There has been considerable attention as of late on how the GPS signal could be affected by interference from ancillary terrestrial broadcasts in the Mobile Satellite Service (MSS) band adjacent to the GPS L1 frequency band. The Aerospace Corporation has undertaken an effort to determine how various receiver types would be affected by such broadcasts, specifically: digital television (Samsung LN52B530); FM radio (Sony STRDH100); and three types of civil GPS receivers (Garmin Montana 650t; uBlox LEA-6A, and Novatel OEM 628).

> Mr. Parkinson noted the assertion made by some that GPS receivers "must be defective if they can be easily affected by out-of-band interference."
>
> Dr. Powell responded that the goal is to introduce data into the discussion.

Dr. Powell continued presenting the particulars on the bandwidths tested, including: non-FM signals transmitted to the left and right of the FM bandwidths; and television signals bounded by non-television bands. The standard methodology used was to initiate a competing signal and then increase its power until the test device ceased functioning. That is, when the television goes blank; when the radio goes silent, or when the GPS signal fails. The power of the interference signal is then calculated as a ratio of the power of the desired signal. Follow-on testing is conducted where the variable is the closeness of the competing signal to the pertinent device boundary. Results show that when an interference signal moves closer to the boundary, the level of power required to disrupt its operation decreases. An allowance was made for the fact that FM radios and television receivers have much stronger signals compared to GPS.

The objective of this analysis is to show operation is affected by the interaction of competing signal strength and proximity. Dr. Powell presented a graph where the X-axis is the *Interference Signal Frequency Offset from Desired Signal Band* (measured as a percent), and the Y-axis is the *Interference to Signal Power Ratio for Device Failure* (measured in decibels). Results show that GPS is, in fact, superior in its resistance to out-of-band interference even though the entire GPS signal lies below the thermal noise level. Follow-on analysis was performed to plot how background noise affects the result shown by the GPS signal and, as expected, adding background noise somewhat lowers the performance of GPS but its results are still superior.

Dr. Hermann asked about the design characteristics of the Novatel device.

Dr. Powell speculated that this device has front end that "brought in" everything and a series of filters for various signals, including GPS. Generally speaking the intent of these tests was to conduct a simple experiment, not an exhaustive effort. However, these tests have clearly shown that all receivers (and not just GPS receivers) are sensitive to adjacent band interference and, thus, it is possible to cause any receiver to fail if the power of the adjacent band is sufficiently strong. Therefore, compatibility assessments should consider relative signal powers of adjacent band services.

Dr. Parkinson asked if consideration was given to using a high performance receiver that was not trying to accommodate MSS.

Dr. Powell said that was a good idea, but they had undertaken their effort based on materials available in their lab.

Mr. Murphy asked, regarding the use of Continuous Wave (CW) as the interference source, what would be the effect on intermodal products?

Dr. Powell replied that had not been included in this study, but other materials he has read suggests there is no much sensitivity to the bandwidth of the interference signal. In any case, these tests have achieved a "first order" result.

Mr. Hatch noted that many John Deere's receivers are designed to reject a continuous signal.

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A Day without Space: If our GPS Enterprise was Compromised, what Impact Would it Have on our Nation's Economy?
Mr. David Logsdon, Executive Director
Space Enterprise Council, Tech America

Mr. David Logsdon explained this effort was conducted together with the George Marshall Institute with the objective to determine the impact on national security, agriculture and transportation should space-based PNT capabilities be lost. The GPS Alliance estimates that the economic impact would equal $68 billion annually and affect 3.3 million jobs.

The extent of GPS dependency includes support of the following areas: power grid; banking operations; communications systems, and many others. Circumstances that could imperil GPS operation include electrical brownouts; intentional GNSS jamming; spoofing from low-cost devices; and unintentional jamming. Unintentional jamming is the most prevalent form of interference. The overall impact of the loss of GPS service would cost the economy an estimated $96 billion annually – 0.7 percent of U.S. GNP.

These figures show that GPS should be considered a critical national infrastructure. However, it is important that no additional regulation be introduced since regulation can stifle innovation. Mr. Todd Park, Chief Technology Officer of the United States, and keynote speaker at a recent TechAmerica-sponsored conference, said: "I can think of no other technology that has had an impact as much as GPS on our economy." Mr. Park should be brought in as a potential partner in supporting GPS. Improved mobility is a force multiplier that should prompt listing GPS as a critical national infrastructure element.

The Presidential Policy Directive 21 (PPD-21) on *Critical Infrastructure Security and Resilience"* was released in February 2013. It directed the Executive Branch to update the National Infrastructure Plan and report on the matter within 120 days. It also established an interagency task force where, in Mr. Logsdon's view, GPS could be listed as a critical national infrastructure since the public is invited to submit comment to: *eo-ppdtaskforce@hq.dhs.gov.*

Gov. Geringer referred to the morning's discussion of whether GPS should be included as a critical national infrastructure, and asked whether this implies an increase in government regulation.

Mr. Robert Crane, Senior Homeland Security Advisor, in the audience, commented that the infrastructure effort includes Federal Government outreach to sixteen private sectors and, thus, it is not clear how GPS would fit into something that is designed to reach out to the private sector.

Gov. Geringer said that terminology is important, and wondered whether the term "critical infrastructure" is the best place to put GPS.

Dr. Brecht-Clark, NCO Office Director, also sitting in the audience, commented that the national infrastructure plan is not regulatory in nature. Rather, it is a framework for working with the non-government users of GPS. The approach includes looking at the problem, making plans, and taking steps to identify and detect interference. These steps involve collaboration rather than regulation.

Gov. Geringer noted that he sits on several boards that are required to report to DHS, and asked whether this could be used to support this effort.

Dr. Brecht-Clark said that while such support may be helpful, it may not apply to the national infrastructure effort.

Dr. Hermann said he has "a jaded perspective" that even when DHS has regulatory authority and responsibility for assuring access, there is not much in the NIP that provides great managerial activity.

Mr. Logsdon agreed with the assessment that it is primarily an outreach effort.

Dr. Hermann added that any assertion that the NIP plan actually identifies and mitigates the major problems facing the infrastructure of the country is overstated.

Dr. Schlesinger said he believes that the FIRC has the authority to draft rules, but these require the approval of the industry in question to have effect. Such rules, therefore, are entirely voluntary.

Dr. Hermann said that regulation is an awkward tool for addressing the systematic aspects of vulnerability.

Dr. Schlesinger noted that industries characteristically go to Congress to get prospective directives cancelled, and are generally successful.

Mr. Hermann said he does not wish to undermine the process on the grounds that the nation's well-being may be at risk.

Ms. Neilan noted that PPD 21 states that: *"The term critical infrastructure means systems or assets whether physical or virtual so vital to the United States that the incapacity or destruction of such assets would have a debilitating impact on security, national economic security, national health, or any combination of these."*

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"Nibbles": Three Essential Attributes for any GNSS - Availability, Affordability, Accuracy
Dr. Bradford Parkinson, Vice-Chair
PNT Advisory Board

Dr. Bradford Parkinson introduced the concept of "nibbles." If one "nibbles" at an apple, eventually the core is reached. Similarly, if one "nibbles" at a seemingly insuperable problem, then one may reduce it to something that can be readily solved. The three significant "A's" of GPS are: availability, affordability (which including ground infrastructure costs), and accuracy. Accuracy can also be measured in terms of integrity by asking whether the system performing to one's expectations and how often it fails to do so. Availability is typically measured in the number of minutes an outage occurs on any given day. In steep terrain, such as Afghanistan, outages of ten hours a day can occur even if only two GPS SVs in the constellation are out of commission. Availability, of course, increases when the number of GPS SVs in the constellation is increased beyond the nominal 24 SV's. The costs of a single satellite and the total number of satellites a given budget can afford are related to one another. This is a major concern given the current "DoD budget crunch." The annual satellite includes the cost of the satellite *and* its launch, divided by the satellite's useful life. The end-result should be to place satellites in orbit at reasonable cost. A hypothetical constellation could include 15-18 'full GPS' satellites (which include secondary payloads) which are then complemented with 15-18 "nibblesatellites" that only retain the navigation function of GPS. The "nibblesatellites" carry all the navigational signals but would not carry surge power or other payloads. The only addition would be a laser retro-reflector, which is a small and passive payload. The general goal would be to increase the number of satellites in orbit supporting navigation while limiting the overall cost.

Dr. Schlesinger asked whether Dr. Parkinson regarded doubling the number satellites as "nibble."

Dr. Parkinson responded that the "nibble" aspect comes from being able to afford "the apples that are going into my apple pie." The general idea is to reduce satellite weight, complexity and power. This includes lower manufacturing cost of the satellites and allowance for dual-launch of satellites (or single launch on smaller, and cheaper, launch vehicles). He believed it was possible to reduce the in-orbit cost of a satellite by 50 percent. This, he argued, would make a 33-satellite constellation affordable.

Dr. Parkinson then addressed the "nibblesatellite" size, weight, and power requirements. The current GPS satellite navigation payload has a raw Direct Current (DC) power requirement of about 2,200 Watts. Replacing the 5-degree masking angle with a 20-degree masking angle would reduce the antenna complexity. This and other steps could lead to an overall 40% in power requirements. The RF Power Conversion Efficiency is the most important factor when determining the required solar panel size. Current gallium-arsenide technology offers 25 to 30 percent efficiency, whereas a gallium-nitride approach could potentially raise the efficiency as high as 50%. Also, the use of traveling-wave tubes (TWT) could further increase the efficiency. The DC power requirement is the RF power divided by the efficiency and, thus, the power requirement could be reduced by two-thirds by reducing both the output power and increasing the efficiency. In consequence, the operating satellite would produce two-thirds less heat which, in turn, allows for a reduction in the heat pipes, thereby reducing weight and complexity. This approach, however, requires some caution because: (1) one should maximize existing designs, which might foreclose the TWT option; (2) some of the overhead costs may be difficult to reduce; (3) in some areas redundancy is desirable or required; and (4) by fault of its virtue there is no allowance for additional payloads to be carried. At present it costs $400 to $500 million to build and single-launch a satellite. With dual-launch the cost per satellite decreases to approximately $340 million. Using the proposed "nibble" design the cost per satellite could notionally (further analysis is needed) be as low as $125 million if launched in threes (triple-launch). Were this approach used, a 36-satellite constellation could cost less than a constellation of 30 "full up" GPS satellites. Specifically, 12 "nibblesats" could be added at a cost $1.8 billion while six additional GPS Block IIIA SVs would cost $2.7 billion. A question exists on how reducing the radiated power may affect jamming resistance. There are, however, a number of approaches, such as integrating inertials in the receiver that improve jamming resistance. In summary, the "nibble" approach could reduce the minutes of unavailability per day by creating a larger but more affordable constellation. Also, a larger constellation produces improved geometry which in turn improves the ranging accuracy.

Dr. Hermann asked how good the proposed inertial chip is. If, for example, two inertials are added how well do they average? Would there be added value for redundancy in the inertial chip?

Dr. Parkinson said that the inertial allows to average over a greater number of cycles. One does not need a low drift rate for the long term. What is needed is low drift rate for the short term. This is much less expensive.

Mr. Murphy noted that it appears Dr. Parkinson is talking about a deeply integrated inertial to aid GPS tracking.

Dr. Parkinson agreed, and added that airlines have put "a lot of real estate" in play for antennas being capable to receive in-air signal for passengers to view television.

Capt. Murphy responded that in aviation, "the passenger entertainment stuff" pays for itself. A good system design would use the same inertial being used to steer the beam antenna, and use that as the integrating tool.

Dr. Schlesinger asked whether Gen Whelan could explain why the Air Force appears to resists less expensive approaches such as this one.

Gen Whelan commented that Gen Shelton and AFSPC are currently looking at ways to build a smaller/cheaper satellite with a secondary payload removed. This approach, however, brought complaints from a customer of the secondary payload who was contributing to pay for GPS.

Dr. Schlesinger asked whether Gen Whelan was referring to the Department of Energy.

Gen Whelan responded that in a recent meeting the combat commander had said no architectural changes could occur until the new technologies were proven reliable to him.

Dr. Parkinson said "a lot of convincing" remains to be done.

Gen Whelan noted that Gen Shelton had not said "never" to less expensive satellites. However, he agreed with Dr. Parkinson that there is still a lot of convincing to do.

Mr. Murphy asked, playing "devil's advocate," what is the counter argument to a constellation of 18 full satellites and six "nibblesats"?

Dr. Parkinson said the counter-argument is availability and whether one is trying to provide navigation service to an aircraft or a user on the ground.

Mr. Murphy agreed with Dr. Parkinson's comment that aircraft did not often need ground-based service since they are rarely 'sky-impaired'.

Mr. Faga noted that under typical acquisition rules the simple truth is that if you bring in a more complicated satellite you paid more, but if you bring less complicated satellite you may end up also paying more. The real message is that whatever price you are paying today is likely to be the lowest price you will ever pay.

Dr. Parkinson offered a counter-example, saying that it appears Galileo is launching satellites at a total cost of below $150 million.

Mr. Faga offered a comment on the true cost of secondary payloads. If Dr. Parkinson's financial estimates were even roughly equivalent to real dollars, then the cost of carrying secondary payload would range between $200-300 million. If that is the true cost, wouldn't the value of the payload provided compete successfully under any budget scenario?

Gen Whelan said that AFSPC is currently "chipping away" at that figure. This is one relevant point that had at one time not been open to discussion is now being considered.

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Recognizing GPS Contribution: Benefit Measurement, Spectrum Policy and Analysis, and Needs for Assessing and Communicating Benefits
Dr. Irv Leveson, Founder
Leveson Consulting

Under the current budget environment, it is important for GPS users to make their case vs. the increased demand for broadband. This presentation addresses three related topics: spectrum policy and analysis; GPS benefit measurement, and the need to communicate these benefits. The objective of the cost-benefit study is to improve policy making and provide a performance baseline against which to measure the contributions of GPS.

The study of benefits involves focusing on the productivity gains and cost savings in the various sectors that use GPS. Benefits include such things as: favorable impact on productivity; cost reduction; improved innovation; "consumer and producer surplus" (defined as the value above market price); and "social benefits, which include things that favorably affect life, health, safety, security, and the environment.

Dr. Schlesinger asked if Dr. Leveson was referring to aggregate or net benefits.

Dr. Leveson said that, ideally, one wants both aggregate and net figures when making policy decisions.

Dr. Schlesinger noted that if Dr. Parkinson's "nibblesats" approach were adopted, then the net benefits would increase.

Dr. Leveson agreed since the reduction in cost and improvement in availability would both add to net benefits.

The loss of benefits depends on the context in which the measuring is done. For example, what would the world look like if GPS had never existed? In that case, one has to consider the possibility that some other system may have evolved and supply some of the benefits currently provided by GPS. This is an important consideration but, of course, also highly speculative. Another approach is to consider a short-term loss of GPS service, which would have a number of impacts, particularly on security and risk issues. These impacts become much greater as the loss becomes longer. Benefits could also be lost due to the encroachment on the GPS spectrum, and this could have substantial effects even if disruptions are continuing and intermittent.

Dr. Schlesinger suggested that since GPS *does* exist; doesn't this imply there are some costs that detract from long-run benefits?

Dr. Leveson said this was correct. He also noted that some benefits needed to be detracted, on the grounds that they would have been supplied by some putative alternative system. Further, he said, one needed to look at the cost of those alternatives.

Dr. Parkinson commented that what Dr. Leveson terms as 'short-term outages' should be considered as long-term if they are frequent.

Dr. Leveson agreed, which is why he uses the phrase "*continuing even if intermediate*" to characterize such impacts in the long-term impact.

Dr. Parkinson asked how this could be quantified, and offered a parallel: a laptop computer might be prone to short-term failures and, thus, at what point does its unreliability make it no better than "a piece of junk?"

Dr. Leveson said one can look at how the technology is used and how the interruptions affect users.

Gov. Geringer commented that the PNT Advisory Board is broader than just GPS and, thus, capable of discussing PNT in the broader sense.

Dr. Leveson said this is "a very thorny issue." If one loses GPS, one loses a host of capabilities throughout the economy. PNT capabilities are only part of it.

Mr. Marquez commented that Dr. Leveson spoke about the length of time of service denial, but some sectors in the economy such as Wall Street require a constant timing signal.

Dr. Leveson agreed, and noted this is just a high-level presentation to open the debate on specific applications such as that one.

Dr. Leveson turned next to spectrum policy and its analysis. Spectrum policy is driven by the huge growth in demand and has resulted in the following recommendation and directive:

- The FCC National Broadband Plan recommends that the Commission make available 500 MHz of new spectrum for wireless broadband, including 300 MHz for mobile flexible use, within five years; and
- The President directed, in a June 28, 2010 Executive Order "Unleashing the Wireless and Broadband Revolution," that 500 MHz of new spectrum be made available for mobile and fixed broadband use over the next ten years"

As a result, the FCC is feeling pressure to meet this target. It is interesting that the Executive Order specifically cites the expansion of broadband as a reason even though the benefits claimed for broadband expansion are nearly identical to the benefits already facilitated by GPS. Therefore, when speaking about the need for additional spectrum, one must also speak to the advantages of GPS supplying those benefits. How does the FCC assess the situation? In practice, they look at the number of subscribers who may benefit from such a service. However, they do not look at price increases and how calculations change if you charge by the bit instead of a flat rate. The big unanswered question is how do the incremental benefits of using spectrum that interfere with GPS compare with the GPS benefits lost due to the interference? We are not close to answering this question because the FCC has not made an effort to quantify the benefits.

Mr. Brenner commented that the question would never be answered because the FCC is unwilling to admit that transmissions in the adjacent band pose a hazard to GPS.

Dr. Leveson then presented a series of FCC studies. The typical FCC study looks at the cost of capital it would take to expand spectrum if you do not make additional spectrum available.

Mr. Brenner noted that this assumes there is some level of capital investment that would increase that amount of available spectrum. However, the amount of spectrum is a fixed physical reality.

Dr. Leveson called attention to a February 2012 Council of Economic Advisors (CEA) report that lays out the logic for broadband expansion. The report concluded that "It is too soon for the empirical data to yield reliable estimates of the economic impact of wireless broadband." It short, the FCC is charging ahead even through the CEA said that information is insufficient. In addition, the approaches used to quantify benefits are inconsistent. For example,

- FCC studies measure benefits by the capital spending that is made unnecessary by freeing up spectrum.
- A number of researchers treat additional capital spending that is made possible by the release of spectrum as a benefit that is multiplied to produce even greater increases in GNP.
- No measure is available on the net effect of spectrum reallocation on telecommunications capital spending after allowing for capital spending that would no longer take place and new capital spending, including changes that would take place in the intensity of geographic reuse and/or increases in throughput capacity per MHz.

Therefore, it is unclear whether broadband would prompt greater or lesser capital spending. The overall effects of broadband are unknown. The FCC's entire quantitative basis is "up in the air." More study is considerably needed, including more information on each sector and the effects of other aspects of the economy. Furthermore, information is also needed on societal benefits, future development costs, and cost alternatives.

GPS stakeholders should learn how to present GPS operations in story form. For example, at the Boston Marathon bombing, GPS was here; "when ET calls home," GPS was there; and so on. One could create a series of stories that makes GPS more human and, therefore, more understandable as a part of people's lives. Currently the value of future benefits and the cost of loss of benefits are not well presented. The ultimate goal is to be able to compare the cost of alternate spectrum uses.

The Tuesday, May 7, 2013 session of the PNT Advisory Board adjourned at 5:04 p.m.

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Session of Wednesday, May 8, 2013 convened at 9 a.m.

Mr. James J. Miller, reconvened the PNT Advisory Board. He expressed the wish to recognize longstanding members that have served on the Advisory Board since its inception and are now leaving the body, which includes: Mr. Keith R. Hall, Dr. Robert J. Hermann, and Gen James P. McCarthy. Mr. Miller said that speaking for himself and on behalf of NASA he wanted them to know that their expertise has been valued and their company enjoyed.

Dr. James Schlesinger said he felt as though the PNT Advisory Board was "being stripped of our four-star general officers and our intelligence officer." This, however, would not preclude the PNT Advisory Board from expressing opinions on military or intelligence matters in the future. Mr. Keith Hall is former head of the National Reconnaissance Office, an authority on space, and has served on the Intelligence Committee at Capitol Hill. Dr. Schlesinger noted that he has known Dr. Hermann for forty years, and had once flown Dr. Hermann, who was then working for the NSA, to California to brief the German Defense Minister; and as a result turned around relations with the Germans on intelligence matters. Dr. Schlesinger also noted that the next two names on the list Gen James McCarthy and Gen Lance Lord "did some spectacular things while at Air Force Space Command." Finally, Mr. Charles Trimble "has had an illustrious career in GPS development and technology."

Dr. Parkinson said the five individuals named are persons of enormous intellectual capacity.

At this point, Mr. Miller distributed bronze medals to the three retiring members who were present, and expressed the hope that for those being honored the coins would serve in the future as a reminder of fine times.

Dr. Hermann said he it had been an honor to have been chosen to serve with so distinguished a group of professionals.

Mr. Miller then named the individuals who would be joining the Advisory Board:

- Admiral Thad Allen, Commandant of the U.S. Coast Guard (retired)
- Dr. Penina Axelrad, Chair, Aerospace Engineering Sciences, University of Colorado
- Dr. John Betz, MITRE Corporation Fellow
- Dr. Elizabeth Cannon, President, University of Calgary
- Dr. Matt Higgins, Faculty Research Fellow, National Bureau of Economic Research (NBER)
- Mr. T. Russell Shields, telecommunications pioneer and innovator

Mr. Miller explained that these individuals have been nominated and approved by the agencies comprising of the PNT Advisory Board and are awaiting final approval from NASA Administrator Charles Bolden.

Dr. Parkinson reminded the PNT Advisory Board that it had also wished to formerly add two technical advisors to the group per charter allowance, Mr. Kirk Lewis, and Dr. Thomas Powell, with the understanding that these were volunteer positions similar to actual Advisory Board membership.

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<u>International Member Regional Updates & Perspectives *(at member's discretion)*</u>

Dr. Gerhard Beutler, *Switzerland*

> Dr. Gerhard Beutler said he would report on topics related to the IGS, including the use of GPS and GLONASS to: determine the precise location of Earth's Center; determine Earth's rotational axis in space and on the surface; and derive polar motion. The different inclinations of the orbits of GPS and GLONASS satellites, and the time each take to complete a ground-track, are important factors to this analysis. The IGS tracks these satellites and collects data, which may be used to study Earth's dynamics.
>
> Solving for the center of mass of the earth is done by analyzing the effects of the gravity field on the orbit of the satellites. The center is estimated using the combined data of GPS and GLONASS orbits. Both systems see "more or

less" the same geo center, with GPS data resulting in plus/minus 5 cm accuracy in the x & y components of the reference frame. The GLONASS data was rather "noisy" back in 2008, but since 2010, the system has been virtually complete and its data yielded similar results for the X & Y components. However, what was not expected is that GLONASS shows a large variation in the Z-axis component, up to plus/minus 20 to 30 cm. This result has been quite amazing and there have been many potential explanations on why this happens, but the most likely explanation is the effect of solar radiation pressure on the orbit of the satellites, which for GLONASS, is stronger in the perpendicular direction relative to the orbital plane. When this is factored into the analysis, there is good correspondence in the results, and an RMS between 2 and 2.5 cm.

Dr. Parkinson asked for a rough estimate of the acceleration in the "Z" component due to solar radiation pressure.

Dr. Beutler said it is approximately 10^{-9} m/s^2. This is very small, but when applying this analysis to GPS the match is so good that one can almost not see any distinction between the estimated and the reconstructed curves. The overall size of the perturbation is generally less than 5 cm, and the difference in the determined center of earth mass is below 1 cm.

Dr. Hermann asked why the GLONASS excursion is still larger than GPS even after applying this correction.

Dr. Beutler said this is still under research.

Dr. Hermann asked if, perhaps, the difference in size between GPS and GLONASS satellites could influence the solar pressure each experiences.

Dr. Beutler said that was not likely. However, the difference in the number of orbital planes (six for GPS, and three for GLONASS) could be a factor since there are more satellites within the same plane that experienced the same solar pressure. GPS has much better probing of this force due to its geometry, and this makes a big difference.

Dr. Beutler turned to the topic of polar motion. The IGS has been monitoring polar motion since 1993. Earth's rotational axis is not constant. It moves along changing circles with a variation of one to four meters. In consequence, the geographic "north pole" shifts by several centimeters a day, and this must be taken into account when undertaking measurements. Polar motion is one of the IGS key products. The effect is very small effect but, nonetheless, it is an effect that needs to be understood, in particular why GPS and GLONASS "see" slightly different centers of mass and polar motion.

Dr. Hiroshi Nishiguchi, *Japan*

Dr. Nishiguchi said he would address the topic of space utilization in Japan.

In July 2012, the Office of Space Policy was established within the Japanese Cabinet. Studies of the QZSS architecture program were then activated and completed, including Technical Specifications and Requirements.

The Basic Space Plan was renewed in January 2013, and covers a number of scopes over a ten-year period. There are two keynotes that merit emphasis: first is the spreading of space utilization, and second is ensuring autonomy.

The three priority issues for space-based activities are: (1) national security and effective disaster management; (2) fostering the growth of GNSS application to industries (including smart agriculture and robotic civil engineering); and (3) opening the space science frontier.

There are also four essential social infrastructures, including: (1) space-based PNT and the QZSS system in Japan; (2) space-based remote sensing; (3) advanced telecommunications and broadcasting satellites; and (4) space transport capability. These activities rest on six basic pillars:

1. Space use for peaceful purposes
2. Enhancement of better quality of life
3. Encouraging industrial competitiveness
4. Progress of social benefit services
5. Large contributions to the international community
6. Consideration of global environmental concerns

QZSS is at the core of these pillars.

Social benefit services accrued from space-based PNT include climate change, tourism, combating piracy, business development, water resources and air pollution, biodiversity, logistics, transport, sea transport and forest and fishery resources. Other activities include laying the foundations for space industries; data gathering, research and analysis; promotion of diplomacy through space-user collaboration; consolidation of national security, and the appropriate care of the whole space environment.

In late March 2013, the Mitsubishi Electric Corporation group had been awarded the contract for manufacturing three additional QZSS satellites. A consortium led by the Nippon Electric Company, Ltd., received the contract for the ground-based segments, and would also be undertaking operation and maintenance of QZSS for 20 years.

There is high public interest and expectation regarding the improvements to GPS and the addition of the QZSS system. This includes the potential for improved road-based services, the provision of "precise point positioning" services and IT-aided agriculture and civil engineering, improved enforcement capability through the "Red Rescue System." There has also been acceleration by the Japan Aerospace Exploration Agency (JAXA) and Academia of Multi-GNSS Asia campaign activities.

The implementation of a Multi-GNSS Monitoring Network is moving forward. This will enable sharing Multi-GNSS Monitoring Data, which contributes to applications such as weather forecasting and natural disaster management. A number of Multi-GNSS Joint Experiments have started over the last year. A government fund has been established to support human resources development, and an Asian university consortium is taking the lead in establishing international collaboration schemes.

Gov. Geringer asked if QZSS constantly receives both the QZSS and GPS signals.

Dr. Nishiguchi replied that QZSS transmits the same signals as GPS. As for the power level for signal reception, this is also set to the same level.

Gov. Geringer asked if the correction with QZSS is made by comparison to GPS.

Dr. Nishiguchi said it was. Regarding monitoring stations, because the Geodetic Survey Institute has such information, the correction information is uploaded and then the QZSS satellite receiving such correction information can provide the data to users.

Dr. Schlesinger asked if a permanent committee is in place to advise the Prime Minister on matters related to GNSS. He noted that Japan has somewhat frequent changes in Prime Minister, and wondered how this could affect the consistency of the government's position as it relates to GNSS.

Dr. Nishiguchi explained the advice received by each Prime Minister is consistent because the committee (which came into being through the Basic Space Law) is permanent and, as such, the advice is consistent.

Gov. Geringer said that from his earlier conversation, his understanding is that continuity follows from the reappointment of three key leaders by succeeding prime ministers.

Dr. Nishiguchi said the committee itself has independence because it was comprised of non-partisan academic and technical experts.

Mr. Marquez noted that the Japanese legislature, or Diet, has been very steadfast in its support for broad applications in space. Therefore, even if the Prime Minister may change, the legislative body provides great continuity. In particular, the Liberal Democratic Party is very supportive of broad applications in space.

Dr. Nishiguchi further elaborated on this point. The Japanese parliament has legislated three acts related to space-based activities. These acts are legislated in a nonpartisan way and, as a result, there is strong support coming from parliament for space utilization. Further, key members of the Liberal Democratic Party who had previously been working on space-based issues have now been appointed to ministerial and vice-ministerial posts.

Dr. Rafatt Rashad, *Egypt*

Dr. Rashad said he will speak about GNSS economic issues, vulnerability concerns, and public awareness.

GPS is no longer the sole GNSS system. Other nations have recognized the political, strategic and economic value of GPS systems, and have moved or are moving to develop their own systems. By 2020 the European Galileo, the Chinese Compass/Beidou, and the Russian GLONASS should be at full capability. GPS must maintain a footprint on a larger portion of the globe to ensure leadership. A cost-benefit analysis is something generally needed to enable decision-makers to determine the value of a project. Obviously, the cost of any such project will be higher during the initial stages. As time passes, however, the payback point is reached and the benefits become much higher than the initial investment. As long as the sum of the benefits exceeded the sum of the costs, the project is a success. In regards to GPS, the initial investment was paid decades ago and, thus, now is an appropriate time to study its benefits. The economic issue is difficult to address because it is hard to quantify all the benefits to users. Many great assumptions have to be made, uncertainties will remain, and the discount rate will fluctuate. We should focus on areas such as social and environmental services, including increased security, increased efficiency of freight transportation; job creation; enhanced innovation; increased quality of information, and improved safety of life services.

Dr. Rashad explained he has undertaken a study of the cost-benefit of GPS to Middle Eastern countries for the European Union, and it focuses mainly on transportation modes such as aviation/safety-of-life, maritime, railroads and highways.

Regarding vulnerability, the past two years have proven the system is vulnerable to all manners of interference, including friendly and unintended interference. The possible responses are: do nothing; do something minimal; or do everything that's possible. Currently the most readily available technology to protect GPS is eLoran. It is essential that the GNSS community inform taxpayers what would happen should GPS not be available. This includes, for example, the price of bread and butter going up; increased transportation costs, etc. Efforts should be made to promote the development of groups who understand these technical and economic issues.

Gov. Geringer asked if the EU report was available.

Dr. Rashad said his report is freely available.

Dr. Parkinson noted that a number of PNT Advisory Board members have attended the annual conference hosted by Egypt, and it has been a wonderful activity.

Gov. Geringer said he believed 25 countries were represented at that meeting.

Mr. Arve Dimmen, *Norway*

Mr. Dimmen said there has been no other economic comprehensive assessment of the global value of GNSS since the report from the EU presented last year, which estimated the market at 200 billion Euros.

There has been a steady increase in the passage of ships by the northern sea route. Three or four years ago, only half a dozen or so ships took this route, whereas in 2012 the total number was 47. These numbers are very small compared to, for example, transit through Suez Canal but both the number and size of ships is increasing. The time period during which transit is possible was also increasing.

Norway is mostly concerned about the Spitsbergen and other northern areas. Norway has undertaken a number of activities over the past year, including new mapping activities and communications systems for navigational messages. Consideration is being given to installing a GNSS augmentation system. The Arctic would be a perfect place to try to fuse such augmentation systems with the European Geostationary Navigation Overlay Service (EGNOS) and, perhaps, GLONASS. Norway is working to get test studies. While interoperability of systems was important, augmentation systems are just as important to the maritime user. Norway has just renewed its land-based GPS station, and it should be "good to go" for many years.

The Norwegian government has decided to terminate operation of the Lawrence Chain as of 2016. The system is used very little and is becoming technically outdated. This raises the possibility of finding something useful for the infrastructure that would remain in place.

Ms. Neilan asked if the GPS stations serving the maritime user are primarily located along the coast or inland.

Mr. Dimmen said they are mostly along the coast. There are 12 stations with a range of 300 km.

Dr. Parkinson asked if the approach used involves a considerable redundancy of coverage.

Mr. Dimmen said it is considerably redundant, but it is wise to do so given the local topography.

Dr. Schlesinger asked Mr. Dimmen what his reaction is to 15 years of stable world temperatures.

Mr. Dimmen replied that his task is to determine the safety level of ships at sea, and it is others to determine if the cause for changes in climate and the effect of increased traffic through the arctic sea.

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The Innovations of Civil GPS Applications in the United States
Dr. Nam D. Pham, Managing Partner
NDP Consulting Group

Dr. Nam D. Pham explained that he would present his study on innovations in civil GPS applications in the U.S. and their effect on the economy. This includes a list of GPS innovations, a timeline for civil applications, and an outline of a method for determining their economic value. The three key objective of this study are:

1. Identify major innovations of civil GPS applications.
2. Synthesize findings of the economic impact, business impact and cost-and-benefit analysis of GPS.
3. Estimate the economic and social benefits of GPS applications on particular commercial and noncommercial sectors.

The economic impact of the GPS sector, such as the value of GPS receivers manufactured, is significant. However, a far greater impact comes from the use of GPS services and products. According to *ABI Research*, the sales of GPS equipment have increased from $25 billion in 2005 to $60 billion in 2013. The largest purchasers fall into three markets: converged, automotive, and timing and synchronization. ABI Research has surveyed eleven market segments, which does not cover the entire market, and estimates a stock of 2 million 'GPS units' in North America. The estimate does not include GPS-capable chips in cellular phones.

The study sought, from government officials, an estimate of the number of people in the United States who use GPS in a given day, but officials said they did not know. His estimate is that daily GPS use, excluding cellphone calls, involves "north of" 250 million people.

Mr. Lewis clarified the reason for excluding cellphones is that in some fields – for example, precision agriculture – one can calculate an economic value whereas the economic value of a cell phone call may not be readily quantified.

Dr. Pham explained that he would like to gather information on forecasts made over time. Current evidence shows that forecasts typically end up substantially underestimating the level of GPS activity.

Dr. Parkinson agreed it is difficult to arrive at the economic value of daily cell phone calls.

Gov. Geringer noted that at some point in the past reference to a GPS unit meant either a Garmin or Trimble unit, but nowadays it could mean anything that is GPS-enabled, including cell phones. Furthermore, cell phones are time-dependent and need PNT enabled in order to work. In any case, for the purpose of this briefing, a definition is needed for direct sales of GPS equipment.

Dr. Hermann agreed that a cell phone is of limited use without its timing component. As far as a statement of value, however, asking for the value of a chip is akin to asking what the value of a person's heart. The response is that it's just as valuable as your head. Therefore, some logical structure could be created.

Dr. Brecht-Clark noted there are many more uses of GPS. How can one quantify the value of all the financial transactions, all the agricultural uses, and tracking uses? Also, how far reaching does one need to be in defining GPS activities, and how rigorous in determining the value of each?

Mr. Lewis identified 'quality of life' as a category. Indirect capabilities are difficult to measure and, therefore, the public needs to be educated on such indirect benefits of which they are typically unaware.

Dr. Pham said he intended to update the study by ABI Research. In doing this, any additional source material from members of the Advisory Board would be helpful. Also, it is important to distinguish between the commercial and non-commercial benefits, as the commercial market is easier to measure.

Dr. Parkinson suggested that while there are cell phones with GPS, it is not clear whether they would fail without GPS. Clarity is needed as to when GPS is essential and when it is not. Therefore, any assessment should be based on a centralized theme and, also, unless the top-level report explains the breadth of the subject, the value remains uncertain.

Dr. Pham then presented data on 'GPS units' sold. The economic assessment can be divided into two pieces: (1) what is the contribution of the GPS manufacturing sector; and (2) what is the contribution of GPS-enabled equipment to other sectors. The prime North American Industry Classification System (NAICS) code areas were assessed: radio and television broadcasting; navigation equipment; and other measuring and control devices. The "indirect and induced" effects are:

1. Job multiplier: 2.3 – 3.1 for every job
2. Wage multiplier: $1.8 - $2.2 for every dollar paid
3. Output multiplier: $1.9 - $2.3 for every dollar in output

These multipliers were obtained from U.S. Bureau of Labor Statistics.

Dr. Parkinson noted that the GPS payback in agriculture comes within two to four months, and once it occurs one continues to accrue benefits.

The contribution made by GPS manufacturers themselves is approximately $60 billion. The multipliers reflect the fact that GPS manufacturers are themselves purchasers of good. When including indirect and induced efforts, the total contribution equals $145 billion (approximately one percent of the U.S. GNP).

Dr. Schlesinger said that unless one assumes some degree of unemployment, it is not clear where the job multiplier comes.

Ms. Neilan noted that the multiplier effect comes from measuring the jobs involved in the companies that supply components to the GPS manufacturers.

Dr. Leveson added that 'jobs multiplier' means one has the capacity to gather the resources necessary to go into production. Depending on the state of the national economy, one either pulls people from other sectors or from unemployment into the labor force.

Since 1983, GPS has resulted in many innovations for civilian applications. This is open-ended because new applications are also being developed.

Dr. Parkinson and Mr. Hatch added that the most significant early GPS use was for surveying since it allowed people to do work in hours that had previously taken weeks.

The annual value of GPS to the commercial sector is between $67 and $122 billion, with precision agriculture, engineering construction, and commercial surface transportation being the largest beneficiaries. Three other general areas that impact the economy are: geological services; NextGen (Next Generation aviation navigation); and better economic planning and advice as evidenced by household surveys (specifically a Gibson & McKenzie survey). While further study is needed, a rough estimate is that GPS' benefit to the commercial sector is between eight and fifteen times its cost. Future studies should include an analytical framework to assess GPS benefits, which would involve literature review, data and information collection, a focus on selected segments, and an assessment of the overall impact of GPS on the U.S. economy.

Dr. Parkinson noted that construction and mining had not been mentioned.

Dr. Pham said he did not plan to address all sectors affected by GPS. The proposed subset is just a starting point. Sources will include academic journals, government assessments, industry analysts, and manufacturer surveys.

Ms. Neilan noted that in her own efforts she had encountered thousands of papers just about IGS. The IGS is currently trying to determine the benefit of its actions, and this information would be available for this study.

Dr. Pham noted that farmers receive two key benefits – improved productivity and cost savings, including labor and fuel.

Dr. Parkinson commented that additional side benefits include less fertilizer and pesticides being used, which has environmental benefits. Most studies thus far focused on economic benefits, but environmental benefits should also be considered.

Dr. Pham said he did not believe he was underestimating the savings in the agricultural sector. Innovation will continue and even greater savings will accrue over time.

Mr. Hall noted that the direct expenditures for the construction and launch of GPS satellites are substantial and, therefore, also need to be included. A good way to express the intangible value of GPS to people would in story form – for example, accounts in which lives are saved. Also, when taking credit for economic multipliers, we also need to acknowledge that improvements in productivity could cost jobs elsewhere.

Dr. Schlesinger noted that agricultural employment has steadily declined as the result of rising productivity. This makes it difficult to infer what the job multiplier effect is.

Dr. Hermann reported having taken part in a study showing that while the level of manufacturing remains about the same the number of jobs in the sector declines. It is difficult to claim that productivity always produces jobs; productivity produces productivity.

Dr. Parkinson observed that, for example, because of productivity, bread is cheaper.

Dr. Hermann noted that, however, it is doubtful more surveying would be done simply because it can be done more efficiently with GPS.

Dr. Parkinson disagreed: the quantity of surveying is continually increasing.

Mr. Hall said the dilemma could be resolved by eliminating the multiplier.

Dr. Leveson noted that the information technology sector has been the fastest growing and has created many jobs outside its sector. When new products are developed, and new markets created for those products, it leads to increased investments and higher incomes, which invariably outweighs any initial job loss. This point is much easier to show in macroeconomic models than the input-output models being presented.

Dr. Hermann said he found it difficult to justify this statement.

Dr. Leveson said there are many generally accepted models that show how growth takes place.

Dr. Hermann said he believes such models do not adequately address the effect of globalization.

Dr. Leveson said this was true at one time, but not in more recent models. Increased U.S. productivity improves the country's competitive position internationally.

Dr. Schlesinger said that for 1,000 years people have taken pride in reducing the work week from 70 hours to 40. Is this reduction where the multiplier is coming from? The matter was not clear.

Dr. Hermann said one is increasing employment if those productivity improvements lead to outsourcing.

Dr. Beutler said the term "productivity" is being misunderstood. The assumption made is that productivity means making more of the same things faster. The reality is that with GPS, "the same thing" is not being made. What is being made are entirely new things and of greater value. For example, if GPS lets you make a map in hours, as opposed to 30 years, then the map is not just less expensive to create but is also more accurate and of greater value. Hundreds of surveys are now being done routinely that would not even have been contemplated prior to GPS and satellite imagery.

Dr. Parkinson noted that GPS has created entirely new ways of doing things.

Dr. Beutler said that's his point.

Mr. Hall said that increased productivity allows industry to meet an increasing demand that would otherwise not be met. Food production is higher; without GPS there would be more starving people around the world. The volume of

ship traffic handled safely is also higher. Such changes can be initially disruptive, of course, and we should not ignore resulting jobs displacement.

Capt. Burns said that GPS use saves 3,000 pounds of fuel on every Hawaii to San Francisco flight.

Mr. Hatch said that in the mid-1980s, he had spent much of a day helping his father conduct a survey across a river. Today the task can be accomplished in minutes by GPS.

Dr. Schlesinger added that employment at times falls because of productivity increases elsewhere.

Mr. Khosla said he has worked closely with farmers, and GPS is making them more productive. A Purdue University study of farmers in 33 states showed that 76 percent are using some form of GPS. However, he has never heard a farmer reporting having laid anybody off. They were stretched thin to begin with, so if productivity increased by ten percent they would not lay off anybody. Also, GPS is creating new types of jobs for the agriculture graduate. Any cooperative that sells seeds or fertilizer now hires additional employees who understand GPS and can explain it to farmers. They need more trained salespeople to talk to farmers about how to take advantage of precision agriculture. Farmers have more questions now than ever before. Everyone who sells to the agriculture sector needs to hire more, not fewer, people and these hires require higher skills.

Dr. Pham said the multiplier is not a statement about jobs being created in this sector. It is a statement about how many outside jobs are required to support GPS manufacturing.

Dr. Parkinson said this is a thorny matter and, thus, suggested the conversation be tabled. A day could be set aside prior to the next PNT Advisory Board meeting to discuss these matters. In the meantime, individual Advisory Board members are welcome to communicate with Dr. Pham.

Mr. Miller said the "bottom line" is that Dr. Pham was just beginning this study. The PNT Advisory Board should aim at having a report ready for the following PNT EXCOM session later in the fall.

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PNT Advisory Board Discussion

Gov. Geringer presented ways to organize the work that needs to be done. He noted how "The essence of science is to ask an impertinent question and you are on your way to the pertinent answer," and in his view, the PNT Advisory Board has been adequately impertinent. The PNT Advisory Board's charter provides an open field for matters related to PNT. The following topics have been already identified:

1. Economic value of GPS to the United States
2. Spectrum allocations/re-allocations
3. PNT unavailability
4. Affordability options
5. Foreign GNSS contribution

Gov. Geringer added that another issue is whether PNT is part of critical infrastructure, and it appears it is indeed.

Dr. Parkinson said topic #1 is being addressed in the study led by Dr. Pham. Several members have indicated an interest in working on topic #3.

Ms. Neilan said she wished to work on topic #5, but also had interests elsewhere.

Mr. Brenner and Mr. Faga agreed to work on topic #2, spectrum allocations.

Gov. Geringer commented that where spectrum allocation is concerned, it is important to build a positive case for GPS.

Mr. Neilan asked whether non-members could be used as consultants.

Mr. Miller said the Advisory Board charter permits this. However, anyone appointed not as a Representative becomes an SGE and is subject to conflict of interest standards.

Gov. Geringer said Mr. Miller would coordinate the involvement of outside experts.

Mr. Miller said he thought external experts would be beneficial to the PNT Advisory Board's efforts.

Dr. Parkinson urged Mr. Hatch to work on topic #2.

Mr. Hatch noted that John Deere has hired a spectrum advisor who keeps him current with developments. This individual would be an excellent source of information.

Gen McCarthy advised the Board to maintain awareness of the activities of the Air Force, which has been becoming more dynamic in this area and a mean is needed to monitor its activities.

Dr. Parkinson suggested redefining topic #4 as 'Availability and Affordability'.

Dr. Hermann said that at some point, each task group will present a product, and these should be products the entire Advisory Board can stand behind. We need to remember it is a substantial effort to produce a good analytical professional product that can bear scrutiny.

Mr. Miller noted a NASA Advisory Council (NAC) generally operates by presenting a recommendation, the reasons for the recommendation, and the consequences if the recommendation is not acted upon. The PNT Advisory Board could follow a similar approach.

Dr. Hermann added that the NAC process is one of assembling a consensus view among acknowledged experts. Gathering a consensus of experts is simpler than studying a topic "from page one" and producing something that would stand professional scrutiny. The latter requires considerable research.

Dr. Parkinson said that on some topics, sufficient expertise is at the table to write a convincing one-page statement. On other subjects – particularly economics – not everyone has a firm grasp and that is why at outside study has been commissioned.

Dr. Hermann cautioned that Dr. Parkinson's assessment of the affordability is a series of arguments and estimates that need a great deal more analysis behind them.

Dr. Parkinson agreed and said he would not go beyond the argument that one has to "make satellites affordable."

Dr. Brecht-Clark noted that the PNT Advisory Board has set money aside to undertake the study of economic impacts. The PNT EXCOM is scheduled to receive an update on this subject at its June 11, 2013 meeting. This update should include a full outline, anticipated outcomes, and timeline.

Dr. Parkinson said that's his expectation.

Gov. Geringer said that it is also the responsibility of the PNT Advisory Board in responding to the PNT EXCOM if that body has any new tasks.

Dr. Schlesinger addressed the issue Dr. Parkinson has raised on affordability. The discussion assumed the demand for satellites is elastic but, perhaps, it is not so. Does making satellites less expensive actually mean more satellites will be created?

Dr. Parkinson said that if one is going to get to 30 satellites, one has to do so within a budget.

Gen McCarthy said the problem with this discussion is that the full set of consequences of DoD decisions is not being addressed.

Dr. Schlesinger said this is because the United States government is organized around regulatory bodies that have little interaction with each other.

Gov. Geringer asked for any final comments.

Dr. Schlesinger closed the meeting with the observation that the day is May 8, better known as "VE Day," marking the surrender of Nazi Germany to the Western Allies. He offered the view that had GPS existed at the time, the war would have been over much sooner.

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The Wednesday, May 8, 2013 session of the National PNT Advisory Board adjourned for a working lunch at 12:05 p.m.

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Appendix A: Space-Based PNT Advisory Board Membership

Special Government Employees

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

Representatives

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

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

Biographies available at: http://www.gps.gov/governance/advisory/members/

Appendix B: Presentations made at the PNT Advisory Board meeting, May 7-8, 2013

- Space-Based PNT Executive Committee: Recent and Emerging Issues/*Jan Brecht-Clark*
- GPS Modernization Activities: Progress and Challenges/*Maj Gen Martin Whelan*
- Update: Laser Ranging of GPS III Satellites/*John LaBrecque*
- GPS in 2030: Operating in a Multi-National, Multi-GNSS Environment/*Steve Moran*
- GPS/PNT User Equipment: Military/Civil/Commercial: A Guide to Trends in GPS/PNT/*Don Jewell*
- United States Federal Radionavigation Plan [FRP]: Infrastructure Update/*Karen Van Dyke*
- The Global Differential GPS System/*Yoaz Bar-Sever*
- International GNSS Real-Time Service: New Products for Real-Time Applications/*Mark Caissy*
- U.S. GPS Program and Policy Update/*David A. Turner*
- Implementing Galileo/GNSS to GPS Time Offset: Moving Further Toward Interoperability through "Time"/*Edward Powers*
- Adjacent Band Interference to Consumer Receivers/*Tom Powell*
- A Day without Space: If our GPS enterprise was compromised, what impact would it have on our nation's economy/*David Logsdon*
- Recognizing GPS Contributions/*Irv Leveson*
- Nibbles/*Bradford Parkinson*
- The Innovations of Civil GPS Applications in the United States/*Nam D. Pham*
- Geocenter and Polar Motion viewed by GPS and GLONASS/*Gerhard Beutler*
- Implementation of QZSS Update/*Hiroshi Nishiguchi*
- PNTAB Organization/*James Geringer*

These presentations are available at: http://www.gps.gov/governance/advisory/meetings/2013-05/

Appendix C: Attendees

Tuesday, May 7, 2013

PNT Advisory Board Members:

James Schlesinger, Chair
Bradford Parkinson, Vice-Chair

James Miller	PNT Advisory Board Executive Director
Gerard Beutler	AIUB
Dean Brenner	Qualcomm Inc.
Joe Burns	United Airlines
Arve Dimmen	Norwegian Coastal Authority
Per Enge	Stanford University
Martin Faga	MITRE Corporation
Jim Geringer	ESRI
Keith Hall	Self
Ron Hatch	John Deere
Robert Hermann	Self
Raj Khosla	Colorado State University
L. K. Lewis	IDA
David Logsdon	Tech America
Peter Marquez	Ascending Node
Jim McCarthy	U.S. Air Force Academy
Tim Murphy	Boeing
Ruth Neilan	NASA Jet Propulsion Laboratory/IGS
Hiroshi Nishiguchi	Japan GPS Council
Rafaat Rashad	Arab Institute of Navigation

Other NASA Attendees:

Barbara Adde	NASA HQ
Yoaz Bar-Sever	NASA Jet Propulsion Laboratory
Juan Ceva	NASA Jet Propulsion Laboratory
Craig Dobson	NASA HQ
John LaBrecque	NASA HQ
A. J. Oria	NASA HQ / Overlook
Trent Skidmore	NCO / NASA
Stephanie Wan	NASA HQ / Overlook

Other Attendees:

Ken Alexander	National Coordination Office
Jeff Auberach	U.S. Department of State
Philip Basso	DOD NextGen LSO
Jan Brecht-Clark	National Coordinating Office
William Burns	United States Coast Guard
Jim Burton	NCO/Overlook
Mark Caissy	Natural
Chalis Cohen	PNT Holdings
Robert Crane	Department of Homeland Security
Brian Daugherty	Joint Staff J6
Dee Ann Davis	Inside GNSS
Anita Eisenstadt	NCO
Rick Foote	NGS & PNT
Scott Grantham	Department of Defense
Steve Grupenhagen	SAF/AQSL
Rick Hamilton	U.S. Coast Guard NAVCEN
Don Jewell	IDA

Jason Kim	National Coordination Office
Irv Leveson	Leveson Consulting
Harold Martin	National Coordinating Office
Steve Moran	Raytheon
Mitch Narins	Federal Aviation Administration
Dave Olsen	Federal Aviation Administration
Harrid Park	
Nam D. Pham	NDP
Scott Pace	George Washington University
Tom Powell	Aerospace Corporation
Ed Powers	United States Naval Observatory
Doug Taggart	Overlook
Jim Slater	Self
David Turner	Department of State
Tom Watson	DHS/NPPD
Gen Martin Whelan	Air Force Space Command/A5

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Wednesday, May 8, 2013

PNT Advisory Board Members:

James Schlesinger
Bradford Parkinson
Gerhard Beutler
Martin Faga
Keith Hall
Ron Hatch
Bob Hermann
K. Lewis
Jim McCarthy
Tim Murphy
Hiroshi Nishiguchi
Rafaat Rashad

Other NASA Attendees:

Yoaz Bar-Sever	NASA Jet Propulsion Laboratory
A. J. Oria	NASA HQ / Overlook
Juan Ceva	NASA JPL
Stephanie Wan	NASA HQ / Overlook

Other Attendees:

Mark Bernstein	ASRC
Anita Eisenstadt	National Coordinating Office
Col Harold Martin	National Coordinating Office
Nam Pham	NDP
Tom Powell	Aerospace Corporation
Trent Skidmore	National Coordinating Office
Jim Slater	

Appendix D: Acronyms / Definitions

AFSPC	Air Force Space Command
CEA	Council of Economic Advisors
CIR	Critical Infrastructure Resiliency
CIO	Chief Information Officer
CNAV	GPS Civilian Navigation Message
COMPASS	Chinese GNSS Constellation (also referred to as Beidou)
COTS	Commercial-off-the-Shelf
CW	Continuous Wave
DAGR	Defense Advanced GPS Receiver
DARPA	Defense Advanced Research Projects Agency
DC	Direct Current
DHS	Department of Homeland Security
DLR	German Aerospace Center
DME	Distance Measuring Equipment
DoD	U.S. Department of Defense
DOT	U.S. Department of Transportation
EGNOS	European Geostationary Navigation Overlay Service
eLoran	Enhanced Loran
ESG	Executive Steering Group (under the National Space-based PNT EXCOM)
EU	European Union
EXCOM	PNT Executive Committee
FAA	Federal Aviation Administration
FACA	Federal Advisory Committee Act
FCC	Federal Communications Commission
FM	Frequency Modulation
FRP	Federal Radionavigation Plan
FY	Fiscal Year
GALILEO	European GNSS Constellation
GDGPS	Global Differential GPS System
GGTO	GPS to Galileo Time Offset
GLONASS	Russian GNSS Constellation
GNP	Gross National Product
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPS IIA	GPS Block IIA
GPS IIF	GPS Block IIF
GPS III	GPS Block III
GPS IIR	GPS Block IIR
GPS IIRM	GPS Block IIR(M)
GVRS	Global Virtual Reference Stations
HEOMD	NASA Human Exploration and Operations Mission Directorate
IAG	International Association of Geodesy
ICD	Interface Control Document
ICG	International Committee for GNSS
IGS	International GNSS Service
IGSRTS	IGS Real Time Service
ILRS	International Laser Ranging Service
IRT	Independent Review Team
IT	Information Technology
ITRF	International Terrestrial Reference Frame
JAXA	Japan Aerospace Exploration Agency
JPL	NASA Jet Propulsion Laboratory
KHz	Kilohertz
L1C	GPS 4th Civilian Signal (interoperable with the Galileo Open Service)
L2C	GPS 2nd Civilian Signal (for science applications & surveying)
L5	GPS 3rd Civilian Signal (for safety-of-life, such as aviation)
LRA	Laser Retro-reflector Array
MGEX	Multi-GNSS Experiment
MHz	Megahertz

MOU	Memorandum of Understanding
MSS	Mobile Satellite Service
NAC	NASA Advisory Council
NAICS	North American Industry Classification System
NASA	National Aeronautics and Space Administration
NASCTN	National Advanced Spectrum & Communications Test Network
NCO	National Coordination Office
NDGPS	Nationwide Differential GPS
NIP	National Infrastructure Protection
ns	Nanosecond
NSA	National Security Agency
NTIA	National Telecommunications and Information Administration
OCX	GPS Modernized Operational Control Center
OMB	Office of Management and Budget
OS	Operating System
PLGR	Precision Lightweight GPS Receiver
PPD	Presidential Policy Directive
ps	Picosecond
QZSS	Quasi-Zenith Satellite System
RNSS	Regional Navigation Satellite System
RTCM	Radio Technical Commission for Maritime Services
RTG	Real Time GIPSY
RTGX	New GPS OCX orbit determination software
S/A	Selective Availability
SGE	Special Government Employees
STEM	Science, Technology, Engineering, and Mathematics
SV	GPS Space Vehicle
TWT	Travelling Wave Tube
PNT	Positioning, Navigation, and Timing
UAV-SAR	Unmanned Air Vehicle – Synthetic Aperture Radar
UK	United Kingdom
USNO	US Naval Observatory
USSTRATCOM	US Strategic Command
UTC	Universal Coordinated Time
WAAS	Wide Area Augmentation System