SPACE-BASED POSITIONING
NAVIGATION & TIMING

NATIONAL ADVISORY BOARD

2007-2008 National Space-Based PNT Advisory Board

Proceedings

June 18, 2009

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2007-2008 NATIONAL SPACE-BASED
POSITIONING, NAVIGATION, AND TIMING [PNT]
ADVISORY BOARD

PROCEEDINGS

James R. Schlesinger
Chair

Bradford Parkinson
Vice-Chair

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Executive Summary

The U.S. Space-Based Positioning, Navigation, and Timing Policy (PNT) of December 8, 2004 established a permanent National Space-Based PNT Executive Committee (EXCOM). This policy provides guidance for:

- Development, acquisition, operation, sustainment, and modernization of the Global Positioning System (GPS) and U.S.-developed, owned and/or operated systems used to augment or otherwise improve the GPS and/or other space-based positioning, navigation, and timing signals.
- Development, deployment, sustainment, and modernization of capabilities to protect U.S. and allied access to and use of the GPS for national, homeland, and economic security, and to deny adversaries access to any space-based positioning, navigation, and timing services.
- Foreign access to the GPS and U.S. Government augmentations, and international cooperation with foreign space-based positioning, navigation, and timing services, including augmentations.

The fundamental goal of this policy is to ensure that the U.S. maintains space-based positioning, navigation, and timing services, augmentation, back-up, and service denial capabilities that:

- Provide uninterrupted availability of positioning, navigation, and timing services.
- Meet growing national, homeland, economic security, and civil requirements, and scientific and commercial demands.
- Remain the pre-eminent military space-based positioning, navigation, and timing service.
- Continue to provide civil services that exceed or are competitive with foreign civil space-based positioning, navigation, and timing services and augmentation systems.
- Remain essential components of internationally accepted positioning, navigation, and timing services.
- Promote U.S. technological leadership in applications involving space-based positioning, navigation, and timing services.

The National Space-Based PNT Advisory Board is a federal advisory committee established by the National Aeronautics and Space Administration (NASA) on behalf of the EXCOM. The Advisory Board consists of experts from outside the U.S. Government who provide advice on U.S. space-based PNT policy, planning, program management, and funding profiles in relation to national and international space-based PNT services. The Advisory Board meets at least twice a year and meetings are open to the public unless it is determined that a meeting, or portion of a meeting, will be closed in accordance with the Federal Advisory Committee Act (FACA). The first PNT Advisory Board was formed in 2007 for two years duration, during which time NASA sponsored the Board.

The PNT Advisory Board Charter was renewed by Christopher J. Scolese, NASA Acting Administrator, on January 26, 2009 for two additional years.

A Vision for GPS

The key to the future of GPS is leadership. GPS is the GNSS world standard and it would be advantageous to the U.S. to maintain that position, especially in the light of rapidly expanding foreign GNSS and augmentation capabilities. The U.S. vision for PNT is a world with multiple, interoperable space-based PNT systems; user equipment that leverages these multiple systems; and a ubiquitous and seamless integration of space-based PNT as part of the daily lives of users worldwide. The U.S. would manage the transition to GPS III in such way as to ensure policy stability and service guarantees better than exists today. This would maintain trust among the domestic and international user base and provide free, stable, and reliable GNSS service based on a constellation of 30 or more optimally distributed satellites. Such an expansion of the GPS constellation would include discussing non-DoD funding mechanisms for the expanded constellation. An active PNT EXCOM, with the equitable representation of current participating agencies, is required to assist the agencies in implementing this vision. Use of the PNT EXCOM should be maximized to include the following: additional ground-based PNT services beyond GPS Augmentations; PNT enablers such as developing common GNSS standards; facilitating PNT technology development; and GPS evolution oversight. In supporting the Vision for GPS, the Advisory Board makes the following key recommendations:

Key Recommendations

1. **Ensure GPS policy stability and service guarantees**
2. **Expand the nominal GPS constellation to 30 optimally distributed satellites**
3. **Maximize the use of the EXCOM**

Recommendations

The key recommendations discussed under the *Vision for GPS* are the result of consolidating the discussions and recommendations that emerged during the four Advisory Board meetings held in 2007-2008. Further details are provided in the Advisory Board Proceedings.

Recommendation 1: Ensure GPS policy stability and service guarantees

It is essential to place GPS III quickly under contract with early delivery to mitigate potential service disruptions. Many of the current GPS satellites are nearing their design lifetime and the first GPS III satellite will not be available for launch until 2014. GPS III will provide significant improvements over the current GPS constellation and early implementation would provide insurance against service shortages, or "brown-outs" that could impact millions of users world-wide. Adequate satellite replenishment is essential to avoid such GPS brownouts.

A sensible fast track approach to acquisition should be utilized. Expensive, complex satellites could threaten the schedule as well as the constellation size. Where feasible the board recommends that use of alternative platforms be assessed so GPS satellites are not overly burdened by payloads that do not support PNT operations and prevent the launch cost savings in inserting two GPS satellites into orbit with one launcher. A dual launch may save $50 million per satellite.

There should be a transparent evolution of GPS which includes updates to Interface Specifications of signals used by civilians, GPS requirements process, and development of new capabilities. Also essential for this evolution is policy stability, and assurance relative to the GPS constellation, such as the predictability of long-term service levels to enable civilian use of GPS signals. In order to assure civil user communities, the transition from current service levels to new GPS signals must be seamless. The recently released General Accounting Office (GAO) report on GPS again raised the issue, in a very public way, of the performance capability and availability of the GPS constellation. Narrowly this translates to the question of how many GPS satellites will be sustained in the future. While one might question the utility of the hypothetical presumptions of the calculations and charts, the Report raises legitimate concerns about future GPS constellation sustainability that could undermine the global, commercial, and civil trust in the GPS system. At minimum, the government needs to describe the system it intends to implement and then execute that intention.

As GPS transitions, the U.S. should engage our international partners in evaluating the system and service changes. Involving partners would ease in resolving issues, and promote cooperation towards interoperability and realizing a true ‘System of Systems’.

Recommendation 2: Expand the nominal GPS constellation to 30 optimally distributed satellites

This commitment would enable civilian users to take full advantage of GPS's proven capabilities. In addition, it is recommended that a 30+ GPS satellite constellation be geometrically optimized (additional details are provided in section 5.14 of the Proceedings). A larger constellation would improve the ability of surface users in obstructed terrain conditions, such as in urban environments, to receive GPS signals and also ensure the availability of GPS to the military in uneven terrain such as mountainous regions. In addition it would provide improved Receiver Autonomous Integrity Monitoring capabilities. With this level of service, GPS would compare to the projected capabilities of China's COMPASS and the European Union (EU) Galileo systems. The board urges that alternative constellation designs be reviewed and compared to determine the designs that will best enable compatibility and interoperability. Also, it is recommended that once new satellites have completed in-orbit validation, that full capability on all available signals be enabled.

Recommendation 3: Maximize the use of the EXCOM

In supporting the PNT mission of GPS it is essential to implement laser retroreflectors on GPS III. It is advantageous to provide an independent calibration, validation, and quality assessment capability to determine GPS orbit and clock performance. Currently, the GPS signals are used to generate satellite orbit and clock information. Satellite Laser Ranging (SLR) can provide independent determination of these essential products which the panel believes to be mandatory. The panel notes that SLR retroreflectors will be on all GLONASS and Galileo satellites. This capability is also essential for maintaining the robust global standard terrestrial reference system (International Terrestrial Reference Frame (ITRF)).

PNT enablers include, for example, a reference frame and timing for GPS that is common with other GNSS systems. GPS should be based on a common reference system which must be interoperable with the other GNSS systems. The ITRF is internationally accepted as the de-facto best global reference frame. The GPS reference system, World Geodetic System 1984 (WGS 84), currently maintains a close alignment with ITRF. The pervasive and global use of GPS for timing applications is largely unrecognized; as use of other and new GNSS systems increases, it is essential to know the accurate difference or offset between GPS and other systems. Exploiting multiple GNSS systems is critical for future PNT applications and interoperability of the geodetic reference and timing systems.

An expanded EXCOM should support efforts to mitigate, detect, measure, and geolocate interference. Since GPS is an element of the global critical infrastructure, it requires a means to detect, measure, and geolocate interference to mitigate its effects, e.g., for situational awareness. In addition, agencies need to account for mitigations to GPS disruptions should disruptions occur.

It is recommended that adequate funding for space and ground infrastructure be assured. For example, the recent announcement to discontinue Loran funding has been met with dismay and concerns among many of our international partners who see the combination of all the operational systems worldwide as an essential backup to GPS and GNSS capabilities not only for navigation but also for positioning and timing.

The U.S. needs to provide a leadership model for support of international investments in ground infrastructure. Numerous applications depend on the global civil tracking network of stations, many of which are implemented by U.S. agencies and international partner organizations. This ground infrastructure is aging and needs resources to enable it to meet the modernized GPS and multi-GNSS capabilities to maintain application derived benefits. This is increasingly urgent in less economically developed areas of the world and particularly throughout Africa.

Science applications are specifically mentioned in the U.S. PNT policy and the EXCOM needs to underscore the ways that GPS has advanced the understanding of Earth Science. The use of GPS in the civil community is pervasive and global scientific use must be underscored for its truly remarkable applications and achievements as demonstrated by the intellectual fervor stemming from GPS. GPS has advanced our understanding of Earth Science by enabling atmospheric and ionospheric sciences, sea-level change, glacier melt, climate change, earthquakes, volcanoes, gravity field, deformation, many satellite missions through GPS geodesy, and geodynamics applications. This important information is disseminated in such diverse environments as international conferences, workshops and forums where training and coordination meetings are held to support efforts to bridge the digital divide.

In summary, use of the PNT EXCOM should be maximized. For example, it should include ground-based PNT services; PNT enablers such as developing common GNSS standards; PNT technology development facilitation; national plan; and GPS evolution oversight. The PNT EXCOM is urged to step up to a higher level rather than simply providing coordination.

Transitioning to the 2009-2010 Advisory Board

During the 2007-2008 two-year tenure of this PNT Advisory Board there have been notable successes including:

- The recommendation from the board to eliminate Selective Availability (S/A) capabilities from GPS III which was finally implemented. The capability for S/A removal from GPS III satellites by Deputy Secretary of Defense England was officially announced on September 18, 2007. This decision was warmly received by the international community.
- Additional recommendations have been made to the EXCOM including:
  - Begin transmitting navigation message on L2C as soon as possible.
  - Support for favorable EXCOM decision to designate eLORAN as back up to GPS.
  - Take actions to maintain current level of GPS service, including placing GPS III quickly under contract with early delivery.
- Substantial progress has been made on the issue of engaging with the international community through the International Committee on GNSS (ICG) and the GNSS Providers Forum.

The PNT Advisory Board believes more progress needs to be made on other issues. It is recommended these issues be addressed by the upcoming 2009-2010 PNT Advisory Board. Advisory Board themes for the next Administration include:

- Maintain the policy for an open signal free of direct user charges.
- Seek to ensure GPS remains the signal of first use.
- Implement laser retroreflectors on future GPS to support the continued improvement in PNT capabilities.
- Ensure policy transparency and stability in the evolution of GPS.
- Develop means to detect, measure, locate, and mitigate radio interference or jamming in support of the National Security Infrastructure.

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1. Background and Structure

1.1 Establishment of the National Space-Based PNT Advisory Board

The U.S. Space-Based Positioning, Navigation, and Timing (PNT) Policy of December 8, 2004 established a permanent National Space-Based PNT Executive Committee (EXCOM), co-chaired by the Deputy Secretaries of the Departments of Defense (DoD) and Transportation (DOT) and with representatives at the equivalent level from the Departments of State (DOS), Commerce (DOC), and Homeland Security (DHS), the Joint Chiefs of Staff (JCS), and the National Aeronautics and Space Administration (NASA). Since 2008, the Departments of Agriculture and Interior have also had representatives on the PNT EXCOM. NASA renewed and amended the National Space-Based Positioning, Navigation, and Timing Advisory Board Charter to revise the title in order to be in compliance with Public Law 109-364, Section 911(a)(3), signed into law by the President on October 17, 2006. The Board solely operates in an advisory capacity as directed by the Policy and in accordance with the Federal Advisory Committee Act (FACA), 5 U.S.C. App § 1 et seq.

1.2 Objectives and Duties

The Advisory Board provides advice, as directed by the PNT EXCOM and through NASA, on U.S. space-based PNT policy, planning, program management and funding profiles in relation to the current state of national and international space-based PNT services. This advice consists of assessments and recommendations to facilitate the accomplishment of the goals and objectives of the Policy on behalf of the EXCOM. NASA, in close coordination with the EXCOM, tasks the Board and defines the full scope of responsibilities and schedules required for each task assigned. The Board evaluates national and international needs for changes in space-based PNT capabilities, assesses possible trade-offs, and provides independent advice and recommendations to the Executive Committee on PNT requirements and program needs. These evaluations are considered by the Executive Committee in recommending a National PNT strategy and developing annual updates to the 5-Year Space-Based PNT Plan. The United States reserves the right to hold "U.S.-only" meetings of the Advisory Board, as required, in full compliance with the FACA and related U.S. statutes and regulations.

1.3 Tasking

The PNT Advisory Board tasking supports the Executive Committee with a balanced representation that reflects national needs in the newly emerging global environment of international cooperation and competition. In full compliance with FACA and related U.S. statutes and regulations, the Advisory Board may also hold "U.S.-only" meetings (i.e., without foreign nationals present) as required and appropriate. As sponsor of the Advisory Board, NASA is responsible for establishing, funding, and managing the Advisory Board on behalf of the EXCOM. Specifically, the Board shall examine GPS and augmentation modernization opportunities to:

(1) provide uninterrupted availability of positioning, navigation, and timing services;

(2) meet growing national, homeland, economic security, civil requirements, and scientific and commercial demands;

(3) continue to provide civil services that exceed or are competitive with foreign civil space-based positioning, navigation, and timing services and augmentation systems;

(4) retain essential components of internationally accepted positioning, navigation, and timing services; and

(5) promote U.S. technological leadership in applications involving space-based positioning, navigation, and timing services.

1.4 Membership

The Advisory Board is comprised of acknowledged experts with extensive public and private sector experience both domestically and internationally. In October 2006 the Co-Chairs of the National Space-Based PNT EXCOM approved the membership of the National Space-Based PNT Advisory Board. The advisory board membership for 2007-2008 included the following:

U.S. Members:

Phil Boyer	Aircraft Owners and Pilots Association (AOPA)
Joe Burns	United Airlines
Ann Ciganer	U.S. GPS Industry Council
Susan Cischke	Ford Motor Company
Per Enge	Stanford University
Martin Faga	President and CEO of MITRE
Keith Hall	Booz-Allen Hamilton
Robert Herman	Global Technology Partners, LLC

Chet Huber	OnStar Corporation - General Motors
David Logsdon	U.S. Chamber of Commerce
Lance Lord	Retired U.S. Air Force (USAF) - Former Commander Air Force Space Command (AFSPC)
Tim Murphy	Boeing Commercial Airplane Group
Terence McGurn	Retired Central Intelligence Agency (CIA) - currently private consultant
James McCarthy	Retired USAF (currently professor)
Ruth Neilan	Jet Propulsion Laboratory (JPL)
Bradford Parkinson	Stanford University Aeronautics and Astronautics
James Schlesinger	MITRE Corporation and Lehman Brothers
Charles Trimble	Founder of Trimble Navigation (currently private consultant)

International Committee:

Gerhard Beutler (CH)	International Association of Geodesy (IAG) Switzerland
Arve Dimmen (NO)	Maritime Safety of the Norwegian Coastal Administration
Suresh Kibe (IN)	Indian National Satellite System
Keith McPherson (AU)	Airservices Australia
Hiroshi Nishiguchi (JP)	Secretary General of The Japan GPS Council
Richard Smith (UK)	International Association of Institutes of Navigation

1.5 PNT Advisory Board Structure and Approach

The Advisory Board is comprised of acknowledged experts with extensive public and private sector experience both domestically and internationally. The Advisory Board Chair, Dr. Schlesinger, divided the Board into three fact finding panels with each focusing on one of the three topics tasked for research. Dr. Parkinson is the chair for the Leadership Panel; Ms. Neilan chairs the Strategic Engagement and Communication Panel; and Mr. Trimble chairs the Future Challenges Panel. Each panel member is tasked to address the topics using their particular experience and insights. The Panel Chairs report their progress and findings to the Advisory Board at the Advisory Board meetings. The Advisory Board, which meets twice a year, receives briefings from Advisory Board members and other government experts. The Board also conducts open discussions after each presentation and presents summary statements by board members at the conclusion of the meeting. The Panel findings and results, combined with the meeting results, form the basis of the recommendations from each panel.

The first PNT Advisory Board meeting was announced in the Federal Register / Vol. 72, No. 174 / Monday, September 10, 2007 / Notices (Appendix B) and held on March 29-30, 2007. Additional PNT Advisory Board meetings were held on: October 4-5, 2007; March 27-28, 2008; and October 16-17, 2008.

1.6 2007-2008 PNT Advisory Board Proceedings

This report provides a summary of the PNT Advisory Board activities and discussions, for the 2007-2008 cycle. These proceedings include a high level summary of the briefings presented by invited speakers, board discussions on these briefings, and round-table discussions.

The full Meeting Minutes and briefings are available at the National Coordination Office (NCO) website: **http://www.pnt.gov**

2. First Meeting: March 29-30, 2007

2.1. Location and Agenda

Ronald Reagan Building and International Trade Center
1300 Pennsylvania Avenue, NW,
Polaris Suite
Washington, D.C. 20004

Thursday, March 29

9:00	BOARD CONVENES	
9:00 - 9:15	Opening Remarks	Dr. Michael Griffin NASA Administrator
9:15 - 10:00	Announcements & Introductions	Dr. James Schlesinger, Chair Dr. Bradford Parkinson, Vice-Chair
10:00 - 10:25	President's 2004 PNT Policy	Dr. Philip Ritcheson White House/NSC
10:25 - 10:50	DoD PNT Challenges & Opportunities	Dr. Linton Wells Principal Deputy Assistant Secretary, NII
10:50 - 11:00	BREAK	

11:00 - 11:25	DOT PNT Challenges & Opportunities	Mr. John Bobo Acting Administrator, RITA
11:25 - 11:50	NASA PNT Challenges & Opportunities	Dr. Scott Pace Associate Administrator, PA&E
11:50 - 12:00	Morning "Wrap-Up" & Announcements	
12:00 - 1:30	WORKING LUNCH	
	FACA Overview	Ms. Diane Rausch Executive Director, PNT Advisory Board
	Ethics Briefing	Ms. Rebecca Gilchrist Senior Ethics Attorney, OGC, NASA
1:30 - 1:55	DOC PNT Challenges & Opportunities	Mr. Edward Morris Director, Space Commercialization
1:55 - 2:20	State PNT Challenges & Opportunities	Mr. Ralph Braibanti Director, Advanced Technology
2:20 - 2:45	DHS PNT Challenges & Opportunities	Capt. Curtis Dubay Chief, Systems & Architecture
2:45 - 3:00	BREAK	
3:00 - 3:25	GPS Service & Performance Overview	Col. John Hyten (Brig. Gen. Select) Commander, 50th Space Wing
3:25 - 3:50	GPS Status & Modernization	Col. Allan Ballenger Commander, GPS Wing
3:50 - 4:50	PNT EXCOM Taskings & Discussion	Mr. Michael Shaw Director, NCO
4:50 - 5:00	Afternoon "Wrap-Up" & Announcements	
5:00	ADJOURNMENT	

Friday, March 30

9:00	BOARD CONVENES	
9:00 - 11:00	Board Member Feedback - "Round Table" Building on DSB & IRT Efforts	Dr. James Schlesinger, Chair Dr. Bradford Parkinson, Vice-Chair
11:00 - 12:00	Board Structure and Tasking Assignments Set-up of Work Groups and/or Sub-Groups	All
12:00 - 1:00	WORKING LUNCH - PNT Advisory Board "Wrap-Up" Discussions	
1:00	ADJOURNMENT	

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2.2. Opening Remarks

GPS is a spaced-based system that provides accurate radionavigation and timing information anywhere in the world. The service is now equivalent to a public utility and we would have a hard time today getting along without it. In 1993 President Reagan issued a Directive which emphasized the dual-use nature of GPS and specified that service would be provided without direct fees to the public. GPS is now the best known acronym around the world. The market value for the industry involved in GPS receiver design and manufacture, as well as the development of GPS-based applications, will surpass $30 billion in 2008.

GPS is also being used more and more in space. For example, the International Space Station relies on GPS for orbit and attitude control. Another example is the new NASA Ares launch vehicles and Orion spacecraft, part of the U.S. vision for space exploration, which will use GPS in combination with Inertial Navigation Systems (INS) for navigation during critical phases of flight. As we return to the moon, a lunar navigation system similar to GPS may be used.

In summary, our entire approach on how we navigate in space is being changed by GPS.

Dr. Michael Griffin, NASA Administrator

2.3. Introduction

The current average age of GPS satellites in operation is about 9 years. The next generation of satellites, called Block IIF, is being developed. The current constellation has 30 satellites in orbit and users are relying on the service that number of satellites provides. Block IIIA is now in the System Design Review stage. The Request for Proposal (RFP) for those satellites is, at the time of this briefing, still held up in the Pentagon.

There are five primary objectives for GPS and strategies to meet them:

1. Assured availability of GPS through a reasonable constellation size.
2. Resistance to jamming and interference through use of multiple signals.
3. Accuracy levels measured to the 50th percentile, which is determined by parameters such as constellation size, geometry, additional and improved signals, and reduced ranging errors.
4. Bounded inaccuracy to limit “wild points” (usually the 95th or 99th percentile), which is through more stringent GPS constellation parameters.
5. Integrity, which is obtained through the elimination of erroneous signals by means of independent cross checking with the Wide Area Augmentation System (WAAS) and satellite self-checking.

There are three additional concerns the board needs to consider in the implementation of GPS:

1. Avoiding potential outages in GPS services, or GPS ‘brownouts’, by proceeding immediately with GPS Block IIIA.

2. Keeping GPS IIIA simple and affordable by avoiding requirements creep, and ensuring development on time and on budget.
3. Mitigating the risk and effects from interference by means of contingency systems such as eLORAN.

Dr. Bradford Parkinson, PNT Advisory Board Co-Chair

2.4. President's 2004 PNT Policy

The President, in 2004, issued a new national policy because GPS was both integral to national security and had turned into a global utility for many additional purposes. The Policy's new features are being implemented today. The Policy scope focused more directly on a full suite of PNT activities, and the GPS goals and objectives were clarified and refined. These include: uninterrupted availability free of direct user fees; meeting growing requirements in the security and commercial arenas; improving the capability to deny hostile use; continuing development at a steady pace—with sustained attention to improvement; requiring that GPS exceed or be competitive with foreign PNT services; and encouraging foreign systems to be compatible, or ideally interoperable, with GPS. The Policy also provides for improved management of GPS. It establishes the National Space-Based PNT EXCOM, National Coordination Office (NCO), and the National Space-Based PNT Advisory Board.

The Policy was issued in response to emerging domestic and international PNT players. New roles for participating agencies had to be defined to specify how they would execute their responsibilities. The Policy also provides for improved management and as a result, the U.S. is now properly aligned to improve PNT availability with input from civil agencies. Continual innovation is important to meet the challenge of protecting space assets and the PNT services delivered to the Earth's surface. The current charge is to continue to build on leadership and international engagement in order to produce greater precision, accuracy, availability, and access. The Board's Charter calls for it to provide advice and recommendations.

Three topics for the Board have been suggested by the EXCOM: (1) Leadership; (2) Strategic Engagement and Communication; and (3) Future Challenges.

Dr. Philip Ritcheson, White House / National Security Council

2.5. PNT Challenges and Opportunities

This section provides a summary of the main PNT challenges and opportunities as viewed by various U.S. agencies.

Department of Transportation

The DOT's two main PNT goals are to improve safety and to mitigate congestion. The DOT has a stewardship role to play in GPS civil funding. The goal of the civil PNT architecture is one of interoperability with other systems around the world.

Mr. John A. Bobo, Jr., Acting Administrator, Research and Innovative Technology Administration (RITA)

Department of Defense

The DoD has to comply with national policy and retain GPS as the preeminent standard. There is an increasing demand for precision and system functionality in urban areas, as well as over open oceans. Reliance on precision weapons can be improved down to centimeter-level accuracy. There are several concerns regarding the proliferation of jamming capabilities, increased competition in the Radionavigation Satellite Service (RNSS) spectrum as new international GNSS systems emerge, and concerns over the GPS M-code (military code) overlapping other GNSS signals. There is an increasing dependency on the timing function of GPS, which is something everyone must be aware of. The exact degree of dependency on the timing function needs to be addressed by the Board.

Dr. Linton Wells, Principal Deputy Assistant Secretary, OSD/NII

National Aeronautics and Space Administration

The STS-115 was the first shuttle to use GPS for navigation. GPS has now flown on many flights, enabling NASA to retire expensive radar systems. GPS is being used at sub-millimeter levels for gravity maps and other science applications in the ionosphere, oceans, atmosphere, and within solid Earth. GPS is also being augmented for space navigation. Differential GPS corrections are made possible by the Tracking and Data Relay Satellite System (TDRSS) Augmentation Service for satellites (TASS). GPS is also utilized for Search and Rescue (SAR) operations on a prototype basis with a system called Distress Alerting Satellite System (DASS). In conjunction with Search and Rescue Satellite (SARSAT), DASS has contributed to saving over 20,000 lives to date. DASS uses uplinks from 406 MHz beacons, and enables a position fix to be obtained within 5 to 6 meters in only a few minutes. NASA has invested substantially in this system. Research activities have been completed and it is time to hand this system over to the U.S. Coast Guard (USCG), National Oceanic and Atmospheric Administration (NOAA), and the DoD for operational implementation as part of GPS III. Another potential capability for GPS III, somewhat different from gaining data via standard GPS signals, involves laser ranging to laser retroreflectors on GPS satellites. This method of measurement is independent from radiometric GPS signals derived from the WGS 84 reference frame, and will enable performance improvements in GPS by providing an independent means to verify precise satellite orbits and improve the ITRF. There is a user need to obtain accuracies to the sub-centimeter level and SLR is essential because it gives an independent measurement and provides a way to calibrate the system when co-located with GPS signals. Many other satellites use SLR retroreflectors. The International GNSS Service (IGS) is engaged in measuring subtle errors in GPS tracking and monitor station position. SLR is the only tool that enables an independent assessment. Also, GPS side lobes can be picked-up about two thirds of the way to the Moon. NASA is seeking to use standards similar to GPS in order to move seamlessly from Earth into space and to the Moon and beyond. For lunar missions, NASA may use either small satellites, or surface beacons, that transmit GPS-like signals. Landing the first time within 100 meters is not that difficult; landing at the same place the next time that presents a more demanding challenge. Finally, GPS time has advantages such as not being tied to a particular planetary surface, and relativistic effects on this time must be taken into account, since the spacecraft are moving through space at high speeds. There are different reference frames calling for adjustments and it is critical to use a common time standard, such as a notional 'solar system Zulu time'.

Dr. Scott Pace, Associate Administrator, PA&E, NASA

Department of Commerce

The key GPS tenets from the DOC perspective are:

- Provide civil GPS and augmentations free of direct user fees on a continuous, worldwide basis;
- Provide open, free access to information needed to use civil GPS and augmentations;
- Improve performance of GPS and augmentations; and
- Seek to ensure that international space-based PNT systems are interoperable with civil GPS and augmentations or, at a minimum, are compatible.

Mr. Ed Morris, Director Office of Space Commercialization, Department of Commerce

Department of State

In 2004 the U.S. and the European Union signed a landmark agreement on GPS-Galileo cooperation. The agreement recognizes the importance of compatibility and interoperability. The Air Force has also done a lot of work on this issue. Japan, whose status as a world leader in GPS applications and user equipment, is an important partner in international cooperation. Discussion topics with Japan include Japan's regional augmentation system and interoperability between GPS and Japan's planned Quasi-Zenith Satellite System (QZSS). U.S.-Russian working groups are also pursuing GPS-GLONASS interoperability. A U.S.-India Joint Statement on GNSS cooperation was issued in February 2007 and, in addition to an augmentation to GPS, India has a plan to build a regional navigation constellation of six satellites. There is an on-going need to continue technical work to promote compatibility and interoperability with foreign GNSS systems. Consultations on PNT issues need to be broadened to include more countries.

Mr. Ralph Braibanti, Director, Space and Advanced Technology, Department of State

Department of Homeland Security

The U.S.'s critical infrastructure relies on GPS and there is a widening dependence on GPS systems which has made them increasingly vulnerable. The Department of Homeland Security (DHS) is focusing planning efforts to coordinate U.S. capabilities to identify, analyze, locate, attribute, and mitigate sources of interference to the GPS and its augmentations. A PNT working group has been set up to develop a formal plan for interference, detection, and mitigation. An important issue is the DHS plan to protect GPS users and assure continuity of service for "The National Infrastructure Protection Plan". The DHS Interference, Detection, and Mitigation (IDM) plan is oriented to the "homeland." It is important to understand the many interdependencies to include international issues such as Australian laws prohibiting interference devices to help mitigate jamming and interference.

Captain Curtis Dubay, US Coast Guard, Department of Homeland Security

2.6. GPS Service and Performance Overview

The Air Force GPS mission is to provide the best space-based positioning, navigation, and timing capability in the world 24/7/365. The GPS constellation was completed in 1994 and those satellites are now being replaced. Civilian users at first had been forced to work around Selective Availability (S/A), which was the intentional degradation of the GPS Standard Positioning Service (SPS). Military user equipment demands grew faster than the military equipment could be supplied. In 1991 there were approximately 15,000 civilian receivers with the primary GPS uses of land surveying, maritime navigation, and precision timing. During Operation Desert Storm, there were 10,000 civilian GPS units and 8,000 military GPS units. That is, many more DoD personnel were using civilian receivers, despite their limitations, instead of military receivers.

There is an ongoing transition from a satellite operations focus to a focus on effects-based operations. The increased accuracy and signal integrity is providing improved military effects. There is a lack of full synchronization across all system segments. In today's civilian market, there are over 15,000,000 receivers and the primary uses include (1) cell phone communication/ precision timing source; (2) navigational purposes (airlines, trucking, recreational); (3) surveying and geodesy (oil drilling, mapping); (4) precision agriculture; (5) intelligent railroads; and (6) just-in-time delivery.

Thirty-one satellites are currently in operation, with one being a test satellite. Since September 11, 2001 GPS operations changed in a significant way. Today, many users are first responders who have embedded GPS capabilities in their first responder capabilities. Although today there are over 100,000 military GPS units in use, it is only a small percentage of the required receivers. GPS has brought about a fundamental change in warfare and the big challenge in the future is to bring about full system integration. There will be a need to integrate multiple military and civilian signals.

Col John Hyten, Commander, 50th Space Wing

2.7. GPS Status and Modernization

The U.S. Air Force GPS Wing Commander is responsible for the GPS acquisition and Air Force Space Command is responsible for the GPS operations. The GPS Wing's mission is to acquire and sustain survivable, effective, and affordable global positioning service for customers. The total budget is $900 million to $1 billion a year. The GPS system includes a User Segment (M-Code, Defense Advanced GPS Receiver (DAGR), Selective Availability/Anti-Spoofing Module (SAASM), Combat Survivor/Evader Locator (CSEL), and Miniature Airborne GPS Receiver (MAGR) 2000, a 30+ Satellite Space Segment (Block IIR/IIR-M, Block IIF, and Block III), and the Control Segment (4 Ground Antennas, 11 Monitor Stations, and Schriever Master Control Station). While there are currently 30 'healthy' satellites, the baseline is 24 satellites in 24 orbital slots. The new acquisition strategy for the next generation GPS includes a back-to-basics approach. Mission success is taken very seriously and the key performance measures are (1) accuracy, (2) bounded inaccuracy, (3) assured availability, (4) integrity, and (5) resistance to radiofrequency RF interference and jamming. The overall GPS modernization program includes assuring the availability of signals from space, and capability modernization with new signals. The control segment is being transitioned from a legacy to a new architecture/system. Block III will fit two satellites to a booster.

Col Allen Ballenger, Commander, GPS Wing

2.8. PNT Executive Committee Tasking and Discussions

The NCO serves the National Space-Based PNT EXCOM. The NCO and EXCOM were established by the same Presidential Policy that established the PNT Advisory Board. The three topics that the EXCOM would like the Board to address are: (1) leadership; (2) strategic engagement and communication; (3) future challenges. Topic one is leadership and the tasking is to recommend areas where GPS and its augmentations can be made more competitive. Topic two is strategic engagement and communication and the tasking is to recommend ways to promote and demonstrate current and future capabilities of GPS and its augmentations to the U.S. and international communities. Topic three is future challenges and the tasking is to assess technology and market trends as the number of worldwide GNSS providers increase.

Mr. Michael Shaw, Director, National Coordination Office

2.9. Defense Science Board Task Force

The Defense Science Board (DSB) Task Force has identified six national PNT objectives:

- Provide uninterrupted availability of positioning, navigation, and timing services;
- Meet growing national, homeland, economic security, and civil requirements, and scientific and commercial demands;
- Remain the pre-eminent military space-based positioning, navigation, and timing service;
- Continue to provide civil services that exceed or are competitive with foreign civil space-based positioning, navigation, and timing services and augmentation systems;
- Retain essential components of internationally accepted positioning, navigation, and timing services; and
- Promote U.S. technological leadership in applications involving space-based positioning, navigation, and timing services.

The third objective, "remain the pre-eminent military space-based positioning, navigation, and timing service," requires funding over current levels. The Board believes there has been insufficient attention on the ground control and user components both in the planning and budgeting process. GPS is a system of systems: ground control, user equipment, and satellites and therefore cannot just focus on the space component. A minimum constellation size of 30 satellites is needed to support ground forces in varied terrain and to support the other users. Satellite mass must be controlled for cost purposes, as it is essential to maintain the flexibility to launch two satellites on the same launch vehicle. Additionally, emphasis should be relaxed on anti-spoof and increased attention paid to anti-jam.

Defense Science Board Briefing

2.10. GPS Independent Review Team

The mission of the Independent Review Team (IRT) is to identify opportunities and provide strategic and technical recommendations to Space Command for the successful development of future positioning and timing service for all users. The team believes that the military must work with civilian, and coalition partners, in developing new capabilities. The major challenge on the issue of vulnerability is that the users are often concerned that solutions will cost money. Therefore they would rather simply change tactics and procedures to mitigate this issue. The IRT's goal is for increased accuracy for precision operations and situational awareness. GPS should be the signal of choice, although other systems are also required. Also, not all signals need to be provided from space. The GPS system must be robust enough to be available in challenged environments, e.g., urban canyons, mountainous areas, heavy vegetation, and areas of significant RF interference. The "Big Five" performance measures of effectiveness are (1) Assured availability of GPS signals for operations – including impaired situations; (2) Resistance to jamming and interference; (3) Accuracy – one meter for fixed (3 meter for moving) targets and other operations; (4) Bounded inaccuracy – to meet critical safety of life limits and to limit collateral damage and fratricide; and (5) Integrity – eliminating erroneous signals.

The IRT's priorities include: (1) ensuring continuous service to all users; (2) monitoring the evolution of technologies which are increasingly becoming dependent on GPS positioning and timing service; (3) advocating for GPS signals to be fully enabled as soon as they become available; (4) expanding National Security notions beyond combat operations; (5) ensuring the economic well-being of the U.S. GPS industrial base; (6) emphasizing to the DoD that it is important to national security that GPS signals remain the service of choice around the world; (7) promoting a more effective dialog with users; (8) working to adequately reflect the ground forces' requirements and properly integrate smart weapons with GPS; (9) correct the lack of horizontal integration understanding by the services; (10) improve the understanding of operational performance in stressed environments; (11) work to fix the requirements process; (12) advocate that GPS satellites be kept simple; (13) develop more effective user equipment transition plans; (14) ensure built-in forward flexibility while maintaining backward compatibility; (15) provide continued improvement in service through "spiral development" of user equipment; and (16) continue with operational testing of GPS use in stressed environments.

Major General Rosenberg, Chairman, GPS Independent Review Team

2.11. Advisory Board Roundtable Discussion

GPS Funding: Current GPS funding issues include: budget limitations; no process within existing budgets to prioritize requirements; no attribution for requirements; and turnovers and personnel changes; all of which are hindering programs. Additionally, we must be careful not to ignore that there are already significant PNT services capabilities in place which are not being fully exploited. The board participants acknowledge that GPS is an important national interest and funding is needed to match the PNT objectives. The Board believes that by pursuing individual user payment instead of national-level funding may result in failure. The EXCOM provides an opportunity to address these issues. While there is policy and activities, currently there is not a business plan in place. Also, it is important to clarify that thirty satellites are needed to meet both military and civilian needs while, of course, understanding that GPS cannot afford to meet all new PNT user requirements. A GPS business plan could help to resolve these issues.

Aviation Users: GPS is a significant part of airline operations, such as those of United Airlines. The number one concern is protecting the spectrum in which GPS operates. Airlines are concerned about control and accuracy being degraded by interference. Interoperability with regard to Galileo is also a big concern. Airlines like the system that is in place today rather than some plans that would mandate the use of certain PNT over specific air spaces. Airlines do not want to implement several sets of navigation equipment to operate in different parts of the world because the cost would be prohibitive and there is no room in the aircraft to locate the equipment. Air operators also need at least 30 evenly spaced operating GPS satellites to ensure adequate redundancy and integrity in places where ground-based augmentations, such as WAAS, are not available and to support applications such as autonav landing.

Non-PNT Payloads on GPS: There is value in placing secondary payloads on GPS such as the Nuclear Detection Systems (NDS) and the Distress Alerting Satellite System (DASS), but the board is concerned about non-PNT payloads increasing in size and taking over a much larger portion of the service vehicle. There are currently five NDS missions: one classified, three relating to the Cold War, and one for international treaty-monitoring. The objective of DASS is to develop and maintain U.S Search and Rescue capabilities once the current international Low Earth Orbit (LEO) and Geosynchronous Earth Orbit (GEO) -based Search and Rescue Satellite System (SARSAT) system is discontinued. However, where feasible the board recommends that use of alternative platforms be assessed so GPS satellites are not overly burdened by payloads that are not part of primary PNT operations. The board acknowledges that there are on-going efforts to reduce the overall impact of secondary payloads to the GPS service vehicle.

International Users: International partners with limited or no ground-based augmentations purchase licenses in order to protect frequencies. When two or three GPS satellites are down the partners' ability to meet navigation requirements suffers. The board recommends there be an analysis on the consequences to such users when GPS satellites are taken out of service. Such an analysis could include a 'forecasting tool' to show the impact on, for example, Australia, South America, Africa, and most of the southern hemisphere.

Ground Users: Users such as General Motors OnStar Corporation, depend on accuracy. A degraded environment poses unknown risks to their operations and users. Backward compatibility and interoperability are important from the commercial perspective and benefit from the stability of GPS. GPS is critical to the provision of services such as first responders who save lives. There has been a massive growth in the use of GPS by the civil sector and, as a result, turning on S/A is not really a viable option. GPS even played a role in helping people to evacuate New Orleans during Hurricane Rita.

Interagency and International Coordination: The International Association of Institutes of Navigation (IAIN) supports (1) greater coordination among the government agencies; (2) additional satellites to meet the current requirements; (3) containment of the GPS payload to the core navigation needs; (4) recovering costs for add-ons; (5) international standards; (5) opposition of unilateral imposition of carriage requirements (with international agency help); (6) formal removal of S/A capabilities from GPS III; and (7) continual back-up to GPS for navigation. There is an increasing need to improve situational awareness and positional accuracy of users. The IGS uses both GLONASS and GPS, and intends to fully utilize Galileo. The main driver for the Chinese to enter the GNSS world, and for the Russians to not give up on GLONASS, is their military requirement.

Geodetic Users: The IAG is responsible for defining reference systems and time-keeping is highly important to this effort. IAG will use every signal that is made available. To date GPS is the leader and its accuracy and impact cannot be overstated. GPS will not be alone in the future and IAG supports the idea of removing S/A and everything else that could be used as an argument against GPS. There will be a white paper distributed to the Board on the reasons S/A currently serves no purpose and should be disabled. Satellite laser ranging will be used by the competitors and should be made a mandatory part of the GPS system in order to obtain the highest possible accuracy. One geodesic coordination system should be recognized and timing, as a component, will become more important in the future. The U.S. Naval Observatory plays an important role here.

Maritime Users: Maritime users world-wide use GPS for transit as well as port and harbor operations. For them, bounded integrity is more important than increased accuracy. There is a new automatic identification system which relies on GPS. This system gives the master of a ship situational awareness of his surroundings and traffic on the coast. There is a need for back-up systems. Norway, in the geographical areas above 67 degrees, has the same concerns as Australia. There are also driverless cranes on wharves that are relying on GPS.

2.12. Board Structure and Tasking Assignments

Dr. Schlesinger divided the Board into three fact-finding panels. Board members were assigned to the three panels as follows:

- Leadership Panel: Dr. Parkinson (Chair), Mr. Faga (Co-Chair), Mr. Hall, Gen Lord, Mr. McPherson, and Mr. Murphy.
- Strategic Engagement and Communication Panel: Ms. Neilan (Chair), Mr. Logsdon (Co-Chair), Dr. Beutler, Mr. Boyer, Mr. Huber, Mr. Kibe, Mr. McGurn, and Capt. Smith.
- Future Challenges Panel: Mr. Trimble (Chair), Dr. Herman (Co-Chair), Capt. Burns, Ms. Ciganer, Mr. Dimmen, Prof. Enge, Gen McCarthy, and Mr. Nishiguchi.

3. Second Meeting: October 4-5, 2007

3.1. Location and Agenda

Doubletree Hotel
1515 Rhode Island Avenue NW
Washington, D.C. 20005

Thursday, October 4

8:30 - 8:35	BOARD CONVENES Call to Order	Ms. Diane Rausch, NASA PNT Board Executive Director
8:35 - 8:45	Welcome & Opening Remarks	Dr. Scott Pace, Associate Administrator, NASA Program Analysis & Evaluation
8:45 - 9:15	Introductions, Announcements, & Agenda No Selective Availability (S/A) for GPS III	Dr. James Schlesinger, Chair Dr. Bradford Parkinson, Vice-Chair
9:15 - 9:30	Update on GPS, PNT Policy, & PNT EXCOM	Mr. Michael Shaw, Director, National Space-Based PNT Coordination Office
9:30 - 10:30	International Member Feedback & Regional Reports	

- Gerhard Beutler (CH), International Association of Geodesy (IAG) Switzerland
- Arve Dimmen (NO), Maritime Safety of the Norwegian Coastal Administration
- Keith McPherson (AU), Airservices Australia
- Hiroshi Nishiguchi (JP), Secretary General of the Japan GPS Council
- Richard Smith (UK), International Association of Institutes of Navigation

10:30 - 10:45 BREAK

10:45 - 12:00	Leadership Panel Fact-Finding Report	Dr. Bradford Parkinson, Stanford University Mr. Martin Faga, former CEO, MITRE
12:00 - 1:00	LUNCH	
1:00 - 2:15	Strategic Engagement & Communication Fact-Finding Report ▪ Geodesy Presentation ▪ Precise Time Presentation ▪ Outreach Presentation	Ms. Ruth Neilan, Jet Propulsion Laboratory Mr. David Logsdon, Space Enterprise Council
2:15 - 3:30	Future Challenges Fact-Finding Report	Mr. Charlie Trimble, founder, Trimble Navigation Dr. Robert Hermann, Global Technology Partners
3:30 - 3:45	BREAK	
3:45 - 4:15	Update on GPS Performance Standards DoD Perspective	Brigadier General Donald Alston, Director, Space and Nuclear Operations - HQ USAF
4:15 - 4:45	Update on GPS Performance Standards Civil Perspective	Mr. Hank Skalski, Civil Liaison, Air Force Space Command - GPS
4:45 - 5:00	Afternoon "Wrap-Up" & Announcements	
5:00	ADJOURNMENT	

Friday, October 5

8:30	BOARD CONVENES	
8:30 - 8:35	Chair/Vice-Chair Feedback "What We Want the PNT Board to Accomplish"	Dr. James Schlesinger, Chair Dr. Bradford Parkinson, Vice-Chair
8:35 - 9:05	Future of E-LORAN GPS Alternatives & Back-Ups - Timing	Captain Curtis Dubay, Chief, DHS Systems & Architecture
9:05 - 9:35	Future of NDGPS Infrastructure & Funding Status	Mr. Tim Klein, Program Sponsor, DOT/RITA
9:35 - 10:05	FAA NAS Modernization Automatic Dependent Surveillance-Broadcast	Mr. Rick Day, ATO Vice-President, FAA Enroute & Oceanic Services
10:05 - 10:20	BREAK	
10:20 - 12:00	Board Member Feedback - "Round Table" Board Assignments and Future Taskings	All
12:00 - 1:00	WORKING LUNCH PNT Advisory Board "Wrap-Up" Discussions	
1:00	ADJOURNMENT	

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3.2. Opening Remarks

Everyone is becoming increasingly dependent on the GPS. The PNT EXCOM member discussions have emphasized the importance of ensuring that GPS remains robust and accessible to all, even as budget priorities are reexamined in tighter fiscal environments. To this end many good ideas have been received on ways to do this. The PNT Advisory Board can provide assistance in setting national priorities for GPS that are similar to that provided by the National Academy of Sciences. The ICG is an important mechanism to bring GPS issues into the international arena.

Dr. James Schlesinger, Dr. Bradford Parkinson - Co-Chairs, PNT Advisory Board

3.3. GPS, PNT Policy, and PNT EXCOM

The GPS constellation is robust with 30 operational satellites in 24 orbital slots. The first GPS IIF satellite is projected for launch in late 2009. An update to the GPS SPS Performance Standard (PS) is in progress and, at the time of this meeting, is expected to be completed in 2008. A contract award to upgrade the GPS ground segment is at the Request for Proposal (RFP) source selection stage and contract award is anticipated by the end of October 2007. The next generation of GPS satellites – GPS IIIA – is also in source selection and an award is anticipated in January, 2008. WAAS has recently expanded service into Canada and Mexico. The DOT is working to complete an assessment of the need for the inland component of the NDGPS by the end of January, 2008. The maritime component will not be affected by this assessment. A notice about the assessment was published in the Federal Register in August 2007 and the comment period ended on October 1, 2007. The current budget status for GPS will require a sustained funding line to protect the resources to assure continued linkage between the ground stations and the constellation. The budgets will be reviewed to assure continued operations. The previous recommendation to open the discussions to international members has come to fruition.

The space-based PNT service providers will grow from two countries (U.S. and Russia) to six or more countries by 2020. China launched its COMPASS medium Earth orbit satnav satellite on April 16, 2007. The U.S. is actively engaged in diplomatic efforts to promote GPS. The ICG, held its second meeting in Bangalore, India, in September 2007. The participants included the following GNSS providers: U.S, EU, Russia, China, and Japan. The U.S. will host the third ICG at NASA JPL/Cal Tech on December 8-12, 2008. There have been ongoing discussions with Russia, as well as the U.S. and Japan 5th annual consultation held on May 24, 2007. The U.S. and India issued a Joint Cooperation Statement on February 28, 2007, which was to ensure interoperability between WAAS and India's GPS-Aided Geo Augmented Navigation (GAGAN) system. The U.S. and Australia also issued a Joint Cooperation Statement on April 19, 2007. On July 26, 2007, the U.S. and EU adopted a new improved civil signal structure (MBOC). The EU, on June 8, 2007, abandoned its plan for funding through a public/private partnership and is now examining governmental funding opportunities. The implementation of the President's 2004 PNT Policy is progressing with very active senior U.S. Government leadership. International cooperation is a top priority for the government as evidenced by its active engagement in both multilateral and bilateral consultations. The theme as new space-based GNSSs emerge globally; interoperability is the key to "success for all."

The EXCOM is meeting regularly. Items addressed by the EXCOM are: S/A, IDM, National 5-Year Plan for Space-Based PNT, National PNT Architecture, and EXCOM 2008 Work Plan.

Mr. Mike Shaw, Director, National Coordination Office

3.4. International Member Feedback & Regional Reports

International Association of Geodesy

GPS and GNSS systems have an important role in geodesy and geodynamics. Geodesy is based on and provides information for geometry and the kinematics of and on the Earth and its environment, Earth orientation and rotation, and the Earth's gravity field, including its variability. This makes it necessary to define, realize, and maintain unique reference systems on Earth and in the sky, and to monitor the transformation between them. The space age brought about a revolution in geodesy and led to the creation of several important services, including the International Earth Rotation Service (IERS), the IGS, and the International Laser Ranging Service (ILRS). There are currently 30 GPS satellites in six orbital planes, but independent precision ranging should continue to be refined through techniques such as laser ranging. There are a varying number of satellites in the Russian system (GLONASS), while Galileo has one prototype satellite (Giove-A) in space sending out test signals.

The IGS was initiated in 1989 and became an official service in 1994. At first, it was a pure GPS service. Today however, the IGS is an interdisciplinary service providing support to all Earth sciences. Its Central Bureau is located in the United States. Its Director, and one of its founders, is PNT Advisory Board member Ms. Ruth Neilan. In 1992, the IGS was based on 20 geodetic receivers, and has grown to over 400 receivers today. The IGS started off as an orbit determination service for about 20 GPS satellites. Today it provides ephemerides' (with an accuracy of 2-4 cm) for all active GNSS satellites including about 30 GPS satellites and 10-17 GLONASS satellites. In addition, the IGS is providing products that are accurate, reliable and robust. These products included serving as an archive of GNSS observations, satellite and receiver clock corrections, length of day monitoring, and atmospheric information. IGS has been instrumental in the new age of gravity field determination, participating in the launch of the German small satellite (CHAMP) in 2000, and the Gravity Recovery and Climate Experiment (GRACE) in 2002 which explored the use of inter-satellite measurements to study the time variability of the gravity field. The Gravity Field and Steady-State Ocean Circulation Explorer (GOCE) in 2007 made use of the 3-D gradiometer to derive the "best possible" stationary gravity field.

The International Association of Geodesy (IAG) and IGS have expectations concerning GNSS including: the scientific community combining the measurements from all systems rather than switching from one GNSS to another; the same information available from GPS today will continue be openly available without fees for all emerging GNSS systems, and be made available for use by the same receivers; the GNSS constellations differ considerably and that different systems improve the geometry, which helps to understand systematic errors.

Mr. Gerhard Beutler, IAG, Switzerland

Norwegian Coastal Administration, Maritime Safety Division

Important issues for the Norwegian Coastal Administration include E-Navigation, Galileo, and "the Arctic challenge".

E-Navigation is defined as "the harmonized collection, integration, exchange, presentation, and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment." The key elements of E-navigation are situation awareness, instant data sharing, the ability to act upon someone else's data, robust networking, and a system of systems approach. It requires navigation and timing capabilities that currently only GPS can provide globally.

Galileo has "passed the point of no return", and it is important to continue to develop the cooperation to try to achieve "interchangeability" between GPS and Galileo.

The Arctic challenge occurs because the polar ice cap is disappearing more rapidly than estimated only a few years ago. Satellite images show that the Northwest Passage was free of ice in August of this year. There are two main drivers that make the Arctic area important in this respect. First, 25 percent of undiscovered oil resources are estimated to be in this area. Second, if the ice decreases sufficiently, tankers and container vessels will start to use the Northern sea routes, since it will shorten the time to sail between Europe and East-Asia considerably, maybe as much as 30-40 percent. The space based GPS augmentation systems are generally not used north of the Arctic Circle due to coverage limitations. This can create a precision navigation / integrity problem. There is very sparse infrastructure in the Arctic areas for harbors, navigational aids, and most importantly search and rescue and pollution response capabilities. The challenge is to maximize the benefits of international cooperation to combine ground-based and space-based services from all service providers.

It is now predicted that the northern sea routes may be used commercially within the lifespan of GPS III. The U.S. Geological Service estimates that it will determine information regarding undiscovered oil and gas resources. Ruth Neilan added that the IGS is using GPS to accurately measure sea-level rise and the disappearance of glaciers.

Mr. Arve Dimmen, Maritime Safety of the Norwegian Coastal Administration, Norway

Airservices, Australia

The Ground-Based Augmentation System (GBAS) program is up and running. A certification process is underway and certified production systems are expected in late 2008. Better antennas are also expected. All six runways at Sydney's airport have been programmed and are using the GBAS Cat-1. The Sydney airport requires flexible approaches for several reasons. Community noise is a major consideration. Displaced thresholds can increase throughput, and provide shorter taxi-times. Multiple glide-slopes would also become available to help overcome environmental noise issues. The Ground-Based Regional Augmentation System (GRAS) will work the same way as WAAS. GRAS is needed for several reasons. The WAAS footprint over the Pacific was moved 35 degrees further east in July, 2007. There are no wide area augmentation systems in the southern hemisphere and GAGAN does not cover the Sydney-Melbourne area on the east coast. The Australians expect a certified production system in 2009. In addition, there are sovereignty issues. The GRAS system allows one box to suffice in an airplane's cockpit. The forecast for major GPS outages is exacerbated by piggy-backing GPS satellites. Thirty satellites with "piggy-backing" provide only twenty-four satellites in positions which are actually useful. During some periods, only five satellites are visible.

Mr. Keith McPherson, Airservices, Australia

Japan GPS Council

In Japan, people without GPS cannot lead their routine lives anymore. Given the high level penetration of GPS into everyone's lives and the demands with respect to the safety of life, the need for GNSS assurance and reliability is continually increasing. In that regard, the announcement that S/A will be turned off for GPS III has generated an enormously favorable impact. A GNSS implementation plan has been generated and will come out in November. The goal is to achieve cooperation between the Japanese industry and government. The GNSS industries have been talking with the government resulting in a new commanding body being instated in the Japanese Cabinet.

Mr. Hiroshi Nishiguchi, Secretary General of the Japan GPS Council, Japan

International Association of Institutes of Navigation, United Kingdom

The International Association of Institutes of Navigation has institutes all over the world. The largest is in China and the smallest is in North Korea. Their role is to promote disseminating information on navigational matters and to promote cooperation. There has been a warm welcome to not having S/A on GPS III. The message, however, has yet to percolate down to the public and there remains a misperception over the continuation of S/A. There is total agreement in support of a 30+ satellite constellation. A GNSS back-up system is still desired and LORAN keeps coming up. There is no desire for any financial charging mechanism as proposed for the Galileo system. The failure of the private finance element has thrown the Galileo budget into disarray.

Mr. Richard Smith, International Association of Institutes of Navigation, United Kingdom

3.5. Panel 1 – Leadership: Fact-Finding Report

The recommendation from this panel on the elimination of S/A capabilities from GPS III has finally been implemented. S/A was removed by Deputy Secretary of Defense England at the urging of Dr. Schlesinger; the removal was officially announced on September 18, 2007. The Panel now has four remaining recommendations:

- The first is to place GPS III quickly under contract with early delivery. GPS III provides significant improvements over GPS IIF and provides insurance against "brown-outs" that could impact 150 million users. It is imperative to avoid GPS brown-outs. The current GPS average on-orbit life is 8.9 years. The first GPS III will not be available for launch until December 2013.
- The second recommendation is to formally commit the U.S. to the current level of service. This would enable civilian users to take advantage of GPS's proven capabilities. This service calls for 30 + satellites to be geometrically optimized for users. The masking angle affects the ability to use GPS because many users cannot see down to the horizon. The 30 + satellite constellation would insure military availability in regions with uneven terrain. It would compare to the projected capabilities of China's COMPASS and the EU's Galileo systems. It would also support worldwide use to reduce aircraft congestion under a program known as RRAIM. This is a new development that provides the integrity to allow aircraft to land at regional airports in bad weather and to use lightly instrumented developing-nation landing fields safely.
- The third recommendation is to ensure affordability to enable service without brown-outs. A sensible fast-track approach should be utilized. The expensive, complex satellites could threaten schedule as well as the constellation size. Where feasible the board recommends that use of alternative platforms be assessed so GPS satellites are not overly burdened by payloads that are not part of primary PNT operations.
- The fourth recommendation is to place the GPS signal specifications under a true national organization such as the RTCA (formerly, Radio Technical Commission for Aeronautics) to ensure transparent, technical excellence for all users. This would assure that the signal is truly compatible and help maximize its usefulness. It would call for strong participation by users as well as government agencies.

Geometry is the key in the Southern Hemisphere, where geometrical dispersion is extremely important and piggy-backing is a problem. The right orbits are needed. There was an additional request for information about dual launches. The tests should be started now because the savings could be tremendous. It was noted that there is no dual launch for GPS III, and therefore dual launch for the next group of GPS satellites will not be available. More satellites are more important than adding unnecessary functions or complexity. Currently there is no representation from civil and commercial users in this process but a national committee process may enable their participation which may help eliminate major mistakes from being made as user requirements would be considered from the beginning. One aspect of affordability is the assumptions and methodology used to estimate a satellite's lifespan. Different assumptions allow calculations showing a longer life of satellites than the mean lifespan. Some form of operational risk assessment is needed. A large number of satellites is down to no back-up; a single string. There were also recommendations to be strong on the affordability issue and to launch new satellites as soon as possible after they are delivered since they are only useful in orbit. A full operational risk assessment is essential. The track record must be taken into account and there is a need for a gap analysis. More good data is needed to enable knowledgeable decisions. A severe GPS brown-out would affect most weapons systems and most civilian users.

Dr. Bradford Parkinson, Co-Chair PNT Advisory Board

3.6. Panel 2 – Strategic Engagement & Communication: Fact-Finding Report

Geodesy Presentation

It is critical to have standardized reference systems. The reference system answers the questions such as: (1) where am I? (2) what is the location of some object or someone else? For the military, the reference system is used for missile launch sites, precision weapons, and land mines. For the general civilian, the reference system is used for borders, car, ship, or plane navigation, and to locate mineral resources. For the scientific community, it is used to determine crustal motion and sea-level change. To do all these activities, there is a need for a terrestrial reference system. To create a foundation and structure, we define a set of conventions, constants, models, and parameters which form the mathematical basis for representing locations on, above, or below the Earth. If every country implemented a different version of a geodetic reference system much of the accuracy would be lost in translating one system to another. The IERS maintains the standard and is located in France. The ITRF is defined or rationalized to be a geocentric coordinate system. The ITRF is aligned to the mean equator of 1900 and Greenwich meridian.

The U.S. DoD World Geodetic Survey (WGS) has been a global geocentric terrestrial reference system since the 1950s. It was needed because satellite tracking and inter-continental ballistic missiles required global coordinate systems. There was a WGS 1960, 1966, 1972, and 1984. DoD world geodetic systems have always conformed to and adopted international standards. They are applied to all DoD products and services: maps, charts, airfields, features data, topography, satellite orbits, real-time positioning, etc. For DoD, this system has to be applied across the board. The WGS 84 reference frame is defined or realized by the coordinates of a globally distributed set of reference points on the topographic surface of the Earth which is constituted solely by a network of permanent GPS stations. The WGS 84 reference frame is periodically adjusted to maintain close alignment with the ITRF. The positions of the reference points (DoD monitor stations) are estimated using GPS observations. The result is the DoD station coordinates and by definition the WGS 84 reference frame is coincident with the ITRF within some level of uncertainty. The process accounts for plate tectonic motion. The DoD WGS 84 reference stations are around the world. There will continue to be a need to exploit GNSS in the future and to standardize multiple satellite constellations to maintain the reference system.

There will be GPS III, GLONASS, Galileo, COMPASS, and space-based augmentation from India, Japan, and the U.S. WAAS. Users and manufacturers want interoperability, compatibility, and standardization. This leads to improved signal availability, improved integrity, and higher accuracy, which leads to real-time, seamless operations. Improvements are derived because each system uses different positions for its satellites. Some systems may use satellites that simply trail our satellites and that would not help much. Each system uses different phases. The user community wants to be able to tap into all of these systems. The Russians have had GLONASS up for a while and their stations have been offset from the ITRF and WGS 84. Also, they only have tracking stations on Russian soil. The last few years, they have been trying to improve their orbit positioning and are trying to align with WGS 84.

There are concerns in exploiting GNSS performance. These are quality assurance and enhanced performance for GPS III. There are four long-term geodetic objectives: (1) achieve a stable geodetic reference frame; (2) maintain a close alignment of the WGS 84 with the ITRF; (3) provide an independent quality assessment capability independent of current radiometric measurements used to determine GPS orbit and clock performance; and (4) ensure the interoperability of GPS with other GNSS systems. These objectives make the case for putting laser retroreflectors on GPS III. The laser retroreflectors will be on GLONASS and Galileo. A Global Standard Terrestrial Reference System is critical to future positioning and navigation with Global Navigation Satellites. Multiple systems will need to be exploited to support the increased demands of a wide range of users. The WGS 84 reference frame has been and will continue to be periodically realigned to the ITRF.

WGS 84 will continue in use. It is not clear whether COMPASS will move to the ITRF standard. The Chinese are aware of the need for standardization and are pushing towards that objective. The scientific community would gain advantage if GPS had retroreflectors in addition to them being on Galileo. The scientific community deals with very small differences and high precision applications. The retroreflectors would be 10-20 pounds or possibly less than 10 pounds and would not require wattage. The IAG offered that there are variations of one to two centimeters showing up that are very important to the scientific community which will continue to look for the highest possible accuracy. There is an Interagency Forum on Operational Requirements (IFOR) managed by Air Force Space Command that has recommended that satellite retroreflectors be incorporated into the GPS Capabilities Development Document (CDD) for the GPS IIIB block. The capability is now in the millimeter range. The recommendation is that we build this capacity now.

Dr. James Slater, Basic and Applied Research Office, National Geospatial-Intelligence Agency

ITU-R Working Party 7A Presentation

The International Telecommunication Union (ITU) is the leading United Nations agency for information and communication technologies. ITU-R is the radiocommunication core sector. The ITU-R is responsible for both terrestrial and satellite Standard Frequency and Time Signal (SFTS) services. The goals of Working Party 7A are to develop and maintain ITU-R recommendations in the TF series and Handbooks relevant to SFTS activities which cover the fundamentals of the SFTS generation, measurements, and data processing. The ITU-R recommendations are of paramount importance to telecommunication administrations and industry to which they are first directed. They also have important consequences for other fields, such as radio navigation, electric power generation, space technology, and scientific and metrological activities.

Coordinated Universal Time (UTC) originated as a common reference for coordinating time signals as a compromise between continuous atomic time and solar mean time (Universal Time). There is an issue on the future of the UTC timescale and proposals to modify the UTC definition. One modification would be to eliminate the leap second. More and more systems are adopting their own system time and there is a proliferation of international time links. This gives rise to concern that the increasing number of systems could potentially result in a multiplicity of system time scales. UTC should be the single common reference time. Many GPS users assume that UTC is the global reference, but many use GPS time directly. GPS Time is the system internal continuous timescale. It is primarily used for positioning and navigation. It is secondarily used for disseminating time. GPS has become the primary method of providing and coordinating time and frequency services worldwide. Its use in telecommunications is extensive for both the civil and military community. These uses include public switched telephone networks, wireless mobile, paging services, the internet, Network Time Protocol (NTP) servers, banking, financial transfers, sensor networks (geophysical and remote sensing), power generation, and power distribution. The full extent of GPS use is difficult to determine due to the ready availability of off-the-shelf equipment. GPS availability and capability has greatly impacted the time and frequency industrial base since time and frequency users are the majority of the users of GPS.

One issue regarding the leap seconds is that the Earth's rotation varies and additional leap seconds will be need to be inserted in coming years as NASA's space architecture is built and operated. In essence, preparing for leap seconds is like preparing for a mini-Y2K rollover event several times. Many would like to see the leap second eliminated however, there is not unanimous consent with the astronomical community. Japan is developing "trusted time" in which they just turn the system off for a second. Astronomers cannot accept leap seconds, although it is debatable whether leap seconds are needed for the atomic time scale and the Earth's rotation. A one hour difference could take a thousand years to accumulate. The use of optical clocks is coming and will be more accurate than atomic clocks.

Mr. Ronald Beard, ITU-R WP7A Chairman, Naval Research Laboratory

Options for Promoting GPS to Vendor, New User, & Global Communities

There are four recommendations to market GPS to the global GPS vendor community: (1) reinforce commitment to preservation of the current civilian signal through performance, availability, reliability, usability, backwards compatibility, and cost, i.e., no user charges; (2) issue press and media releases to alleviate foreign doubts about the U.S. commitment to GPS as a global utility for the indefinite future (Board members could host interactive sessions at key GNSS forums); (3) increase the U.S. presence at foreign GNSS sessions and actively explore opportunities to augment and enhance GPS performance with other GNSS; and (4) solicit feedback from the Board members prior to initiating any GPS signal changes or upgrades.

There are four recommendations for marketing GPS to potential new users:

- First, promote the capabilities of GPS in leading U.S. and international magazines and journals as an excellent tool for real-time computation of location, speed and altitude; for an accurate and precise source for timing; and as a free ubiquitous global utility.
- Second, identify niche areas to target for possible applications using GPS. These areas could include communication, transportation, construction, emergency services, agriculture, banking, and commerce.
- Third, encourage experts in the field to write technical articles about potential applications using GPS.
- Fourth, have Board members host town-hall style meetings on the web; use current and futuristic internet based tools such as YouTube and Second Life.

GPS is a true public utility that the average American citizen ends up using many times a day for wireless cell phone networks, electrical power distribution, and for public safety and emergency services. GPS as a key enabler for many other services that make key contributions to the U.S. economy in aviation, transportation, civil engineering, navigation, trip guidance, and farming. There is a case study focusing on the General Motors' OnStar program. GPS location and clock time are critical enablers for all OnStar services. OnStar uses GPS to be an effective advocate against crime. It is used for targeted amber alerts with the National Center for Missing Children, for stolen vehicle locations, and to provide information to assist persons in crisis. OnStar will be standard in all General Motors retail vehicles in the U.S. and Canada. There was a film presented that showed how current research by General Motors is using GPS to prevent automobile accidents. The commercials about babies being rescued and returned to their mothers thanks to OnStar could reference the GPS signal. Congress has to understand the perception that GPS is bigger than currently realized. General Motors is working on a fully self-guided system. There have been two major technological revolutions: (1) internet, (2) GPS. The public fully understands the internet, but not GPS. This needs to be corrected. The Panel still needs to work on crafting its recommendations. The Panel liked the suggestion for a GPS Capitol Hill Day. The GPS Capitol Hill Day should involve the Congressional leadership, the American Electronics Association, and the Air Transportation Association.

Mr. David Logsdon, Space Enterprise Council

Panel 2 Summary

The Panel presented the results of fact-finding on three topics: the reference frame, timing, and promotion options. It is important to consider system performance, a commitment to 30+ satellites, adding laser retroreflectors to GPS satellites, avoiding user fees, avoiding a mandate to use a specific GNSS, spectrum protection, and interference detection. They will also review the San Diego, California, radio frequency interference (RFI) event. The International Traffic in Arms Regulations (ITAR) must be dealt with even though the regulations are burdensome and stifle innovation. There is a need for broader engagement with international organizations and standards bodies, and interchangeability is a key factor for consideration.

Ms. Ruth Neilan, Jet Propulsion Laboratory

3.7. Panel 3 – Future Challenges: Fact-Finding Report

GPS is the GNSS world standard and it would be advantageous to the U.S. to maintain that position. The key is leadership and the Panel has four recommendations in that area: (1) transparent evolution of GPS with policy stability and predictable change and the seamless transition from one set of capabilities to another for civil integrity; (2) commitment to the 30+ satellite constellation for the value to the U.S. military, the national air space, and the international community; (3) maximize use of the EXCOM with its adequate existing structure, a national plan, and oversight of the evolution of GPS; and (4) international collaboration to include international partner involvement in testing changes and easing problem solving. The EXCOM should be urged to step up to a higher level, rather than simply providing supervision.

The following challenges have been identified. The first is that organizations in the Executive branch are difficult to access; therefore the EXCOM should identify tasks where they may engage. The House of Representatives has cut $150 million from the GPS budget. This budget cut is not conducive to policy stability or to the earliest possible deployment of GPS IIIA. The Congressional appropriation committees may have to go to conference and mitigate the damage. The Panel recommends reinstituting the transparent Interface Control Document (ICD) deliberative process to help all parties and describing the plan to Congress with the need to apply discipline to the process to make it a national effort. The EXCOM membership at the Deputy Secretary level should understand the position of each department and have a better national and global perspective.

It is recommended that the Board put together an industry team that briefs the presidential candidates on the importance of GPS and how it has enhanced the American bottom line.

Mr. Charlie Trimble, founder, Trimble Navigation

3.8. Update on GPS Performance Standards

DoD Perspective

The Precise Positioning Service (PPS) PS was published in February 2007, and defines the current service provided to military and authorized PPS users. The PS states the DoD commitments, i.e., the performance that PPS users can count on and is the basis for military GPS safety certifications. The SPS PS, which was published in October of 2001, defines the standard service provided to non-military GPS users, and it states the current DoD commitments for the SPS users. The SPS PS is the basis for all civil GPS safety certifications. The SPS PS upgrade process should have a revised final document in May 2008. The updated SPS PS will be a significant step forward in the evolution of GPS performance.

Brigadier General Donald Alston, Director of Space and Nuclear Operations, U.S. Air Force

Advisory Board Discussion on DoD Perspective

The Board has interest in a 30+ satellite constellation and a request for a commitment to current performance. If we fail to impress the international community, America and its allies would be at a substantial disadvantage. The DoD is working to protect GPS assets from hostile interventions, in addition to concerns over radiation and vibration. The concern is primarily about the signal in space. The 30+ satellite parameter is also important to the FAA. The 2001 PS calls for 31 meter accuracy and currently has 10 meters. It was stated that committing to the size of the constellation makes all the difference. The difference is geometric (exponential), not linear, and the extra satellites are necessary to support integrity. They must preserve backward compatibility. The current requirements process does not include consultations with the end users; however, an opportunity for comments from people outside the government might save money by considering the perspective of the maritime unions, the airlines, and other non-government users.

On January 11, 2007, the Chinese successfully proved their anti-satellite capability and stated that their achievement was not a surprise. In our effort to posture ourselves for what will follow in the coming years, it will be useful to understand how the combatant commanders will handle space combat. We have to go forward and demystify how they are depending on space. Broadly, folks have a great appreciation for how space helps, but they do not understand how it is done. We must understand and bring forward a resulting protection and augmentation strategy while understanding the dependencies. The combatant commanders have different priorities. The targeting problem has to be made more challenging and risk mitigation efforts are needed from platforms down to ground stations. The Panel recommends an effects-based approach to more fully articulate the criticality of GPS to national security. Wherever the military fights, it will have to depend on resources made available by civilian agencies and the GPS SPS PS should take that into consideration.

Advisory Board Discussion on Civil Perspective

In May 2007, AFSPC formed the GPS SPS PS Update Coordination Team to craft and informally draft an update of the 2001 SPS PS. The basic ground rules call for informal coordination only, with formal coordination occurring after the update is sent to Air Force Headquarters. The update is to document the status and services to be delivered by the current GPS constellation; in other words, a snapshot in time. Unresolved issues are to be appropriately noted, documented, and sent forward for discussion and resolution during the formal review. Only U.S. Government civil agencies participated in the crafting and review of the draft SPS PS update. The agencies included, among others, the FAA, DHS, USCG, DOC, DOS, U.S. Geological Service (USGS), Federal Highway Administration (FHWA), NOAA, and NASA. In addition, civilian comments were solicited and 261 were received. Those comments were either accepted or adjudicated. The informal review process was completed in late July 2007, and overall the civil team was satisfied with the draft GPS SPS PS update. They are now waiting for DoD to establish the process and schedule for the formal government review.

Mr. Hank Skalski, DOT Liaison to Air Force Space Command

Advisory Board Discussion on DOT Perspective

The Board is concerned that the PS does not reflect the constellation that is currently flying if it reflects 21+3 satellites. The decision-making process is unsatisfactory. The document has to be a snapshot as of today. The performance standard is the committed level of performance that the U.S. Government will guarantee to provide. The actual performance level is much better. Future consequences also returns to the piggy-back issue where an at risk satellite has another satellite put next to it. Currently, the performance standard can only reflect the Federal Government's committment. The issue is remains "where the commitment is; where is the lever?" There is concern over budget cutting decisions and the fear that we will end up at 21+3 satellites in the constellation. We need to start with the CDD to state the commitment, not the PS. The range error is not as important as having 30+ satellites.

The CDD starts with the Joint Requirements Oversight Council (JROC). The JROC polls the users, civilian and military, on their needs. Then there is an analysis, and they develop the CDD. The CDD goes to the JCS and then to the acquisition community. The Board asserted that nothing new is required other than an acceptance that 30 satellites are what are needed. The response was that no one has provided Air Force Space Command with the proof that 30 is the number that is needed. The highest advisory board, the Defense Science Board, did bring it forward.

The issue is that the Air Force has delivered more than was specified and the users got used to it. It was predicted that a lot more than 30 satellites on orbit would be the result if the specification was 98% availability for 30 satellites on orbit. This would be especially true if new satellites were launched on availability, regardless of the health of the constellation. The budget and priorities are on the table and there is not an understanding on how to influence the process. The Board needs to influence the representatives to the EXCOM. The number of satellites is a budget issue; 33 satellites will be needed for a 30 satellite constellation. It was noted that it has been recommended to make the satellites simpler and send up two per launch; this could save enough to pay for the additional satellites. The EXCOM will consider this strategy.

The Board has an opportunity to affect the receivers which come out into the market faster than the satellite processes. Within the requirements process the basic premise is to identify the requirement and bring it forward. Backward compatibility is also an issue; eventually it can't be forever. Backward compatibility will create problems in the military, and it has an impact on the rate at which we can bring out the new technology. The goal should be to make the PS a relevant document to indicate what the community can depend on the U.S. Government to provide. A buffer is needed and that, clearly where it is now, it is not relevant. It is important to have some degree of stability in the SPS document. People are making economic decisions and are counting on what they will get tomorrow.

3.9. Future of E-LORAN

The USCG briefed the Board on the current Enhanced Loran (eLoran) situation. Loran is a potential GPS alternative and backup. Congress first directed the program in 1999. Funds for improvements have been approved in the amount of $160M to modernize and enhance the system. The DOT and DHS have been tasked with the responsibility to make a decision on whether to continue to maintain it. Several steps have been taken. Last August, DOT initiated an Independent Assessment Team (IAT) to assess the national need for continuing Loran and DHS was subsequently brought in to the effort. The IAT received nearly 1000 comments; 92% favored retaining or expanding eLoran, and 80% thought it was needed as a backup to GPS. A decision was made to use existing PNT structures for the decision-making process. Both DOT and DHS have PNT Executive Committees, similar to the national level EXCOM.

The eLoran system is based on Loran-C, which has existed for the past 50 years. It provides a back-up for frequency and timing and can be used as a backup or complement to GPS. It is terrestrially based, with high power and low frequency (the inverse of GPS) making it inherently less susceptible to deliberate interference. It is GPS-like in that it requires digital user equipment. It presents position data in latitude/longitude coordinates. It provides maritime harbor entrance and approach accuracies from 10-20 meters. It meets aviation required navigation performance requirements of 0.3 nautical miles for non-precision approach and integrity. It provides coverage in many obstructed areas not served by GPS. The system is in a transitory state. New timing equipment has been installed but not yet turned on. There are 24 U.S. Loran-C stations; 19 have been updated and modernized to transmit the extra data services. The monitoring network has not yet been installed. Three new stations must be installed to expand coverage. Five additional stations remain to be built, all in Alaska. Senator Stevens is interested in having this work completed.

No funds were appropriated for 2007 and currently there are no funds for 2008. A decision is needed on whether to continue to invest in the system. To get to a full eLoran system would cost up to $400M. System modernization or enhancement would cost $15-$25M a year. The intent is to convert the sites to unmanned bases. This de-staffing will lead to lower operational costs and those savings can be redirected to modernization and enhancement. The Loran data channel is the mechanism that enables the stations to transmit the enhanced signal. Only five stations are currently transmitting the Loran data channel and another is being tested in Boston.

The Administration is reviewing the recommendation to improve the system. DOT and DHS are also reviewing the recommendations, and a joint announcement is expected by the end of the year. The question of whether the FAA was willing to use eLoran receivers as a replacement for gyros was posed. The cost of user equipment would be very high. The Assessment Team concluded in their report that the incremental cost could be affordable. Mr. Jim Darvey, a real hero, had helped arrive at the conclusion that eLoran was a prudent, affordable back-up to GPS, and a real deterrent to terrorist actions; the report was unanimous.

Twelve companies have developed prototypes for integrated GPS/eLoran receivers or eLoran/timing device receivers. It is a “nascent” industry. The FAA is a market that will provide a price umbrella for the receiver. The cost is very small. It is uncertain whether there is a commercial market. The interface for the user would cost very little more and it is not a hard decision to make. It would be difficult to recover from discontinuing the service. The eLoran back-up role is important. It produces a megawatt signal; to defeat it you would need a 40 foot antenna and 40 watts and also, the signal penetrates buildings.

DOT will provide a copy of the Assessment Team's report and a briefing if requested. A DOT representative in the audience stated that other nations are looking for the U.S. to assume a leadership role for this technology. The eLoran system needs to be codified into a formal standards document and that other countries are looking for this since they support the effort. DOT and DHS EXCOM members have clear direction to pursue eLoran and make it happen, and to prepare it for a formal Secretarial decision by the end of the year.

The estimated annual operating costs, assuming modernization are $22M per year. The concern is that it would not be a back-up without users being willing to purchase the equipment and that the real problem is figuring out how to generate a market. It was stated that the incremental cost of adding this equipment for the people for whom timing is important is so small that it would not be a problem. It is currently being discussed whether eLoran might expand to the Southern hemisphere for the U.S. although sovereign control is an issue. It is up to foreign governments to provide the system. It is a great way to provide a terrestrial based navigation system. It would be 100% backwards compatible; old receivers can use the signal, but their users would not see the upgraded accuracy or time.

Captain Curtis Dubay, Chief, Systems & Architecture, Department of Homeland Security

3.10. Future of Nationwide Differential GPS

Research and Innovative Technology Administration (RITA) and DOT briefed the Board on the Nationwide Differential GPS (NDGPS) program infrastructure and funding status. The NDGPS program is implemented jointly with the DOT (FHWA, Federal Railroad Administration, and Office of the Secretary of Transportation); the DHS (U.S. Coast Guard); DOC (National Geodetic Survey and Forecast Systems Laboratory); and the DOD (U.S. Air Force, U.S. Army Corps of Engineers). NDGPS is an augmentation system and consists of the U.S. Coast Guard maritime Differential GPS (DGPS) receivers for harbor/entry approaches at 39 sites, U.S. Army Corps of Engineers receivers for inland waterways at 9 sites, and DOT inland receivers for terrestrial applications at 38 sites.

NDGPS affords sub-meter accuracy in multiple terrestrial applications and provides accurate real-time positioning in all surface environments, including impeded environments, such as mountains, valleys, tunnels, and urban canyons. Post-processed data affords increased accuracy for resource management and mapping. There are multiple user communities. Parties currently relying on NDGPS data are national and cooperative Continuously Operating Reference Stations (CORS), NOAA, and the University Navstar Consortium (for tectonic plate monitoring).

The terrestrial mode is used to facilitate train control, and also for farming and construction. There has never been a requirements document created for the inland DGPS. DOT is performing a complete assessment of the need for the inland component. If it finds that there are insufficient transportation requirements or other Federal user requirements, DOT intends to develop a decommissioning plan for that component. The assessment is due January 30, 2008. There have only been 50 responses to a Federal Register Notice seeking comments. The Army Corps of Engineers (ACE) was not part of the assessment. There was also outreach outside the United States. The current funding is $5M for FY08 and the system has been funded with carryover funds from FY06 and FY07. Maritime coverage will be continued and operated by the USCG. In addition, the ACE will continue to operate and maintain the system for the Mississippi.

The system's large supporters were the Association for American Railroads, and the State Governors' Association. Individuals from the U.S. Geodetic Survey have spoken up. The equipment is essentially the same as eLoran and the two signals can be issued from one antenna. No one has suggested bringing eLoran and DGPS together. The assessment has looked at putting additional equipment on the eLoran towers. The towers are insulated, however, and multi-coupling would be required. The effect on the integrity calculation of the eLoran service would need to be calculated and the question regarding water vapor sensors at these sites.

It should be determined what response would be sufficient to justify maintaining the system. It has never been determined who is using it. The system is embarrassingly inexpensive. Ninety-two percent of the area in the lower 48 states has single coverage and 65% has dual coverage. Canada provides the service for the St. Lawrence River. The station in the San Diego incident area went down and the source of interference was in the San Diego harbor. The DGPS signal was lost during a three hour outage. It has been suggested to broadcast eLoran corrections over the beacon system. While the bandwidth for doing this is available it would take two to five years to switch over to another system.

Mr. Tim Klein, Program Sponsor, Department of Transportation / RITA

3.11. GPS Constellations & Support for Separation Standards

The MITRE Corporation has conducted a separation standards analysis on the applicability of GPS. The objective was to determine the GPS constellation configurations that support various separation standards for the En Route and Terminal domains. The GPS SPS PS defines the minimum requirements for GPS performance. In support of the service availability standard, 24 operational satellites must be available on orbit with a 0.95 probability. At least 21 satellites in the 24 nominal plane/slot positions must be set healthy and transmitting their navigation signal with a 0.98 probability. GPS performance has historically exceeded the minimum SPS requirement. The current constellation has 31 satellites that are operational, with 28 usable as of August 29, 2007. The availability of a defined level of integrity is the basis for determining the GPS constellation's ability to support FAA separation standards. The integrity is referred to as Navigational Integrity Category (NIC). The current separation standards and the MITRE Close Approach Probability Model are the basis used for determining the integrity or NIC values that support a defined separation standard. The current system is today's radar environment. The goal is to push for lower separation standards. The first discussion point was the assumptions used for assessing the current specified 24 satellite constellation. Then the discussion was on the various satellite constellation configurations for two and five degree mask angles. The study showed that only the GPS constellations with 30 satellites provided an availability of >0.99999 to support all current separation standards and provided a NIC that supports reduction of separation standards. In this constellation, a single satellite failure does not impact the availability of applying all current separation standards. Two satellite failures would reduce the availability of applying all separation standards.

A connection was made to the OnStar presentation where it was noted that it is important to reduce the separation standards due to the fact that new runways are unlikely to be added to legacy spaced airports to manage the risks. Twenty-one satellites would not be adequate for the performance-based standards for FAA future requirements. An equivalent to the radar separation calls for a NIC value of 7 or 8, dependent on the satellites in view. A NIC of 9 was dictated by the Notice of Proposed Rule Making (NPRM). The NPRM talks about classes of airspace. The mandate is higher in the major metropolitan areas. The study assumed that S/A would be on.

The FAA regards the appropriate number of GPS satellites to be 27 to 30 in order to provide separation standards equivalent to those that radar affords. The new national space design has already begun. The standards and procedures are charted and in use today. The demonstration project has been progressing in Alaska since 1999 where they will prove the safety case to assure the signal and accuracy for separating aircraft. Once the safety case is proven, the project can be deployed nationwide. By 2013, services will be provided in a few areas, and that will serve as the basis for expanding nationwide. The full nationwide system, subject to funding, may be completed by 2016, and the current system would not be adequate at that time. There is an aviation rule-making committee that has been charted by the Administrator to identify incentives for early equipage.

With increased traffic and the gains from spacing, it is inevitable that a contribution from the GPS will be needed that exceeds that currently provided. During the interim, people need to decide what to invest. This utility will require a long lead time and continuity is needed. The FAA requirements must be known for the community to determine what to invest in. The separation standards were developed with industry based on current performance standards. The Acting Administrator is aware of the need for more satellites. The U.S. should focus leadership in this area,focused on the FAA, which has the ability to enable things for the future. The longest lead time involves getting the U.S. to realize that a 30 satellite constellation is required. The national level leadership needs to understand that the FAA sees the need for a 30 satellite constellation. The former FAA Administrator had announced that the goal was to sustain the existing constellation – not the current performance standard. The FAA now needs to get back to the EXCOM, but cannot do it by the November meeting. They are trying not to be myopic – there are surveillance pieces and navigation pieces that need to be addressed and integrated to come up with overall aviation requirements. The study could be completed in 2008 to provide the FAA Administrator with the data to make a recommendation. It is also important to understand that the number of satellites in orbit is meaningless if they are not properly located. The FAA needs to understand forward policy. The FAA believes that dual frequency is critically important and must weigh which services are on which satellites.

The FAA had to fight hard with the Air Force to get a 21 satellite guarantee. There are other documents in the Air Force system where they can change the performance standards without changing the 21 satellite commitment. Much of the country's air space is used only for military purposes, which affects capacity. The lead time is needed to complete the rule-making process and to equip fleets of aircraft with new equipment for the mandate for the 2020 introductory date. There is also the need to consider legacy aircraft. The FAA is considering whether to provide services to RTCA Do-260 fitted aircraft or only to Do-260A fitted aircraft. It involves concerns over how to stimulate equipage and how to permit a payback for having installed equipment. It was clarified how NIC values were determined; rich and complicated interface and with fundamental issues affecting the values. The question is the wisdom in shifting integrity management to the aircraft for the responsibility to determine the efficacy of the constellation status if we are just replacing radar surveillance with GPS surveillance. Congestion is a global issue and the rest of the world looks to the FAA for leadership. WAAS receivers will be required and the FAA should try not to be parochial because they do influence the rest of the world.

Mr. Rick Day, ATO Vice-President, Enroute & Oceanic Services, Federal Aviation Administration

3.12. Advisory Board Roundtable Discussion

The Board believes there is a need for an affordability paper to identify value-added from increasing the GPS constellation to 30+ satellites. The Performance Standards should be reviewed noting that the planned level of performance over a period of time is important and being aware that the current performance specification document is vague in its utility. There is more than a gap between the performance standards and the future requirements for both the FAA and the military and it requires attention. The National Academy of Sciences (NAS) should perform a study on the ways in which GPS has become a public utility. The NAS already performed a study on GPS in the late 1990’s, and it would be worthwhile asking them to get involved again. There needs to be a study clearly exploring the values added for the country or the world from the range of available GPS options and alternatives.

The Leadership Panel recommends a formal commitment to, at least, the current GPS level of service. The current level needs to be clarified to distinguish diverse orbits versus satellites placed in piggy-back orbits. The rationale is that the current level of service is poor in parts of the world. The Australian part of the world needs a better level of service and needs the satellite constellation to be geometrically optimized. It is also recommended to place GPS III quickly under contract with early delivery. It is important to avoid redesigning the GPS III satellites and, also, it would be desirable to trade more satellites for less sophisticated and less complicated ones. While within the Air Force there has not been ample support for the larger GPS constellation, the Air Force accounts for 80% of the DoD fuel costs. Those fuel costs could be significantly lowered with reduced separations enabled by GPS, and could be a way to get some buy-in from constituencies in the Air Force. Studies on this subject are underway to quantify these potential savings. United Airlines is currently engaged in performing a similar study. Preliminary results from the United Airlines study show that the fuel savings amount is substantial (well over hundreds of millions U.S. dollars). Qantas had also engaged in a similar study that could be useful and they will also request those results. There is a lack of opportunity for nongovernmental users to provide meaningful input into the decision-making process. The national GPS users should have an opportunity to participate in the decision-making process early and often. Former Secretary of Defense Robert McNamara once said that he could only slay a limited number of dragons in one day. The JROC process might be avoided in some cases. There is a need for a process similar to the RTCA which would help to avoid the phase-in problems that have been described above. A move toward a more open national decision-making program will, however, have to await the arrival of the next Administration. The simplest recommendation in the short term is to ask the Air Force to return to the ICD process. Up until several years ago there was a process that allowed outsiders to participate and currently, governmental agencies are not a good substitute for professional expertise from the private sector. With respect to air traffic management the expanded use of unmanned aircraft should be taken into consideration. The problem in Afghanistan should be quantified to show the value-added proposition. This will be expanded and presented in a draft paper. It was stated that the IFOR had approved the GPS III geodetic requirement for GPS IIIB, but not on IIIA. Galileo will use laser retroreflectors to meet its geodetic requirements over the next 30 years. As a result, laser retroreflectors may need to become a GPS IIIA requirement in order to keep GPS III competitive with the other new systems. One example that the Board discussed was that more and more aircraft are flying into Beijing even though the current Chinese air traffic control system is not optimal. A 30+ GPS satellite constellation would impact much of the world; the U.S. would not be doing this for China but rather for the air traffic flowing into China and other areas with less than optimal air traffic control systems.

3.13. Board Assignments & Future Tasking

The next EXCOM meeting is tentatively scheduled for the March 27-28, 2008 timeframe.

The Board endorses the GPS Capitol Hill Day and views it as critical. It is suggested that a statement showing the importance of the 30+ satellite constellation to homeland security be issued and it will be evaluated further.

At this stage tasks for Panel 1 and Panel 2 have been identified and assigned. There is an ITAR issue to deal with in regard to Panel 3 – Future Challenges, as well as continuing work on a vision paper.

4. Third Meeting: March 27-28, 2008

4.1. Location and Agenda

Embassy Suites
1250 22nd Street Northwest
Washington, D.C. 20037

Thursday, March 27

9:00 - 9:05	BOARD CONVENES Call to Order	Ms. Diane Rausch, Executive Director, NASA, National Space-Based PNT Advisory Board
9:05 - 9:15	Welcome & Opening Remarks	Mr. Badri Younes, Deputy Associate Administrator, NASA Space Communications and Navigation
9:15 - 9:30	Introductions, Announcements, & Agenda Vision - What we want to	Dr. James Schlesinger, Chair Dr. Bradford Parkinson, Vice-Chair

	accomplish	
9:30 - 9:50	U.S. Update on GPS, PNT Policy, & PNT EXCOM	Mr. Michael Shaw, Director, National Coordination Office for Space-Based PNT
9:50 - 10:40	International Member Update & Regional Reports (Up to discretion of Intl. members)	

- Gerhard Beutler (CH), International Association of Geodesy
- Hiroshi Nishiguchi (JP), Japan GPS Council
- Arve Dimmen (NO), Norwegian Coastal Administration
- Keith McPherson (AU), Airservices Australia
- Richard Smith (UK), International Association of Institutes of Navigation

10:40 - 11:00	BREAK Group Photo	
11:00 - 11:20	U.S. State Department GPS Initiatives International Cooperation/ICG	Mr. David Turner, Deputy Director, State Dept. Space & Advanced Technology
11:20 - 11:40	FAA NAS Modernization GNSS Evolutionary Architecture Study	Mr. Leo Eldridge, GNSS Group Manager, FAA Air Traffic Organization
11:40 - 12:00	Department of Commerce GPS Priorities Level-Playing Field & Open Access	Mr. Edward Morris, Director, DOC Office of Space Commercialization
12:00 - 1:00	WORKING LUNCH Annual Ethics Briefing	Ms. Rebecca Gilchrist, Senior Attorney, NASA Office of General Counsel
1:00 - 1:30	Protecting RNSS Spectrum Domestic & International Activities	Mr. Karl Nebbia, Associate Administrator, NTIA Office of Spectrum Management
1:30 - 2:00	GPS III Requirements Development Process for Civil/Industry	Lt. Col. Harold "Stormy" Martin, Air Force Space Command - GPS

	Input	
2:00 - 2:30	DoD GPS Management & Authorities GPS Performance Standards & ISs	Dr. Steven Huybrechts, Director, DoD Space Systems, OSD/NII
2:30 - 2:45	BREAK	
2:45 - 3:45	Leadership Panel Updates & Recommendations	Dr. Bradford Parkinson, Stanford University Mr. Martin Faga, former CEO MITRE
3:45 - 4:45	Strategic Engagement & Communication Panel Updates & Recommendations ▪ PNT Hill Day Report ▪ Aviation Benefits Briefing	Ms. Ruth Neilan, Jet Propulsion Laboratory Mr. David Logsdon, Space Enterprise Council
4:45 - 5:00	Afternoon "Wrap-Up" Discussion & Announcements	
5:00	ADJOURNMENT	

Friday, March 28

9:00 - 9:05	BOARD CONVENES Call to Order	Ms. Diane Rausch, Executive Director, NASA, National Space-Based PNT Advisory Board
9:05 - 9:15	Chair/Vice-Chair Feedback 2008 Priorities & Work Plan	Dr. James Schlesinger, Chair Dr. Bradford Parkinson, Vice-Chair
9:15 - 10:15	Future Challenges Panel Updates & Recommendations	Mr. Charles Trimble, founder Trimble Navigation Dr. Robert Hermann, Global Technology Partners
10:15 - 10:30	BREAK	
10:30 - 12:00	Board Member "Round Table" Discussion 2008 Board Assignments & Panel Taskings	All
12:00 - 1:00	WORKING LUNCH PNT Advisory Board "Wrap-Up" Discussions	
1:00	ADJOURNMENT	

4.2. Opening Remarks

The NASA Space Communications and Navigation (SCAN) program activities regarding program oversight and policy were previously divided across several NASA Mission Directorates and have now been brought together under a single office. NASA has had long-term reliance on GPS and GNSS: both are critical to space exploration. NASA has taken these capabilities from the ground to low-Earth orbit, past the GPS constellation, and eventually to the Moon. NASA has also worked to secure and protect the spectrum necessary for GPS and GNSS; and, subsequently, taken the lead in space-to-space applications. NASA is currently engaged in multiple activities to improve system accuracy. The Space Enterprise Council of the U.S. Chamber of Commerce is working with NASA on development of the lunar architecture, which includes navigation. The Space Enterprise Council is eager to assist NASA in defining standards and technology requirements. The NASA architecture includes navigation requirements such as in-space navigation, rendezvous, and lunar landing among others. The specific requirements are in the process of being defined and, once ready, NASA will welcome the Council's help in executing them. The preliminary architectural roadmap is, at this time, anticipated to be ready by December 31, 2008.

Mr. Badri Younes, Deputy Associate Administrator, Space Communications and Navigation Program, NASA

4.3. GPS, PNT Policy, and PNT EXCOM

Since the last Advisory Board meeting the following actions have been accomplished: (1) contract for upgrade of the GPS Operational Control Segment (OCX) has been awarded; (2) National Coordination Office completed its Five-Year [2008-2012] Plan for Space-Based PNT and forwarded it to the White House; and (3) FY 2009 budget assessment has been completed.. The Five-Year Plan is the first comprehensive look at the full range of activities where the Federal government intends to invest over the next five years. Both the Five-Year Plan and FY 2009 budget document include an assessment and resource allocation.

In September 2007 the FAA Administrator wrote a letter to the International Civil Aviation Administration (ICAO) to reiterate the U.S. Government offer on the GPS positioning services and extending it to WAAS; both free of direct user charges. This offer was received and accepted in December 2007. The GNSS Providers meeting was held in Vienna, Austria, in February 2008 as part of the ICG. There has also been on-going work on the PNT architecture with nineteen recommendations under final consideration. The 2007 annual report for the executive committee and coordination office has been published. Also, the Maritime Information Operations Center at the Navigation Center (NAVCEN) south of Washington D.C. has been upgraded. Finally, the DOT has decided to continue supporting the inland component of nationwide differential GPS. Close attention is being paid to securing the necessary budget support. There is a longstanding objective that there should be no degradation in service due to funding issues, which is also tied to issues of GPS performance standards.

Federal budget support: FY 2008 marked the first year funding lines appeared in civil budgets for GPS civil capabilities. This budget includes $7.2 million in the DOT, split equally between the FAA and the Federal Housing Administration (FHA). The FY 2009 figure is $27.0 million in the FAA budget. Regarding degradation of services, from the civil perspective, a key issue is to promote compatibility with other constellations; interoperable signals can prevent service degradation.

On future matters, the 2008 work plan was completed in August 2007. The plan targeted 50 items for completion by the close of the current Administration; 30% of these are at this time complete. Given the pending Presidential transition, the National Coordination Office is compiling a transition book on space-based PNT.

Mr. Mike Shaw, Director, National Coordination Office

Summary of Advisory Board Discussion on GPS, PNT Policy, and PNT EXCOM

The Board is concerned that money is not following the policy mandates and some areas are not receiving adequate funding. Furthermore, some activities are not being adequately tracked, e.g. determining where interference occurs and what could be done about it. All departments are currently building their FY 2010 budgets; the FY 2009 budget before Congress contained only 'placeholder' money.' The FY 2010 budgets show which decisions are being implemented. The November 2008 EXCOM meeting will review the FY 2010 budget work before it goes to the President. The Board believes the DHS Interference Detection and Mitigation effort appears to be directed largely toward mitigation; now the question is whether there are efforts underway to improve detection. Currently those efforts are limited and this should be addressed in the DHS FY 2010 budget. The Federal departments' unreleased budget figures are highly sensitive and, thus, it has been difficult for the NCO to secure budget information. GPS-related funding falls within multiple departments; each department's budget might be reviewed by a different Congressional committee and not all committees are equally generous to GPS. The EXCOM's senior leadership could help reinforce these requests. Knowledge of what is happening internationally is readily available; there were few surprises as schedules rarely 'moved to the left' but 'often moved to the right', e.g. originally Galileo planned to achieve full capability by 2008; the current target date is 2014. With the current launch schedule, the U.S. should remain competitive and remain the 'gold standard'. The Board also urges the DOS to not settle for just compatibility with Galileo, but to seek interoperability as well, and to add a third criterion - interchangeability. A user should be able to substitute a Galileo-based signal for a GPS-based signal with no loss of accuracy; this will require addressing relevant concerns up front.

4.4. Regional Reports

International Association of Geodesy (Switzerland)

GNSS has played an essential role in geodesy in maintaining and densifying the International ITRF; monitoring earth rotation; atmosphere monitoring; and Precise Orbit Determination (POD) of LEO satellites. It is anticipated that this role will continue for 30 years or more. The IGS provides ephemerides for all currently active GNSS satellites, both the U.S. GPS and Russian GLONASS, and other functions. Many important space/Earth science programs, including CHAMP, GOCE, and GRACE A & B, would not function without the highly accurate information the IGS provides.

There are also issues regarding GNSS constellations. GPS was designed based on a daily repeat orbit; consequently, a specific receiver in Australia might never see a particular satellite; a problem of this constellation. GLONASS satellites present a different pattern, as they operate on an eight-day repeat cycle. A receiver anywhere in the world sees every satellite over an eight-day period. Performance analyses (number of simultaneously visible satellites at 9x% of time in a latitude band of ±xy degrees) between the actually maintained 30-satellite configuration (in 24 orbital slots) and the 'guaranteed' 24-satellite constellation are not insignificant. Also, 30-satellites in a 30 orbital slot configuration made, at least on paper, GPS look less good than other GNSS proposals with 30 satellites. In practice, however GPS to this day still remains the 'gold standard' since the other systems are not in full service yet. In order to be 'really useful for science,' all GNSS system providers should share full technical information on the space segment and signal structure. Further, the scientific community, organized as the IAG, is committed to exploiting the full potential of all GNSS systems which will require combining all systems measurements in a single analysis; placing laser retroreflectors on all GPS/GNSS satellites; and expanding the GPS constellation to 30-plus equally-spaced satellites. Currently 400+ receivers track GPS; only 30-40 receivers track both GPS and GLONASS. It is believed that a 30-satellite constellation is needed to address many biases in the system. The number of GLONASS monitors has been increasing for the past three years.

Another key issue for the International GNSS Committee is the 'utility of making information available'. Without receipt of comprehensive information, the combination of signals from different systems becomes difficult. The establishment of a single system reference frame is crucial, and must be emphasized to the providers at the ICG. System utility improves when transparency is established.

IGS had a working group to address the role it may play in the development of an integrated ground receiver network that could monitor all GNSS constellations. This work was proceeding in concert with the receiver manufacturers since it could not be achieved without the willingness of industry to produce combined receivers. The Novatel Company was committed to providing receivers and currently it was producing Galileo receivers for the European Space Agency. Ground equipment should be available. Few ground-based GLONASS receivers had been established because, first, the constellation had originally had limited commercial utility; and, second, because the Russians lacked a good track record on maintaining a given number of satellites in orbit.

The Advisory Board expresses strong support for laser retroreflectors on GNSS satellites to meet future geodetic requirements; these are completely passive and weigh only a few kilograms. NASA is generally prepared to pay for the acquisition of retroreflectors. Retroreflectors will become even more important in the future when multiple systems are in operation.

Mr. Gerhard Beutler, International Association of Geodesy, Switzerland

Japan GPS Council (Japan)

The basic Japanese law promoting the utilization of geospatial information was established in May 2007. The implementation plan following this law will be published in March 2008; it currently only awaits Cabinet approval. There are two important points regarding this law. First, the law legislates PNT utilization in terms of monitoring the security of the nation and its borders; and, second, it recognizes the importance of looking in four dimensions rather than the two-dimensional view traditional to Japan. This law places definitions of the geospatial service, Geographic Information Systems (GIS), and space-based PNT within a legal framework. There is also Japanese counterpart to EXCOM. To make effective use of GNSS (including GPS), the government needed to provide stable service of space-based PNT to assure Japanese citizens of continuity in PNT services. The next step for the private sector is to promote a basic law for space utilization. There will be a case for the importance of space-based PNT at a special committee meeting to be held on the subject.

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

Norwegian Coastal Administration: Maritime Safety Division (Norway)

On February 26, 2008 there was an event involving GPS SVN23 at which time the satellite gave out erroneous position information. Several maritime Automatic Identification System (AIS) users noticed this immediately; the problem affected only a few ships in limited areas. Nonetheless, this points to potential problems which underscore the need for transparency and for the industry to pay attention to its responsibilities. Also, at the previous Board meeting in October 2007 a map showing diminishing Arctic ice coverage was presented. With this diminishment, Northeast Passage or the “direct Polar route” will likely emerge as an important global shipping route within the lifespan of GPS III. Safety of navigation in that region will be of increasing importance. Challenges include the effects of GNSS orbits, since for this region it is more difficult to achieve vertical solutions compared to other parts of the world. This is further complicated by the sparse distribution of reference stations. There are two on-going strategies: first, add more ground stations or second, improve network interchangeability. Constellation size is also important given the issues of terrain masking common along the Norwegian coast. While there are reports that ice coverage in the Arctic had increased since the previously-shown photograph, measurements of stationary ice made over time shows it is thinner.

Mr. Arve Dimmen, Norwegian Coastal Administration, Norway

Air Services (Australia)

GBAS in Australia is pre-certified for operations with some restrictions at Sydney International Airport. Since November 2006 nearly 1,000 landings have occurred using the system. A single GBAS ground station provides precision approach paths to all six runways at Sydney. There are four GBAS manufacturers in the world; one of which (Honeywell) will be certified by the end of 2008. Experience to date shows that benefits derived from these technologies are specific to each setting; the advantages accruing in Sydney might not be the same as those achieved elsewhere. Pre-certification systems are in use at Sydney, Australia (Qantas); Bremen, Germany (TUIfly); and Guam (Continental Air Micronesia). Another system is at Malaga, Spain, for testing.

Mr. Keith McPherson, Airservices, Australia

International Association of Institutes of Navigation (United Kingdom)

The International Association of Institutes of Navigation has been 'spreading the word' about the work of the PNT Board. This has been done mostly at a meeting with the chair of the British Parliamentary Committee on Transport. The most common queries received regard implementation of GPS III. In Europe there is an on-going perception of GPS being a military system; underscored by quoting several comments to this effect. Those who advance this view are not likely to yield it. Separately, the decision to proceed with eLoran had been widely welcomed.

Capt. Richard Smith, International Association of Institutes of Navigation, United Kingdom

4.5. U.S. State Department GPS Initiatives

The primary objective of the 2004 Policy is to achieve GNSS compatibility defined as 'the ability of U.S. and non-U.S. space-based PNT services to be used separately or together without interfering with each individual service or signal'. 'Almost as important' is interoperability, which is defined as 'the ability of civil U.S. and non-U.S. space-based PNT services to be used together to provide the user better capabilities than would be achieved by relying solely on one service or signal'. Interoperability is one step beyond compatibility and would allow navigation to occur with one signal from each of four different systems with no additional receiver cost or complexity. Another definition for interoperability is that any four GNSS satellites provide seamless positioning with no loss of performance. The term 'No loss of performance,' sets a more rigorous standard. Currently there is still no agreed upon definition of interchangeability.

The Department of State has many on-going activities with Europe, Russia, Japan, India, and Australia. The 2004 agreement focused on GPS and Galileo and led to working groups on near-term technical issues, longer-term technical issues, trade, and security. The perception that Europeans may be dismissing GPS as a military system has not affected the technical cooperation on the task force work. Cooperative discussions with Russia followed from a 2004 joint statement and included a pending satellite conference in Moscow. The Japanese QZSS system is the most interoperable with GPS; with all frequency bands compatible. India had completed an augmentation system and initiated design of a regional system called GPS-IRNSS (Indian Regional Navigation Satellite System). Australia is also a good example of cooperation with a nation that provided important ground support; including the April 19, 2007 signing of a joint U.S./Australian Statement on Civil Use of GPS. The International Committee on GNSS is a voluntary, multinational body where providers and users address such topics as compatibility and interchangeability. The ICG goal of 'encouraging compatibility' is a bit different from the U.S. policy of 'ensuring compatibility'. Not all nations placed the same emphasis on compatibility as did the U.S. The U.S. is hosting the third ICG meeting near Pasadena, California, in December 2008.

As the ICG matures it may become a mechanism for private sector participation in GNSS, such as the ITU has with communications. This would help identify unintended consequences for the private sector that might result from government actions. Nothing has, of yet, been organized on the international level for GNSS. In the meantime industry participation will be welcome at the next ICG meeting through the Department of Commerce and Industry Council.

Mr. David Turner, Deputy Director, Space & Advanced Technology, Department of State

4.6. National Airspace System Modernization

GPS Performance

The FAA is critically dependent on GPS performance. GPS alone is not suitable for safety-of-life applications but via two augmentation systems it helps meet the FAA's prime objective to provide safety-of-life services, such as precision approaches. The first system, WAAS, will be fully operable by the end of year for en-route navigation. The second system, Local Area Augmentation System (LAAS), provides landing services down to zero visibility. LAAS is currently provided throughout North America; 50 airport facilities use it to provide a much higher level of service than came from existing legacy services. An additional non-precision capability, Required Navigation Performance (RNP), is a two-dimensional service for which WAAS provides coverage. RNP monitoring stations currently do not exist in the southern hemisphere.

WAAS

The WAAS enterprise schedule is working toward completion of the second of four phases. The final target date for a future dual-frequency system (L1/L5) is more difficult to define. Completion should come five years after a full constellation of 24 satellites with L1/L5 is available. Aircraft equipment generally has a 10 to 15 year lifecycle so system changes should not be too difficult to upgrade. WAAS flagged an 'event' that occurred on October 8, 2007, and no interruption of service took place.

GNSS Architecture

The GNSS Architecture is an ongoing study to provide a worldwide capability of LPV-200, which allows aircraft to descend down to 200 feet above the runway. It is difficult to prove an aviation system will not fail since it is required to account for everything that might go wrong during an expected 40-year existence. The study assessed options for determining integrity with aircraft-based, ground-based, and satellite-based approaches. The conclusion is that a 'layered approach' made the most sense. The satellite approach offered the best way to eliminate errors that might contribute to time-to-alarm; ground-based offered greatest accuracy; and aircraft-based offered greatest flexibility. The question is to determine the trades that should be made to produce the best system. The alternatives are: GPS Integrity Channel (GIC); RRAIM, and Absolute RAIM. Relative RAIM is only effective when 27 or more satellites are available; Absolute RAIM requires 30 satellites.

Pending the necessary engineering work and DOS success in bringing about GNSS interoperability, the FAA may be able to achieve its needed higher confidence levels with the number of GPS satellites currently in orbit. Presently 30 to 32 satellites ensure a nominal population of 24 GPS orbital slots. Providing full benefits would require a satellite pattern of 6 x 5, with 36 satellites in orbit to maintain these 30 orbit slots.

While, theoretically, 24 fully interchangeable satellites might be sufficient, it remains to be proven in practice. First, it requires running the control segments of Galileo through 'all the snares and traps' that have been run on GPS. Interchangeability is a 'noble goal,' but it is uncertain the political desire exists. GPS is an extraordinarily well operated and maintained system. In the past 10 to 20 years there had been 60-70 'notable events' caused either by "mother nature' or by system faults that could have caused hazardously inaccurate information to be relayed to aircraft.

Mr. Leo Eldredge, GNSS Group Manager, FAA Air Traffic Organization

4.7. Department of Commerce

The role of DOC in PNT extends to NOAA, the National Institute of Standards and Testing (NIST), and the Census Bureau, among others. The Department's role as a space-based PNT provider and developer includes the National CORS network; the Online Positioning User Service (OPUS); and the Analysis Center Coordinator for IGS. In these activities the DOC has provided atmospheric modeling; guidelines for real-time networks; and research and development related to the atomic clocks and frequency standards. The DOC also has a role as a promoter of space-based PNT; hosting the NCO as a member of the PNT EXCOM; and representing commercial and civil interests in PNT policy processes.

The Department is particularly aware of the economic value of space-based PNT and continues to advocate modernization funding. No DOC agenda for 2008 is more important than ensuring U.S. industry of access to the Galileo markets for equipment, infrastructure, and value-added activities. The second priority is to undertake studies that tell the broader story of GPS benefits to national security, civil life, and economic progress, with emphasis placed on the third. There is now a bill before Congress whose goal is to ensure that DOC's work relative to PNT be written into law. Among other things, this bill would provide a 'permanent home' for the National Coordination Office and ensure that the current PNT-related activities are carried into the next Administration.

There is an ongoing concern in the community that the DOC may lean too far in the direction of promoting economic benefits at the expense of protecting the spectrum. There is a DOC action item to work on this particular issue. Similarly, the NCO is tracking the matter to ensure continued GPS frequency band protection.

Mr. Ed Morris, Director, Office of Space Commercialization, Department of Commerce

4.8. Protecting Radionavigation Satellite Service Spectrum

NTIA

RNSS spectrum protection is both domestic and international. NTIA takes a different approach to the RNSS wavelength compared to other radio spectrum activities. Historically the NTIA set emissions limits consisting of an on-channel power level, along with limits on out-of-band transmissions. Commonly, the latter is set at 40 or 60 dB down from the main signal and without reference to other radio signals. These standards are accepted domestically and internationally. However, as RNSS has been subject to continuous technological change and provision for its protection it is likely to conflict with existing generic standards. This, in turn, requires other members of the radio community to adjust their practices. The Communications Act of 1934 established the Federal Communications Commission (FCC) and NTIA as co-equal regulators. The FCC is for non-federal users while NTIA is for federal users. This is shared management and, consequently, the NTIA lacks the authority to dictate processes and procedures favorable to GPS. NTIA has on-going efforts to develop rules for new technologies and respond to aspects of FCC rulemakings that might impact RNSS or the GPS system, e.g. when mobile satellite service first appeared, NTIA set limits for those services to protect GPS reception in the aviation environment.

Ultra-Wideband

The development of ultra-wideband (UWB) rules without impinging on other bands has been difficult. NTIA undertook to negotiate an agreement that sets a number of limits; significantly, the previous standards for unwanted emission levels had been changed to create limits specifically designed to protect something specific, i.e. performance of RNSS. This constituted an exception level of protection as NTIA had not acted to prevent other issues from interference from these devices. Part of the issue is that the GPS requirements on the receiver side continue to change; for example, the discussion on protecting the aviation environment occurred before GPS devices were common in automobiles, cell phones and elsewhere. One reality is that one 'simply cannot change the rules for the radio community every year.'

Mobile Satellite Service/Ancillary Terrestrial Component

The scenario used for Mobile Satellite Services was developed in 1994; GPS was then only an emerging application. The scenario was theoretical and concerned landing an aircraft with an antenna on its top at an airport with 10 degrees of masking angle, and with a single unlicensed Mobile Satellite Service (MSS) emitter within a 100 meter radius. Prior to 2000 the ITU lacked the necessary information on civilian GPS receivers to perform the needed interference analysis. When that interference analysis was done, the MSS community at the ITU had agreed that this particular scenario (-70 dBW per megahertz for out of bandwidth emissions) should be limited to the big LEO satellites. Further, the ITU concluded that any additional new service or new entrant technology would require additional study to determine appropriate standards. Yet despite this, the FCC continued to put forward the -70 dBW standard for each new entrant technology, e.g. this had been used when the FCC had a rulemaking introducing ATC (Ancillary

Terrestrial Component) into mobile satellite service bands. The GPS Industry Council negotiated with the sole U.S. MSS operator and reached an agreement to improve the -70 standard to -90 or -95 for handsets, while maintaining the -70 for satellite phones. When a negotiated agreement was reached with the sole member of an industry, the proposed rule based on that negotiation was adopted. However, in this instance, the NTIA and the FCC had continued use of the -70 standard. In consequence, the NTIA now has more work to do because rules must be individually negotiated with each individual proponent. This was done because such proponents had GPS in their products. There is a potentially severe problem and the concern of finding a lever for resolving it. The administration could apply pressure and resolving the matter was in everyone's interests. The NTIA has two options for protecting RNSS: (1) focused steps to manage the spectrum, or (2) entirely recast the management of the spectrum. The 'one size fits all' approach to out-of-band emission limits for RNSS to protect the noise floor is not an attractive option. A 'rational case-by-case approach' promotes the introduction of the new technology without risking GPS innovation.

MSS is no longer just a few handsets talking to satellites; rather, MSS is, potentially, a whole environment of cell phones connected into the system. The FCC had stalemated on the question of the value to be set for protection. NTIA and FCC have agreed that the -70 dB standard would remain for the time being, and all new systems need to come to NTIA for approval. The FCC resisted creating a blanket policy because there had been considerable debate over what protection levels were required, particular in relation to UWB. 'Rational heads' have opposed undertaking open rulemaking, believing that firming up the GNSS protection requirements needs to occur first. For the manufacturers the issue is not one of the requirements themselves which the manufacturers can meet but with the consequences of 'drawing a line in the sand.'

GPS is a global utility and at the recent World Radiocommunication Conference (WRC), a proposal that ATC be added to the MSS band was introduced rather late in the proceedings. At the time, rules for more than one MSS provider carried the improved out of bandwidth emission limits [-90, -95], but that the FCC removed them arguing it lacked technical information for any basis other than -70. Adding ATC to the GPS bands affected GLONASS, COMPASS and Galileo by raising the level of noise floor within that band. It is unfortunate that the benefits of the U.S. rules cannot be carried into the international arena until these issues are settled domestically. The persistence of the -70 standard is distressing. The 6-foot separation scenario produced a figure of -105. There is a request to work to eliminate the -70 standard from U.S. regulations.

GPS Re-Radiators

The NTIA has addressed GPS Re-radiators because these were being sold as unlicensed devices, which are not permitted to operate in restricted bands. GPS Re-Radiators have now been removed from retail shelves and their manufacturers 'clearly informed' that they could be sold in the U.S. only to specifically authorized individuals. There have been many requests for exceptions, but no sufficient justification has been presented. These devices are still sold internationally. In practice, a limited number are available from non-U.S. firms through the Internet.

Summary

The NTIA is the guardian of the Federal spectrum; budget authorities cast ‘a greedy eye’ on the spectrum, viewing it as something to be auctioned. It is NTIA’s responsibility to protect the necessary Federal uses of the spectrum.

Mr. Karl Nebbia, Associate Administrator, Office of Spectrum Management, NTIA

4.9. Space-Based Positioning, Navigation, and Timing

The recently issued 4650.05 directive on PNT governance within DoD realigned existing functions among new entities. This was reflected in the 2006 memorandum from the Deputy Secretary of Defense that recommended that a single office be responsible for PNT. The directive establishes responsibilities with respect to policies and procedures. One change was that Assistant Secretary of Defense Networks and Information Integration (ASD/NII) has been put in charge of PNT policy and all aspects of GPS. This does not affect the Air Force’s responsibilities for GPS acquisition and operation. Additional responsibilities were added related to navigational warfare; approval and publication of the PPS PS; and oversight on behalf of DoD of an interagency PNT Architecture effort.

Dr. Steven Huybrechts, Director, Space Systems, Department of Defense

4.10. GPS III Requirements Development Process

This briefing illustrated a history of GPS III capabilities development and IFOR process for GPS III. It addresses several issues including the Defense Science Board's desire to limit each satellite's mass to permit dual launch; activities of the High Performance Team (HPT); and interagency GPS IIIA requirements and notional GPS III Timeline.

Lt Col Harold Martin, Air Force Space Command

Board Discussion

The Advisory Board is concerned about the effect of early decisions in the GPS program such as single launches, and the effect they are having on current costs. The board believes that $60 million should not be added to future launch costs simply based on the past practice of using a single launcher per satellite vehicle when it is capable of launching two satellites into different planes. The general issue back in the early days was related to decisions that forced cost increases that resulted in decisions to reduce the number of satellites in the constellation, which worked against the desired outcome. The Board also believes that dual launch could potentially reduce launch costs, thereby permitting deployment of additional satellites. The GPS III CDD does not contain mass restrictions as a requirement. However, in practice, a single satellite was launched to replace one that had failed; satellites generally did not fail at the same time.

The Board is also concerned about the venues available to discuss GPS interfaces and specifications. The GPS requirements process is supposed to be an interagency process with all agencies engaged in making GPS better. In practical terms, however, schedule is generally driven by budget and budget is not always closely related to performance. Also, there are non-PNT payloads on the GPS that are driving launch costs up. However, the Air Force believes that adding requirements without proper validation would substantially raise the cost of each satellite which could cause cost increases on individual satellites that would work against the goal of having more satellites.

Also, there seems to be some confusion as to the AF commitment to maintain the GPS constellation. While the only number 'out there' is the current military requirement of 24, it is not clear whether this is stated as 24, or 21 plus three spares. There is no relevant document stating the exact number; rather, the focus is on the accuracy the system was expected to provide.

Many public and private agencies are pushing for a 30-satellite (equally spaced) standard. Assuming a 12-year lifespan, raising the standard constellation from 24 to 30 would cost about $100 million annually. One way to control costs could be to limit satellite mass; instead, some non-PNT payloads continue to design heavier packages to put on the satellite. The heavier payloads raise mass, which increase costs, and in turn reduce the ability to have more satellites in the constellation.

Another issue is foreign user input to the GPS IFOR process. There are, for example, 'major problems' with open pit mining in Australia which would be resolved by additional GPS satellites. The IFOR, as currently structured, does not permit international participation. Currently the Civil GPS Service Interface Committee, which was intended to provide foreign countries with an interface to the U.S. Government on GPS issues, is not a formal advisory board, but an avenue where other nations could represent their interests. In theory, the DOT and DOC take information presented there and fold it into their representation of civil needs. This, however, has not worked to effectively represent the foreign users.

4.11. Panel 1– Leadership: Report

The IRT has identified the 'Big Five' essential GPS performance criteria: assured availability; resistance to interference; accuracy; bounded inaccuracy; and integrity. The panel is currently working to connect these performance criteria to prospective mission needs; particularly, for those missions that would be 'envelope pushing.' The objective is to recommend what these missions might require from GPS, and then discuss how those various mission requirements might frame tradeoffs that system designers might face.

For example, there is an 'obscured visibility problem' when a U.S. Army Ranger in a mountainous area wishes to call in an Air Force-delivered weapon on a target across a deep valley one kilometer distant. There are four key design tradeoffs: number of satellites; satellite ranging area; jamming resistance, and integrity. One measure of effectiveness is how many sorties were required to produce a 95 percent probability that the bomb would land within a specified radius. The constraints are mountainous terrain; desired all-weather availability; possible enemy countermeasures; possible collateral damage (missed distance exceeding one percent) and system integrity (a time to alarm of less then 6 seconds). Design choices include the satellite constellation; the weaponry employed; and jamming interference. The system is actually driven by 'envelope' missions which are very sensitive to the number of satellites. There may be a 'knee in the curve' which has been suggested at 30 GPS satellites. This number would provide a significant difference; for example, in achieving the 95 percent probability with a single sortie. More generally, making assessments of design choices versus measures of effectiveness would give a systems designer a handle on how to consider systems tradeoffs.

Improvements in civil aviation expected from a space-based air traffic control system cannot be realized with the current GPS constellation. Some airline analyses show that at least 27, and preferably 30, is the recommended number of GPS satellites for civil aviation. In addition, many aircraft have not yet been equipped for WAAS because this is a U.S.-centric system while most airlines operate internationally. Also, SBAS is not a global system since it only covers the northern hemisphere. If GPS were improved to accommodate approach and landing in the absence of WAAS, then WAAS might not be needed; this might present a financial calculation that could have political impact. For example, Australia is already achieving a similar capability with the RNP, also known as performance-based navigation (PBN) which is a global capability. However, while RNP/PBN is a global capability, aircraft cannot carry a variety of only locally-useable equipment.

Dr. Bradford Parkinson, Panel 1 Lead

4.12. Panel 2 – Strategic Engagement and Communication: Report

PNT Day on the Hill,

The ‘PNT Hill Day’ event was comprised of separate panels for U.S. government users and private industry users. Both panels enjoyed capacity crowds at the Rayburn House Office Building, with many Capitol Hill staffers from appropriate committees attending. Congressman Mark Udall, Chair, House Science Committee, Space and Aeronautics Subcommittee, gave the opening remarks.

The Space Enterprise Council Briefing included a discussion of the January 22, 2007, San Diego, California, interference event. It is astonishing that no one was injured during this four-hour anomaly. Events like this one underscore the importance in allowing commercial and civil users to have a voice in plans and procedures such as the DHS Interference Detection and Mitigation (IDM). For example, commercial users could contribute to an interference reporting system. There are currently five million vehicles equipped with OnStar and that number is expected to double in the next three years. OnStar currently does anomaly reporting to Verizon.

There are also concerns about a potential GPS ‘brownout’ since 15 satellites are already on their final string. In recent decades GPS-related innovation had driven return-on-investment (ROI) in several industry sectors. For U.S. government users, modernization is a key criterion; for commercial users, a robust signal provided with no user fees is crucial as it allows funds to be transferred into innovation. This is one of the reasons why the Board favors full funding of eLoran and would act to help secure the necessary funds.

The ‘PNT Hill Day’ made clear that GPS has many champions, including those willing to speak on behalf of GPS at industry sector forums, energy conferences, climate conferences, and similar events. It was recommended that the U.S. Chamber of Commerce convene panels on such ‘hot button issues’ as the economy, energy and climate including conferences focused on the interrelationships of PNT.

Mr. David Logsdon, Space Enterprise Council

Aviation Benefits Briefing to the Hill

GPS allows operations at greater capacity; improved operations in all-weather; better timing through improved flow management; and improvements in position awareness, all of which lead to better safety. GPS is credited with reduced fuel burn and reduced block times. Current GPS capabilities such as GPS-augmented Area Navigation (RNAV) permit significantly improved path control, thereby allowing more aircraft to operate in the same airspace. In Atlanta, RNAV has permitted a five-minute reduction in block time per aircraft. The Regional Area Augmentation System (RAAS) provides precise positioning for aircraft on the ground, which is just as important as positioning in the air since 44 percent of runway incursions follow from a loss of position awareness.

The Automatic Dependent Surveillance-Broadcast (ADS-B) will allow use of GPS both by the pilot and ground control. This does cause some issues, however, since currently if a pilot loses

GPS, ground control has additional independent means of determining aircraft position. It is currently unclear how redundancy issues would be addressed but, it is believed, that once pilots become accustomed to flying the new system, few would wish to go back. Eventually the realization would come that an independent surveillance system is needed. Current ADS-B technology may only be helpful if used to reform how the airspace is used, e.g., by allowing aircraft to fly closer together or to fly routes not previously possible because radar would not support them. An independent and difficult to jam system such as eLoran might be the solution.

There are major GPS benefits to aviation in terms of fuel savings. Studies show that the impact of various fuel-saving measures aggregate to an annual savings of $100 million. In a marginal year, that sum could be the difference between profit and loss for an airline.

Captain Joe Burns, United Airlines

Panel 2 Report

First, the panel regards the 30-plus satellite constellation as critical for availability, accuracy and integrity. It urges that alternate constellation orbit designs be reviewed to determine how they compare in compatibility and interoperability. The panel also believes that six or more additional satellites would be critical to all users. Further, the panel strongly recommended that retroreflectors be placed on GPS satellites as soon as possible and, also, believes that individual accuracy tests should be considered mandatory, not a luxury.

The second recommendation regards situational awareness. It is important to know when 'bad stuff is out there'; where it is originating; and what mitigating measures may be taken. DHS has a working group that is developing a plan which focuses on coordinating information on detection, not on identifying the interference source. The past record on interference is mixed. The San Diego incident was first identified not by the system's stewards but by the system users who were causing the interference. Similarly, ten years ago antenna testing at Rome Lab, in New York State, caused interference which affected air traffic coming into Albany, New York. Once again, the interference was discovered by those creating it. This is not a satisfactory way to identity interference. While welcoming DHS actions, the panel believes DHS is not adequately addressing the tougher issue of identifying and localizing the source. Perhaps this is because those engaged are looking for the 'big solution.' The panel recommends two actions. One is to review the DHS plan on this matter and the second is to call attention to the importance of the common reference frame and timing.

Third, the Panel urges efforts to assure adequate funding for space and ground-based infrastructure. GPS-related work in Africa is moving very slowly; it is difficult to obtain adequate resources to address GPS needs of developing countries.

Ms. Ruth Neilan, Panel 2 Lead

4.13. Panel 3– Future Challenges: Report

The ideal U.S. vision for PNT is a world with multiple, space-based PNT systems; user equipment that leverages multiple systems; and a ubiquitous and seamless integration of space-based PNT as part of the daily lives of users worldwide. From a GPS perspective, the U.S. would manage the transition to GPS III to maintain trust among its international user base and provide free, stable and reliable GNSS service based on a constellation of 30 or more satellites. This vision would enable GPS to remain the 'gold standard' for PNT. However, this position is totally ours to lose.

There are short term issues that need to be addressed. The first is to amend the SPS PS to incorporate the currently provided level of service. This is the only document that would require 'heavy lifting.' The SPS PS should establish performance levels; define the process for changing the commitment over time with the FRP; and specify how these commitments and changes would be funded, scheduled, and communicated. The important, and inexpensive, steps include: turn on the navigation message on L2C; solidify the schedule for L5 with the navigation message; pursue interoperability between augmentation systems; and restore the ICD process from the current IS (Interface Specification) process.

The ICD and IS are DoD documents that define the activity of particular satellites. The ICD requires inputs from outside DoD prior to decisions. The IS does not. The ICD has shared military/civilian authority; the IS is military. Since the military pays most of the expense, its preferences tend to dominate.

The Panel urges action to build civil and commercial trust in GPS domestically and internationally. It also urges use of the Federal Radionavigation Plan (FRP) to report broad national policy decisions. Also, it suggests that a very inexpensive way to sustain current GPS utility is to protect the RNSS noise floor.

It is urged that the FCC be asked to adopt commercial practice band emissions specifications for MSS and to abandon the decades-old MSS Out-of-Band Emission (OOBE) accommodation.

The panel also opposes separating the National Telecommunications and Information Administration (NTIA) from the Executive Branch of the Federal government; it believes only the military has sufficient weight to influence the FCC. The only alternative, although unlikely, is for Congress to give the FAA or DOT veto power over any action that might imperil air traffic safety.

Another important factor, which is not widely understood, is the signal-to-noise problem; since GPS signals are below the level of noise. While this could be addressed by putting more power on the satellites, a less expensive approach might be simply to prevent emissions into the band. GPS is the most protected U.S. frequency band. The ITU provides more protection than the FCC. Europeans are both more sensitive to spurious emission and anxious to protect the requirements of Galileo. The panel believes U.S. problems followed from the 1996 Telecommunications Act, which stripped the FCC of its technical capabilities; the agency, therefore, lacks the 'horsepower' to understand 21st century technical questions. A further influence was that the FCC had been directed to listen to its constituency base, i.e., the broadcasters.

Additional transition needs include strengthening check-and-balance mechanisms to ensure broad trust and support for U.S. actions; strengthening U.S. outreach and transparency to domestic and international users; and formalizing the coordination of private sector input for U.S. positions in domestic and international forums (beyond the ITU) which impact GPS.

Mr. Charlie Trimble, Panel 3 Lead

4.14. PNT Advisory Board Roundtable Discussion

At this point the PNT Advisory has a number of preliminary recommendations to enable GPS to maintain its leadership role in the ever evolving GNSS world. These will be reviewed and expanded at the next meeting in October 2008.

The Leadership Panel's recommendations are as follows:

- **Place GPS III quickly under contract with early delivery**. GPS III provides significant improvements over GPS IIF and provides insurance against "brown-outs" that could impact 150 million users. It was noted that it is imperative to avoid GPS brownouts. The current GPS average on-orbit life is 8.9 years. The first GPS III will not be available for launch until December 2013.
- **Formally commit the U.S. to the current level of service.** This would enable civilian users to take advantage of GPS's proven capabilities. It calls for 30+ satellites to be geometrically optimized for users. The masking angle affects the ability to use GPS because many users cannot see down to the horizon. The 30+ satellite constellation would ensure military availability in impeded regions. GPS would compare to the projected capabilities of China's COMPASS and the EU's Galileo systems. It would also support worldwide use to reduce aircraft congestion under the RRAIM program. This is a new development that provides the integrity to allow aircraft to land at regional airports in bad weather and to use lightly instrumented developing nation landing fields with safety.
- **Ensure affordability to enable service without brown-outs**. Expensive, complex satellites could threaten the schedule as well as the constellation size. Where feasible the board recommends that use of alternative platforms be assessed so GPS satellites are not overly burdened by payloads that are not part of primary PNT operations and may prevent achieving savings from inserting two GPS satellites into orbit with one launcher. A dual launch could save $50 million per satellite.
- **Place the GPS signal specifications under a true national organization such as the RTCA to ensure transparent, technical excellence for all users.** This would assure that the signal is truly compatible and help maximize its usefulness. It would call for strong participation by users as well as government agencies.

The Strategic Engagement and Communication panel recommendations are as follows:

- **30+ satellite constellation critical for ALL user applications in terms of availability, accuracy, and integrity.** The panel urged that alternative constellation designs be reviewed to determine how they compare in compatibility and interoperability.

- **Laser retroreflectors should be placed on GPS satellites as soon as possible.** It is advantageous to provide an independent quality assessment capability independent of current radiometric measurements used to determine GPS orbit and clock performance. SLR could provide independent accuracy checks which the panel believes to be mandatory. The panel noted that SLR will be on GLONASS and Galileo. A Global Standard Terrestrial Reference System is critical to future positioning and navigation with Global Navigation Satellites. Multiple systems will need to be exploited to support the increased demands of a wide range of users. The WGS 84 reference frame has been and will continue to be periodically realigned to the ITRF.
- **A need for situational awareness since GPS as a global critical infrastructure requires a means to measure, detect, and geolocate interference.** To that end the National PNT plan for Interference, Detection, and Mitigation and the Implementation Plan should be reviewed. A small group from the panel will perform this review.
- **The policy of openly available with no user fees' should be maintained as a means of promoting GPS capabilities to users around the world.**
- **GPS should be referenced to a common reference frame.** There are several relevant geodetic objectives: achieve a stable geodetic reference frame; maintain a close alignment of the WGS 84 with the ITRF; and ensure the interoperability of GPS with other GNSS systems
- **It is recommended that adequate funding for space and ground infrastructure be assured.** The U.S. should provide a leadership model for support for ground infrastructure international investments.
- **The importance of GPS in the civil community has to be underscored (see section 2). GPS, as discussed earlier, has advanced our understanding of Earth Science.** This importance can be disseminated in such diverse environments as the U.S.-China Workshop on earthquake research (May 08) and in Africa at the AREF, where training and coordination meetings are held which support developing countries to bridge the digital divide.

The Future Challenges Panel believes that the key to the future of GPS is leadership. GPS is the GNSS world standard and it would be advantageous to the U.S. to maintain that position. The panel's recommendations are as follows:

- **There should be a transparent evolution of GPS. This calls for policy stability and predictable change.** For civil integrity, the transition from one set of capabilities to another has to be seamless.
- **There should be a commitment to the 30+ satellite constellation.** This is valuable for the U.S. military; the national air space; and the international community.
- **Use of the EXCOM should be maximized.** Its existing structure is adequate; it should provide for a national plan; and it should oversee the evolution of GPS. EXCOM should be urged to step up to a higher level, rather than simply providing supervision.
- **There should be international collaboration.** As we transition, we should involve our international partners in testing the changes; involving partners would ease in solving problems.

5. Fourth Meeting: October 16-17, 2008

5.1. Location and Agenda

Gallery II -- Second Floor, Hilton Arlington
950 North Stafford Street
Arlington, Virginia 22203

Thursday, October 16

9:00 - 9:05	BOARD CONVENES Call to Order & Welcome	Ms. Diane Rausch, NASA PNT Board Executive Director
9:05 - 9:15	Introductions, Announcements, & Agenda What we want to accomplish -- Preparing for Report to PNT EXCOM on November 5	Dr. James Schlesinger, Chair Dr. Bradford Parkinson, Vice-Chair
9:15 - 9:45	U.S. Update on GPS, PNT Policy, & PNT EXCOM PNT EXCOM Expectations, Transition	Mr. Michael Shaw, Director - National Coordination Office for Space-Based PNT

	Planning	
9:45 - 10:15	U.S. International Initiatives Update on Intl. Committee on GNSS, Galileo, GLONASS, & Compass	Mr. David Turner, Deputy Director Space and Advanced Technology U.S. State Department
10:15 - 10:30	International Member Regional Updates (at member's discretion) ▪ Gerhard Beutler (CH), International Association of Geodesy ▪ Arve Dimmen (NO), Norwegian Coastal Administration ▪ Hiroshi Nishiguchi (JP), Japan GPS Council ▪ Richard Smith (UK), International Association of Institutes of Navigation	
10:30 - 10:45	BREAK	
10:45 - 11:10	GPS in the National Airspace System WAAS, LAAS, and ADS-B	Mr. Leo Eldridge, SatNav Program Manager, Federal Aviation Administration
11:10 - 11:30	GPS Space Service Volume Increasing Utility of GPS for Space Users	Dr. Michael Moreau, Flight Dynamics Analysis Branch, NASA Goddard Space Flight Center
11:30 - 11:50	GPS and Homeland Security [CANCELED] Interference Detection & Mitigation - Implementation Strategy - Central Data Repository And Interference Analysis	Mr. John Merrill,Manager DHS Geospatial Management Office
11:50 - 12:00	Morning Session Discussion & Announcements	All
12:00 - 1:00	LUNCH	
1:00 - 1:30	Pseudolites Augmenting GPS in Regions of Reduced Geometric Availability	Dr. Bradford Parkinson, Vice-Chair Stanford University
1:30 - 1:50	Distress Alerting Satellite System Advantages of a MEOSAR System	Mr. Chris O'Connors, NOAA SARSAT Program Manager

1:50 - 2:30	Civil Input to GPS III IFOR Update - SLR & DASS Examples	Mr. Hank Skalski, Civil Liaison, AF Space Command Col. David Buckman, AF Space Command
2:30 - 2:45	BREAK	
2:45 - 3:30	"Big 5" and Civilian Service Panel Findings	Dr. Bradford Parkinson, Vice-Chair Stanford University
3:30 - 4:00	Future GPS & Free Services PNT Policy "Lessons Learned"	Dr. Scott Pace, Director Space Policy Institute, GWU
4:00 - 4:45	Getting to 30+ satellites Panel Discussion -- Next Steps	All
4:45 - 5:00	Afternoon "Wrap-Up" Discussion & Announcements	
5:00	ADJOURNMENT	

Friday, October 17

9:00 - 9:05	BOARD CONVENES Call to Order -- Good Morning	Ms. Diane Rausch, NASA PNT Board Executive Director
9:05 - 10:15	Board Recommendations 2007-08 Messages for the Transition Team ▪ Review PNT Board Report Summary & prepare for PNT EXCOM Briefing ▪ Address critical Panel issues and positions that should be included in the Administration transition plan	Dr. James Schlesinger, Chair Dr. Bradford Parkinson, Vice-Chair
10:15 - 10:30	BREAK	
10:30 - 11:30	Transitioning & Strengthening the PNT Advisory Board ▪ Discuss changes that could be made to the PNT Board Panel structure and processes to be more effective ▪ Panel Work Assignments - Prep. for 2009-10	Panel Leads/All
11:30 - 1:00	WORKING LUNCH PNT Advisory Board "Wrap-Up" Discussions	
1:00	ADJOURNMENT	

5.2. Opening Remarks

The PNT EXCOM has been briefed on the issues raised at its March 2008 meeting. The briefing emphasized the need for an earlier enabling of a navigation message on the L2C civil signal. The IIR(M) satellites have been broadcasting a signal since the launch of the first L2C-enabled satellite in 2005 and at this time a navigation message is not scheduled to be enabled until the fourth quarter 2011, resulting in the loss of this IIR(M) capability for six years of a twelve year life expectancy. As a result of follow-on discussions it was agreed that a navigation message for L2C would be enabled on all IIR(M) satellites at the next upload scheduled for May 2009. This will provide manufacturers with the opportunity to fully test new designs in a real world environment. In the current global environment, with systems to be provided from other countries, the timing of the implementation of new capabilities is essential for continued U.S. leadership. It is anticipated that there will be one further meeting of the Advisory Committee before the charter expires. Therefore, the present PNT Advisory Board meeting includes both updates from previous meetings and briefings on topics to be addressed by the next meeting. Following the U.S. Presidential election the Board is likely to find itself in a position to advise a new administration. A potential topic for a new administration could include a discussion on how international PNT systems are expected to evolve and how they could be integrated and made interoperable. The key word is interchangeability, which goes beyond compatibility and interoperability in including the ability to interchange a GPS, Galileo, or other GNSS satellite in providing a navigation solution.

5.3. U.S. Update on GPS, PNT Policy, and PNT EXCOM

This presentation included the 2008 EXCOM Work Plan; the Advisory Board tasking of March 2007, and the ‘Way Ahead.’ The EXCOM Work Plan was approved in August 2007 and carried 61 items, 44 of which were from the original plan and 17 were subsequently added. The NCO director is responsible for providing a monthly status report to the Executive Steering Group (ESG), which operates a level below the EXCOM. The Work Plan is intended to provide a smooth transition into the next Presidential administration. At the time of this meeting 42 of the 61 items have been accomplished; six are on schedule; two are ‘at risk’, and eleven are overdue.

Many key accomplishments have occurred since the PNT Advisory Board’s March 2008 session. The intent of the 2004 decision was that FY08 would be the first year in which civil funding for GPS was to be provided to the Air Force. Civil unique capabilities beyond the current 2004 program baseline are to be covered. The DoD budget will fund IIR(M) and IIF to include the L2C and a third civil signal on L5. Civil agencies requiring the fourth civil signal, L1C, are expected to fund capabilities beyond these including performance monitoring. As such the DOT has completed transfer of $7.2 million to the Air Force. While this was a small portion of the Air Force GPS budget, it is an important first step. The pending FY09 budget figure was $20.7 million; the FY10 budget figure was $40.4 million (the latter being tentative since the budgets fall under a new administration).

Additional items presented include the update to the GPS Performance Standard. The standard includes daily observed performances which are expected to improve with new systems and signals. However, because of uncertainties that stretch into the future, it was important not to over-promise. The Performance Standard reflects what the Air Force has concluded it could reasonably provide for the near-term.

The Board's current charter expires in March 2009; given the uncertainty likely to characterize a new administration, it is hoped the charter will be renewed before the end of the calendar year. A revised performance standard for WAAS is due this month; and DoD, DOT and DHS are expected to publish the 2008 Federal Radionavigation Plan, (FRP) which is the senior-most plan, established in 1978. ICG sessions are to be held in December at JPL in Pasadena, California with 150-200 participants expected to attend. Finally, DHS is expected to complete the update of the vulnerability studies.

Mr. Mike Shaw, Director, National Coordination Office

Board Discussion

Regarding L1/L2 semi-codeless tracking, the board suggests the December 31, 2020 transition date should be delayed if L5 was not adequately on line at that time. Also, the current underlying understanding is that there will be phase continuity on the modernized GPS signals. The assumption is that the modernized signals would continue to have phased continuity. While Phase continuity is reflected in the IS-GPS-800 (L1C), formerly known as an ICD, at the time of this meeting it is yet to be reflected in the IS-GPS-200 (L2C).

The board is interested in knowing how the standards differ from actual performance and whether these standards numbers may be overly conservative. Concerns include that if civil agencies work to the performance standard rather than to actual performance they would be held far below what they could actually achieve and, thus, urges 'pushback' on the Air Force over this circumstance where the board believes it costs considerable time, effort and money, particularly within civil aviation. In response, the briefer explained that the reason for being conservative was that the current satellites are in their later stage and that there are not any IIF satellites ready for launch at this time. The standards represented a 'conservative but realistic estimate' of system capability.

The board noted that the U.S. provided transparency on the service level being provided and concern whether the Air Force should be the agency which decides the service level that could be depended upon. Based on available data it appears the FAA or DOT could make their own assessment. For example, it is unfortunate that the RAIM algorithms currently in use had been designed around use of S/A and, as a consequence, aviation cannot achieve higher levels of navigation services from GPS. It is estimated that 80% of GPS receivers in the field still operate as though S/A were still on. The board believes this underscores the concern of the enormous delay and enormous expense entailed in swapping out equipment and that the longer the Air Force took to report actual performance the harder this change would be to accomplish. It should be noted however, that if system performance exceeded requirements; it could be used as a reason to reduce program funding. This issue needs to be a factor when estimating the degree to which a standard needs to be conservative.

5.4. U.S. International Initiatives

Briefing and Board Discussion

The board discussed the potential benefits of international cooperation on GNSS to avoid an over proliferation of non interchangeable GNSS systems resulting in 150 satellites in orbit doing the job of only 30 satellites. However, while there are no advantages to the average user, there are national and security reasons for the United States, Europe, Russia, and China and, to some extent, India wanting to pursue their own independent GNSS systems. Thus, in attempting to shape international systems to leverage synergies it is still required to address national and security equities which are not apparent from the civilian/commercial perspective.

The board also discussed the perception of whether the U.S. is perhaps not providing enough leadership. The briefer addressed this issue by describing the two planned regional augmentations, and five augmentation systems in which the U.S. State Department has been involved. While the U.S. cannot tell other nations that they may not field a satellite system, the goal of U.S. PNT policy is to ensure compatibility of systems and attempt to achieve interoperability. In addition, instead of the term 'interchangeability' as the board has proposed, the State Department is defining "ideal interoperability" as allowing navigation with one signal each from four or more systems with no additional receiver cost or complexity. It is doubtful that attempting to limit the number of GNSS satellites in use would be fruitful. Also, if systems are designed for both civilian and military use, then other nations see this as justification for creating their own systems which fall outside the persuasive range of the U.S.

The board also suggested that the phrase 'with no degradation of accuracy' be added to the definition of interchangeability. The briefer called this a fair point; the broad idea being that all GNSS systems need to work better collectively than independently. Also, the U.S. has a performance standard and encourages all other systems to establish and publish performance standards; once this is achieved a collective performance standard could be created. Also, there has been progress on interoperability including bilateral discussions with Russia, Japan, India, and the European Union. In addition, three bilateral meetings have been held with China. These discussions continue at the ITU on RF compatibility and have been surprisingly cooperative and successful despite tensions over U.S. arms sales to Taiwan.

The board agrees that great mutual interest exists in making various systems work together and, further, other nations developing systems could learn a great deal from the United States. The briefer explained that such work is already proceeding within the Asia Pacific Economic Cooperation (APEC), the GNSS Providers Forum, and the ICG. The ICG is an important venue for discussing both technical and service provision issues. The second ICG Conference in India, September 2007, established a providers' forum to address common issues, and a third ICG meeting was scheduled in Pasadena, California, for December 2008 including invitations to industry. Six space segment providers were represented at the ICG-Provider's Forum and established consensus on general definitions for compatibility and interoperability. This is a good example of U.S. efforts to shape the system.

Mr. David Turner, Deputy Director, Space and Advanced Technology, Department of State

5.5. International Member Regional Updates

Japan GPS Council (Japan)

Two acts have been enacted in Japan to secure the synergistic effectiveness of the PNT system and space-based utilization. They have grown out of interactive discussions by the major parties in the Japanese Diet where consensus had been reached. The first is the Principle Act on the Promotion of National Spatial Data Infrastructure (NSDI) passed in May 2007; the second, the Principle Act on Space Development & Utilization passed in May 2008. The NSDI Implementation Plan was published in April 2008 with Cabinet approval; the implementation plan for the Space Principle Act is in preparation and expected to be published in March 2009 pending Cabinet approval.

The Space Act establishes a commanding body to promote the integrated and planned exploration of space. This body was established in September 2008 and is currently being organized; Mr. Nishiguchi is an ex-officio member. The NSDI Act calls for the promotion of the geospatial data infrastructure and appropriate measures for GIS and PNT in an integrated and systematic manner through use of the GNSS technology, which plays an important role in providing precise timing information. It underscores satellite-based positioning as a powerful means of space utilization. Therefore, the act called for communication and coordination regarding satellite positioning technology and research and development (R&D).

The Principle Space Act focuses on the interpretation of a phrase in the 1969 Resolution on the Basics of Space Exploration and Utilization that states it be done only for ‘peaceful purposes.’ At that time main space-based uses in the world were military. However, with the end of the Cold War, the uses for space-based activities have been broadened to include the prevention of terrorism, response to natural disasters, assessment of global warming, and other tasks. Under this new setting, the various agencies of the Japanese government have acted in concert to develop a new policy.

The objectives of the Principle Space Act are the improvement in human life, development of economic security, and the promotion of world peace and human welfare. The basic concepts of the Act are to use space for peaceful purposes; enhance standards of living; foster industry; develop space science R&D; promote international cooperation; and consider environmental preservation. The administrative structures were established by the political leadership to further national policy. The Space Act establishes a Command Center, chaired by the Prime Minister and co-chaired by the Director of Cabinet Secretariat and the Space Exploration Minister, to develop basic plans. Additional legal framework would be required for such things as international treaties.

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

International Association of Geodesy (Switzerland)

Geodesy includes three aspects of the Earth – orientation, geometry, and gravity field; as well as the space tools routinely used to perform these tasks. GNSS tools are very important to this effort and be expected to remain in use for at least two decades. GNSS has a role in maintaining, and 'densifying' the ITRF; monitor earth rotation; monitor the atmosphere; determine very precise LEO orbits, and determine the Earth's gravitational field.

The Russian GLONASS, which had 25-28 monitoring stations available in 2006, has a combined network of 53 stations as of today and contributes to generate many geodetic products. The IGS strives to aid civilian users of the broader GNSS community by creating products with the highest level of accuracy possible. This requires the study of systematic errors, system peculiarities, and combinations of GNSS systems to enhance user benefits. This perspective is the reason the IGS recommends implementing laser retroreflectors on all GNSS systems to enable SLR collocated with radiometric measurements. To support improved services, the IGS has made available to the full GNSS community precise GPS, GLONASS, and (in the future) Galileo, orbits and clocks on a common reference frame. An effective combined GNSS operation requires the individual systems to operate on a common reference frame. Great strides had been made since 2007 in the effort to add laser retroreflectors to GNSS satellites, and an interagency team led by NASA is continuing to work through the GPS requirements process on implementing them for GPS III.

The GPS and GLONASS constellations differ considerably in inclinations and repeatability of ground tracks (one-day for GPS; eight-day for GLONASS). When comparing the standard azimuth elevation diagrams for GPS and GLONASS both systems have a gap on their northern ends. The GPS satellites have, essentially, the same track each day while the GLONASS tracks 'move all over the place' during their eight-day cycle since GLONASS satellites are not in sidereal synchronous orbits their ground tracks slide. GPS didn't do it this way since the U.S initially wanted to conduct an extensive test program which required the six initial satellites to converge over the same instrumented test area at least once a day. Thus, GPS satellites are in sidereal synchronous orbits. The 'sliding orbit' concept has been proposed for Galileo. As a result, from a geodetic perspective GPS is longitude-dependent rather than latitude-dependent. This arrangement accentuates resonances that would otherwise be smoothed out. However, while orbital resonances may be exaggerated, from a scientific perspective this provides an opportunity to learn more about them.

Mr. Gerhard Beutler, International Association of Geodesy, Switzerland

Maritime Safety of the Norwegian Coastal Administration (Norway)

Norway has nine international airports, nine medium-sized airports and 28 regional airports (small but had regular commercial traffic and were important to local communities). Two lethal aircraft accidents in the late 1980s and early 1990s prompted the decision to install better systems. Many regional airports are located in topographically difficult settings. A decision to implement Special Category-I (SCAT-1) was made in 1996 and inaugurated in October 2007. SCAT-I is certified for 17 types of aircraft. At present, two airports have been certified; the remaining 26 were to be certified over the next three years. The system's development is to be described in detail at the International GPS/GNSS Symposium in Tokyo, November 2008.

Mr. Arve Dimmen, Director, Maritime Safety of the Norwegian Coastal Administration, Norway

International Association of Institutes of Navigation

The objective of the IAIN is to exchange information on navigation. To this end, the group supported various activities, including the ICG. Currently the IAIN is focused on its three-yearly conference, which allowed participants to gather information on the world's GNSS systems.

At the March 2008 meeting of the Advisory Board there was a discussion on some problems in the development of Galileo, which included the then-recent collapse of Galileo's public/private partnership and the subsequent decision by the EU to allocate of 3.46 billion Euros to the project. Since then there has been improvement when the European Commission was clearly in charge of the project as Galileo's owner and retaining the same aim - to establish a 30-satellite constellation (including three spares). Services offered remain similar: an open service, a commercial service (the rules yet to be released), a safety-of-life service for aviation, a publicly regulated service, and a search and rescue service. The second test Galileo satellite was launched in April 2008 and is working as expected. On procurement, contract notices had been issued July 1, 2008 under EC procurement rules, including competition within the process; the competitive dialog phase of procurement began in September 2008. Contracts are expected to be signed in the first half of 2009 with the system fully operational by 2013.

Capt. Richard Smith, International Association of Institutes of Navigation

5.6. Update on eLORAN

Efforts are continuing to refine thinking on LORAN and GPS. The longstanding 'hanging chad' is whether GPS requires a systemic backup. DHS has, in the past, viewed eLORAN as the only practical system. LORAN systems have been in use for several decades and are now almost ubiquitous. The cost estimate for developing eLORAN from the existing LORAN system has been revised downward from $400 million to $200 million since if system modernization includes the replacement of the solid state devices now in use, this would permit a reduction in staffing at those sites. Further savings are expected from the more precise signal eLORAN would permit. Combined, these might make the introduction of eLORAN feasible within existing appropriation levels.

Dana Goward, Director, Maritime Domain Aware, U.S. Coast Guard, Department of Homeland Security

Board Discussion

The Advisory Board believes there is a paradox between the statements suggesting an improved 'way forward' on eLORAN while, at the same time, other discussions question the operative assumptions. First, the need for systematic GPS backup has been questioned and many users report sufficient backup to handle an outage. Second, if backup were needed, is eLORAN the appropriate solution? These questions require affirmative answers before eLORAN can be pursued. It is hoped that planned senior level meetings can resolve these issues before the November 5, 2008, EXCOM meeting. Even the chair of the independent review team on eLORAN has reservations as to its need but, nevertheless, the cost of taking out this 'insurance policy' is so small as to be compelling. An Institute of Defense Analysis (IDA) report, from a group that included many participants originally opposed to eLoran, has unanimously endorsed of eLORAN as a prudent measure. The principal players and decision makers in this decision are DHS, DOT and the White House; a meeting is going to be called by the President's office. Currently it is believed that eLORAN could be implemented within the existing line in the U.S. Coast Guard budget.

The key consideration over the past decade has been: 'If the LORAN system is to be terminated, why improve it?' The projected annual operating costs for eLORAN are $25 to $30 million, which many consider inexpensive for an insurance policy. On the other hand, while everyone agrees that GPS needs a backup, each user groups asserts it already has one. The Advisory Board believes parallels may be drawn to the origins of GPS which, probably, would have never been created without 'civilian leadership' at DoD. Individual services opposed the idea out of fear they would have to finance it, but eventually the broader view had prevailed and it is hoped the same could happen with eLoran.

5.7. GPS in the National Airspace System

The FAA undertook WAAS and LAAS back when GPS had 21 satellites with 98% availability and, thus, not sufficient to provide for all aviation requirements. The objective was for WAAS to provide regional coverage and an approach service down to 200 feet above a runway and LAAS to provide coverage down to the surface for category III operations.

Currently 37,000 units of WAAS avionics have been sold and two additional products coming on line in 2009 should raise the rates of acceptance among business aircraft. Additionally, WAAS can provide approach information to a rooftop with interest in its use growing among helicopter manufacturers.

There are currently 1,333 WAAS LPV approach procedures, a figure that exceeded the number of instrument landings. This represents an astonishing rate of progress. The goal is to have a published WAAS procedure for every instrument runway in the nation by 2018. Publishing in Canada is close to the U.S. level while in Mexico it lagging somewhat (a team would be meeting with Mexican officials in November 2008). Signal coverage in Canada is very good and required U.S. operations in Canada have been placed further north to strengthen the Canadian system. Coverage in Mexico is good but the system has begun to break down near the equator.

The WAAS Enterprise Schedule Phases II is now complete. If L5 were delayed a reassessment of final WAAS availability (FOC) will be required. As an augmentation system WAAS is constricted by whatever affected the GPS system itself. The long term schedule for WAAS shows that for Phase III five years would be required to develop the relevant standards and five years more for the associated avionics to be complete.

There have been questions whether GPS III completion would remove the need for WAAS. According to the current master plan GPS could meet aviation needs by about 2030 and ten additional years would likely be required to transition user equipment. While this may seem like a long time, GPS was approved in 1995 and aircraft were still not equipped 13 years later. These figures suggested that a 12-year extension on the current lifecycle for WAAS is reasonable and a reassessment would be appropriate between 2015 and 2020.

It is expected that LAAS could provide accuracy three to four times higher than WAAS; less susceptible to outages caused by ionospheric storms; and permits greatly increased surveillance capabilities. The FAA anticipates design approval of the Cat-I prototype system being operated in Memphis by Federal Express early in 2009, with Cat-III prototype validation in 2010, and system design approval in 2012.

Airline operators engaged in the implementation of GPS find it difficult to proceed because deadlines kept moving. For some airlines WAAS installation was simple, but the schedule had been progressively pushed back and other airlines about to make a massive investment in avionics are uncertain on how to proceed. Airlines find LAAS was attractive but the 2012 date for its availability is prompting hesitation. There had been a continual need to reinforce the original vision of WAAS and LAAS because makers of some high-end aircraft said they did not require systems such as WAAS. Based on production rates for the procedures, however, acceptance is being rapidly achieved. There are some gaps in the available guidance materials.

For example, it is not clear that if WAAS were installed on an aircraft, exactly how it would be used to fly an RMP approach. Efforts are underway to resolve these issues.

Mr. Leo Eldredge, Manager, GNSS Group, Federal Aviation Administration

5.8. GPS Space Service Volume

Many NASA and DoD applications use GPS for spacecraft positioning, navigation and timing. Up to 3,000 kilometers, performance was very similar to that for terrestrial users in terms of availability and signal levels. Between 3,000 and 8,000 kilometers the signal availability begins to drop off and some signals are received in cases where the GPS satellite is crossing over the limb of the earth and furthermore. These signals are weaker due to radiation effects. Above 8,000 kilometers virtually all signals arrived over the limb of the earth and periods occur when no GPS satellites were in view. Consequently, a specially designed receiver was required, with performance dictated by receiver sensitivity and other factors.

The AO-40 experiment satellite operates in a highly elliptical orbit with apogee well above GEO, and has been able to collect data through a full orbit. This data made it very clear that significant variations occurred in the constellation in terms of service levels to space users; among them is that orbit performance of GPS varied from block build to block build. From this data, Space Service Volume (SSV) requirements for GPS have been developed. Since there would often be times when four GPS signals are not in view, these were specified in terms of pseudo-range accuracy, received power, and signal availability. NASA is continuing to work on various missions such as the Constellation program and lunar missions with the assurance that GPS would be available to augment ground-based tracking. This combination improves navigation, increases on-board autonomy, and reduces the burden on the NASA-operated communication-channel tracking networks.

Space users regard GPS as an important component of the space positioning, navigation, and timing infrastructure. The space user community has been particularly vulnerable to design changes and, thus, has developed user requirements based on altitude and baselined them into GPS III. This provided a ‘green light’ for the high priority missions mentioned above to rely on GPS. There is a great opportunity for interoperability among space users if similar requirements were incorporated by others, including Galileo.

The Navigator receiver, in development at NASA’s Goddard Space Flight Center for over five years, will result in a new space receiver designed for geostationary and other high earth orbits and include the ‘horsepower’ to acquire a GPS signal. The capability could undertake weak signal tracking techniques and it is estimated that it will offer an estimated 10dB improvement over previous systems.

Dr. Michael Moreau, Constellation Program, NASA Goddard Space Flight Center

5.9. Distress Alerting Satellite System (DASS)

SARSAT is one of the components of the national search and rescue response efforts coordinated by DHS. As lead agency, NOAA works with NASA, additional domestic organizations, and 38 countries around the world. Response time requirements are set by those rescue forces which are system customers: several set it at five minutes but the objective is to reduce this to one minute. SARSAT includes participation of U.S., European, and Indian satellites. While there is an agreement for Russian participation currently there are no Russian polar-orbiting satellites available; though the launch of two such satellites is anticipated for next year.

There are four major classes of distress beacon users: maritime, commercial fishing, aircraft, and personal locator beacons. The SARSAT constellation provides very good coverage between 60 degrees north and 60 degrees south; beyond that issues of topographic shading occur. At present it takes 47 minutes to fix a location near the equator (which was the slowest time). This was well above the standards recommended by the International Civil Aviation Organization (ICAO) and International Maritime Organization (IMO). In rescue situations, the first hour is the most critical, so having to spend 47 minutes to locate the distress site limits the activities that can be accomplished. The system is credited with annually saving 300 lives in the U.S., and 1,300 worldwide, with over 22,000 lives saved internationally since 1982.

A typical Personal Locator Beacon (PLB) is available to commercial users; many pilots carry them to supplement emergency locator transmitters (ELTs). The cost of PLBs containing a GPS chip range from $600 to $1,000; those without a GPS chip range from $300 to $600. On February 1, 2009 international use of 121.5/243 MHz terminates after a decade long effort to switch users to 406 MHz. This new frequency produces fewer false alerts and, thus, reduces danger to rescue personnel.

There are systemic limitations to the LEO satellite constellation, including single failure risks. Second, extensive problems have occurred in securing the Russian commitment for GEO satellites. Third, the long time between satellite passes contributes to delays in determining the distress location. An additional concern was that the French government had announced in 2004 that it would no longer donate the processing instrument used on the satellites and, instead, is moving to provide a secondary payload on Galileo. The loss of the French contribution to SARSAT will result in service degradation beginning in 2017 and complete failure by 2020. This situation has the potential to leave millions of people with no way to send a signal.

Efforts to develop DASS began about the time of the French announcement. Nine Proof-of-Concept (S-Band downlink, not certified for SAR) DASS-capable GPS satellites are currently in operation and will increase to 22 with the deployment of GPS Block IIF. DASS reduces response time from 47 minutes to 12 minutes, and perhaps even as low as 5 minutes. It also improves accuracy from 3-5km to 1.7 km or less; eliminates terrain masking issues; increases redundancy; and permits the number of ground stations to be reduced. In sum, a Medium Earth Orbit (MEO) -based approach to distress efforts offers significant benefits. In July 2008 a set of requirements had been submitted to the GPS IFOR and are now under review. Canada, who currently provides the repeaters on geostationary satellites, has offered to supply repeaters to the GPS III. This $70-$90 million commitment would considerably reduce costs to the U.S.

government. The new constellation would be fully compatible with current beacons and no current users would be left behind.

The prospective Galileo search and rescue package also operates at 406 MHz. If Galileo was operational with 30 satellites in 2014, and each satellite carried the needed repeater the requirements for global search and rescue would be met since analysis shows that 22 SAR-enabled GNSS satellites provide global coverage. The question is whether the U.S. should defer to Galileo, or maintain its own capability. The least expensive option is to do nothing and hope that Galileo comes through; from the U.S. standpoint, however, DASS on GPS appears to be the best option. Search and rescue was a joint military and civilian need.

Chris O'Conner, Program Manager, Search and Rescue Satellite-Aided Tracking, National Oceanographic and Atmospheric Administration

5.10. Civil Input to GPS III

The PNT Command Lead at U.S. Air Force Space Command was recently created as the single point of contact for PNT activities. Current experience with the GPS Interagency Forum for Operational Requirements (IFOR) has provided lessons that needed to be incorporated into the process to include cost and funding, a security assessment, and a technical assessment. Once the IFOR process is completed a requirement goes to the JCIDS (Joint Capabilities Integration and Development System) process. The time required for the JCIDS process can vary. The goal for the JCIDS timeline is 229 days, but a more realistic assessment is 340 days. The current GPS IIIA review will provide additional experience.

Current civilian requirements in the IFOR include GPS III Geodetic Requirements and DASS.

The requirements for Geodetic Requirements, and recommendation of implementation through SLR, were submitted in April 2007; and IFOR approval for Geodetic Requirements for GPS IIIB followed. On August 2007, the GPS Wing was requested to review the Geodetic Requirements for impacts on the GPSIII vehicle and that analysis was completed in June 2008. A joint USAF/Civil-led IFOR working group was currently working to address technical issues that had been identified. It was noted that completion would be followed by JCIDs review, which could take nearly a year.

The DASS requirements package was submitted for IFOR review on August 1, 2007; the response, which included the statement that DASS would be a secondary payload, was received July 28, 2008. Cost and technical analysis and national security analysis are underway.

Col Dave Buckman, Air Force Space Command

Board Discussion

The Advisory Board noted that it appeared from the process diagram that a General Officer was not involved sufficiently early in the IFOR process; the schedule steps were generic. The briefer noted that Gen Robert Kehler, Commander, Air Force Space Command, would be involved prior to the initiation of JCIDS.

The Board believes these paper trails are a major impediment to building a satellite: GPS Block I went from approval to launch in 44 months; now, the time involved might be 14 years. Indecision has been a reason but paperwork was the larger factor. There is concern whether there is a sufficient sense of urgency to tighten approval processes so that completion dates were not progressively extended. The General Accounting Office (GAO) had queried why approvals took so long. GPS was not unusual in this regard; process length reflected such standard things as requirements stability, funding stability, technical readiness levels, etc. Meetings on GPS at the Pentagon seemed to show that no one in that building appeared to evidence a sense of urgency; instead, a 'marching army was being ground up.' This made the project a target for continued cost reductions since it was easy to hit a slowly moving project. It is believed that the necessary approvals could be achieved in two months; GPS III is essential both militarily and economically and should be so presented. The question was asked whether the Air Force was ready to address the real danger of brownouts. A 'train wreck' was pending as the number of operating satellites decreased, and that the lack of urgency was contributing to it. The Air Force had identified 'brownouts' as a subject for review in the coming year.

The Advisory Board noted that the arduous requirements process is not peculiar to GPS III. Two years could likely pass before financial planning could begin and programmatic decisions made which meant there was no way funds could subsequently be spent rapidly enough to be effective. The Board, in its transition document, recommends calling attention to this 'bizarre circumstance' which was 'sufficiently outrageous as to create outrage.' For example, during the Second World War, the Pentagon had adopted the 'concurrence' system, which required any number of signoffs on every step. General Creighton Abrams tasked with determining the post-World War II role of the horse cavalry, spent a year garnering the necessary agreements that the horse cavalry had no function. The briefer requested that the Board's transition report might urge that decision authority be moved to the organized, trained, and equipped services even though it was noted that the recent trend had been in the opposite direction.

5.11. 'Big Five' and Civilian Service

The purpose of this briefing is to provide an update to the presentation made at March 2008 meeting. The objective of this effort is to relate system characteristics to such measures of effectiveness as assured availability; resistance to interference; accuracy; bounded accuracy and integrity; which in aggregate created the performance envelope. The approach is to hypothesize 'envelope-stretching' missions and see what tradeoffs might exist for their execution. Example missions included a CAT-3 aircraft landing; FAA air traffic control for ADS-B; and target designation in a visually impaired region. Another example is a military observer on a steep hillside trying to direct delivery of a small bomb to an enemy structure.

In these various cases, the masking angle is 45 or 60 degrees and the number of operational GPS satellites is either a 24 or 30. A 'dramatic increase' in accuracy occurs when a 30 satellite constellation is in place, with availability nearing 100 percent. The accuracy of the bomb guidance system was factored into the analysis with use of an improved target locator. The analysis addresses measures of effectiveness in trying to determine the consequences on accuracy of the satellite population, the deployment of GPS III, and other factors. If, for example, two satellites in a 24-constellation array were not functioning, the results were 'virtually hopeless.' The effectiveness would increase over time but the user may lack the luxury of assuming that the target would remain available.

The civilian envelope mission depicts a CAT III Precision Landing. The measures of effectiveness employed include the long-term probability that CAT III was available without RF interference; the longest interval of unavailability; the loss-of-continuity problem when RF interference was suddenly introduced; and the availability probability when RF interference persisted. The analysis was conducted for 12 U.S. airports, based on 24, 23, 22, or 21 satellites operating; commonly one or two satellites were out of operation. The analysis shows a significant drop in availability as the number of satellites decreases. A 30-satellite array provided all airports with 99.9 percent availability at all times.

Also, the civilian mission analyzing ADS-B support of air traffic control requires a certain level of system performance, so that when the system cannot provide that level then the system cannot be used at all. Data shows that as the number of satellites fell, a substantial drop in RRAIM and Autonomous RAIM integrity occured.

There were no calculations made of how tighter flying in the airspace affected fuel burden. The central limiting factor was on the ground in terms of tools for doing air management. The case for 30 satellites should be made by its beneficiaries; specifically, by the airlines and the FAA.

Dr. Bradford Parkinson, Co-chair, PNT Advisory Board

Board Discussion

Single-shot capabilities may be derived by dividing the results for 1000 cases by 1000, but it was agreed that collateral damage and the sorties required for success needed to be played back into the system. Another issue is if this is a worthwhile approach to demonstrate the advantages of a 30- over a 24-satellite constellation and, also, how often there'd be a military observer on a 60 degree slope. Another issue is the advisability of basing expenditures on the needs of that single individual. Measures of merit should be based on more likely real world proportions. While tactical circumstances are dictated by the command needs of the moment, investment decisions should be made on an aggregate of cases. The capability described might not be available for ten years; therefore, should a long-term investment decision be based on a current tactical need in Afghanistan. Authorities would need to determine whether the performance difference of a larger satellite constellation would provide justification for the investment that array would require.

The intent of this study was to develop hypothetical missions that pushed the envelope so that informed choices could be made between options; the Afghan example is, thus, just a case in point. Commanders in Afghanistan are faced with 'keep out' areas in which the GPS system did not work sufficiently well. The case was based on military capability; however it should be noted the Army and Marines are not involved in using that argument to advance the case for 30 satellites. The burden of argument for 30 satellites rests on those who would benefit from such a system and many are simply unaware of the pertinent information. While 30 satellites are not needed by persons on the plains of Kansas, they might be needed for persons operating on the edge of the performance envelope.

The analysis may require a larger analytical context that would, for example, address the question of how many fighter planes should be purchased vice how many satellites should be put in the air. Thus the analysis, while precise, is insufficient. Determinations of sorties required and fuel consumed might give a better view of the economic return; however, the actual situation might also come down to a Special Forces officer saying: 'For that cost, I'd like to see it done.' Also, while future involvement in Afghanistan is plausible other scenarios should be developed. One scenario could be of an urban terrorist incident occurring amidst tall buildings that might restrict GPS use. There are existing examples of GPS use by police and fire departments in the urban setting. An additional issue is whether the problem would be handled solely by GPS or if something else would be required, and if so, how much of the requirement would remain for GPS? These questions should be entered into investment decisions.

It would be necessary to illuminate multiple cases, identify the alternatives that might provide the needed result, and then determine how these played off against each other. GPS came about because a number of people 'stuck to their guns' and good decisions were more likely to be made in that way than by 'dumping a lot of stuff into a JCIDS funnel' to see what consensus ensued.

The case does address a plausibility argument: a 30-satellite constellation provided huge advantages over a 24-satellite one. The analysis was true and useful; however, it was not conclusive, and would simply be fed into the next process. Recent legislation requires the Armed Forces to include fuel burden costs. If a larger GPS system could cut the number of sorties by five that would reduce costs which were now a legally required mandate in assessing capabilities.

5.12. Future GPS and Free Services

The relevant physics and economic facts of GPS have not changed since the mid-1990s when the commitment to free GPS service was made. GPS funding issues were framed by the military requirement that the receiver be passive. Consequently GPS was akin to a super-lighthouse that the U.S. built and provided as a charitable act. GPS could accommodate an infinite number of users; the marginal cost was zero; and use was difficult to monitor.

Three funding options were identified: (1) DoD provided funding; (2) various government or foreign agencies undertakes cost-sharing; (3) charge users. Regarding the second option, the U.S. was highly dependent on GPS; therefore, spreading control through multiple agencies or permitting control to leave the U.S. would be dangerous. The fact that GPS was free protected the system since a competitor would either have to charge 'less than nothing' or establish restrictions that required use of another system. Regarding the third option, excise taxes on GPS-related equipment would be difficult to collect; the market for such equipment was highly price sensitive and taxation might simply send business offshore. The optimal cost for something was equal to its marginal cost; with GPS, marginal cost was zero. The optimal cost was marginal cost, provided overall costs were covered.

Regarding liability issues, the U.S. government could potentially face lawsuits for failures in GPS services; warning notices on equipment were an important protection against this. As a related issue, integrity monitoring was important to maintaining international trust. However, there were two doubts. First, integrity monitoring was technically difficult. Second, integrity monitoring of GPS conducted by the U.S. might appear self-serving, and not overcome the skepticism of other nations. Maintaining trust in the system required a government, military, civilian dialog, of which the Advisory Board was an example.

The economic argument for the 'free rider' question of 'Why should others freely benefit from a system the U.S. paid for?' was that protecting the utility of the system was more important than any fees one might collect. The national security argument was that keeping the system free of interference was more important than charging for its use.

Discussions in the mid-1990s anticipated the issues of future compatibility with other nations. There had been no expectation that GPS would remain a U.S. monopoly; open international standards were considered. Two things were striking: first; the effort in the late 1990s to re-allocate safety of life spectrum; and, second, the extent to which Europe sought its own system. Other countries might want their own integrity systems or to compete in the open market. However, the European Commission rated the integrative and political cohesion value of Galileo more highly than we would have.

The future plan for GPS is "Don't mess it up." Planned signal modernizations should be completed; backwards compatibility maintained; and European countries publish their standards. In addressing the 30 satellite issue, the U.S. air navigation concern is crucial, including how to finance six additional satellites. Perhaps some 'horse trading' within the Federal Government could resolve the matter of paying for the six satellites. A more diffused interoperable system is preferable to coordination with other national systems in an international system that had the 'right' number of satellites.

A robust system is of high military and economic importance. The fact that the system is in no single cabinet secretary's 'job jar', and no individual secretary carried the entire set of national objectives, underlines its importance from a national perspective. This ties to the question of GPS funding; GPS paid for itself in DoD terms. Various DoD budget pressures, however, make it unlikely that DoD could remain as the sole financer. There needs to be a political discussion on how to finance additional satellites. The only party objecting to DoD financing all of this is, however, the DoD. Even though the United States is sovereign it could be allowing itself to be sued, though various warnings mitigated that risk. Lawsuits are more a danger to private operators.

The impact of GPS on the Gross Domestic Product is unknown. GPS has contributed to economic growth to the extent that growth was reflected in tax revenues. Two estimates of GPS value to agriculture are $4 billion per year and $40 billion per year. GPS is also important to aircraft which were the nation's leading export.

Dr. Scott Pace, Director, Space Policy Institute, George Washington University

5.13. Pseudolites – Augmenting GPS in Regions of Reduced Geometric Availability

The need for 30 satellites could potentially be met through the use of pseudolites on the ground or carried by blimp, by Galileo, or by some other national system. To assess this argument each option needs to be inserted into the mix at their optimal performance to see how this compared with the cost of creating a 30-satellite constellation. Pseudolites have been used in capturing blind aircraft landings and, occasionally, in open pit mining. An assessment needs to include ranging accuracy, signal geometry, and operations. Various issues have been identified: does the signal help the solution? Was the geometry of the signal source of use (or was there already a satellite there)? The conclusion was that a given ground or air-based pseudolite tends to benefit only a narrow area; pseudolites need to be supported so users can be informed of the necessary corrections; and receivers need to be specially configured. The use of pseudolites requires locating an antenna on the underside of the aircraft; placing an antenna on a large aircraft could cost $10,000. There are niche markets for pseudolites such as open pit mining where the pit screened the GPS signal, but they cannot compete with the inherent advantage of GPS that it is free. The U.K. lighthouse authority had undertaken a trial on Scotland's west coast: using five, favorably placed pseudolites. The assessment was that pseudolites might be fine for an emergency in a benign setting, but not otherwise. Thus, a satellite-based system is preferable. An update to the ICAO standards is in process with all references to pseudolites being removed, including placeholder references.

Dr. Bradford Parkinson, Co-Chair, PNT Advisory Board

5.14. Getting to 30+ Satellites: Round Table Discussion

To date two propositions have been advanced for getting to 30 satellites: (1) DoD pays for them; or (2) DoD does not pay. When combined they've become a barrier to further discussion. If one of the propositions specifies a U.S. national objective, but then said it may only be reached if all relevant agencies independently agreed on a course of action, then there is no point to proceeding. Answers reached in the past have not been 'bottoms up'. If investment resources are dedicated to a fragmented purpose then one is likely to end with fragmented resources. There is an analogy to the 'tragedy of the commons': a common objective would be reached only if someone with sufficient power decided to make it happen. In time of war, decisions were not compartmentalized; a coherent way that rose above departmental concerns was needed to deal with national level problems. The current approach seems to be, however, limited to a wide range of people trying to press the case without a national authority to force an outcome.

It may be countered that the national authority is the Executive Branch and the Legislative Branch and this authority being described as the agency which controlled 'the gold,' other than DoD. For example, a decade ago a political party ran on the premise that the country needed missile defense, and when the new Secretary of Defense reached office he did not consult the Joint Chiefs on the issue because a decision had been already made. In that case the 'national authority' had been an elected President and an appointed Secretary of Defense. Not all problems were handled that way and resulted in the current fractioning of authority. Lacking a national authority, things were left to various constituents, and that process produced the 'tragedy of the commons.' This problem is not resolvable within the context of the 'commons.'

The Advisory Board's general task has been to sit down and spend two years producing a thoughtful set of recommendations as to what the nation should do with GPS; then present those recommendations to a new administration in the hope that some political appointee would read them and be inspired. This has been attempted on the issue of 30 navigation satellites. Also the board has assisted in 'driving a stake through the heart of S/A' in terms of eliminating the possibility for its implementation on GPS III. There have been instances where tremendous wealth had become concentrated in non-government organizations, e.g., the Bill and Melinda Gates Foundation., but it would be very difficult to obtain a similar public-private partnership on funding additional navigation satellites solely based on the potential saving they could produce for such private parties. This is something the U.S. Government should do.

The Secretary of Defense could order the Air Force to so act; however, the Secretary has limited political capital and needs to be persuaded that this was the issue on which it'd be worth expending it. Further, whatever one says to the President, others could similarly say: 'Mr. President, you have a limited amount of political capital, you must husband it and six more satellites are simply not that important.' Thus, it appears favorable executive action is likeliest at the start of an Administration. A new President might observe that decision-making is flawed, not just on GPS, but generally. A general revision of the decision-making process would likely be a more generic approach than deciding on obtaining the additional satellites. It may be destabilizing to make everything a 'heroic cause.' The U.S. decision-making process has been changed at various times and, perhaps, an incoming President could address the matter afresh instead of pressuring individuals.

Even if individuals of rank agreed on the 30-satellite issue, their agreement might not be sufficient to make it happen. The issue was what more the Advisory Board could do as a body. The 'pushback' has been not over whether this argument was necessary but whether it was sufficient. The most persuasive case for 30 satellites had been advanced by aviation and they urged representatives of agriculture, energy and other fields to address the cost savings that would stem from the additional satellites. Energy security appears to be the 'issue of the day' and further, energy efficiency is a goal strongly endorsed by the main political parties. The case for GPS could perhaps be advanced by tying it to the general need of energy efficiency as the vehicle to put this proposal through.

It has been said that not enough analysis has been done on alternate approaches to providing a 30-satellite service level. At first the proposed 36-satellite COMPASS constellation was for the most part just a statement of intentions, but the Chinese government has shown strong interest in furthering international prestige, e.g. the Olympics, and such a system would fall into this category. On the other hand, there is an obvious contrast with the U.S. decision-making processes where a decision by former Secretary of Defense Donald Rumsfeld to speed GPS development had, in fact slowed it down as '112 offices' had been asked to comment. The Advisory Board believes it was not necessary for a Secretary of Defense to seek everyone's permission before proceeding.

Message for the Transition Team

The observation of Victor Hugo about 'a time when an idea becomes irresistible' was likened to the idea of a 30-satellites GPS constellation becoming irresistible. However, it may be counterproductive to 'push on a closed door' and the 'door' at the DoD is currently closed. That is, efforts to secure funding would be unproductive in the near term and potentially increase resistance in the long term. The Board needs to tie the case for additional satellites to the 'banner of energy efficiency.' The savings in energy costs that a 30-satellite constellation would provide could prove to be appealing. These savings would have direct appeal to the U.S. Air Force which had a significant fuel bill to fly its airplanes.

5.15. Panel Reports and Round Table

Panel 1 (Leadership)

The draft report of the Board's recommendations and the executive summary had been reviewed by Panel 1 - Leadership, which had concluded that the summary accurately reflected the group's thinking. No changes were made.

Panel 2 (Strategic Engagement and Communications)

The panel regards the executive summary as in good shape. The recommendations should be presented as a Board consensus. Second, it should be stated that the Board expressed considerable concern with the difficulties of the requirements process. Third, the report should give recognition to those items that were going well, i.e., the NCO had been a useful undertaking.

While this panel had been tasked with looking at detection and mitigation of interference it has not made much progress. The panel remains unclear as to DHS intentions in this area. For instance, one might not support concepts like eLORAN, but at present it was the only backup available. This issue needs to be added to the list of transition issues: first, the U.S. policy stating that aircraft safety would be achieved through GPS alone; second, the separate part that guaranteed one was unlikely ever to achieve certification with GPS alone.

The panel is aware of tremendous GPS activity internationally and individuals on the civil side internationally would probably welcome a process and procedure to make useful contact with colleagues and peers in the military.

Panel 3 (Future Challenges)

The panel believes the report should have a covering executive summary that conveyed in strategic terms the work of the Board. The current document is primarily a listing of what the various panels had compiled. An executive summary should present a 'story line' that framed those things that the Board considered most important, with suitable references to supporting documents. A three-four page executive summary would be the document most likely to be read. There was no disagreement with the key recommendations.

Round Table Discussion

The Vision Statement should be presented as a prime product of the committee since it was the 'skeleton upon which everything else hung.' It will be modified appropriately in the Board documents. The Vision Statement should also be included in the report's summary. The draft Vision Statement language from the draft report: 'the ideal U.S. vision for the PNT world is with multiple space-based systems; user equipment that leverages multiple systems, and a ubiquitous and seamless integration of space-based PNT as part of the daily lives of users worldwide.' The balance of the paragraph, which made reference to GPS remaining the 'Gold Standard' would be moved out of the vision and into tactics and used separately so that the statement was clear to all reading it, before the U.S. position was introduced.

The group agreed to revise the executive summary; place the Vision Statement prominently within it; include unanimous panel recommendations; and celebrate the successes that had been achieved. The executive summary would tie to the transition statement by reporting what had and what had not been achieved and then flow naturally into the transition document. A prior task was to ensure the basic document was correct before editorial changes were undertaken. A revised report involving the changes identified in the previous paragraph could be completed shortly after this meeting and work would then begin on the presentation to be made November 5, 2008, to the EXCOM.

Another possible modification relating to international shaping strategy is the Oct. 16 State Department presentation which failed to address how international cooperation was to be reconciled with the security concerns of various nations. 'Tactical vectors' have been presented but no overall strategy. Attempting to articulate an international shaping strategy may open 'a Pandora's box' such as whether outsiders such as the Board could usefully contribute to finding ways to align the military equities of possible future combatants into a total solution. The international civil community has a commonality of interest that was not shared by various military agencies from those nations; the motivation for the new satellite systems is military, not civil; there were many complications on this path.

There are differing views of how nations ought to behave. First, if you held a 'constitutional convention,' much mischief could occur: 'we have met the enemy and he is us.' International discussions are not open and transparent, but characterized by the 'winking and nodding' of mid-level bureaucrats over deals that have been cut. If the Advisory Board's client were an executive authority that viewed the world in those terms, then the Board would be in no position to contradict it. However if the U.S. did better when it made clear what the country wanted and then proceeded intelligently to secure it, then the view on the advisability of pursuing the direction first suggested would be more favorable. However, if the executive authority had an advisory board which presented no clear understanding on how the country ought to proceed relative to international developments then there would be dissatisfaction. The question is not whether the Advisory Board should take responsibility for advocating a model for international GNSS development, but whether there is any intrinsic value in investing energy in advocating a planned economy as that model.

Current activities are moving toward interchangeability. Two alternatives exist: first, devise a grand plan for international GNSS; second, devise a strategy for how best to capitalize on a world in which interchangeability was a given. It is yet uncertain how far interchangeability will proceed. The new proposal could be addressed in the transition document; for the moment, a placeholder could be created while the Advisory Committee determined to what degree it wished to pursue the planned economy model.

Is GPS a 'top down 100 percent Government-provided utility', or is the role of the government to enable signals that entice a diverse entrepreneurial impulse? The infrastructure is provided by U.S. public dollars, as also anticipated for the European, Russian and Chinese systems. The space segment now offers an entrepreneurial context but it does so only because governments had funded its creation.

Discussions of interoperability have so far been only about the civil signal. The U.S. GPS system had been created top-down, with military concerns primary. The U.S. military had done 'yeoman's duty' in making the system available to the civil community; still, the fundamental GPS decisions had been made for military reasons. The issue with a placeholder is that it may allow that box to be opened. It is essential that the discussion proceed on moving from interoperability at the signal level to interoperability at the performance level. Such a discussion, however, would presently risk becoming a 'pooling of ignorance' since not enough was known about what would happen, but nevertheless independent judgment could still be exercised as to what one thought should happen.

It is believed that the published U.S. policy that it reserves the right to turn GPS off undermines U.S. efforts to make GPS the Gold Standard for the world. The U.S. has that right but should carefully weigh the impact.

The aviation sector believes 21 or 24 satellites are insufficient for safety if GPS were to be the only system available. One advocacy approach is to design a series of scenarios, each of which required 30 satellites; while a given listener might not be concerned with all scenarios they might be concerned with at least one.

The Board believes that GPS may be in more perilous condition than was commonly appreciated; citing the issues of interference, the shortage of satellites, and the possibility of brownouts. The number of operational satellites could potentially drop below 24 for reasons such as IIF developing problems after launch; unavailability of launch vehicles; or damage to a launch pad.

The Advisory Board's report needs to call attention to the value of international cooperation; further, it should state that the Board served an important purpose and should be continued. It is important to observe with pride and enthusiasm that the U.S. Government had moved in directions recommended by the Board.

Interactions in international settings confirmed that the Board gained respect by including international representatives. International participation in this Board was highly valuable; it placed a pressure on parallel bodies elsewhere to do likewise. The role of international partners played within this body needs be highlighted in its report. Greater international support and understanding will be required for GPS to remain the Gold Standard; in the past the U.S. had been insufficiently alert to international public relations.

The report states the composition of the committee is a combination of technical specialists and stakeholders and interest parties. It is an important achievement that presence of international members on the Board may have encouraged the Europeans to have U.S. representation on Galileo; another success of this Board.

The executive summary and the transition statement need to be concise, similar and compatible; the transition statement should be consistent with the Vision Statement and a few bulleted points. The transition document should highlight the major issues to be studied; the Board's added value; and its wish to go forward with its current balance of membership. The transition document should be a single page with the executive summary as an appendix.

Transitioning and Strengthening the PNT Advisory Board

If the Advisory Board is re-chartered, there will be some change in membership. Representatives should be added from the Departments of Energy and Agriculture to provide validation beyond that coming from the aviation industry. The Board should also encourage continued representation from both a working airline and an aircraft builder. The DoD has provided good feedback; however, other branches and agencies have pretty much just provided a 'thank you.' The feedback received at EXCOM meetings had been positive. NASA has been a proud sponsor of the Advisory Board. The Board membership came from names advanced by the various PNT executive agencies which had been widely circulated within the government. The current charter expires on March 2009. The Advisory Board's future is to be discussed at the November 5, 2008 PNT EXCOM meeting.

Statements made in Advisory Board meetings need to be communicated more rapidly to the operating level; especially when they may affect Air Force and Departmental decisions. The Board's formal communication consisted of its meeting minutes. In addition, the Board could draft and release press releases.

Further consideration of the executive summary included the Board's role in removing S/A from the GPS IIIA satellites has greatly aided with the standing of GPS among the international community.

The Board also urges the removal of the statement on the U.S. having the prerogative to turn off GPS. Turning off the GPS system would be more hurtful to the United States than to any other country. There needs to be clarification on policy that if the U.S. planned to drop GPS it be mandated to provide six years' notice to users. It appears no policy existed for turning the system off temporarily; rather, it was that any country that decided to abandon a navigation service was obligated to give six years notice to ICAO or IMO. A military decision to remove the effectiveness of GPS in a local military conflict is a different issue from whether one was going to close down the system generally. The U.S. reserving the right to deny service regionally has been on the table for some time. This policy relates to every type of signal the U.S. provides, not just GPS. A clarification is needed before the board can decide if any action is warranted. If so the Advisory Board might consider the following statement: 'while we recognize that under the ICAO the U.S. must give six years warning if it planned to turn off a navigation aid, the U.S. government has no intention of terminating GPS service.' This type of statement had been made to ICAO ten years ago, had been reaffirmed in 2007, and made to IMO in 2008. Therefore it could be advantageous to affirm that view by adding the following, 'we take note that this assurance has been given repeatedly, and we reiterate that assurance.'

With regard to the Presidential Transition, the Board should neither announce in advance nor freeze in advance what one intended to say in the new situation; rather, hold that expression until one knew more about the nature of the new Administration. Once the new administration appointments are identified and filled, the Board understanding of future prospects and intentions would improve.

6. Conclusions and Recommendations

After completing their study tasks, the Advisory Board presents the following recommendations to enable GPS to maintain its leadership role in the ever evolving GNSS world.

6.1. Panel 1: Leadership

The Leadership Panel' recommendations are as follows:

- *Place GPS III quickly under contract with early delivery:* GPS III provides significant improvements over GPS IIF and insurance against service shortages, or "brown-outs" that could impact over 150 million users. Adequate satellite replenishment is essential to avoid such GPS brownouts. Many of the current GPS satellites are nearing their design lifetime and the first GPS III will not be available for launch until 2014.
- *Formally commit the U.S. to the current level of service:* This would enable civilian users to take full advantage of GPS's proven capabilities. In addition, it is recommended that a 30+ GPS satellite constellation be geometrically optimized for users. A larger constellation would improve the ability of surface users in obstructed terrain, such as in urban environments, and also ensure the availability of GPS to the military in impeded regions such as mountainous regions. GPS would compare to the projected capabilities of China's COMPASS and the EU's Galileo systems. It would also support worldwide use to reduce aircraft congestion under the RRAIM program. This is a new development that provides the integrity to allow aircraft to land at regional airports in bad weather and to use lightly instrumented developing nation landing fields with safety. The board urges that alternative constellation designs be reviewed to determine how they compare in compatibility and interoperability. Also, it is recommended to enable full capability on all available signals once new satellites have completed in-orbit validation.
- *Ensure affordability to enable service without brown-outs*: A sensible fast track approach should be utilized. Expensive, complex satellites could threaten schedule as well as the constellation size. Where feasible the board recommends that use of alternative platforms be assessed so GPS satellites are not overly burdened by payloads that are not part of primary PNT operations and may prevent achieving savings from inserting two GPS satellites into orbit with one launcher. A dual launch could cost $50 million per satellite.
- *Place the GPS signal specifications under a true national organization such as the RTCA to ensure transparent, technical excellence for all users:* This would assure that the signal is truly compatible and help maximize its usefulness. It would call for strong participation by users as well as government agencies.

6.2. Panel 2: Strategic Engagement and Communication

The Strategic Engagement and Communication Panel recommendations are as follows:

- *Implement laser retroreflectors on GPS III:* It is advantageous to provide an independent calibration, validation, and quality assessment capability to determine GPS orbit and clock performance. Currently, the GPS signals are used to generate satellite orbits and clocks. Satellite Laser Ranging (SLR) can provide independent determination of these essential products which the panel believes to be mandatory. The panel notes that SLR retroreflectors will be on all GLONASS and Galileo satellites. This capability is also essential for maintaining the robust global standard terrestrial reference system, the International Terrestrial Reference Frame (ITRF).
- *Develop means to mitigate detect, measure, and geolocate interference:* Since GPS is a global critical infrastructure, it requires a means to detect, measure, and geolocate interference to mitigate its effects, e.g., and for situational awareness. To accomplish this there should be a comprehensive review of the: (1) National PNT plan for Interference, Detection, and Mitigation; and (2) the implementation of this plan. A small group from the panel will perform this review when the new board convenes.
- *Use a reference frame and timing for GPS that is common with other GNSS systems:* GPS should be based on a common reference system which must be interoperable with the other GNSS systems. The ITRF is internationally accepted as the de-facto best global reference frame. The GPS reference system, World Geodetic system 1984 (WGS 84) currently maintains a close alignment with ITRF. The pervasive and global use of GPS for timing applications is largely unrecognized, as use of other and new GNSS increase it is essential to know the accurate difference or offset between GPS and that system. Exploiting multiple GNSS is critical for future PNT applications and interoperability of the geodetic reference and timing systems is essential.
- *Assure adequate funding:* It is recommended that adequate funding for space and ground infrastructure be assured. The U.S. should provide a leadership model for support for international investments in ground infrastructure. Numerous applications depend on the global civil tracking network of stations, many implemented by US agencies and international partner organizations. This ground infrastructure is aging and needs resources to evolve to modernized GPS and multi-GNSS capabilities in order to maintain application derived benefits. This is increasingly urgent in less economically developed areas of the world, and particularly throughout Africa.
- *Underscore how GPS has advanced understanding of Earth Science:* The use of GPS in the civil community is pervasive, and global scientific use must be underscored for truly remarkable applications and achievements – as has been demonstrated by the intellectual fervor stemming from GPS. GPS has advanced our understanding of Earth Science by enabling atmospheric and ionospheric sciences, sea-level change, glacier melt, climate change, earthquakes, volcanoes, gravity field, deformation, many satellite missions,… many through GPS geodesy, and geodynamics applications. This important information is disseminated in such diverse environments as international conferences, workshops and

forums where training and coordination meetings are held to support efforts to bridge the digital divide.

6.3. Panel 3: Future Challenges

The Future Challenges Panel believes that the key to the future of GPS is leadership. GPS is the GNSS world standard and it would be advantageous to the U.S. to maintain that position. The panel's recommendations are as follows:

- *Ensure civil and commercial participation in the evolution of GPS:*

  As the space segment transition to the era of GPS III, commercial and other non-DoD users continue to be uneasy and with what they observe on the part of the Departments of Defense and Air Force as they implement their responsibilities to the non-DoD users. These users need to understand what the program and system characteristics are going to be in order to make both the political and financial investments necessary for them to gain commercial or functional success. From their perspective, the actions of the DoD and the Air Force are not achieving these objectives. The analytic and decision processes within the DoD and Air Force are not transparent and their actions often display an insensitivity to the needs of the commercial and civil users. This seems particularly true with respect to the need for openness, long-term assurance and sensitivity to the burden of users during transition between the current environment and the transition to GPS III. The Panel believes the Advisory Group should continue to press this topic as an issue of discipline in execution.

  Phase coherence for GPS signals is an example of the consequence of the lack of assurance in the current process and requires early attention. Stable phase between code and carrier and between L1 and L2 signals is key for current high precision GPS performance. If L1C and L2C in modernized GPS are to provide equal or better capability , these modernized signals must have fixed phase relationships. The original signal specification for L2C called for a fixed phase relationship. Failing to preserve L1C/L2C fixed phase relationships is more than a technology issue regarding the implementation of flex power (which apparently triggered the need for specification change). It is a policy change regarding GPS modernization.

  When the DoD/NII announced that GPS modernization was governed by the characteristics of the civil signals which are defined in interface specifications located on the GPS Wing Website, it appeared to many in the international civil community that the GPS Wing's signal specifications, which were a work in progress represented a possible policy change. This perception can be corrected by changing the interface specification for L2C phase stability to its original definition at introduction and by reiterating a policy statement committing the United States to a modernized GPS with at least equal high performance GPS as the legacy system.

  The National Positioning, Navigation and Timing System Engineering Forum (NPEF) conducted significant outreach to the user community to establish four technical solutions for implementing flex power without affecting stable phase relationship on L1C. Because of the strategic importance of this issue, any change to this interface specification for this L1C fixed phase relationship on the GPS Wing Website should be dealt with as a policy decision rather than a routine technical decision.

- *Continue promoting international collaboration:* The Futures Panel continues to believe that more robust international collaboration in the PNT area would be useful. Currently Russia, China, Europe and the U.S. have indicated that they intend to create and maintain a collective total of space elements well in excess of what any one of them would have invested in separately. While some of that duplication is fundamental to the sovereignty needs of each, we think there remain substantial room for a cooperation to achieve better performance more efficiently. In addition, there are regional augmentation systems driven primarily by the precision needs of air traffic control. To be effective, these combined space and other augmentation systems need to present a consistent and dependable interface so that airlines as well as national and regional air traffic control systems will invest in this approach.
- *Maximize use of PNT EXCOM:* Use of the PNT EXCOM should be maximized and, for example, also include ground-based PNT services; PNT enablers such as developing common GNSS standards; facilitating PNT technology developments; provide for a national plan; and oversee the evolution of GPS. The PNT EXCOM is urged to step up to a higher level, rather than simply providing coordination. GPS constellation assurance, and policy stability, is also essential. The recently released General Accounting Office (GAO) report on GPS raises again in a very public way, the question of the performance of the GPS constellation. Narrowly, this translates to the question of how many GPS satellites can users depend on being sustained in the future. While one might question the utility of the hypothetical presumptions of the calculations and charts, they represent a legitimate concern and display a prospective future that undermines the global, commercial and civil trust in the GPS system. At minimum, the government needs to describe what it intends and then execute that intention.

6.4. *Future Vision for GPS*

The key to the future of GPS is leadership. GPS is the GNSS world standard and it would be advantageous to the U.S. to maintain that position, especially in the light of rapidly expanding foreign GNSS and augmentation capabilities. The ideal U.S. vision for PNT is a world with multiple, space-based PNT systems; user equipment that leverages multiple systems; and a ubiquitous and seamless integration of space-based PNT as part of the daily lives of users worldwide. From a GPS perspective, the U.S. would manage the transition to GPS III to maintain trust among its international user base and provide free, stable and reliable GNSS service based on a constellation of 30 or more satellites.

6.5. Transitioning to the 2009-2010 Advisory Board

During the 2007-2008 two year tenure of this PNT Advisory Board there have been notable successes, including the following:

- The recommendation from the board to eliminate S/A capabilities from GPS III which was finally implemented. The capability for S/A removal from GPS III satellites by Deputy Secretary of Defense England was officially announced on September 18, 2007. This decision was warmly received by the international community.
- Substantial progress has been made on the issue of engaging with the international community through the ICG and the GNSS Providers Forum.

The PNT Advisory Board believes more progress needs to be made on other issues such as, GPS interference, detection, and mitigation. Also, there is a need to explore the issue of how to engage with allies on military use of GPS. It is recommended these issues be addressed by the upcoming 2009-2010 PNT Advisory Board.

The PNT Advisory Board Charter was renewed by Christopher J. Scolese, NASA Acting Administrator, on January 26, 2009 (Appendix C).

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Appendix A. Acronym List

ACE: Army Corps of Engineers
ADS-B: Automatic Dependent Surveillance-Broadcast
AFSPC: Air Force Space Command
AIS: Automated Identification System
AOPA: Aircraft Owners and Pilots Association
APEC: Asia-Pacific Economic Cooperation
ASD: Assistant Secretary of Defense
ATC: Ancillary Terrestrial Component
AU: Australia
CDD: Capabilities Development Document
CDMA: Code Division Multiple Access
CEO: Chief Executive Officer
CH: Switzerland
CHAMP: CHallenging Min-satellite Payload; German small satellite
CIA: Central Intelligence Agency
CORS: Continuously Operating Reference Stations
CSEL: Combat Survivor/Evader Locator
DAGR: Defense Advanced GPS Receiver
DASS: Distress Alerting Satellite System
DGPS: Differential Global Positioning System
DHS: Department of Homeland Security
DOC: Department of Commerce
DoD: Department of Defense
DOI: Department of Interior
DOS: Department of State
DOT: Department of Transportation
DSB: Defense Science Board
EC: European Commission
eLORAN: Enhanced LOng Range Aid to Navigation
ESA: European Space Agency
ESG: Executive Steering Group
EU: European Union
EXCOM: Executive Committee
FAA: Federal Aviation Administration
FACA: Federal Advisory Committee Act
FCC: Federal Communications Commission
FHA: Federal Housing Administration
FHWA: Federal Highway Administration
FOC: Full Operational Capability
FRP: Federal Radionavigation Plan
FY: Fiscal Year
GAGAN: India's GPS-Aided Geo Augmented Navigation System
GAO: General Accounting Officer

GBAS	Ground Based Augmentation System
GEO:	Geosynchronous Orbit
GIC:	GPS Integrity Channel
GIS:	Geographic Information Systems
GLONASS:	GLObal'naya NAvigatsionnaya Sputnikovaya Sistema
GNSS:	Global Navigation Satellite System
GOCE:	Gravity field and steady-state Ocean Circulation Explorer
GPS:	Global Positioning System
GRACE:	Gravity Recovery and Climate Experiment
GRAS	Ground-based Regional Augmentation System
HPT:	High Performance Team
IAG:	International Association of Geodesy
IAIN:	International Association of Institutes of Navigation
IAT:	Independent Assessment Team
ICAO:	International Civil Aviation Administration
ICD:	Interface Control Document
ICG:	International Committee on GNSS
IDA:	Institute of Defense Analysis
IDM	Interference, Detection, and Mitigation
IERS:	International Earth Rotation and Reference Systems Service
IFOR:	Interagency Forum on Operational Requirements
IGS:	International GNSS Service
ILRS:	International Laser Ranging Service
IMO:	International Maritime Organization
IN:	India
INS:	Inertial Navigation System
IRNSS:	India Regional Navigational Satellite System
IRT:	Independent Review Team
IS:	Interface Specification
ITAR:	International Traffic In Arms Regulations
ITRF:	International Terrestrial Reference Frame
ITU:	International Telecommunications Union
ITU-R:	International Telecommunications Union-Radiocommunication Sector
JCIDS:	Joint Capibilities Integration and Development System
JCS:	Joint Chiefs of Staff
JP:	Japan
JPL:	Jet Propulsion Laboratory
JROC:	Joint Requirements Oversight Council
LAAS:	Local Area Augmentation System
LEO:	Low Earth Orbit
LORAN:	LOng Range Aid to Navigation
LPV-200	Approach with Vertical Guidance – 200 ft minimum
MAGR:	Miniature Airborne Global Positioning System Receiver
MBOC:	Civil signal structure
M-code:	Military code
MEO:	Middle Earth Orbit

MSS:	Mobile Satellite Service
NAS:	National Academy of Sciences
NASA:	National Aeronautics and Space Administration
NAVCEN:	Navigation Center
NCO	National Coordination Office
NDGPS:	Nationwide Differential GPS
NDS:	Nuclear Detection System
NGS:	National Geodetic Survey
NIC:	Navigational Integrity Category
NII:	Networks and Information Integration
NIST:	National Institutes of Standards and Testing
NO:	Norway
NOAA:	National Oceanic and Atmospheric Administration
NPRM:	Notice of Proposed Rule Making
NSC:	National Security Council
NSDI:	National Spatial Data Infrastructure
NTIA:	National Telecommunications and Information Administration
NTP:	Network Time Protocol
OCX:	Operational Control Segment
OOBE:	Out-of-Band Emission
OPUS:	On-line Positioning User Service
OSD:	Office of the Secretary of Defense
PBN:	Performance Based Navigation
PLB:	Personal Locator Beacon
PNT:	Positioning, Navigation and Timing
POD:	Precise Orbit Determination
PPS	Precise Positioning Service
PS	Performance Standard
QZSS:	Quasi-Zenith Satellite System
RAIM:	Receiver Autonomous Integrity Monitoring
RAAS:	Regional Area Augmentation System
R&D:	Research and Development
RF:	Radio Frequency
RFI:	Radio Frequency Interference
RFP:	Request for Proposal
RITA:	Research and Innovative Technology Administration
RNAV:	GPS Augmented Area Navigation
RNP	Required Navigation Performance
RNSS:	Radio Navigation Satellite Service
RRAIM:	Relative Receiver Autonomous Integrity Monitoring
RTCA	Radio Technical Commission for Aeronautics
S/A:	Selective Availability
SAASM:	Selective Availability/Anti-Spoofing Module
SARSAT:	Search and Rescue Satellite
SCaN:	Space Communications and Navigation
SCAT-1:	Special Category-1

SFTS:	Standard Frequency and Time Signal
SLR:	Satellite Laser Ranging
SPS:	Standard Positioning Service
SSV:	Space Service Volume
STS:	Space Transportation System
SV:	GPS Service Vehicle
SVN:	GPS Service Vehicle Number
TASS:	Tracking and Data Relay Satellite System Augmentation Service for Satellites
TDRSS:	Tracking and Data Relay Satellite System
UK:	United Kingdom
U.S.:	United States
USAF:	United States Air Force
USCG:	United States Coast Guard
USGS:	United States Geological Survey
UTC:	Coordinated Universal Time
UWB:	Ultra Wideband
WAAS:	Wide-Area Augmentation System
WGS 84:	World Geodetic Survey 84
WRC:	World Radiocommunication Conference
Y2K:	Year 2000

Appendix B. Federal Register Notice

51686 Federal Register / Vol. 72, No. 174 / Monday, September 10, 2007 / Notices

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

[Notice (07–064)]

NASA Advisory Council; Science Committee; Heliophysics Subcommittee; Meeting

AGENCY: National Aeronautics and Space Administration.

ACTION: Notice of meeting.

SUMMARY: The National Aeronautics and Space Administration (NASA) announces a meeting of the Heliophysics Subcommittee of the NASA Advisory Council (NAC). This Subcommittee reports to the Science Committee of the NAC. The Meeting will be held for the purpose of soliciting from the scientific community and other persons scientific and technical information relevant to program planning.

DATES: Tuesday, October 9, 2007, 8:30 a.m. to 5 p.m. and Wednesday, October 10, 2007, 8:30 a.m. to 5 p.m. Eastern Daylight Time.

ADDRESSES: NASA Headquarters, Room 9H40, 300 E. Street, SW., Washington, DC 20546.

FOR FURTHER INFORMATION CONTACT: Ms. Marian Norris, Science Mission Directorate, NASA Headquarters, Washington, DC 20546, (202) 358–4452, fax (202) 358–4118, or *mnorris@nasa.gov*.

SUPPLEMENTARY INFORMATION: The meeting will be open to the public up to the capacity of the room. The agenda for the meeting includes the following topics:

—Heliophysics Division Overview of Program Status.
—SMD Strategy for Mission Cost Containment.
—NASA and the American Competitiveness Initiative (ACI).
—NAC Lunar Science Recommendations.
—Preparations for Next Heliophysics Science Roadmap.

It is imperative that the meeting be held on these dates to accommodate the scheduling priorities of the key participants. Attendees will be requested to sign a register and to comply with NASA security requirements, including the presentation of a valid picture ID, before receiving an access badge. Foreign nationals attending this meeting will be required to provide the following information no less than 5 working days prior to the meeting: full name; gender; 9-digit social security number; Greencard information (resident alien number and expiration date); date, country and city of birth; citizenship; visa information (number, type, expiration date); passport information (number, country of issue, expiration date); employer/affiliation information (name of institution, address, country, telephone, fax, type of business conducted); and title/position, field of research, and e-mail address of attendee. To expedite admittance, attendees with U.S. citizenship can provide identifying information 3 working days in advance by contacting Marian Norris via e-mail at *mnorris@nasa.gov* or by telephone at (202) 358–4452.

Dated: August 30, 2007.

P. Diane Rausch,

Advisory Committee Management Officer, National Aeronautics and Space Administration.

[FR Doc. E7–17731 Filed 9–7–07; 8:45 am]

BILLING CODE 7510–13–P

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

[Notice (07–063)]

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

AGENCY: National Aeronautics and Space Administration.

ACTION: Notice of meeting.

SUMMARY: In accordance with the Federal Advisory Committee Act (Pub. L. 92–463, as amended), and the President's 2004 U.S. Space-Based Positioning, Navigation and Timing (PNT) Policy, the National Aeronautics and Space Administration announces a meeting of the National Space-Based Positioning, Navigation, and Timing Advisory Board.

DATES: Thursday, October 4, 2007, 9 a.m. to 5 p.m. and Friday, October 5, 2007, 9 a.m. to 1 p.m. Eastern Daylight Time.

ADDRESS: Doubletree Hotel, Washington DC, 1515 Rhode Island Avenue NW., District of Columbia, USA, 20005.

FOR FURTHER INFORMATION CONTACT: Ms. Barbara Adde, Space Operations Mission Directorate, National Aeronautics and Space Administration, Washington, DC 20546, (202) 358–1912.

SUPPLEMENTARY INFORMATION: The meeting will be open to the public up to the seating capacity of the room. The agenda for the meeting includes the following topics:

- Update on President's 2004 U.S. Space-Based Positioning, Navigation and Timing Policy, and Global Positioning System (GPS) Modernization.
- Exploring Opportunities for Making the Global Positioning and Timing Grid more Robust Through Infrastructure Technologies and Applications.
- Examining Emerging Technical and Market Trends for PNT Services in U.S. and International Arena.
- Optimizing and Prioritizing Current and Planned GPS Capabilities and Services.
- Updating GPS Standard Positioning Service Performance Standards.
- Maintaining U.S. GPS Technological Leadership and Competitiveness.
- Initiating U.S. Strategic Engagement and Communications on PNT Services.
- Addressing Future Challenges to PNT Service Providers and Users.

It is imperative that the meeting be held on these dates to accommodate the scheduling priorities of the key participants. Visitors will be requested to sign a visitor's register.

Dated: August 30, 2007.

P. Diane Rausch,

Advisory Committee Management Officer, National Aeronautics and Space Administration.

[FR Doc. E7–17726 Filed 9–7–07; 8:45 am]

BILLING CODE 7510–13–P

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION

NARA Draft Plan for Digitizing Archival Materials for Public Access; Request for Comment and Public Meeting

AGENCY: National Archives and Records Administration (NARA).

ACTION: Request for comment; notice of public meeting.

SUMMARY: NARA is seeking public comment on its draft *Plan for Digitizing Archival Materials for Public Access, 2007–2016*. The document is available at *http://www.archives.gov/comment/digitizing-plan.html* or from the contact listed in this notice.

DATES: Comments should be received by November 9, 2007.

A public meeting on the draft Plan will be held on October 4 at 10:30 a.m. See the **ADDRESSES** paragraph for additional information.

ADDRESSES: Comments should be submitted by e-mail to *Vision@nara.gov* or faxed to 301–837–0319.

The public meeting will be held at the Jefferson Room in the National Archives Building, Washington, DC 20408, on October 4, 2007 at 10:30 a.m. Please enter through the Constitution Avenue

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Appendix C. Charter Renewal

National Aeronautics and Space Administration

Charter of the
National Space-Based Positioning, Navigation, and Timing
Advisory Board

Establishment

The U.S. Space-Based Positioning, Navigation, and Timing Policy of December 8, 2004 (the Policy) established a permanent National Space-Based Positioning, Navigation, and Timing (PNT) Executive Committee (the Executive Committee), co-chaired by the Deputy Secretaries of the Departments of Defense and Transportation, or by their designated representatives, and currently comprised of representatives at the equivalent level from the Department of State, Department of Commerce, Department of Homeland Security, Department of Interior, Department of Agriculture, the Joint Chiefs of Staff, and the National Aeronautics and Space Administration (NASA). NASA hereby renews the National Space-Based Positioning, Navigation, and Timing Advisory Board (hereinafter, "the Board") Charter for another two years, but it is NASA's intention to transfer formal sponsorship of the Board to another Federal agency at the conclusion of the first year (no later than December 31, 2009). The Board will operate solely in an advisory capacity as directed by the Policy and in accordance with the Federal Advisory Committee Act (FACA), 5 U.S.C. App.

Objectives and Duties

The Board will provide advice, as directed by the Executive Committee and through NASA, on U.S. space-based PNT policy, planning, program management, and funding profiles in relation to the current state of national and international space-based PNT services. This advice will consist of assessments and recommendations to facilitate the accomplishment of the goals and objectives of the Policy on behalf of the Executive Committee. NASA, in close coordination with the Executive Committee, will task the Board and define the full scope of responsibilities and schedules required for each task assigned.

The Board will evaluate national and international needs for changes in space-based PNT capabilities, assess possible trade-offs among options, and provide independent advice and recommendations to the Executive Committee on requirements and program needs. These evaluations will be considered by the Executive Committee in recommending a national PNT strategy and developing annual updates to the 5-Year Space-Based PNT Plan. The United States reserves the right to hold "U.S.-only" meetings of the Board, as required, in full compliance with the FACA and related U.S. statutes and regulations.

Members and Chair

The Board will consist of not more than 25 members to be approved by the co-chairs of the Executive Committee and appointed by the NASA Administrator to ensure a balanced representation in terms of the points of view represented and the functions to be performed. Most members will serve as Special Government Employees (SGEs), although representative members from critical industry sectors, academia, or space-based PNT user application areas may also serve as deemed necessary and appropriate. Members will be identified as SGEs or Representative members when they are appointed, which will be reflected in the individual appointment letters. International participation on the Board may be considered.

Members will be appointed for the duration of this Charter, not to exceed two years. Vacancy appointments shall be for the remainder of the unexpired term of the vacancy. Information classified for national security reasons may be provided to appropriately cleared members of the Board to support the mission of the Executive Committee.

The Board Chair and any Vice Chairs, as appropriate, will be approved by the Executive Committee co-chairs and appointed by the NASA Administrator.

Committees, subcommittees and/or task forces may be established to conduct special studies requiring an effort of limited duration. Committees, subcommittees and/or task force membership and terms of reference will be approved and appointed by the NASA Administrator in consultation with the Executive Committee. Consultants with special expertise may also be designated to assist subordinate groups on an ad hoc basis. Such committees, subcommittees and/or task forces will report their findings and recommendations to the Executive Committee through the Board Chair. Duration of committees, subcommittees and/or task forces will be determined by the terms of reference under which they are established.

Administrative Provisions

The Designated Federal Official will be appointed by the NASA Administrator and will serve as the Executive Director of the Board.

The Board will meet at least twice each fiscal year. Meetings will be open to the public unless it is determined that the meeting, or a portion of the meeting, will be closed in accordance with the Government in the Sunshine Act, 5 U.S.C. 552b(c).

Members of the Board will not be compensated for their services, but will, upon request, be allowed travel and per diem expenses as allowed by 5 U.S.C. 5701 et seq. and the FACA as amended.

The estimated annual operating costs are $170,000, which includes the approximate costs for meeting logistics, travel, report generation, subordinate meetings, and U.S. Government staff support. U.S. Government staff support is expected to require .5 work years of effort.

Duration

Since the Board is a Presidential advisory committee, this Charter shall become effective upon the filing of this Charter with the Committee Management Secretariat of the U.S. General Services Administration and shall terminate two years from the date of the filing unless earlier terminated or renewed.

/signature of C. J. Scolese/
Christopher J. Scolese
Acting Administrator
National Aeronautics and Space Administration
January 26, 2009
Date

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