SPACE-BASED POSITIONING NAVIGATION & TIMING

NATIONAL ADVISORY BOARD

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

Seventh Meeting
October 14-15, 2010

Omni Shoreham Hotel
2500 Calvert NW
Washington, DC 20008

Meeting Minutes

James R. Schlesinger
Chair

James J. Miller
Executive Director

Session of Thursday, October 14, 2010

Mr. James Miller convened the meeting at 9:00 a.m., thanking all those in attendance for their contributions of time and energy. He noted that much had been accomplished by the U.S. and other nations in creating interoperable systems that permitted free and unfettered use regardless of which nation oversaw a particular system.

Mr. Miller noted that the Positioning, Navigation, and Timing (PNT) Board had been created in 2004 as part of the Presidential PNT Policy under the guidance of the Federal Advisory Committee Act (FACA), which means that meetings are open to the public and that all discussions are a matter of the public record unless meetings are closed in advance for good reason. He noted that the Board was required to be balanced in terms of point of view represented. He was confident a proper membership was being maintained with the many sectors currently represented. He noted that the Board consisted of Representatives and Special Government Employees (SGEs) who were selected and vetted by the individual PNT Executive Committee (EXCOM) agencies to be appointed by the National Aeronautics and Space Administration (NASA) Administrator.

Mr. Miller noted that the Board had not met since November 2009 due to Administration transitions and new taskings being developed by the PNT EXCOM. He stated that Mr. Anthony Russo, Director of the National Coordination Office (NCO), would brief the Board on its new taskings shortly, which had been compiled with the approved by all PNT member agencies. He believed it was important that FACA committees existed outside of regular government channels, as this allowed individual members to bring unique subject perspectives for consideration that might otherwise be missed.

Mr. Miller reported that Dr. James Schlesinger, PNT Board Chair, would be briefing the National Space-Based PNT Executive Committee on November 5, 2010, to provide perspectives on how these taskings would be addressed by the PNT Board work assignments.

Mr. Miller noted that the PNT Board currently had seven vacancies and efforts to fill these were nearly complete. He added that at the recent International Committee on GNSS (ICG) meetings in St. Petersburg, the Russians were reporting on their actions set up an advisory board for GLONASS very similar to this Board for the Global Positioning System (GPS), an action he felt confirmed the appropriateness of the U.S. approach to seeking counsel from constituents and the user community.

Mr. Miller noted that the SGEs would receive the required annual Government Ethics Briefing during lunch.

Dr. James Schlesinger noted the great public attention focused on the rescue of 33 Chilean miners. He added that NASA engineers had been in Chile to examine the equipment and methods used and he wished to congratulate NASA for this effort.

Dr. Schlesinger said the Board's work had a positive impact on improving and preserving GPS services for many users, and that he looked forward to another two years of productive effort. He recognized that service on the Board was time consuming, however he thought it essential that the Board continue to present advice grounded on a solid intellectual basis. He welcomed the forthcoming addition of seven new members, which he believed would allow a broadening that could include such disciplines as precision agriculture, communications, transportation and one or two new international members. He noted that on November 5, 2010, he would describe to the EXCOM how the Board would focus on its new taskings over the next two years. The Friday session of this meeting would allow a round table discussion of the appropriateness of these taskings. Dr. Schlesinger then sought comments from the group.

Dr. Bradford Parkinson identified 'three overarching issues': the first was that of maintaining the necessary number of satellites to avoid a blackout; the second was robustness – how secure was GPS to jamming (in relation to this, he stated he believed GPS should be declared a critical national infrastructure); and the third was the question of interchangeability with other systems, which he believed called for continued vigilance.

Dr. Schlesinger noted that North Korea appeared to be undertaking jamming as a focused national activity. Dr. Parkinson said that a small cigarette lighter-sized device was capable of jamming GPS locally and that these devices were very hard to trace. This, he believed, underscored the need to have GPS designated as critical infrastructure so there would be an active program to shut down jammers and prosecute those who use these devices in a nefarious manner.

Mr. McGurn said that it did not appear that the U.S. government was doing anything substantive about mitigating jamming and interference. He believed further discussion was merited.

Dr. Schlesinger noted that General Robert Marsh had produced his report on infrastructure thirteen years ago, however little progress had been made since then.

Ms. Neilan called attention to next week's committee meeting of the ICG. Interchangeability was one topic. She reported that the ICG had established a task force on reference frame timing. A report from Chinese colleagues would be heard on this subject. Dr. Parkinson asked if the Chinese would present details of their evolving signal structure. Ms. Neilan said she believed a template had been developed for the system providers; how forthcoming the Chinese would become would be learned from the meeting.

Mr. Dimmen said he believed it was important to discuss the integration of the augmentation systems.

Dr. Enge said the jamming concern was legitimate, and it will be addressed by several speakers at this Board meeting.

Mr. Murphy said he believed the threat of interference was real, as it was already impacting aircraft landing systems such as at Newark airport. The existence of the 'car cigarette lighter'

jammers was delaying operational approval of such a system. The whole subject of backup systems required more attention. He noted considerable discussion about moving ahead to NextGen, which was very GPS dependent, however such plans begged the question of hazards from using GPS without appropriate backups.

Capt Burns said that NextGen was a multi-billion question for the users, who were concerned about proceeding to rely upon a system that will be highly dependent on GPS.

Ms. Ciganer observed that when interchangeability was increased, receiver selectivity was also increased. This should be taken into account in discussions of interchangeability. Additionally, she wished to congratulate the Air Force on its recent flex-power testing, which was a major achievement without disruption.

Gen Lord noted that the Secretary of Defense had stated the goal of achieving $100 billion in savings. He thought this made it likelier that a conclusion would be reached that GPS was adequate as is. He claimed as 'urban legend' that inexpensive jammers were being used by taxi drivers who did not wish their dispatchers to know where they were.

Mr. Hall said relative to interchangeability, the technical issues were less daunting than the bureaucratic issues, and that perhaps ways of achieving greater international cooperation should be sought.

Mr. Faga had no comment.

Mr. Nishiguchi stated the importance of not introducing "indirect" user charges such as "type authentication" for the quality of civil GPS receivers, even if for receiver selectivity, since the PNT Policy only explicitly states that no direct fees for GPS will be charged.

Dr. Schlesinger noted that Capt Smith was unable to attend the PNT Board meetings this round due to the serious illness of his wife. Dr. Schlesinger then expressed the group's sympathy and best wishes to Capt Smith's family.

Mr. Murphy suggested that the Board's next meeting address the subject of space weather monitoring and its impact on GPS users, as he believed the Board would benefit from knowing about the variety of technology packages being developed in this area. Mr. Miller commented that a space weather symposium was being held that day in Washington D.C. He added that NASA was reviewing how the future Tracking and Data Relay Satellite System (TDRSS) constellation could aid space users in the future by broadcasting space weather events. Dr. Hermann asked if NASA considered space weather monitoring something for which it was to be held accountable. Mr. Miller said the responsible party for this was the National Oceanic and Atmospheric Administration (NOAA), with whom NASA had a cooperative effort.

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PNT Advisory Board Taskings
Anthony Russo, Director
National Coordination Office

Mr. Anthony Russo said he welcomed this opportunity to convey to the Board its taskings for the new two-year cycle. These taskings were approved by the full PNT EXCOM after an extensive review by all EXCOM member departments. He noted that the Board was requested to submit to the EXCOM in one year a concise written progress report on in the areas being designated.

First, Mr. Russo said he doubted a good path forward existed on one potentially expensive issue: this was that companies were building receivers not in compliance with Interface Control Document (ICD) specifications. He noted that one might define this as a problem for the manufacturers; however, when systems failed due to software changes, it often fell to government organizations such as the GPS Wing to do the troubleshooting from a potential signal interference perspective. There are simply far too many receiver types for federal government groups to oversee, and therefore the responsibility for ensuring receiver robustness lies with the manufacturers.

Dr. Parkinson said that at times specifications were so detailed that people acting in good faith found themselves unable to follow them. Mr. Russo said this was true. He would welcome some equivalent to the Underwriters' Laboratory (UL) approach, whereby an agency funded by manufacturers set certification standards. He noted an episode in which one million Japanese-built receivers ceased working: How, he asked, could industry be incentivized to meet standards? Dr. Schlesinger asked if any penalties applied. Mr. Russo said penalties inadvertently fell on the user while the government as was blamed as the cause for the receivers not functioning properly. Dr. Schlesinger asked if foreign or domestic firms were involved. Mr. Russo said both were. Dr. Hermann endorsed the UL approach. This he defined as a marketplace approach to the problem, which was an area in which he doubted heavy government intrusion was needed.

Mr. Russo then addressed the PNT Architecture Implementation Plan. The creation of this plan had largely been out-sourced. The consequence was the creation of a National PNT architecture, in which the space-based PNT architecture was embedded. Agreement had been reached on several enterprise-level recommendations, and an implementation plan had been assembled over the past several years. The Board was being tasked with providing advice on the most efficient ways to implement such a system – various approaches existed, and the Board was being looked to for its independent assessment. Dr. Schlesinger asked if the Office of Management and Budget (OMB) had been encouraged to 'ride herd' on this. Mr. Russo said no, but there had been White House interest in the architecture effort. Dr. Parkinson asked if civil and commercial inputs had been sought; the answer was yes. Dr. Hermann said the Board's role appeared to be to assess how best to implement an established plan, however was the Board authorized to take issue with aspects of the plan? Mr. Russo said the plan had been signed-off by DoD and DOT leadership. Dr. Hermann noted that if "it was done by man, it can be undone by man." He believed the task offered an opportunity to deal with what he viewed as the flawed management scheme the nation used as standard. What mattered, he believed, was that a plan be connected to

resources, schedule and accountability. Mr. Russo said that the Board, in effect, did have the authority to "color outside the lines," an answer that satisfied Mr. Hermann.

Mr. Russo then addressed commercial outage assessment (Slide #5). He had been working with GPS jamming issues since 1992, and although it had taken a decade, he had persuaded the military that there were structural problems to be addressed in terms of overreliance on GPS without appropriate backup. He believed that civil departments were aware of the issue and would finally respond when forced. Delay, he said, had been causing the 'so what?' factor. Meaning, so what if there were 500,000 small jammers out there, what are the specific consequences at the national level – particularly for civil users? Resources would not be targeted to the issue until it was accepted that it was a problem. As yet, it was unclear whether jamming could "take down" first responders. This was a matter he hoped the Board would address. Dr. Schlesinger asked if recent legislation required the Department of Homeland Security (DHS) and the U.S. Coast Guard (USCG) to determine whether a national backup system to GPS was needed. Mr. Russo said such a report was due within 180 days. He said the general attitude was that while people would admit a problem existed, they would assert it was largely a problem for someone else, who should be called upon for the requisite funds to resolve the issues when they became apparent. Dr. Parkinson said these circumstances were similar to the 'tragedy of the commons' scenario.

Returning to the taskings for the Board (Slide #6), Mr. Russo urged the group to focus on the outcomes of secondary impacts of GPS outages on functioning such as the Internet or telecommunications synchronization.

The final tasking (Slide #7) followed from the fact that the Board's charter allowed for the creation of subcommittees. Mr. Russo suggested it might be useful to have an independent assessment of semi-codeless services evaluated. He noted that semi-codeless was being phased out in 2020 due to the anticipated multiplicity of civil signals coming online. He believed these issues were very technical, and suggested it might be wise for the Board to establish a subcommittee so that it could review such matters.

In closing, he noted that final approval was being sought from the EXCOM on the seven additional individuals to be appointed to the Board.

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GPS Constellation Update & Modernization Plan
Meeting Current and Future Requirements
Brigadier General James E. Haywood
Director of Requirements
Air Force Space Command

Gen Haywood said he would provide a briefing on the constellation overview, modernization activities, "expandable 24," and signal planning. Gen Haywood said he believed the

constellation was healthy, with 31 satellites, including three additional satellites in residual status to enable things like expandable 24. The next II-F launch is expected in mid-2011. He believed performance was improving over time, and was now consistently in the sub-meter range. Gen Haywood reported on the GPS Civil Focus Day (Slide #4), which convened on February 3, 2010 in Colorado Springs, with a variety of interagency participants. The meeting's objective, he said, was to foster collaboration on key GPS issues with U.S. civil agencies, such as ensuring that GPS remains the world's gold standard; messaging on how to inform the community that upgrades have been put in place; and anticipating what test events would need to occur. Discussion also occurred about L2C and the U.S. commitment to maintaining phase capability. Here, he introduced the notion of signal planning: what do we need to do well out into the future? Eventually, we will be producing eight signals; what do we need to do to sustain this? Dr. Schlesinger asked whether Gen Kehler's successor at Air Force Space Command will continue this activity. Gen Haywood replied that he believed he would.

Gen Haywood then addressed GPS modernization in the space segment (Slide #5). He noted that a fourth civil signal, L1C, would be broadcast in the future. In the Ground Control Segment, he noted the Architecture Evolution Plan (AEP) and the Next Generation Control Segment (OCX), calling attention to the $1.5 billion contract award made in February 2010. Gen Heywood said his own task was to make sure that all requirements documents were in place through the Joint Capabilities Integration and Development System (JCIDS) process. Dr. Hermann asked whether, when the JCIDS process was used to confirm requirements, both civil and commercial interests were represented. Gen Haywood said they were. He cited as a recent example GPS-III, where efforts were made to identify the requirements and Analysis of Alternatives (AoA) was conducted. Civil participation, he said, is written into the guidelines. Seeking confirmation, Dr. Hermann asked if civil requirements were written into the JCIDS process. Gen Haywood said they were.

Dr. Parkinson asked what impact the AoA study would have on the PNT Architecture that the Board was to begin studying; he believed the effect could be profound. Gen Haywood said his preference would be that work done on the Independent Review Team (IRT) by this group influence the AoA appropriately, and stated that he expected some give and take on this. Dr. Parkinson added that "at the end of the day" it seemed probable that the AoA would reflect some set of tradeoffs, which, in aggregate, would have a serious impact on the architecture. Gen Haywood agreed, saying that the AoA work could provide a high-level requirements document for GPS-III. He also believed that the AoA was being undertaken correctly as an informed community event. Dr. Parkinson said that, presumably, the National PNT architecture would be driven by the Department of Defense. Dr. Hermann said, presumably, DoD was a signatory of the current architecture plan. Gen Haywood said it was. Dr. Hermann said the reason he pressed the issue is to determine where DoD stands as a department, as opposed to its internal processes for aspects of the architecture.

Hank Skalski (civilian liaison at the Air Force Space Command) said that the Department of Transportation (DOT) had worked with DoD to create an interagency plan, enabling civil participation all through the JCIDS process.

Dr. Schlesinger noted that amongst the alternatives of GPS increments III-A and III-B, is the continuation of III-A satellites instead of transitioning to more advanced III-B satellites, given the budget situation. Gen Haywood said this was under consideration as a means to evaluate all options that struck a balance. The AoA, he added, needed to respond to the ICD higher level documents. Col Bernard Gruber, current program director of the GPS Wing (GPSW), said he thought it was premature to discuss what the AoA would do or not. The AoA study plan had been written and has been in for review; one aspect is the baseline configuration and maintaining that baseline. At present, there were certain aspects – e.g., jamming – which are placed against overall use capabilities. Gen Haywood acknowledged that there were requirements that would not be met by the III-A satellite block. Dr. Schlesinger noted that as launch systems became more expensive, there was a tendency to cut back on the number of launches, which would cut back on the number of satellites in the constellation. This, he said, was a primary concern of the Board.

Gen Haywood then addressed Modernization of the Ground Control System (Slide #6). He noted that the AEP transitioned in 2007, and had increased capacity for monitoring GPS signals. He said planning for the Next Generation Control Segment (OCX) continued to mature; a $1.5 billion contract had been awarded; and a Preliminary Design Review (PDR) was anticipated for April 2011. Dr. Schlesinger sought comment on the Government Accountability Office (GAO) comment that OCX would not be available until 18 months after the first GPS III-A launch: Was this is a concern? Gen Haywood said this was a known issue. Col Gruber said there was a known 15-month gap between OCX going into operation and the initial launch of the first GPS III-A satellite in May 2014. First, we have worked with the team at Raytheon to evaluate what we are doing with the software for those plans. Second, we are evaluating a launch and checkout system that would reduce risk. Dr. Schlesinger said one way to close the gap would be to allow the launch of the III-A to slip, which was not the solution the Board wanted.

Gen Haywood then addressed Modernization of User Equipment (slide #7). Where military use was concerned, he said, the most significant aspect was the Technology Development Strategy that identifies what needs to be developed and determines how the risks entailed in these developments can be minimized. The strategy, he said, was to produce a standard GPS module that could take many form factors. Dr. Schlesinger asked whether the other uniformed services and the nation's allies were being consulted. Col Gruber reported that there were at present allied service representatives working within the GPS Wing. He added that allies were formally consulted through agreements currently in place with 54 countries. Dr. Parkinson asked if foreign program officers remained with the effort; and Col Gruber responded that they did. Dr. Hermann said the effort appeared well coordinated in its technical aspects; however he asked if it was well harmonized with the resources that were being made available to permit individual services to acquire equipment in an operationally coherent way. He believed this had been haphazard in the past. Col Gruber said he believed this existed since components were delivered to enhance capabilities of the system. Further coherence comes from having a robust process for configuration control of standards and interface control documentation, which is made available to users worldwide. Finally, development of a common module continues, through which other users will never be precluded from participating. Gen Haywood stated that how requirements are developed will indeed affect each military service.

Gen Lord said what made him nervous about the process was that the Secretary of the Air Force had recently written a letter to direct how Air Force acquisition would proceed and that space-related matters would be vetted through the SAF-AQ. : The result is that the space programs will be looked at by the Air Force overall, as opposed to separately. This, in itself, did not concern him, provided it was clear that the Air Force overall supported the procedure. Gen Haywood said that since 2001, acquisition decisions were separated in the Air Force between space and non-space. Most recently, the Secretary of the Air Force has since reviewed this, making all acquisition activity part of a single cohesive flow.

Gen Haywood then addressed GPS modernization – and new civil signals (Slide #9), noting that this involves many stakeholders and that considerable time would be needed to plan for any changes. Dr. Enge called attention to what he considered an important dependence – that according to current plans there would be more than 24 satellites in 2018 with several signals for civilian users, with L5 finally supplanting the stable L2 semi-codeless use which is scheduled to be "sunset" in the 2020 timeframe. He thought it highly important that there will in fact be 24 satellites with L5 capability before any semi-codeless satellites were removed from service. Gen Haywood said this underscored the need for a civil signal strategy. Gen Haywood then presented GPS Expandable 24+3 (Slide #10), noting that this implementation had begun already.

Gen Haywood then introduced the topic of signal planning (Slides #11-14). Signal planning was important, he said, because we are moving toward broadcasting eight signals from space. As GPS capabilities will continue to be exploited, at some point one needed to ask whether the spectrum was being overcrowded. He noted that the interagency group Mr. Russo headed had a signal frame working group in action. He believed that, given the complexity of the subject and the number of stakeholders involved, it was never too early to begin this discussion. If one wished to maintain GPS as the "gold standard" for the world, then one needed to have a campaign plan that presented the appropriate message. He said a robust signal strategy involved a definition of the stakeholders and their concerns, the capabilities required, tasks, schedules and the milestones "you will need to be marching to." Ms. Ciganer announced that it was important for the ICD to have symmetry with national policy.

Gen Haywood then addressed the topic of The Way Ahead (Slide #15), noting that collaborative discussions would continue within the National PNT structure; that the GPS Interagency Forum for Operational Requirements (GPS IFOR) had formed a working group to determine the contents of a strategic-level signal planning document and to map a detailed way ahead; and that the next PNT Executive Steering Group (ESG) meeting would be the target for the presentation of that document. In summary, he said he believed a good job was being done; the constellation's accuracy was the highest it had ever been, and plans were in place to modernize. He noted that the general environment was fiscally constrained, and had to be kept in mind. He reiterated the success of the GPS Civil Focus Day, which he believed had laid the foundation for unprecedented collaboration and communication. Such events needed to be repeated.

Dr. Schlesinger noted that the GAO report had called for more oversight of the Air Force by DoD. Gen Lord said he wished to commend the efforts of this group that, he said, were carrying the burden of decisions made prior to its existence. Dr. Parkinson expressed agreement, saying that the group had a difficult task because it had 'this AoA rolling along,' and he was trying to

understand how hard the boundary conditions were. He asked if Gen Haywood believed he was free to "push back" against these standards. Gen Haywood said that was his understanding. He did not as yet know how all this would play out, in part because of the affordability issues. Dr. Parkinson asked if it was yet known who would lead that study. Gen Haywood said it was not. He noted that he had stressed the need to have a technical competent group.

Ms. Neilan called attention to the Board's unanimous recommendation about the addition of laser retro-reflectors to GPS III satellites. Gen Haywood said that issue was being worked. Col Gruber said that a recommendation was in hand; a response from Gen Kehler was anticipated. Dr. Parkinson said he thought it ironic that the one unanimously endorsed civil requirement got "bashed." Mr. Miller reported that NASA was one of six federal agencies with an interest in retro-reflectors. He noted that Air Force Space Command had taken the position that reflectors were not required from a military standpoint. He added that while there might not be a formal requirement, there was certainly a push within the military to make them available. Dr. Hermann noted that a Geodetic Working Group had defined reflectors as required, but apparently this was not a requirement that needed to be acted upon. Mr. Miller said it was an interagency requirement for precise science measurements being championed by NASA, but not a formal military requirement as of yet. That, Dr. Hermann said, was his point -- does DoD honor its commitment to broader national requirements? It appeared to him that it did not.

An audience member said Gen Kehler was prepared to proceed if all the costs would be covered and the retro-reflectors did not adversely affect any other mission requirements. Dr. Schlesinger said this problem had been continuing for 15 years: civil agencies announced requirements, which they expect the Air Force to fund; while the Air Force says it could not fund it. Dr. Hermann noted that it was actions outside of GPS that added to satellite weight in a way that meant they could be launched only one at a time. Dr. Schlesinger noted that while the Chinese were able to launch such satellites three at one time, the U.S. declined to launch two at one time, apparently so as to not intimidate the Chinese. Ms. Neilan noted that it would be difficult to maintain GPS as the "gold standard" when every other Global Navigation Satellite Systems (GNSS) in the world was using reflectors, and GPS was not. Mr. McGurn said he had heard rumors that there was not sufficient space on the satellites to accommodate the retro-reflector. This drew the response that while there was not sufficient "empty" space available, a number of options had been considered and the reflectors could be added if this was ordered done. Mr. Hall noted that costs of integration would likely increase as postponement occurred. Mr. McGurn called attention to a "wonderful paper" published by the Chinese in which retro-reflectors were used not only to determine range but to get satellite clock drift information. Gen Haywood was asked whether the budget funds available to him were consistent with the program he was charged with executing. Gen Haywood said at present the program was fully funded.

Mr. Hall noted that the cost factors of addressing the retro-reflectors had been addressed, but not the schedule factor – that is, that the decision should not interfere with any milestone points in the schedule. At what point did a delayed decision on retro-reflectors have a schedule implication? The response was that the satellites were incremental; that III-A was completed, and the question at issue was laser retro-reflectors on III-B. Dr. Parkinson asked when the first III-B would be launched. The year 2018 was suggested.

Dr. Schlesinger said that when this Board was first comprised, it had considerable complaints about the Air Force. This has notably changed, and the Air Force was being responsive to the Board, which was well appreciated.

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GPS IIF Program Update:
Ken Torok
Vice President, Navigation and Communication Systems
Boeing Space & Intelligence System

Mr. Torok noted Boeing's lengthy history with GPS, having provided 40 of the first 61 satellites. He presented a GPS II-F overview (Slide #3) describing the mission benefits and the additional capabilities for both the warfighter and civilian users. He reported (Slide #4) that GPS satellite IIF-1 was launched and operational. Following a successful on-orbit check-out, this satellite had entered service on August 26, 2010. It boasts the first operational L5 signal and measurements to-date show that it also has the most accurate clock to date.

Mr. Torok reported (Slide #7) that Boeing had developed a modified assembly line approach to satellite construction, derived from other Boeing operations. Individual stations were established; as it took the satellite approximately equal time to have the work of one station completed. Now as the satellites move through each phase the entire line pulses forward. In consequence, he anticipated being able to produce four satellites a year. He noted (Slide #8) that block II-F was the most capable satellite in the constellation, with the highest power and most robust navigation signal. The design life of II-F is formally twelve years, though it is probable this will be increased. Boeing looks forward to the IIF becoming the backbone of the constellation over the next two decades.

Dr. Schlesinger asked what thought Mr. Torok might have given to the GAO report which stated that the GPS III-A program appeared to have avoided the mistakes of the II-F program. Mr. Torok said the matter had been the subject of considerable discussion. His view was that the program had been harmed, first, by being procured during a period when the acquisitions philosophy was very hands-off and there was limited oversight of the prime contractors down into the supply chain. Second, significant requirements changes were made late in the program development process and these were in consequence not executed as smoothly as they could have been. Dr. Hermann asked if this had been an example of mission creep and requirements changes. Mr. Torok noted the flex-power and the modernized signals – M-code and L5 – were introduced four years into the program.

Dr. Parkinson said he wished to commend Boeing. The Board, he said, had been "holding its breath" in regards to the II-F program due to the age of so many satellites currently on orbit and the need to replenish. He asked Mr. Torok what major risks, budgets aside, he saw in completing the remaining eleven II-F satellites. Mr. Torok noted that while Boeing was still in the final development phase; some anomalies had prompted a repetition of thermo-vac testing,

which had now been completed successfully. As each individual satellite is built, the number of problems goes down. Dr. Parkinson asked if any parts problems were foreseen. Mr. Torok replied that the supply line was currently very active; and efforts had been made, he added, to go back and modify designs to make them more robust. The program had been increasing its volume with each supplier. Further, Boeing was using many of the same suppliers as will be used for GPS-III. Dr. Enge queried the statement that II-F had entered service on August 26, 2010 -- did that date apply to all the signals? The response was that what was set as healthy was the satellite as a navigation system; the current GPS system still isn't supporting full operations on the 2nd and 3rd civilian signals (L2C and L5) yet.

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GPS III-A Program Update:
Dave Podlesney
GPS III-A Program Manager
Lockheed-Martin

Mr. Podlesney noted that he had been working on the GPS program since the early 1990s. He reported (Slide #2) that the program had been placed on contract in May 2008, at which time the contract called for two development vehicles, a pathfinder vehicle and a number of simulators. The program was structured as a "back to basics" program, one that would emphasize doing stringent engineering and reinvigorate the specifications. At present, he said, the production option was for eight vehicles, though ten could be produced. He noted that the same basic team has been involved in the satellite effort since the early 1990s.

The power increase in the newest satellites was three to six times greater for the military signal; our specification is for improved accuracy in the III-A configuration; further, the L1C signal that will be compatible with the Galileo Open Service (Galileo is the European GNSS) has been added. Enhanced signal flexibility has also been added – this gives us flexibility in moving power and in changing the signal structure. The III-A configuration was built with the understanding the III-B and III-C would be coming along, so they were planned with the notion that new things would be added in the future allowing for pre-planned growth capability.

Mr. Podlesney said he would like (Slide #5) to address program growth and performance. At the conclusion of the Program Design Review (PDR), we determined that we were well ahead of schedule, so we included a Critical Design Review (CDR) that was in advance of the baseline. The CDR was completed earlier this year. He noted that they were transitioning out of the design activity and into the production period. To date, 13 of the 59 manufacturing readiness reviews have taken place. Next (Slide #6), he outlined the differences between GPS increments III-A; III-B and III-C. Finally, Mr. Podlesney presented GPS III Way Ahead (Slide #7), noting the transition from design to manufacturing; the plans to proceed on a GPS non-flight satellite test bed (he noted that the test bed that will be used will allow them to make sure that fittings are proper; further, it will permit software testing to take place on the ground); the performance

expectation of key subsystems; the starting of production spacecraft long-lead procurement for the next four satellites; and support of analysis of alternatives for future capabilities.

Mr. McGurn asked how additional accuracy would be created with the III-A and III-Bs. Mr. Podlesney responded that the II-R and II-R (M) vehicles, the performance numbers are based on the vehicle built and the thermal stability of the design. These will be combined to provide better accuracy.

Dr. Parkinson asked what issues, other than budget, were of concern. Mr. Podlesney noted that across the industry, the supplier base was shrinking; this was leading to increased costs for supplier base training. At some point, we will need to ensure that the supplier base will keep up with our requirements. Mr. Podlesney said he was aware that he had been asked about problems other than "funding" still, funding was an issue because the program had been structured with the idea that funding would be stable; if it is not, that can effect supplier relations. Dr. Schlesinger commented that if one considered the budget environment, it was likely to become a larger problem in the out-years of a program. Costs were related to the steady growth in the weight of each satellite – he noted that people simultaneously talked about cutting costs while expanding satellite size. He invited comment. Mr. Podlesney said that in present plans, the cost of adding any feature had been included in the estimate. The budgetary constraints may have a different impact, he said, in that they may lead to fewer vehicles being launched. He felt a partial response to that was his organization's capability to build satellites more efficiently.

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GPS OCX Update
Robert Canty
Vice President and Program Manager OCX
Raytheon

Mr. Canty said he wished to talk from the warfighter perspective. He presented (Slide #2) an OCX overview, noting that first, it was an interface to space, to provide command and control planning in space and second, to provide the GPS system with connection with the outside community. The real difference is the move toward a NetCentric system. It was important to OCX that it had an architecture that evolved as the requirements of information assurance evolved generally. More generally, one needed an architecture that was conducive to the variety of changes that might occur. In the last phase of the program, he said, an independent group reviewed the flexibility of the OCX architecture and had reported that it was in the top ten percent of architectures for flexibility. He noted that the anticipation that the system would go Net-Centric was being built into the design.

Dr. Enge said he was surprised by the way integrity and continuity monitoring was being included as an Federal Aviation Administration (FAA) item, as his own understanding was that it was being included for military use with FAA cooperation. In Blocks I and II, the integrity requirement is basically military. He added that if one did not design for possibility early on, it

was very difficult to add them later. His organization was designing for the military but allowing for anticipated changes in the civil system.

Mr. Canty presented information on how OCX will modernize GPS (Slide #3). He noted that the system was moving in the direction of Net-Centric, in which case all information would be available to both the military and civilian side; (Slide #4), outlining the OCX growth path to Full Capability Development Document (CDD) requirements; and (Slide #5) OCX Summary Schedule, which noted that Block 1.0 took over from the legacy system and Block 2.0 brings in the additional civil signals. Mr. Canty noted (Slide #6) that the OCX PDR was scheduled for April 2011; currently, the program was on schedule for all iterations. In Slide #7 he described how each iteration of OCX Phase B would proceed: after iteration 1.5.

Dr. Parkinson noted that the GAO had reported there was formal schedule disconnect: was Mr. Canty saying that the actual delivery of a working piece of software was completely sufficient to handle that first GPS III-A launch? Mr. Canty responded that after iteration 1.5 had been reached, one would have the foundation in place to launch the first satellite. There will be a short period that involved final testing and integration into Lockheed-Martin. Dr. Parkinson asked by what date this was needed in place so as not to delay the launch. Mr. Canty said those details were currently being worked in conjunction with Lockheed. Dr. Parkinson asked if it was Mr. Canty's belief that the problem would be totally solved. Mr. Canty said it would be totally solved. Dr. Schlesinger said experience to date showed that whenever cost increase occurred on space vehicles, somebody reached back to OCX for the money -- one might worry about this in terms of schedule. Mr. Canty noted that from a Congressional budgeting standpoint there were separate budget lines for space and ground aspects. Mr. Canty noted that the chart he had presented was the baseline chart for launch, and was moving forward. Mr. Canty noted that a natural delay occurred between the time a satellite was launched and it was put into service; the satellite would not become fully operational until OCX was included.

Mr. Canty said he believed one started to look at integration from day one of the program, with transition requirements initiated from the beginning. He noted that the first four milestones had been achieved (Slide #7), with software iteration 1.2 due for completion by January 11, 2011, by which time over one million lines of code are to be produced. The next major milestone is the OCX Block I and Block II PDR, which is currently scheduled for April 2011. Mr. Canty discussed Closing on Enterprise Integration (Slide #8), and stressed the importance of the synchronization achieved between Lockheed Martin and Raytheon.

Mr. Canty's summary (Chart #9) stressed that OCX was responsive to today's system requirements; was off to a solid track with on-time Block I delivery anticipated; enterprise integration had been resynchronized, with upfront site integration and transition planning significantly reducing risk. He felt that they had dealt very quickly with all the systems integration issues.

Gen Lord asked if there would be a reduction in the number of operators when OCX came on line. Mr. Canty said yes.

Ms. Ciganer called attention to the difference between providing a signal and providing a service. Dr. Parkinson asked, regarding L1C and L2C, whether the definition of these signals was sufficiently clear that one could build the requisite piece of hardware. Mr. Canty felt that from the team's perspective, they had what they needed. Mr. Parkinson thought L1C still had considerable uncertainty. As an old program manager he remained skeptical until he saw a piece of hardware that thinks it is transmitting the right signal with another piece of hardware that thinks it is receiving the right signal.

Dr. Enge said he shared Dr. Parkinson's concern about L1C and L5; and he believed there was a workshop coming up at the Aerospace Corporation that may delve into these issues further. Mr. Canty said he had the specifications that he was to build to. Dr. Parkinson said that Gen. Lord had touched on the greatest element of risk: -- uncertainty about the budget in the out years. He asked what in terms of AEP did he believe he had learned and addressed with OCX. Mr. Canty said, first, really focusing on an architecture that would evolve with the system; second, designing an architecture plan with the upfront expectation of changes; and, third, having a policy on when you 'fall back' – you can't go to a four-star general every time one wanted to make a transition.

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2010 National U.S. Space Policy
Damon Wells
Assistant Director for Space and Aeronautics
White House Office of Science and Technology Policy

Mr. Damon Wells noted that since the last national statement of U.S. space policy came in 2006, much had changed. These changes included evolving commercial capabilities; an increase in space debris; increased transparency; and the significance space plays in the U.S. economy. Mr. Wells identified as core principles: the exploration of new space for peaceful purposes; the acknowledgement of no claims infringing on U.S. sovereignty; and concerted efforts to preserve the nation's industrial base. Mr. Wells said new themes were the increased use of commercial goods and services, additional international cooperation, and the pursuit of increased stability in space. Further, he noted that for the first time, space-based capabilities were called out in the full space policy; in 1995 and 1996 it had been part of the sector policy. Mr. Wells said the overarching position was that the U.S. must maintain leadership in space with GPS. This would be achieved by continuous worldwide system access; through the encouragement of transparency and interoperability, by operating the GPS system in such a manner that national and international needs are met, and system specifications that are published and public. Mr. Wells urged that focus be placed on the themes and goals that had been emphasized, including transparency and open access as key priorities for the PNT Board as well. The value of having this statement included in the national policy is that it reaffirms that importance of the core policy objectives.

Mr. Wells said that while drafting this policy was difficult, implementing it was more difficult.

Dr. Hermann noted in the description of national policy and national objectives, the final statement touched on implementation. Various government departments had a role to play in this; how did Mr. Wells see this being sorted out? Mr. Faga asked if there had been discussion of establishing a national space policy. Mr. Well said consideration had been given to this, but the decision made had been not to do so. What, he asked, would a strategy do that a policy would not? He noted that the 2005 PNT policy remained in place; it had not been superseded, and, further, that the EXCOM remained the axis of implementation for PNT.

Mr. McGurn noted that, under present OSTP guidelines, the only responsibility related to GPS disruption was given to DoD. Mr. Wells noted there had been no change since the 2005 policy on GPS interference, jamming, and mitigation. Mr. McGurn said that given the importance assigned to PNT, he would have expected more emphasis to have been placed in the area. Dr. Schlesinger noted that DHS had responsibilities for critical infrastructures; although GPS had still not been so designated. Mr. Wells said the purpose of the language was to urge agencies to review their needs for a back-up system. Dr. Schlesinger said it was the long-held view of the Board that the Department of Homeland Security (DHS) should include GPS as a critical infrastructure.

Dr. Parkinson said the Board had delved into the activities of DHS; his strongly held view was that the policy Mr. Wells was presenting was not consistent with the manner in which DHS organized itself. He believed DHS's actions to be woefully inadequate; the agency had no sense of urgency and the problems facing GPS had very little recognition in the upper reaches of the agency. This had been a priority of the Board for some time: someone with a $33 cigarette-lighter jammer could take out portions of the GPS system, yet it did not appear that anyone in government felt it was their responsibility to address. Dr. Schlesinger asked if the new policy foresaw a back-up role for GPS. Mr. Wells reiterated that the 2005 policy had directed agencies to explore back-up capabilities. Dr. Schlesinger reminded Mr. Wells that the Board had reached a firm recommendation on behalf of *eLoran* (Enhanced LOng RAnge Navigation), only to see it suddenly disappear from the previous year's budget. Kirk Lewis stated he hoped discussion had occurred on how to address sovereignty requirements and safety-of-life responsibilities. He did not think there had been any substantive discussion on whether the U.S even had sovereignty needs. Mr. Wells noted that the nation had a policy; it also had requirements developed through the interagency requirements process that were translated into the current program. He believed that the government had stated the requirements for sovereignty and security of life. Gen Lord said there was a disconnect between saying what the requirements were and what the space vision is. Mr. Wells said he did not believe the disconnect was "all that great."

Dr. Hermann said that vision and goals were national in nature; execution of these, he added, was departmental. It was not clear that a robust process existed whereby departmental programs and resources were aggregated into goals and visions previously described. He acknowledged that one could say: 'Well, it's all up to the EXCOM,' but his own view was that if one expected such a management style to work, then he wished them good luck. Restating, Dr. Hermann said that the national goals and objectives that had been identified were not the goals and objectives of any particular department. He did not believe that national objectives could be reached simply by summing the objectives of individual departments.

Mr. Wells said GPS was one of the most complex of interagency undertakings; if one reviewed the policy guidance of the past 15 years, then it is clear there has been an awareness that problems existed. The EXCOM was created to operate at the "Deputy Secretary" rather than the "Assistant Secretary" level. The task of the EXCOM is "to push the ball down the road; not make final decisions."

Dr. Parkinson made reference to the policy statements about the location, mitigation, and prosecution of jammers, but it was clear to the Board that no federal agency was doing it. DHS, he acknowledged, was doing a few things, but not much. There appeared to be no unity of command on the issue, and that more coordination was essential. Dr. Schlesinger asked if the White House was considering issuing an Executive Order. Mr. Wells said not as of yet.

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Diplomatic Activities in Support of International GNSS Interoperability
Ray E. Clore
Senior Advisor on GNSS
Office of Space and Advanced Technology
U.S. Department of State

Mr. Clore began (Slide #2) by restating how essential GPS was to surveying and mapping, personal navigation, trucking and shipping, disease control, precision agriculture, transit operations and other areas. He noted that without GPS cell phones would not work in many regions. Mr. Clore presented a schematic (Slide #5) of the nation's space-based PNT organizational structure: he noted that the Russians were very supportive when they saw this slide. Other nations, he said, were pleased to learn that the U.S. had a broad base to its national PNT policy. Mr. Clore (Slide #6) spoke of the emphasis the Department of State (DOS) put on compatibility and interoperability, along with efforts to secure a fair market for U.S. goods and services.

Dr. Schlesinger noted that the Russians would not have dealings with systems that did not include GLONASS (GLObal'naya NAvigatsionnaya Sputnikovaya Sistema -- the Russian GNSS constellation). Mr. Clore noted that the Russians had "made noises" about establishing a 25% duty on GPS-only equipment; this was still talked about but not put into place. The fact was, Mr. Clore said, that the larger the installed base for GPS the more people would invest in it. Currently, the GLONASS receiver was twice as heavy and twice as expensive as GPS. He believed market preferences would apply. Dr. Parkinson said there would always be a 'black market for GPS receivers in Russia.

Mr. Clore then addressed the topic of international and bilateral cooperation (Slides #7-9). He noted that bilateral talks had occurred with China and were proceeding on an operator-to-operator informal basis. Dr. Schlesinger noted that relations between the U.S. and Chinese military had been tenuous: GPS was a military program. Did Mr. Clore see any "spillback" in

terms of talking with the Chinese? Mr. Clore said that at the most recent meeting the Chinese had agreed to attend the forthcoming ICG meeting in Italy. Dr. Parkinson noted a proposal made by the National Academy for Engineering to go country-to-country to address GPS issues; he regarded this as a good idea and he hoped the Department of State would support it. Mr. Clore said his department supported all efforts to achieve transparency with the Chinese system. At present, China appeared to be directing more energy to developing its system that Europe was doing. He did not believe the Chinese were conceding that the European system would be the next in use. Mr. Clore noted very good relations with Japan, where bilateral agreements have been signed on monitoring stations with NASA and NOAA hosting. He also noted that India – which had last year experienced a launch failure – was relatively inactive at present. Mr. McGurn said he had heard that Russia had signed an agreement with India on GLONASS. Mr. Clore said he had heard this, but had no details. He noted that discussions would be forthcoming with Australia over the location of monitoring stations. Regarding Russia, Mr. Clore said that while six years ago he thought a comprehensive agreement with Russia might be possible, this had not occurred, although a longstanding agreement on "search and rescue" was in effect.

The role of the ICG in bringing the benefit of GNSS to developing nations was raised. Mr. Clore said DoS strongly supported the ICG, and was very pleased by the agreement on transparency reached at in St. Petersburg. He hoped that 'sidebar' meetings with the Russians and the Chinese would take place at the next ICG meeting in Italy.

In summary, Mr. Clore said he believed progress was occurring; he thought that interoperability was the key to success. Dr. Schlesinger asked what level of confidence Mr. Clore had in the transparency agreement. Mr. Clore said efforts would continue. The fact that an agreement existed meant that in time countries would come to abide by it. He understood that individual countries wished to protect their own economic interests; the fact that the GPS system was working so well would most likely induce wider adoption of principals that enabled such success. Mr. Clore thanked Ms. Ciganer for her efforts in international communications. Ms. Neilan noted that one of the ICG working groups was focusing on reference frame and timing interoperability.

Dr. Schlesinger asked Mr. Clore's perspective on Galileo. Mr. Clore said the Europeans were proceeding much more slowly than they had hoped: building and deploying a system was proving more difficult than they had expected. He believed the first Galileo launch would come in 2011. He noted that the Europeans had wished to have a quasi-military signal; they had a keen interest in the Galileo Public Regulated Service (PRS), in making it reliable and in protecting the spectrum for it. He believed they would be "hard-nosed" on these issues in the coming years as other systems such as the Chinese constellation come online. He believed the Europeans would be very happy if the North Atlantic Treaty Organization (NATO) would adopt the PRS as a backup to the GPS military signals. His own view was that Galileo was more likely to be the fourth system in use than the second system. Dr. Parkinson said he did not believe that Galileo had reached the end of their problems: the requirements for "safety-of-life" were not such that they could be reached on the first day of operation. Dr. Schlesinger asked how the two new members, Poland and Hungary, were fitting in. Mr. Clore said that at least for the time being both appeared happy to go along with existing arrangements.

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Lessons Learned from Engaging International Markets
Steve Moran
Director, Space & Environmental Mission Solutions
Raytheon Intelligence & Information Systems

Mr. Moran, presented (Slide #2) on Possible Civil GNSS Futures, and said that not a great deal had changed in terms of growing global interests in PNT capabilities. He noted that Galileo 'no longer just loomed out there' but is becoming a true system to be dealt with. He commented (Slide #3) on India's GPS- Aided Geostationary-Augmented Navigation System (GAGAN) that it was less a competition between companies than between systems. He noted that Raytheon had been awarded the GAGAN demonstration contract in 2004. One lesson learned from pursuing international business was that it was a long-term effort: a four-year pursuit was not uncommon. It was not clear that companies would maintain interest for that length of time. He presented some historical context on U.S. Policy and the GAGAN Acquisition (Slide #5), showing a 12-year timeline of the efforts involved. He noted that NASA, the FAA, and the Department of Commerce (DOC) had all sent letters to their Indian counterparts in support of the venture. In summary, he said, the central tenet is that all countries want to build their own economies: part of this is the desire to develop committed and reliable suppliers, particularly suppliers who wish to create long-term relationships.

Dr. Schlesinger noted that, according to Mr. Clore's presentation, the U.S. had at one point alienated the Indians-- simultaneously alienating the Indians and the Pakistanis was something of an accomplishment. Ms. Neilan asked if the DOS was undertaking development efforts with other countries. Mr. Clore said it was.

* * *

International Members' reports

Mr. Arve Dimmen, Norway:

Mr. Dimmen reported on AISAT-1, Norway's first satellite, launched into orbit this past summer at a total cost of $5 million. In explaining the function of the satellite, Mr. Dimmen presented a map of the land-based AIS network currently used to show the position of ships. This land-based system has a range of 20-40 nautical miles off the coast. The satellite launched had the capability of extending system range into the Arctic Ocean, an area of particular interest. The system had been used to track the first commercial carrier to execute the 'northeast passage' – that is, sailing from a Norwegian port to a Chinese port by a route running north of Russia. The satellite made it possible to track this voyage. He noted that this was a demonstration sailing because where, as a precaution, ice breakers were maintained in the vicinity of this ship at all times.

Dr. Schlesinger asked if the voyage had been subsidized. Mr. Dimmen said it had not. Dr. Hermann asked if a ship required a new piece of equipment of communicate with the satellite. Mr. Dimmen said it did not. Responding to a further question, Mr. Dimmen said that it "would take a lot of" satellites to provide for time-continuous coverage; the satellite altitude, he noted, was approximately 600 kilometers. He noted potential issues with coverage in highly trafficked sea areas where signals from many ships could interfere and reduce detectability.

Mr. Dimmen then reported on Galileo. The program was, he believed, "steaming forward with the money that it has," and anticipated having 18 satellites in service by 2014. These would provide open service, PRS and Search and Rescue (SAR). The current goal for full operation was in the 2016-2018 time period.

Mr. Dimmen stated that he believed much could be done with nano-satellites in the future, moving them from the "toy" area (experimental systems) into actual operational systems. He suggested the GNSS society should take interest in the matter.

Dr. Enge said that he believed there had been a tendency to be sanguine about Galileo, though he judged much of the project's early thinking as naïve. At present, he felt the situation was much improved: the program had now invested more heavily in younger researchers than the U.S. has done and he would suggest less pessimism about Galileo's future.

Mr. Hiroshi Nishiguchi, Japan:

Mr. Nishiguchi reported on the successful September 11, 2010 launch of the first Quasi Zenith Satellite System (QZSS-1) satellite, a regional GPS-augmentation, for which he provided details (Side #2), including information (Slide #3) on the six signals that would be enabled. Mr. Nishiguchi noted that in-orbit validation would be conducted by the end of 2010, with utilization demonstration completed by summer 2011. Hundreds of companies would be participating in this effort. Mr. Nishiguchi said that the structure supporting Japanese space-based activities continued to improve – further, efforts were being made to interest schoolchildren in the undertaking. He noted that the scheduling for QZSS-2 and QZSS-3 still had to be determined; and a joint project team was being established composed of the parliamentary officials from the nine main ministries under the integrated coordination of the Secretariat for Space Policy to do this.

Mr. Nishiguchi reported on the rapid spread of GPS for automotive use (Slide #8), which had increased from fewer than two million in 1997 to over 40 million today; he presented (Slide #9) similar data on the number of Vehicle Information and Communication System (VICS) devices sold in Japan. He called attention to the high share – 95% – of Japanese citizens who were aware of GPS; and he noted that he had surveyed a group of young women who were well aware of the function and usefulness of GPS. He believed it was difficult to make long-term forecasts; however he thought that current popular Japanese support for GPS should aid in making the argument for moving forward withQZSS-2 and QZSS-3. Mr. Nishiguchi (Slide #11) then showed the costs associated with jamming and GPS non-availability.

Dr. Parkinson congratulated Japan on the successful launch of QZSS; as he thought it was a highly innovative undertaking.

Mr. Miller asked about the L1-SAIF (L1 Submeter-class Augmentation with Integrity Function) signal that is compatible with GPS Space-Based Augmentation Systems (SBAS) -- as it intended for aviation use? This was possible – it may happen in the future eventually to operate together with other SBAS satellites, but not for certain. Dr. Schlesinger joined in the congratulations.

* * *

Precise Geodetic Infrastructure: National Requirements for a Shared Resource
Dr. James L. Davis, Columbia University
Dr. Bernard Minster, University of California -- San Diego, CA

Dr. Bernard Minster said he would report on the study conducted the National Research Council (NRC) at the request of various agencies; the intention (Slide #3) was to describe the benefits to society of a high precision geodetic network; review scientific objectives dependent on such a network; describe the required infrastructure; assess opportunities for technological innovation and recommend a national plan for implementing precision geodetic infrastructure. He noted that thirteen scientists from various countries were involved in the effort; and that he was currently the chair for the organization leading such efforts.

Dr. Minster said the group had defined the science of geodesy (Slide #5) as the measuring of the shape of the earth, its orientation in space and its gravitational field, and how these change over time.

Dr. Hermann asked who had sponsored the study. Dr. Minster said these included NASA, NOAA, DoD, National Science Foundation (NSF), United States Geological Survey (USGS), and others.

Dr. Minister presented a diagram showing time scales from seconds to decades, relative to positioning precision required. Applications such as navigation required rapidly available information, but not highly precise information. Applications that related to earth science requirements – such as volcanic activity and sea level rise – start pushing the time constraints. He noted that while geodesy had been a science for many years, it had until recently found it very difficult to do detailed flood plain analysis. He noted that, in general, people wanted results more and more rapidly; and as a practical matter, you need to be able to supply real-time information. Since Sputnik – that is, approximately the past half-century – the accuracy of information supplied has improved by approximately one order of magnitude per decade. There was, he said, no reason to believe the pace was slowing down in 2010.

Dr. Minster noted that one problem identified by previous studies was that some of the networks are too sparse to accomplish their required task. There were for example, a number of sites in the Pacific that were not adequately backed up. Some sites were using equipment that dated to the 1970s; and no single agency had long-term responsibility for addressing this. A second problem, he said, was that the work force engaged was aging: no one was formally undertaking

the task to train successors. Dr. Hermann asked whether universities sufficiently valued the science of geodesy. Dr. Minister said several universities did – he cited Ohio State University and Massachusetts Institute of Technology; and he noted that few of the students came from the United States, with a larger share coming from Russia, Germany and China. Dr. Minster declared (Slide #13): "These combined factors pose a risk of a sudden drastic loss of geodetic observing capability." Dr. Minster said one question was how many geodetic network stations were required. He said the group had received a study indicating that performance did reach a point of diminishing returns as additional stations were added, with a number of studies indicating that 24 was an appropriate number.

Dr. Hermann asked if the National Institute of Science and Technology (NIST) had a mission similar to this one. Dr. Minster said he thought not; that NIST had a mission to supply very high gravity information. Ms. Neilan noted that NIST is mostly involved in the measuring of gravity. Dr. Schlesinger asked how much aid this information would offer to hostile persons wishing to aim cruise missiles at sensitive targets. Dr. Minster noted that anyone with access to the open services of international GNSS systems already had all the information required. Dr. Parkinson said that nothing hostile was being enabled because the incremental improvements being made were irrelevant to the task. Ms. Neilan said that this information was of enormous importance relative to natural hazards – for example, to determine the location and severity of earthquakes; she believed this to be a consequential realization on the benefit of GNSS. Dr. Minister noted that in the case of the 2004 Indian Ocean earthquake, it was some hours before a tsunami moving toward India was identified. Dr. Schlesinger said that it bothered him that in the days of his youth geodetic information was sought to undertake missile targeting of the Soviet Union. Dr. Hermann asked Ms. Neilan if the U.S. geodetic survey had the responsibility to provide for the U.S. scientific position in this area. Ms. Neilan said the U.S. geodetic survey had as part of its charter to maintain both the vertical and the horizontal data; the USGS did this in both real-time and non-real time. Dr. Hermann said one of the requirements was the maintaining of a work force; and so did the U.S. undertake efforts in this area? Dr. Minster said the National Geodetic Survey (NGS) was one agency that complained it was unable to find trained geodesists.

Dr. Hermann asked if anyone in the U.S. was responsible for taking charge of this matter. Dr. Minister said it was his group's impression that no one was undertaking this charge. Mr. Trimble said that what as most important was to develop and maintain a modeling of the earth, in particular, relative to climate change: the earth was changing shape and this needed to be understood before various other things could be understood and solutions engineered.

Dr. Minster asked what was it that would follow from the decision that one needed to have a long-term, stable reference frame. He believed the requirements flowed naturally -- one needed more sites where multiple capabilities could be located. He said his group was reluctant to tell governments what to do; however, it had concluded (Slide #20) that the U.S. establish a Federal geodetic service to coordinate and facilitate the modernization and long-term operation of the national and global precise geodetic infrastructure to ensure convenient, rapid and reliable access to consistent and accurate geodetic data and products by government, academic, commercial and public users." The question, he said, was whether the PNT EXCOM had any specific responsibilities to achieve this? So far as his group could determine, he said, the PNT EXCOM did not have this specific responsibility, although he believed the demand for a global

infrastructure would increase over time and inaction would lead to GPS falling behind as part of the solution. Finally, he said, there was a need (Slide #21) for more trained people: this was not a need the group had anticipated, but which had been raised by a number of agencies. Mr. Trimble said it was not as though the group was seeking a $10 billion solution.

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Terrain Effects on GPS Availability and Accuracy
Mr. David Craig, Orbit Analyst
National Geospatial-Intelligence Agency

Mr. Craig introduced a video presentation showing how the reliability of GPS-based targeting was affected by considerations of terrain and by reductions in satellite signal availability. In the presentation, the top blue line given showed the geographic areas in which the data was insufficient to do a normal GPS position solution.

Dr. Parkinson asked if Mr. Craig could create a simulation showing the affects of two satellites out of service. Mr. Craig said he could create simulations for a variety of options. He added that the loss of a single satellite signal could be critical in some environments. Dr. Parkinson urged those present to pay attention to the performance difference achieved by a 30-satellite constellation, as opposed to one of 24 satellites. He noted that anyone relying on the system for targeting was likelier to be in a secluded spot on the terrain, rather than on open hillside. Mr. Trimble called this problem "front and center" for the U.S. military, because it was the client. The civilian population would be less affected, as it would have access to the Russian, Chinese and European systems. Dr. Hermann asked what feedback was received from current operations in Afghanistan; he had never heard, he said, a representative assessment from the field. Dr. Parkinson said a colonel sent to evaluate the matter had determined that in Iraq the problem was jamming; in Afghanistan, the problem was terrain.

The visibility problems in Afghanistan were such that there were areas in which commanders could not operate. The colonel had attempted to get a copy of one of the maps indicating those areas, but was told it too sensitive as it could inform the enemy of where the U.S. could not operate as flexibly. Dr. Hermann said that if one could not get an organization that was losing lives every day to take this information seriously, then he was somewhat at a loss as to what to do. Dr. Parkinson noted that, early on, the Air Force had on four occasions attempted to cancel the GPS program on the unstated grounds that they did not wish to pay for it. He noted that if one attempted to use pseudolites in a mountainous area, the consequent aiming would be very poor. Dr. Hermann noted the early Air Force opposition was overridden because "a wise leadership" had decided to proceed; he doubted that any sensible private sector company would make use of a requirements process such as that used by the U.S government. Mr. Trimble expressed the belief that the Board had lost its best chance to win this battle several years ago.

Dr. Parkinson said the demonstration showed that the existing constellation wasn't working very well in some regions, and in a few years, the constellation could be down to 24 satellites which

would degrade such service even further. The question was: therefore how satellites could be made less expensive so that this reduction does not occur? The answer, he said, was by launching them two or three at a time, as the launch represented about half the total cost. Mr. McGurn suggested simply placing a receiver in situ in Afghanistan and see how it performed. Mr. Craig said he would like to do this; field test real world data vs. simulated predictions and analyze the results. Dr. Parkinson termed Mr. Craig's presentation as outstanding piece of work.

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Alternative Positioning, Navigation & Timing (APNT) Study Update
Mr. Leo Eldredge
SatNav Program Manager
Federation Aviation Administration

Mr. Eldredge said he wished to share what was under consideration for the next generation of air traffic. By 2025, he said, air traffic was expected to double (Side #2). This traffic volume will be much more than can be handled by the current system of air traffic controllers. Automation tools will therefore be required to produce precise paths and conformance to those paths. The existing system cannot support this capability without the widespread use of GPS. He noted that air operations must be continuous; they cannot be halted because of any interruption on GPS service. He noted (Slide #5) that the existing system could not support aircraft separations of less than three nautical miles. Dr. Hermann asked if the doubling of air traffic was predicted as a U.S. or worldwide phenomenon; Mr. Eldredge said the latter. Tim Murphy said the estimate was consistent with Boeing's global estimate of the world market for aircraft.

Mr. Eldredge noted that the FAA was working in parallel with next generation programs in Europe. Joe Burns asked why the mode of separation measures was still in use. Mr. Eldredge responded that there could be cases where an aircraft was qualified to fly the system but the FAA would not authorize it.

Mr. Eldredge noted that the FAA had studied 135 airports (Slide #8) in the countries within zones 1, 2, and 3. Not all airports generated traffic volumes that would require the implementation of the new system. Mr. Eldredge reported (Slide #9) on GNSS Challenges, noting that 141 outages had occurred, ranging from one hour to 72 hours, with an average duration of 6.63 hours. He observed that most of these outages occurred in the test ranges in New Mexico.

Mr. Eldredge then called attention to (Slide #10) $33 milliwatt jamming devices that were available from the Internet. The penalty for their use consisted on confiscation and revocation of FAA license, if the individual had one. Dr. Hermann asked if this meant that there was no law against attempting to disrupt airlines communications. Mr. Eldredge responded that increasing fines for such actions is in progress; however its adoption might require amendment to the 1935 Communications Act. Tim Murphy reported that Australia exacted a fine of $100,000 Australian Dollars for the simple possession of such a device. Dr Parkinson asked if anyone in the aircraft

industry was working with Congress on the issue. Joe Burns said it was an issue in which the Air Transport Association (ATA) would have a stake. He noted that these products were not made in the United States, but were imported through the Internet. Dr. Hermann stated that if anyone attempted to jam the landing of a military aircraft he is sure there would be appropriate authority to take punitive action. Mr. Eldredge said the FAA was unable to actually test the device because its possession was illegal.

The question of the range of the device was raised. Dr. Parkinson said he believed it was five to ten miles. He noted that larger size jammers were available, which would be sufficient to disrupt the communications at an airport. Dr. Hermann queried whether the operation of the U.S. airway system did not require that system be kept safe? The comment was made that the Federal Communications Commission (FCC) lacks police and arrest powers: it did not have the authority to seize jamming devices. The problem was how to get the "jammer" in front of a judge: neither the FAA nor the FCC was prepared to undertake enforcement in real time. In was further noted that without GPS, the system would have to revert to aircraft separations of five nautical miles, which would cause all sorts of traffic flow problems.

Mr. Eldredge then presented (Slides #15-26) three Alternative PNT (APNT) alternatives. One possibility, he said, was to investigate how the current 1100 Distance Measuring Equipment (DME) systems in use could be improved. He noted that many aircrafts had far better distance measuring capabilities than the system was set for, and he wished to see how far this could be pushed. In a second possibility, Wide Area Multi-Lateration, an aircraft would broadcast its position, and a network of ground stations, acting in concert with distant measurement stations, would be used. The advantage of this system was that it allowed the use of a variety of signal sources that were already in existence. Testing done in Canada showed the accuracy to be quite good; that is, well within that which would be required. He noted, however, that he was not sure integrity monitoring could be achieved from a ground-based solution. This alternative, he added, would require a time source that was independent of GPS; and involved cost questions that needed to be investigated. The third alternative, DME Pseudolites (DMPL) was a hybrid version of the first, and, as such, was the least mature. It still required three sites to compute aircraft locations and still required an independent time reference.

Mr. Eldredge then spoke about the Wide Area Augmentation System (WAAS) L5 for Ground-to-Ground Synchronization (Slide #29). Dr. Schlesinger commented that while Mr. Eldredge addressed the transport problems, he did not address any other technology that might be less vulnerable to personal jamming devices. He said pseudolites might prove a timing capability; however he believed that *eLoran* would also have met this requirement. Dr. Parkinson said another approach would be to build greater jam resistance into the receivers themselves. He believed some approaches that were well known to the military offered much greater jam resistance. He believed this should be considered by the aircraft designers. Capt Joe Burns said that when one considered the additional cost, he did not believe increased jamming resistance to be an absolutely viable alternative. Mr. Eldredge said he was not advocating building new systems, but rather the discussion was about adding features in the years 2025 and beyond. Tim Murphy said that adding an antenna to an aircraft raises questions of cost: a $50,000 to $60,000 antenna is a fairly important component for the accuracy needed. One could, he added, only make the aircraft "so hard" before one stepped back and said that protecting the aviation

environment was a governmental responsibility. He noted, in terms of timing, that if a device was introduced on a new aircraft today, the entire fleet would have them by 2034.

* * *

The Effect of Jammers on GPS in a Maritime Environment
Professor David Last, Consultant
General Lighthouse Authorities of the United Kingdom and Ireland

Dr. Last noted that more goods are moved by ship than any other mode of transport. Recent tests conducted by the Lighthouse Authorities however, had produced worrying results. He noted that the focus of discussion had been eNavigation, which would provide up-to-the-minute charts on shipping and incidents on a single screen. However, eNavigation would only work when a given ship's own navigation systems were robust with redundancy.

Dr. Last reported that "we are seeing" all kinds of hackers and criminals who are employing high-powered jammers. Currently, he said, there are jammers "on the street" that are capable of taking out not only the current but future GPS systems, Galileo, GLONASS and others. His organization thus faced the question: how will these devices affect commercial shipping? In jamming trials conducted from Flamborough, ships gave a variety of false positions and false speeds. One Dutch vessel was tracked proceeding through the Yorkshire countryside. The jammer used in that instance was no more powerful than a mobile phone. These results, Dr. Last stated, were the cause of considerable concern. The problem of false position had been studied in a protected sea area near Newcastle; where the jammer used had 1/1,000th the power of a mobile phone. The *Galatea* lighthouse produced a startling amount of hazardously misleading information – with the charts "simply telling lies"; any pilot paying attention to it would immediately make false course corrections He noted that this single jammer had caused the failure of five different ship systems – the radar system gave an alarm; the gyroscopic system gave an alarm, etc.

Dr. Last presented information (Page #4) on the difficulties of reverting to traditional navigation when electronic based systems were unreliable or inoperative. He noted that the maritime world had changed dramatically: a few years ago, a ship might have a single GPS receiver; now, they carry multiple embedded GPS systems that interact in ways which "no one on board understands." Commercial crews are simply not trained for this. He provided further information on the *Galatea* tests: at one time, it reported itself as proceeding across northern Russia at a speed of 846 knots. This trial, he said, had demonstrated that low level interference caused maritime receivers to provide hazardous information, and there was not a sufficient amount of cross-checking going on. He noted, further, than when malfunctioning GPS systems were turned off, they often refused to turn back on. Dr. Last said it remained the view of the Lighthouse Authorities that *eLoran* provided the best and perhaps the only alternative to GNSS at sea. He believed *eLoran* would provide significant cost savings. Whether or not the maritime world chose *eLoran*, he believed the trial on which he had reported showed that commercial

shipping faced a serious problem and was dangerously vulnerable to low-level jamming. This being the case, he concluded, some complementary system was needed.

Dr. Schlesinger noted that the North Sea – the area in which the tests reported on by Dr. Last had occurred – was not the only heavily trafficked sea lanes in the world -- had Dr. Last speculated about the various straits through carry oil? Dr. Last responded that he did not think any of those straits were safe. He added that low level jamming was actually a larger threat there than high level jamming.

Mr. McGurn commented that one "did not need an intentional spoofer to be spoofed" – that is, many of the incidents reported had been the fault of malfunctioning equipment. The problem, he said, was that there was no obvious means by which one would know that a receiver had failed. Dr. Parkinson commented that receivers varied greatly in how robust they were.

Dr. Last noted that the U.S. adoption of *eLoran* had set off a worldwide response: the later reversal of this position created great uncertainty, though as yet no nation had acted to remove any Loran stations.

Mr. Trimble noted that any time electronic devices were integrated, the manufacturer involved had the responsibility to solve any problems that integration creates. He would be quite surprised that the manufacturers of that equipment did not take some corrective action in response this circumstance. Dr. Last commented that, as a general rule, ship owners did not change or update anything until they had to.

Tim Murphy said the aviation world had learned that there was a "sweet spot" in which GPS could create false information. He said he found it surprising that ships were commanded by single-party navigation. He noted that any time a new "box" was put on an aircraft, steps were taken to demonstrate that no possible failure of the new device could affect the operation of any existing device. Dr. Last said that in the maritime world, standards were not nearly as rapidly implemented -- his organization, he said, by and large dealt with "the best that is out there." The "worst" was not going to be changing anytime soon. Tim Murphy said he doubted that the addition of more redundant navigation equipment was going to achieve anything. Dr. Last said the general intention was to create eNavigation as a base with backup systems.

* * *

Spoofing the Timing Signal: What Else is Vulnerable?
Dr. Todd Humphreys
University of Texas -- Austin

Dr. Humphreys reported that, unfortunately, vast numbers of GPS receivers are "spoofable". Several years ago, he said, the possibility that "spoofing" could occur was generally rejected on the grounds that it would prove too difficult; this, he added, was no longer the case. In the future, he believed attacks could be quite specific – for example, on an individual's automobile.

He reported on a contest between a "spoofer" and a "defender" undertaken in Austin. To create the spoofer, he said, required about $1,000 in materials, plus labor. Dr. Hermann asked whether the spoofer received any feedback on the behavior of the defender. Dr. Humphreys said that was correct: the spoofer could obtain data by placing a receiver of his own near the defender, though one could not be certain that this receiver itself was not being spoofed. He stated that he had never been unsuccessful in a spoofing attack. Dr. Hermann asked if he was learning how to defeat the spoofing. Dr. Last responded that "black" was now winning; "we are able to spoof better than we are able to defend." He then showed a videotape of a spoofer attempting to attack two timing reference receiver such as are commonly used in cell phone towers; the effect of spoofing, he said, was to drag the timing signal off, thus corrupting "the vital heartbeat of a timing reference." Dr. Last then noted that they had been able to incapacitate a cell phone station in an hour, without the system knowing what had caused the problem.

In conclusion, Dr. Humphreys urged the Board to use its influence to have a navigation message verification embedded in CNAV (transitional civil navigation message). Mr. Trimble said it was a fine presentation; he expressed concern that spoofers might become commercially available. Ms. Neilan asked if Dr. Last foresaw spoofing of dual frequency operations. Dr. Last said he thought this entirely possible; he noted that the "spoofer" one simply by making operations difficult for someone else.

* * *

National PNT Architecture Implementation
Mr. Hal Hagemeier, Deputy Director
National Security Space Office

Mr. Hagemeier noted that the Board had been briefed on the taskings on which it would focus for the next two years; he was present to talk about one such task. He reported that the *National PNT Architecture Plan* had been completed several years ago; after that, work began on an implementation plan. The task facing the Board (Slide #2) was to offer its expert advice on where it thought problems were likely to be encountered – how can these problems be avoided; if they are unavoidable, how can these problems be surmounted. He noted (Slide #4) that the PNT architecture had been assembled by both DoD and DOT. Mr. Hagemeier said he learned from dealing with architectures that the word meant different things to different people: most people think of systems architecture. The PNT document was a fifteen to twenty-year look into the future at the requirements or needs that may arise in that time. The implementation plan, approved in July 2010, began with 19 recommendations and then posed the question: what are the tasks needed to implement these recommendations? At one point, 350 tasks were identified; this number was culled down to 40 for the implementation plan.

Dr. Hermann asked if this level of discipline had been applied to any other substantial government function. Mr. Hagemeier said it had, citing as examples communications, information management, responsive space operations, protection of space capabilities and a variety of others. The process, he said, had worked well in some cases. The biggest problem with the architecture was that one of the recommendations of the architecture was left out of the

implementation plan because of a lack of agreement on how to carry out its implementation. His own belief was that if "you really want to herd these cats," then you have to put someone in charge, because it will not happen otherwise, no matter how polished the report is.

Dr. Schlesinger called attention to (Slide #6) and asked whether the path of the black line ("evolved baseline") was necessarily straight and increasing. Mr. Hagemeier said the chart was notional: it was based on the assumption that funds being expended would increase capability, though this need not necessarily be the case. Dr. Parkinson noted that several groups had emphasized the need to make GPS robust and jamming-resistant; an Independent Review Board finding had favored the adoption of *eLoran* as a system backup. Did Mr. Hagemeier believe those involved in the effort were sufficiently aware of the dangers to GPS? Mr. Hagemeier said several aspects of this were reviewed; he noted that the review looked ten to fifteen years into the future, so it did not include everything that was currently under discussion. He noted that this was a national PNT architecture; not simply a space-based PNT architecture, so we had the luxury of looking at a variety of approaches. He added that some recommendations were included talked about a variety of mitigating strategies. Dr. Hermann noted that 19 recommendations had been made, but that these appeared to reflect a certain philosophic nature that did not connect these recommendations to resources and organizational responsibility. He expressed the view that the examples brought forward by Mr. Hagemeier depended heavily on there being a governance framework that would cause the desire outcome to occur. Was it in your 'job jar', Dr. Hermann asked, to tackle his task, as opposed to just getting an affirmative response from everybody at a meeting? Mr. Hagemeier said the answer was: yes and no. Yes, there was a presiding authority; no, there was not an authority that was going to hold someone's feet to the fire.

Ms. Ciganer noted having participated in an Industry Day several years ago in which a briefing on PNT architecture was made. She reported that only one colleague was present from the GPS user equipment community. She thought the low attendance might reflect the circumstance that the PNT architecture appeared to have been written in "government code" – it was not straightforward. This morning, she said, a distinction had been drawn between providing a signal and providing a service. In utility, she said, there was a rich variety in the user base. If this plan applied only to the military, she said, that was one thing: she did, however have a concern when it applied to the full diversity in existence. She also had concern with the phrase "lowest common denominator," as it seemed to imply a one size fits all" strategy, which, she added, suggested that diversity was a weakness. Mr. Hagemeier said he was in agreement with Ms. Ciganer's comments and acknowledged that the phrase "common denominator" was indeed "government speak." At the same time, the architecture needed to be clear that the government could not provide everything that might be needed by any niche user; rather, however, should serve the broad needs. Ms. Ciganer noted that if the document was not written in generally accessible language, it lent itself to misunderstanding among the user base.

The Thursday, October 14, 2010 session was adjourned at 6:20 p.m.

Session of Friday, October 15, 2010

Board Discussion

Dr. Schlesinger noted that he would be presenting to the EXCOM on November 5, 2010. Various suggestions had been made about what should be reported; he suggested querying members for additional possibilities.

Dr. Parkinson said three things had been emphasized in Thursday's session. First, concern that interference and jamming were not recognized as problems by the highest level of government, which he believed GPS should be designated a critical national infrastructure. Second, a continuing availability problem with satellites, as Thursday's data painted a darker picture than that of two years ago. Third, the group had learned that the laser retro-reflectors needed for GNSS interoperability and international cooperation would not be available before 2019.

Dr. Hermann said he saw little value in GPS being declared a critical national infrastructure. A number of things had already been so designated, but nothing happened in consequence. He doubted the inclusion of GPS would raise the chances of anything being done. There was, he added, a *National Critical Infrastructure Plan*: DHS had developed it through a process that involved 'a lot of pleasant meetings' but no movement. He was very concerned about the electrical grid: it was being very badly handled, because the notion that "one might actually get something done" had not taken up residence at DHS. He believed EXCOM was a better forum. What was required was creation of an executive function that said what should be done about this problem. The Board could prepare for the PNT EXCOM a deliverable identifying this as a serious problem and assigned responsibility for its solution.

Dr. Parkinson said seeking critical infrastructure status and approaching the PNT EXCOM about this were not mutually exclusive.

Dr. Hermann said he doubted that the National Security Council (NSC) took the critical infrastructure seriously. Dr. Parkinson noted the failure to fund *eLoran*. Dr. Hermann said persons at the PNT EXCOM could actually give orders; not many people in Washington were authorized to do this.

Dr. Parkinson said the PNT Board had sought a presentation from DHS on what it was doing – "which was either a very deep secret or nothing at all." He noted that this has been a problem for a long time. Dr. Hermann said failure should not overwhelm hope.

Dr. Schlesinger drew the concurrence of the Board that the matter under discussion was substantive. Dr. Schlesinger noted that he wanted to brief from a "White Paper" that could be distributed in advance to members of the PNT EXCOM. Dr. Schlesinger asked for a copy of the FAA briefing as he intended to make use of some of the charts. He suggested that a small task force be assembled to address the jamming problems experienced in the U.S. and UK; as this was something of which the PNT EXCOM should be aware of.

Mr. Faga said interference presented a double-edged argument. One common statement was that systems should be prepared to operate in a GPS-jammed environment. That very argument could undermine the existing constellation by suggesting that alternatives had been provided for. Dr. Parkinson said it was a Hobson's choice: if system vulnerability was broadcast too extensively, the system fell into doubt. On the other hand, absent some rational approach to possible system failure would lead to a larger problem in the future. Mr. Trimble said he did not believe there was a single solution: the signals being received from space were such that if one did not know how to look for them, one would never find them. When safety-of-life issues were involved, vulnerability had to be addressed. He believed that legislation was needed to create the power to arrest and prosecute jammers; the fact was – if you put a large enough jammer next to a GPS receiver the signal would be jammed. Mr. Faga commented that the problem could be addressed at various levels of government.

Dr. Parkinson expressed the view that the GPS system clearly needed help; ultimately, he said, this would require "people with money." He believed satellites were 50% more complex than required; if unneeded functions were removed, he believed the cost per satellites would drop from $100-150 million to $70 million. If satellites were launched three at a time, the overall cost would drop in half.

Dr. Hermann said the Board must wait "until the dust settles" – he believed there was no chance of altering the GPS III-A design program in the near term. Dr. Parkinson said things tended to happen when a continuing drip, drip, drip broke down stone. Dr. Hermann suggested things also happened by "sha-zaam' – as, for instance, *eLoran*, which was a case of 'sha-zaam, it's gone."

Dr. Parkinson stated that GPS wished to be the "gold standard," yet it faced being reduced to 24 satellites. Two other GNSS systems were heading for 30 satellites and the Chinese were heading for 36. Dr. Schlesinger noted that both the Navy and Air Force had managed high/low mixes in aircraft capability: he did not see why the same could not be done with satellites. Mr. Trimble said the Chinese were aiming at 36 satellites for military reasons; if the U.S. military decided its needs were similar, it would proceed accordingly. Civil side needs would be in use of multiple GNSS systems. Capt Burns said thirty satellites, plus spares, were required. Mr. Trimble said that, for the FAA and the military, the issue was not a matter of technical arguments, but of budgets.

Dr. Schlesinger commented that by the time permission was received to take necessary steps in Afghanistan, the U.S. would no longer be there. Actions could have been taken in 2001 that would have solved the terrain problems being faced today, however no one came forward at the time. He believed a number of flexible solutions were needed, each available to be called upon in an emergency, so that "when you needed a place kicker," you had a place kicker to send in, and not just a spare lineman.

Mr. Nishiguchi commented that Japan, too, faced constraints. He looked to Australia, where rather stringent anti-jamming legislation was on place. In Japan, efforts had been made to establish something similar, but these had as yet been unsuccessful due to various legal issues. For the moment, he believed each sector needed to develop its own back-up solution. He was

aware, he said, that the U.S. and the Europeans were employing approaches from which Japan could learn.

* * *

Global Positioning Systems: Challenges in Sustaining and Upgrading Capabilities Persist
Ms. Christina Chaplain, director
Acquisition and Sourcing Management
Government Accountability Office

Ms. Chaplain said her review's first finding was that the Air Force was adopting best practices for the GPS III-A program and credited the Air Force with doing so. She noted that GAO had reviewed programs with billions of dollars of overruns and years of delay and tended to take a pessimistic view. She looked for fewer late changes in the program; in general, the report cited III-A as evidence that space acquisition reform was taking place.

Ms. Chaplain said the second finding was that GAO still doubted that goals would be achieved; III-A delays could reduce constellation size. She noted that her group had not in the past decade reviewed a program that came in on time. She said she had personally reached out to leaders at OMB and the Air Force, and that no one had termed the report overly pessimistic. She hoped that in future reviews substantive discussions with such persons could take place before the report was issued.

Ms. Chaplain stated that the intent and bottom line had been lost: GPS was crucial. Her report had highlighted what could go wrong if the system is not maintained.

Dr. Schlesinger noted that GAO reports were authorized by Congress in its review capacity of executive branch functions. Ms. Chaplain reported that the study had been requested by the House Subcommittee on National Security and Foreign Affairs, as a follow-on review to *Global Positioning System: Significant Challenges in Sustaining and Upgrading Widely Used Capabilities (GAO-09-325).*

Ms. Chaplain said that her team found multi-year delays occurring in the development of GPS ground control and the GPS interagency requirements remained relatively untested and confusing to civil users. She noted that the DoS continued to pursue civil signal interoperability and military signal compatibility.

Ms. Chaplain identified (Slide #5) scheduling as a key concern with III-A. When one considered the undertaking, she said, one realized that it was not a straightforward matter of building a relatively simple satellite; rather, multiple sophisticated changes were involved, each carrying schedule risk. Dr. Schlesinger asked whether GAO had considered whether everything being added to the satellites was needed, or, alternately, did it accept the design as contracted and seek the best outcome with that design. Ms. Chaplain said discussion had occurred as to whether there was a simpler path for placing satellites in orbit more quickly; however, they did take the

program and its design at face value. She believed one risk of building smaller, simpler satellites was that it could come at the expense of the program of record. Dr. Parkinson said he strongly agreed: his hope was not that III-A be redesigned, but that II-F be employed. Ms. Chaplain said the GAO favored approaches that were low risk and simple, e.g. with weather satellites, which were seriously behind schedule, they favored the simple over the exotic.

Dr. Schlesinger noted an Air Force AoA was in progress on alternate ways of achieving goals. As a practical matter, he said, "the GAO was required to accept "the idiocy" of the federal requirements process as established by the executive branch". Ms. Chaplain commented that her team had pointed out problems not associated with acquisition and funding: she believed Congress had imposed some improvements.

Dr. Hermann said the problem was critical to the Air Force and space activities – there was no record of anything ever coming in on time: was this a bigger problem in the space domain than elsewhere in government? Ms. Chaplain said the problem was shared by all major acquisition activities across the federal government: space might receive more attention because as it produced fewer units, its unit costs were higher and tended to "stick out." Further, delays in space program tended to affect a wider array of capabilities than delays elsewhere.

Dr. Parkinson noted the observation of Norman Augustine, whose relevant experience included his recent chairing of the Review of the United States Human Space Flight Plans Committee that all programs tended to take 30 percent longer than scheduled. He believed Congress needed to understand the pressures placed on the average program manager, who was venturing into the unknown. Inevitably, Dr. Parkinson said, there was pressure to extend the time involved. Dr. Schlesinger noted that Admiral H. Rickover always brought his programs in on time and under budget, though this was achieved by first persuading Congress to accept deliberately overestimated time and cost projections. Responding, Ms. Chaplain noted that she agreed programs and program managers faced inherent risks; however, for more than a decade she had found that the government was unnecessarily exacerbating those risks, e.g. by making "late in the game" requirements changes.

Ms. Chaplain then addressed delays in the development of GPS user equipment (Slide #7), saying that severe delays remained in user equipment and satellite capability. It appeared that satellites now in space that carried M-code would likely cease functioning before M-code was used. In the end, she said, capability put into space was wasted because the needed ground equipment was lacking. Ms. Chaplain then addressed (Slide #8) how a delay in GPS III could affect constellation size; she believed (Slide #9) that power management would mitigate the delay, but only incidentally.

Mr. McGurn asked what the major determinant was in the life cycle of a satellite: he had been told that it was the longevity of the power cells. The answer would influence the number of satellites in use at points in the future. This brought the comment that GAO had not undertaken an independent look at individual satellites; it had used the data developed for aerospace by the Air Force.

Ms. Neilan raised the possibility that the GPS system might be reduced to 18 satellites for several years. This brought the response that a two-year slip in III-A would raise a five percent possibility of this happening; a 50 percent or better likelihood remained that the constellation would remain above 24 satellites. Dr. Schlesinger said he thought a two-year slip in III-A was unlikely; Ms. Chaplain said that given existing concerns such a slip was not unrealistic.

Ms. Chaplain then addressed the GPS interagency requirements process (Slide #10), noting that the phrase "secondary mission requirement" was not adequately explained. She did not think it unreasonable that DoD be asked to resolve this. Dr. Schlesinger asked whether the disappearance of *eLoran* demonstrated interagency capability. If so, then while that capability had been tested, it had failed the test. Ms. Chaplain said GAO general emphasized the importance of backup systems.

Ms. Chaplain presented the GAO Recommendations (Slide #12), noting two in particular: First, that a single authority be identified to oversee GPS development as strong lines of accountability were needed. She noted that while this was a general program need, it was particularly important to space programs involving many participants. Second, the Secretaries of Defense and of Transportation should act to strengthen the interagency requirements process. She closed by stressing that the perspective of her study was to call needed attention to the support of GPS. Often, she said, a review might conclude there was no "business case" for a particular agency. This was not so with GPS, which her team was looking to strengthen.

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'On Target with GPS' Video*:*

Mr. Miller presented a video clip on GPS, its definition and civilian and technical uses with a focus on space and science applications that benefit society. Following final edits, it will be released for presentation on NASA television and Pentagon TV. Dr. Schlesinger suggested that perhaps more could have been included on GPS' role in commerce and with the financial community.

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Continued Board Discussion:

Dr. Parkinson said he had been trying to organize the morning's comments into a series of cross-cutting committees, with the following suggestions:

First, a committee on interference and mitigation -- to include Dr. Parkinson; Dr. Enge; Mr. McGurn and others;

Second, a committee on sustainment, availability and affordability -- to include Dr. Hermann; Capt Burns; Mr. Murphy; and Gen Lord; and

Third, a committee on international cooperation and coordination, to include one subgroup, headed by Ms. Neilan and Mr. Trimble, on the formulation of change and a second subgroup, headed by Ms. Ciganer; Mr. Trimble, on GNSS and scientific cooperation.

Dr. Parkinson commented that he did not wish to establish 'strong boundary conditions' on the committee to be headed by Dr. Hermann, as he believed Dr. Hermann had in the past tended to focus on the problem that most needed addressing.

Dr. Schlesinger suggested the question of the acquisition of satellites be addressed. Dr. Hermann expressed agreement. Dr. Parkinson said the Board had been asked about the trade-offs between cost and quality.

Mr. Miller commented that up to seven new members would be joining the Board by its next meeting; some might possess expertise that would make them valuable additions to the effort.

Dr. Hermann said the long-time glaring problem was that there was a flawed management structure directing execution; he would cite this as the single greatest problem. The Board, he noted, might not want to say that the biggest problem was the management of the PNT process, as it was embedded in a much larger system. Dr. Schlesinger said that holding the government to high operating standards was a responsibility of authority. Dr. Hermann said the problem was that while there was a convening authority, there was not a deciding authority.

Dr. Parkinson suggested three white papers were needed. He noted that the Board had only so many 'silver bullets' and urged avoiding matters that were unlikely to accomplish anything.

Dr. Schlesinger, referring to interference and jamming, noted that small jamming devices available through the Internet were a considerable threat, but faced no penalty of law. He suggested the group working this issue find a former government prosecutor to advise it on how appropriate punishment can be made on people using such items. Dr. Parkinson said Leo Eldredge, FAA, could be a strong ally in this effort. Mr. Trimble urged the Board to "come down hard" on this; the motivation was similar to that of hackers trying to see if they could beat the system.

Dr. Schlesinger noted that the Board had been tasked with a third item: to determine to what extent GPS should depend on other constellations. What needed to be pointed out, he said, was that for safety–of-life other constellations could be depended upon and utilized. There remained certain unique military requirement of the U.S. government that the Board should be cautious about. Mr. McGurn suggested the Board look at the performance of the GLONASS constellation as it grew in the early 1990s. Initially, he said, it was a disaster: he would not fly a plane relying on that system. Dr. Schlesinger said one should not be dependent on other systems so long as inadequacies existed. He noted that DoD, being under budgetary pressure, was eagerly looking for ways to rely on other systems. Dr. Parkinson said that GPS should not take the self-assessments made by other systems as definitive.

Dr. Hermann asked if the Board was 'blowing off' any of the taskings assigned to it. Dr. Parkinson said it was not doing so, but it might be better able to deal with than others.

Dr Parkinson proposed, relative to the committees, that drafts be submitted for internal purposes within six weeks. Dr. Hermann asked what quality level was being sought. Six weeks was a short period, particularly as the Board would not be meeting as a group in that time. Dr. Parkinson expressed concern that some deadline by set. How about January 1, 2011?

Dr. Schlesinger noted that relative to the first two committees, "we already know 95% of what we need to know." He believed the third issue – future dependencies – was much more amorphous. Ms. Neilan called attention to the desire to present a paper on jamming to the next PNT EXCOM meeting. Mr. McGurn said the jamming issue had to go either to DHS or to Presidential Decision Directive (PDD) 39; he believed it was a matter for the PNT EXCOM to determine. Mr. Trimble asked whether anyone at DHS "actually gave a damn" about jamming; the problem needed to become a sufficiently high priority that someone would actually look at it. Dr. Parkinson said many organizations achieved what he termed 'learned helplessness'. Dr. Hermann noted, in contrast, that the EXCOM existed as a forum; it had leadership at the highest level and control over resources. He believed PNT EXCOM was the appropriate group to make a decision.

Gen Lord said DHS paid good attention to the use of lasers as these might affect aircraft. Mr. Faga asked, if responsibility were assigned to DHS, would that encourage all others to believe the problem had been solved. Dr. Hermann said he believed designating something, as "a critical infrastructure" prompted no action whatsoever. Dr. Enge said the first thing that needed to be established was that GPS had "crossed the Rubicon" and that actual problems existed. Mr. Miller said the issue of jamming had the attention of all the requisite Assistant Secretaries. He described a recent presentation on the impact of a small jammer and those officials present "were quite surprised" by the impacts and sought action to minimize the threat. He believed the discussion was moving ahead and the Board should not miss the opportunity to push it along.

Dr. Parkinson said a brief teaching paper was required on the subject, so that Dr. Schlesinger could, in advance of the PNT EXCOM meeting, distribute it to those who would be attending and to their advisors. That meant a deadline of Friday, October 22, 2010. Mr. Trimble said $33 jammers were a small part of the problem. He advised including the information presented on maritime jamming, but condensed so that it would be readily comprehensible to the Deputy Secretaries involved. Dr. Enge said he would undertake the first draft. Dr. Schlesinger noted that since the Deputy Secretary of Defense had been handed the problem of dealing with cyber security; he believed it would be useful in engaging the Deputy Secretary's attention if some reference to this is highlighted.

Dr. Enge asked whether *eLoran* should be mentioned in this context. Mr. Trimble said he believed Dr. Schlesinger would have an easier time making a presentation on one system, rather than multiple systems. The mitigation of other systems was more complicated than prosecuting the people who use jammers; the principal problem for GPS was making it relatively painful for people to use $33 jammers. Kirk Lewis said the highest priority was to take the time necessary

to explain the seriousness of the problem; there was no immediate need for the EXCOM to buy into any given solution.

Mr. Dimmen characterized the meeting as two very good days; among other things, it had established that possible GPS system outages were the clearest tasks with which the PNT EXCOM needed to deal.

Ms. Neilan called attention to the International Interface Specification (IS) Workshop to be held in June. The workshop website carried a list of presentations, which included Galileo; GLONASS; ground networks; smart software receivers and other topics. She further urged Board members to go to the website from the 2008 ICG meeting, which captured a lot of very high end applications. She would make sure Board members had the necessary links.

Close: Dr. Schlesinger adjourned the meeting on Friday, October 15 2010, at noon.