Hearing of the Subcommittee on Aviation
Transportation and Infrastructure Committee
U.S. House of Representatives

"A Review of Issues Associated with Improving our Nation's Aviation Satellite-based Global Positioning System Infrastructure"

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Thank you, Mr. Chairman, and thanks to this Committee, for providing an opportunity to discuss this important topic. The subject of today's hearing is a complex one that involves not just aviation infrastructure, but national security, public safety, foreign policy, and the health of economic sectors from agriculture to information technology.

The United States launched the first atomic clocks into space in 1974 on board a Navigation Technology Satellite. The first NAVSTAR satellites that would become the GPS constellation were launched in 1978. In 1983, after the Soviet downing of a civilian Korean airliner, President Reagan offered the use of GPS to the international aviation community free of charge as it became operational. In 1991, GPS came to wider public attention as a result of its extensive and successful use in Operation Desert Storm. GPS has been in development and use for decades, but realization of its significance continues to evolve as new applications continue to be found for precision timing, positioning, and navigation.

I have been involved with GPS issues for over twenty years, beginning with work at the U.S. Department of Commerce around the time of the first Gulf War. While at the RAND Corporation, I supported the Office of Science and Technology Policy during the creation of the first Presidential Decision Directive on GPS in 1996. I have also been involved in domestic and international conflicts over radio frequency spectrum used by GPS for almost as long, including negotiations at the International Telecommunications Union and proceedings before the Federal Communications Commission. I am currently the Director of the Space Policy Institute at George Washington University and am speaking today purely in a personal capacity. My comments do not necessarily represent the views of any agency, organization or company.

Other witnesses have ably described the importance of GPS signals to the transportation needs of their agencies and organizations. These users tend to be very demanding, seeking the most precision, integrity, and accuracy possible. This in turn requires taking in the most information possible not only from GPS signals but also using accuracy augmentation signals that are carried on nearby Mobile Satellite Service (MSS) systems. In the future, it is likely that other Global Navigation Satellite Systems (GNSS) such as the European Galileo system will also be used in conjunction with GPS.

In addition to Federal agencies and industry, state and local governments use high precision GPS for mapping, surveying, and infrastructure maintenance. High precision data is used in Geographic Information Systems (GIS) for asset management, emergency preparedness, disaster response and E911 mapping, public sector water, wastewater and electric utilities, public works, environmental management, dam and structure monitoring, environmental health, insurance rating districts, flood zones, tax appraisals, the provision of geodetic control networks, and a host of other functions.

GPS Operations Require Secure Spectrum

The most commonly used GPS signal, L1, is located in the spectrum band 1559-1610 MHz. This band is specifically "zoned" internationally for Radionavigation Satellite Service (RNSS) systems like GPS, the Russian GLONASS system, and the European Galileo system. On either side of the band, are MSS bands at 1525-1559 MHz, below GPS, and at 1610-1660.5 MHz, above GPS. The key point is that the entire "neighborhood" is oriented to satellite services and such services require "quiet" spectrum as the powers of signals transmitted from space are many orders of magnitude weaker than those transmitted by typical terrestrial stations. Major power differences exist between satellite services as well. The power of an MSS signal is much greater than that of a signal coming from a GPS satellite. Thus MSS and GPS signals operate in adjacent bands where their functions are compatible with each other but they do not operate in the same band since MSS signals would easily drown out the GPS signal.

The bandwidth of the highest precision GPS receivers are designed to receive not only the full range of RNSS signals, including GPS, but also MSS signals in the adjacent band that carry wide-area differential GPS corrections from commercial providers such as Starfire using commercial MSS systems such as Inmarsat. Thus, when talking about receiver bandwidths, it is not enough to receive just the GPS signal, but all the services used for precision positioning, navigation, and timing. The evolution of high precision capabilities has been possible because of carefully considered past spectrum management decisions to use this particular neighborhood for satellite services, not terrestrial ones.

There have been and continue to be many policy and legal risks for GPS, from funding constraints and the transition to modernized signals to international trade barriers and domestic regulations. The most serious threats, however, may not be to GPS itself but to the spectrum environment upon which it depends. Over the past two decades, there have been a number of serious threats to this spectrum. Some of these threats were international and some were domestic, but all involved attempts to undermine or change the protections that had enabled the successful development and evolution of GPS applications. To date, all such threats have been removed or mitigated through strong government-industry cooperation and bipartisan support from multiple Congresses and Administrations.

Sometimes called the "three ways to die" chart, Figure 1 below shows the many ways that the spectrum in which GPS is located can be harmed. The RNSS band is also used for aeronautical radio navigation services (ARNS) that are considered a compatible use.

If incompatible services are allowed to "share" the band, then systems in the RNSS band subject to overlay can be harmed. If the band is "segmented" to allow for a new, incompatible service to have its own band, then this can limit the evolution of RNSS services, such as the addition of new signals to existing systems, the placement of augmentation signals, or the creation of new systems by other countries. If radio energy from services in adjacent bands is allowed to spill over into the RNSS band, these "out of band emissions" (OOBE) can interfere with existing signals such as those from GPS or GLONASS. If even very low power emissions are allowed to flood across the restricted RNSS band, these can raise what is called the "noise floor" in the band. Like trying to hear a single conversation in a crowded room, increases to the noise floor make hearing the low-power GPS signal increasingly difficult.

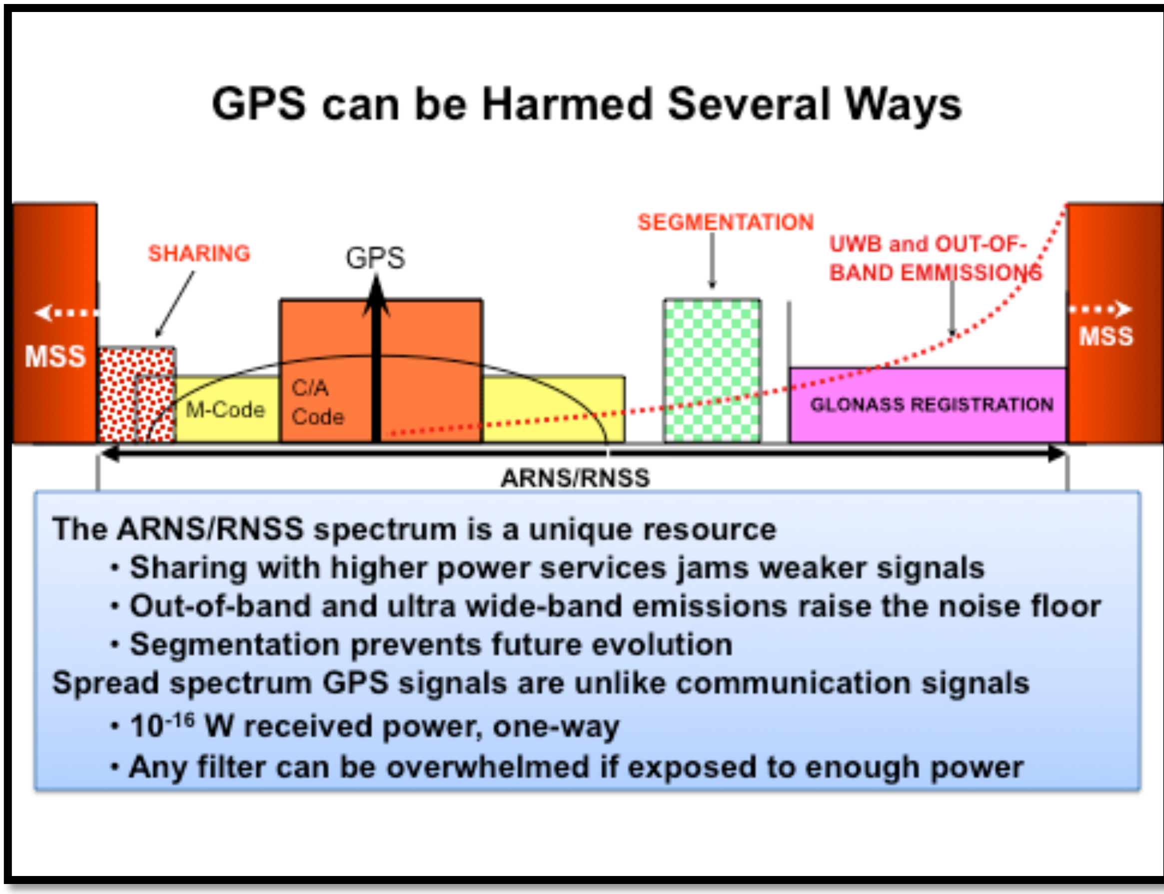

Figure 1 – Possible Means of Harming GPS Spectrum

A fourth way to harm the spectrum would be if the adjacent bands were reallocated from MSS to an incompatible service, such as high-powered, terrestrial mobile services. Even if the out-of-band emissions are kept under tolerable limits, the high energy created in adjacent band can "deafen" the sensitive receivers designed to pick up the low power GPS signals. Filters can reduce the interference, but they can also degrade the performance of the GPS receiver. As with the analogy of trying to pick up a single, soft conversation in a noisy room, wearing ear plugs blocks the noise but also your own ability to hear accurately.

This last point is sometimes hard to understand, even for communications engineers, as GPS is not a communications service. It is not "telling" a receiver what its location is but is using ranging information between the receiver and multiple GPS satellites in view. Location information is derived from measuring the arrival times of transitions in the code message that is modulated onto the GPS carrier frequency and the arrival times of the carrier waves. That is, GPS receivers need to measure the precise times and positions of a known coded sequence. Filtering blurs the ability to measure accurately.

In one of the many filings to the FCC on the LightSquared proceeding, Mr. Glenn Borkenhagen of Cody, Wyoming offered this description that I cannot improve on:

> "Synchronized atomic clocks on each of the satellites tell us when the signals leave the satellites, and when the GPS receiver is tracing four or more satellites the receiver can measure with atomic-clock accuracy when the clean signals arrive at the receiver's antenna. To oversimplify a bit, the important factor about a clean code-message signal is that it has a good sharp and square edge when the digital signal modulated onto the carrier frequency changes from a digital 0 to a digital 1 or vice-versa. We know the signal traveled at the speed of light from the satellite to the receiver's antenna and when we know how long it took to make the trip we know how far the receiver's antenna is from each satellite and can determine the position of the receiver's antenna.
>
> Accurate edge/transition-time detection is necessary to determine when the signals arrive at the receiver's antenna. When heavy filtering is applied to remove strong near-band interference, the signal edge transitions get rounded, blurred, and even time-displaced so determining an accurate arrival time becomes much more difficult if not impossible. It is easy in comparison to filter simple 0s and 1s to transmit a video file, for example – much more difficult to filter code and carrier without destroying the essential ranging information. GPS is essentially determining position using a "measuring stick" that is moving at 3 x 10**8 meter/second."[1]

All receivers take in energy from adjacent bands to varying degrees and any filter can eventually be overpowered. The power of MSS signals adjacent to (but not on top of) the RNSS band is not a problem. GPS receivers can and do filter unwanted MSS signals without harm to their performance. The power of a dense, terrestrial broadband network adjacent to the RNSS band is a problem, even if the OOBE limits are the same. One cannot imagine a more incompatible pairing than placing a high-powered terrestrial communications service next to a low-power, space-based navigation service. This is why such a pairing has not been done to date in the United States or internationally.

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[1] Glenn Borkenhagen, Letter to the Federal Communications Commission, IB Docket 11-109, 30 July 2011.

Proper placement of compatible services in the radiofrequency spectrum is in fact the essence of responsible spectrum planning and management.

<u>Historical Spectrum Conflicts</u>

Threats to GPS spectrum have come from both international and domestic sources. In 1997, Europe attempted to allow sharing 4 MHz of the RNSS band with MSS to support a mobile satellite service proposal by Inmarsat. The proposal was deferred for study at the 1997 World Radiocommunications Conference (WRC). Subsequent studies showed the idea was infeasible and the proposal was rejected at the 2000 WRC.

In 2000, the FCC released a Notice of Proposed Rule-Making on allowing "ultra wideband" or UWB devices to operate as Part 15 unlicensed devices across 1-6 GHz, included the restricted aviation and RNSS bands. Subsequent testing resulted in a 2002 rule that restricted UWB communications to above 3.1 GHz and excluded the RNSS band with specific protection criteria to protect the noise floor in that band.

Later in 2002, there was a proposal by an MSS operator to create an "ancillary terrestrial component" or ATC within the MSS band. This led to technical negotiations with the U.S. GPS industry and an agreement that was adopted by the FCC. This agreement was premised on the MSS band remaining a relatively quiet satellite band, limited the out of band emissions into the adjacent RNSS band, assured non-interference between the ATC and MSS signals of other MSS service providers, and was conditioned on the retention of an integrated satellite service. In 2010, LightSquared petitioned the FCC to waive the "satellite gating" requirement and permit stand-alone terrestrial services. The FCC conditionally granted that request in January 2011, and that decision led to the controversy of the past year.

Sharing, segmentation, out-of-band emissions, noise floor increases, and reallocation of adjacent bands have all been attempted over the past fifteen years. The pressure has primarily come from commercial interests both within the United States and abroad. These examples represent an on-going conflict over the many public and private sector interests contending for the same spectrum where GPS has operated since 1978.

Presidential Policies

To date, four Presidents, two Republican and two Democratic, have issued policy statements regarding GPS. These statements have recognized the dual-use nature of GPS as more than a military system and crucial to a broad range of U.S. interests. In 1983, the White House announced "President (Reagan) has determined that the United States is prepared to make available to civilian aircraft the facilities of its Global Positioning System when it becomes operational in 1988."[2] This opened up GPS to be accepted for international civil aviation.

[2] The White House, "Statement by the Principal Deputy Press Secretary to the President," Office of the Press Secretary, September 16, 1983.

In 1996, President Clinton issued the first comprehensive presidential policy on GPS.[3] In particular, he stated that: "We will continue to provide the GPS Standard Positioning Service for peaceful civil, commercial and scientific use on a continuous, worldwide basis, free of direct user fees…We will cooperate with other governments and international organizations to ensure an appropriate balance between the requirements of international civil, commercial and scientific users and international security interests…(and) We will advocate the acceptance of GPS and U.S. Government augmentations as standards for international use." These commitments accelerated the acceptance of GPS not only for international aviation use but also for many other applications.

In 2004, President Bush updated the 1996 GPS policy to a broader one dealing with "positioning, navigation, and timing" or PNT generally. The 1996 policy did not specifically mention spectrum protection, and the international conflicts at the International Telecommunications Union led to an explicit statement in the 2004 policy that "the Secretary of Commerce shall:

- In coordination with the Secretaries of State, Defense, and Transportation and the National Aeronautics and Space Administration, seek to protect the radio frequency spectrum used by the Global Positioning System and its augmentations through appropriate domestic and international spectrum management and regulatory practices;
- In coordination with the Secretaries of Defense and Transportation, and the Administrator of the National Aeronautics and Space Administration, facilitate cooperation between the United States Government and U.S. industry as appropriate to identify mutually acceptable solutions that will preserve existing and evolving uses of space-based positioning, navigation, and timing services, while allowing for the development of other technologies and services that depend on use of the radio frequency spectrum;"

This direction is made more significant by the fact that the agency responsible for federal spectrum use, the National Telecommunications and Information Agency (NTIA), reports to the Secretary of Commerce.

In 2010, President Obama released a National Space Policy that continued the major themes for GPS established by Presidents Clinton and Bush. The policy referred to GPS as a form of space-based positioning, navigation, and timing and the President said, "The United States must maintain its leadership in the service, provision, and use of global navigation satellite systems." More specifically, this required the "Protection of radionavigation spectrum from disruption and interference." [4]

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[3] The White House, "U.S. Global Positioning System Policy," Office of Science and Technology Policy, National Security Council, March 29, 1996.

[4] The White House, "National Space Policy," Office of the Press Secretary, June 28, 2010.

Competition for spectrum had become more intense, not only around GPS, but for all U.S. government space systems. To address this issue, the current National Space Policy has an explicit section on "Radiofrequency Spectrum and Interference Protection" in which "the U.S Government shall:

- Seek to protect U.S. global access to, and operation in, the radiofrequency spectrum and related orbital assignments required to support the use of space by the United States Government, its allies, and U.S. commercial users;…
- Seek to ensure the necessary national and international regulatory frameworks will remain in place over the lifetime of the system;
- Identify impacts to government space systems prior to reallocating spectrum for commercial, federal, or shared use;
- Enhance capabilities and techniques, in cooperation with civil, commercial, and foreign partners, to identify, locate, and attribute sources of radio frequency interference, and take necessary measures to sustain the radiofrequency environment in which critical U.S. space systems operate;"

These statements made clear that impacts to government space systems needed to be understood prior to any reallocation decisions and that U.S. requirements for space spectrum needed to consider technical and regulatory aspects on a global basis. These are the same considerations that can and should be applied to an aviation infrastructure that is increasingly reliant on GPS.

On the same day as the National Space Policy release, the Obama Administration also released an executive memorandum aimed at expanding spectrum for wireless broadband use. The Memorandum from the President called for collaboration between the FCC and the NTIA to "make available a total of 500 MHz of Federal and nonfederal spectrum over the next 10 years, suitable for both mobile and fixed wireless broadband use." However, the Memorandum cautioned that agencies were to "take into account the need to ensure no loss of critical existing and planned Federal, State, local, and tribal government capabilities...."[5] While not including an explicit mention of GPS, one can certainly read into this statement an intent to understand the impact to government systems prior to making any changes. It would be an understatement to say that GPS is a critical existing capability.

Legislation

Congress has passed numerous bills related to the protection of GPS and its contributions. As of today, federal statutes related to GPS can be found in two areas, Title 10 (Armed Forces) and Title 51 (National and Commercial Space Programs). In addition, the Nationwide Differential GPS (NDGPS) augmentation system is addressed in Title 49 (Transportation).[6] Rather than address all of these provisions, I would like to draw

[5] The White House, "Unleashing the Wireless Broadband Revolution," Office of the Press Secretary, June 28, 2010.

[6] The web site, http://www.gps.gov has a convenient summary of GPS provisions in the U.S. Code.

attention to the ones that are most relevant to protecting GPS for civil applications like air transportation.

10 U.S.C. § 2281 "Global Positioning System" was created by Section 1074 of the National Defense Authorization Act for Fiscal Year 1998. It assigns the Secretary of Defense statutory authority to sustain and operate GPS for military and civil purposes; and directs the Secretary of Defense to: provide civil GPS service on a continuous, worldwide basis, free of direct user fees; coordinate with the Secretary of Transportation on GPS requirements and GPS augmentation systems, and coordinate with the Secretary of Commerce and others to facilitate civil and commercial GPS uses. Finally, the statute directs the Secretary of Defense to develop measures for preventing hostile use of GPS in a particular area without hindering peaceful civil use of the system elsewhere.

51 U.S.C. § 50112 "Promotion of United States Global Positioning System standards" incorporates Section 104 of the Commercial Space Act of 1998. It encourages the continuous, worldwide operation of GPS free of direct user fees, international promotion of GPS as an international standard, and protection of the radio spectrum used by GPS. The statute goes on to say: "In order to support and sustain the Global Positioning System in a manner that will most effectively contribute to the national security, public safety, scientific, and economic interests of the United States, Congress encourages the President to:

(1) Ensure the operation of the Global Positioning System on a continuous worldwide basis free of direct user fees;

(2) Enter into international agreements that promote cooperation with foreign governments and international organizations to
(A) Establish the Global Positioning System and its augmentations as an acceptable international standard; and
(B) Eliminate any foreign barriers to applications of the Global Positioning System worldwide; and

(3) Provide clear direction and adequate resources to the Assistant Secretary of Commerce for Communications and Information so that on an international basis the Assistant Secretary can
(A) Achieve and sustain efficient management of the electromagnetic spectrum used by the Global Positioning System; and
(B) Protect that spectrum from disruption and interference."

Legislation for GPS protection tends to be general and not directed toward specific issues, but the LightSquared controversy has been an exception. The recently signed Consolidated Appropriations Act for fiscal year 2012 included funded for the FCC. Section 628 of Division C bars the FCC from using these funds to remove the conditions of the LightSquared's January 2011 authorization, or to otherwise permit commercial LightSquared operations, until the FCC has resolved GPS interference concerns.

International Agreements

Consistent with Presidential policy and Congressional legislation, the United States has entered into a number of international cooperative agreements, most notably being the ones with Japan and Europe. The 1998 US-Japan Joint Statement with respect to the Global Positioning System was the first international agreement made after the 1996 GPS Policy of President Clinton. In the joint statement, the United States and Japan agreed to:

- Promote compatibility of operating standards for GPS technologies, equipment, and services;
- Help develop effective approaches toward providing adequate radio frequency allocations for GPS and other radionavigation systems;
- Identify potential barriers to the growth of commercial applications of GPS and appropriate preventative measures;
- Encourage trade and investment in GPS equipment and services as a means of enhancing the information infrastructure of the Asia-Pacific region; and
- Facilitate exchange of information on GPS-related matters of interest to both countries, such as enhancement of global positioning, navigation, and timing technologies and capabilities.[7]

As with domestic legislation, a central purpose of this joint statement is to promote the use of GPS and protect the radio frequency spectrum that GPS and its users rely on. As GPS modernizes, the statement is intended to promote the exchange of information so as to retain the trust of Japanese users in GPS, and by extension other users in the Asia-Pacific region.

The 2004 Agreement between the United States and the member states of the European Community was a more complex one as Europe was planning to build its own independent GNSS system, Galileo. The "Agreement on the Promotion, Provision and Use of Galileo and GPS Satellite-based Navigation Systems and Related Applications" contained many articles on how the United States and Europe would ensure GPS and Galileo would not interfere with each other ("compatibility") while striving for the ability to use each other's satellites seamlessly ("interoperability"). Both parties recognized that they had a common interest in spectrum protection and Article 11 states:

> "The Parties shall work together to promote adequate frequency allocations for satellite-based navigation and timing signals, to ensure radio frequency compatibility in spectrum use between each other's signals, to make all practicable efforts to protect each other's signals from interference by the radio frequency emissions of other systems, and to promote harmonised use of spectrum on a global basis, notably at the ITU. The Parties shall cooperate with

[7] The White House, "Joint Statement by the Government of the United States of America and the Government of Japan on Cooperation in the Use of the Global Positioning System," Office of the Press Secretary (New York, New York), September 22, 1998.

> respect to identifying sources of interference and taking appropriate follow-on actions."[8]

Thus even in a situation where their satellite-based navigation systems were potentially in competition, the United States and Europe found common ground in protecting the spectrum both relied upon and in finding and removing potential sources of interference. This was done with caveats with regard to other potential uses of the spectrum but with recognition of the singular importance of GPS and GPS-like capabilities to their respective national interests.

Risks to GPS in Global Infrastructure

GPS applications are more pervasive and well known today compared to when it first emerged to public awareness during the first Gulf War. GPS devices gone from being separate pieces of equipment to being embedded chips in mobile phones and all manner of platforms and information networks. Several countries are seeking to build their own versions of GPS, leading to greater international agreement to protect the international radio spectrum upon which the systems all depend. In addition to regulatory protection of existing allocations, there is increasing interest in detecting and suppressing sources of accidental or intentional interference to GPS from commercial devices – such as small illegal jammers that can be purchased from overseas manufactures.

Areas of regulatory risk to GPS today come primarily from commercial pressures to use L-band spectrum in and around GPS for non-compatible purposes. The forms of incompatibility can be quite varied as described earlier, but the overall effect results in limiting the ability to use GPS signals for some applications. Regulations to date have been successful in preserving the "noise floor" in the GPS band and in maintaining a compatible "neighborhood" in the adjacent bands, but threats to change this situation have been continual over the past 15 years and can be expected to continue. Protecting the spectrum environment for GPS is key to retaining the national strategic advantage the United States has enjoyed to date. Failure to do so would be rapidly noticed worldwide as like it or not, U.S. actions with respect to GPS are closely and continually observed.

Given the strong policy interest in broadband spectrum, it is important to understand that there is as yet no viable or verifiable technological solution that would allow a ground-based broadband communications network to operate in close proximity to GPS signals. This is in part why the band has, for decades, been internationally allocated for space services. Even if some new, as yet unforeseen, technology did appear, the industrial, commercial, and public sector users of GPS equipment routinely take up to 15 years to complete a normal replacement cycle. Equipment installed on aircraft, vessels, agricultural, construction and mining machinery, commercial vehicles, or high cost professional instruments used today are not thrown away after a few years of use; their lifetimes are measured in decades.

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[8] The White House, "Fact Sheet: U.S.-EU Summit: Agreement on GPS-Galileo Cooperation," Office of the Press Secretary, June 26, 2004.

At the same time, there is a desire to provide a more predictable environment for making regulatory decisions about new spectrum uses that may potentially impact GPS. In a January letter to the NTIA regarding LightSquared interference testing, the Deputy Secretaries of Defense and Transportation said:

> "We propose to draft new GPS Spectrum interference standards that will help inform future proposals for non-space, commercial uses in the bands adjacent to the GPS signals and ensure that any such proposals are implemented without affecting existing and evolving uses of space-based PNT services vital to economic, public safety, scientific, and national security needs." [9]

While a reasonable sounding statement, I would have preferred to avoid the word "standards" and talk instead about GPS spectrum protection criteria. The latter is more likely to be useful in practice. However, it is notable that the National PNT Executive Committee is willing to take on this task. In doing so, I would urge that they use the proven successful model of relying on the National PNT Engineering Forum (NPEF) and an extensive, open consultation with industry. This effort should proceed carefully and cautiously, however, to ensure protection of "existing and evolving uses" of GPS as no one agency has complete knowledge of the field. The NPEF should be careful to avoid creating "standards" that would stifle innovation in GPS applications as that would only benefit foreign systems and shift resources and expertise overseas.

The primary risk in this effort is that there will be proposals impose regulatory standards limiting the capabilities or protections afforded to GPS receivers. In general, FCC regulations place limits on radio emissions, not radio reception. There are plenty of industry standards for electronic equipment, international radio regulations for RNSS operation, and specialized performance standards exist for national security and public safety purposes (e.g., aviation). It is difficult to imagine any justification for imposing receiver design or performance standards on commercial GPS receivers as the open market already provides its own discipline on manufactures.

To be fair, the January letter to NTIA does not call for receiver standards, but that is a risk to watch out for. It is a risk because such standards can provide a "safe haven" from competitive forces. Military and aviation receivers that are built to strict, justifiable standards do not show the same rate of innovation as commercial receivers built for the survey, construction, and agricultural markets. Receiver standards can also be a subtle regulatory means of sacrificing some categories of users and their applications. For example, there could be a standard that says that high precision scientific receivers will not be afforded the same protection as a GPS receiver in a mobile phone. Receiver standards can thus be a form of industrial policy that enables regulators to pick "winners and losers" in rapidly, evolving markets. On the other hand, transparent protection for

[9] National Executive Committee for Space-based Positioning, Navigation, and Time, Letter to Larry Strickling, Assistant Secretary for Communications and Information, NTIA, January 13, 2012.

the GPS spectrum environment can provide better predictability for new entrants while not constraining GPS applications.

Given the high stakes involved in preventing risks to GPS, it is tempting to look for a special "policy fence" that would automatically prevent problems from arising. The key problem with this idea is not the "fence" but the "policy" aspect. Should the FCC treat RNSS allocations and systems like GPS as a special case? If so, what would be the legal basis? Should the FCC be required to treat aviation performance standards for GPS as inviolate in their proceedings? Should the National Coordination Office or the co-chairs for the PNT Executive Committee be given a veto over any service that impacts the GPS bands? How would this be different from the authorities already held by the Administration in dealing with an independent regulatory commission like the FCC? What should we do internationally at the ITU? Should the boundary lines for RNSS be moved and some existing MSS allocations transferred to being exclusively RNSS/ARNS?

Given the FCC is an independent regulatory commission that does not report to the President, any special policy fence for GPS will require Congressional action in a very complex area. The spectrum threats in recent years from receiver overload and increases to the noise floor arose in the context of the regulatory rights and responsibilities of users in adjacent spectrum bands. This is one of the most difficult areas of spectrum regulation, both domestically and internationally. For example, there was an issue of adjacent band interference between Iridium and Inmarsat at the ITU that involved over ten years of technical study. The regulatory experts studying the issue in the ITU were unable to agree on a solution, determined that the matter could not be resolved, and further study was halted as a result. The central problem is that regulatory rights in terms of interference protection (e.g., Primary versus Secondary services) are only defined for services operating in the same band, with only a few exceptions such as the protection of passive services and radio astronomy. Attempting to define rights and responsibilities for services operating in adjacent bands would be an enormously complicated endeavor that would set precedents affecting all users of the radio spectrum. As a result, spectrum regulatory agencies worldwide try to avoid such questions.

Non-spectrum Risks

My testimony has focused on the domestic and international spectrum risks to GPS, as those tend to occur outside the direct control of the GPS program or the Administration. However, it is important to remember there is the potential for major "self-inflicted wounds" in the funding and modernization of the GPS constellation. In today's increasingly tough fiscal environment, it may be tempting to slow or cancel the acquisition of GPS III satellites and hope to rely on foreign systems to fill the gaps. This is very dangerous given our nation's reliance on GPS and the lack of demonstrated operational reliability of foreign systems. It is also dangerous as it reduces U.S. influence in international discussions of performance standards, spectrum allocations, and trade barriers as well as reducing confidence in U.S. national security space capabilities. A reduction in international confidence in GPS would inevitably impact international acceptance of satellite-based air traffic management improvements desired by the United States.

A second area of non-spectrum risk would be in any disruptions of service to the existing global installed base of user through modernization. The Air Force is undertaking complex upgrades to the operational control segment (OCX) that manages the GPS constellation. These upgrades are necessary to enable use of modernized signals such as L5 and L1C that are of interest to aviation and civil users. There is and will continue to be a need to explicitly confirm that changes to GPS are backwards compatible with the installed base. If not, then there should be a transition plan that is developed with the relevant stakeholders in government, industry, and even non-government organizations (e.g., advisory committees, scientific societies). The GPS Directorate holds periodic public meetings to discuss updates to GPS interface control documents actively take input from non-government experts and industry. This is a very useful mechanism to ensure the government and commercial GPS manufactures are not surprised and thus crucial to maintaining user trust in GPS as more foreign systems become operational.

Conclusion

GPS is a critical global utility that is particularly important to the safe modernization of the international air transportation management system. Presidential policies supporting and protecting GPS as a dual-use system have been consistent for decades across multiple Administrations. Congressional legislation and existing statues have been similarly consistent and clear. Regulatory processes for rulemaking are well defined in the Administrative Procedures Act. The United States has sufficient law and policy on the books to protect GPS. What has been missing at times is a willingness to enforce those laws and procedures and follow the basics of good government.

Verifiable data should be on hand before making a change that can impact the national security, safety, commercial, or scientific uses of GPS. When characterizing interference, it is important to use multiple approaches. Paper and pencil calculations of potential interference should be compared with testing in controlled environments (e.g., anechoic chambers), and finally with realistic operational scenarios for specific applications. Measurements of “live sky” field tests should be done on qualified test ranges, either government-controlled or independent. These steps reflect current best practices for interference studies when national security or public safety applications are at risk – no one approach is to be trusted but all are used to see if consistent results are achieved.

It is sometimes argued that accommodations by legacy systems need to be made to enable new uses of spectrum and that doing so enables more efficient use of a scarce, natural resource. When it comes to spectrum efficiency, GPS is arguably the most efficient use of spectrum the world has ever seen; almost a billion people are currently benefitting from the 20 MHz GPS signal that is available today. In fact, the entire global population could use GPS without *any* additional spectrum being used. This use represents a massive installed base and source of advantage for the United States, of which international scientific cooperation is but one part. Most importantly, it represents a high degree of trust and confidence in the United States and its stewardship of GPS.

The spectrum neighborhood in which GPS resides consists of compatible services today. That neighborhood should be preserved. As GPS modernization proceeds, the U.S. government should be in consistent, open communication with its agencies, industry stakeholders, international partners, and GPS users to ensure the installed base suffers no disruptions as new GPS capabilities come on line. For the aviation community, it is not an overstatement to say that eternal vigilance is the price of safety.

Thank you for your attention. I would be happy to answer any questions you might have.

Scott Pace

Dr. Scott Pace is the Director of the Space Policy Institute and a Professor of Practice in International Affairs at George Washington University's Elliott School of International Affairs. His research interests include civil, commercial, and national security space policy, and the management of technical innovation. From 2005-2008, he served as the Associate Administrator for Program Analysis and Evaluation at NASA.

Prior to NASA, Dr. Pace was the Assistant Director for Space and Aeronautics in the White House Office of Science and Technology Policy (OSTP). From 1993-2000, Dr. Pace worked for the RAND Corporation's Science and Technology Policy Institute (STPI). From 1990 to 1993, Dr. Pace served as the Deputy Director and Acting Director of the Office of Space Commerce, in the Office of the Deputy Secretary of the Department of Commerce. He received a Bachelor of Science degree in Physics from Harvey Mudd College in 1980; Masters degrees in Aeronautics & Astronautics and Technology & Policy from the Massachusetts Institute of Technology in 1982; and a Doctorate in Policy Analysis from the RAND Graduate School in 1989.

Dr. Pace received the NASA Outstanding Leadership Medal in 2008, the U.S. Department of State's Group Superior Honor Award, *GPS Interagency Team*, in 2005, and the NASA Group Achievement Award, *Columbia Accident Rapid Reaction Team*, in 2004. He has been a member of the U.S. Delegation to the World Radiocommunication Conferences in 1997, 2000, 2003, and 2007. He was also a member of the U.S. Delegation to the Asia-Pacific Economic Cooperation Telecommunications Working Group, 1997-2000. He is a past member of the Earth Studies Committee, Space Studies Board, National Research Council and the Commercial Activities Subcommittee, NASA Advisory Council. Dr. Pace is a currently a member of the Board of Trustees, Universities Space Research Association, a Corresponding Member of the International Academy of Astronautics, and a member of the Board of Governors of the National Space Society.