Hearing of the Committee on Science, Space, and Technology
U.S. House of Representatives

"Impacts of the LightSquared Network on Federal Science Activities"

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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 federal science activities, but national security, public safety, foreign policy, and the health of economic sectors from agriculture to information technology.

Specifically, the Committee has asked that witnesses address the impact of the proposed LightSquared mobile terrestrial commercial communications network on federal science agencies and to discuss the recent report of the FCC-mandated technical working group that was tasked to examine radiofrequency interference with GPS as well as possible mitigation strategies. The technical evidence gathered to date clearly shows that the LightSquared network poses an unacceptable interference threat to all GPS users and especially high-precision scientific users of GPS.

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 and my comments do not necessarily represent the views of any agency, organization or company.

The LightSquared Network Represents A Major Change in Spectrum Use

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 services (RNSS) like GPS, the Russian GLONASS system, and the European Galileo system. On either side of the band, are bands for mobile satellite services (MSS) 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. There are major power differences between satellite services as well. The power of a MSS signal is much greater than that of 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.

Figure 1 shows how proposed uses of the 1525-1559 MHz band next to GPS have evolved over the past ten years. (Attachment 1 provides a more detailed history of regulatory highlights.)

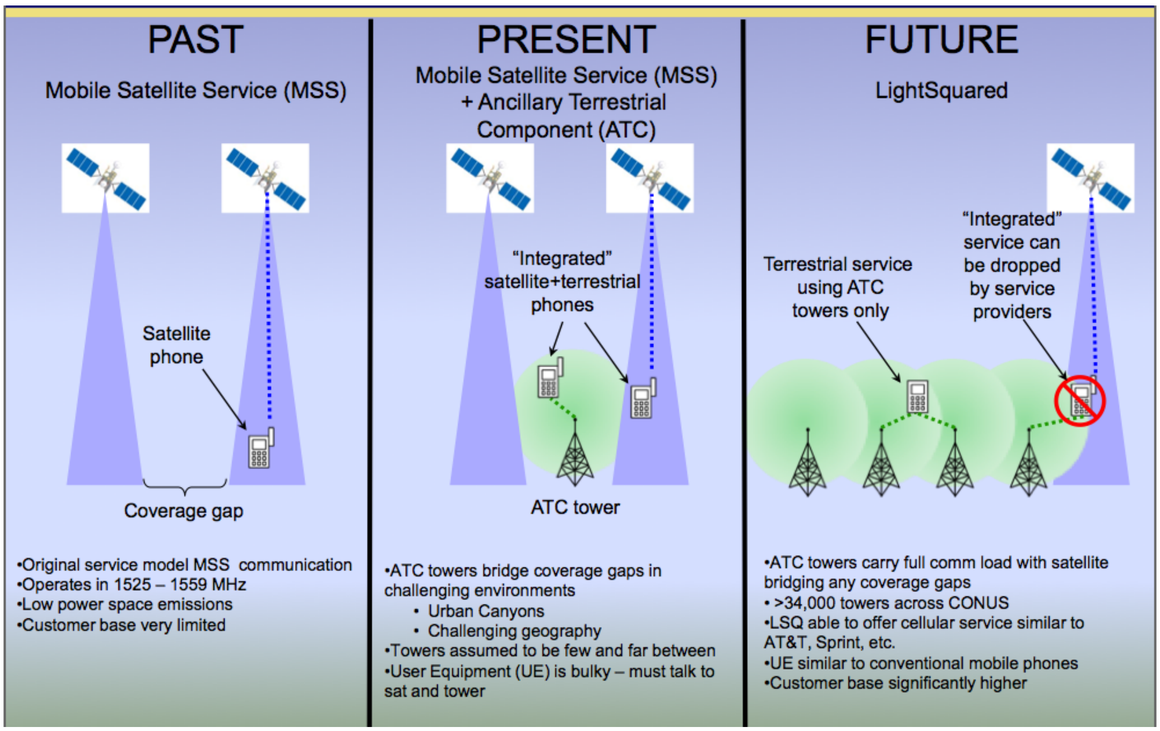

Figure 1 – Evolution of the MSS ATC Concept

MSS services, such as those offered by Inmarsat, have historically operated purely through satellites. This enables service over very wide regions or even the entire globe. However, there will be coverage gaps for areas either outside the satellite service area, or more commonly, when dense urban environments block the weak satellite signals. This led to interest in creating an ancillary terrestrial component (ATC) to the MSS service in which ground-based towers would "fill in" the coverage gaps and thus enable better service to a wider range of customers. The GPS community was concerned the deployment of terrestrial base stations would create interference to the adjacent RNSS band. The U.S. GPS Industry Council negotiated with the proposed MSS ATC operator, then known as MSV, and reached a technical agreement on "out-of-band" emission limits to restrict any harmful spillover into the RNSS band. This agreement was also predicated on the requirement that the ATC would remain tied to satellites and that the need to avoid self-interference between the satellites and terrestrial components of the same company meant the MSS band would remain relatively quiet. This helped ensure compatibility with GPS users next door.

The U.S.-licensed operator of MSS ATC in the L-band went through several ownership changes, including the most recent transfer of license to what became LightSquared in March 2010. The essential operational situation remained unchanged until November 2010 when LightSquared requested relaxation of the "gating requirement" which tied the ground-based ATC system to the satellite service. This would allow the terrestrial network to carry broadband services and the satellites would now be effectively "ancillary" to the ground network as they are not capable of providing broadband level service. In effect, satellite spectrum would be "rezoned" to allow deployment of high-powered, terrestrial base stations in urban areas and across the country. This is the situation that the GPS community sought to avoid a decade ago. Unfortunately, the FCC granted a conditional waiver to LightSquared on January 26, 2011. The waiver was conditioned on the creation of an industry-led technical working group to examine the potential for interference to GPS and possible means of mitigation.

Scientific and High Precision GPS Users Depend on Large Bandwidths

Other witnesses have ably described the importance of GPS signals to their agencies and scientific users. These users tend to be very demanding, seeking the most precision and accuracy possible. This in turn requires taking in the most information possible not only from GPS signals but other Global Navigation Satellite Systems (GNSS) such as Galileo and using accuracy augmentation signals that are carried on MSS systems. Figure 2 shows the 2 MHz wide (pink) GPS signal used by common smart phones. The wider blue region shows the full RNSS band used by more capable receivers, including those designed to receive signals from foreign GNSS systems as well as GPS. The green bars show the proposed upper (close to GPS) and lower (farther from GPS) channels for LightSquared's 4G long-term evolution (LTE) service.

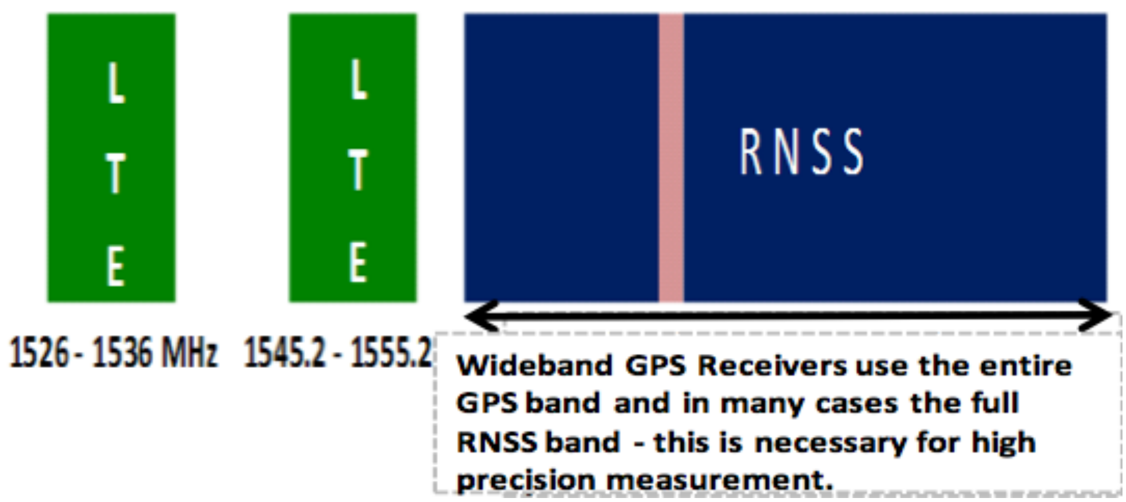

Figure 2 – High Precision Receivers are Wideband Receivers

Figure 3 shows the bandwidth of the highest precision GPS receivers. They 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. Developed by John Deere and precision farming groups, a Starfire-capable receiver can produce centimeter-level position measurements. Powerful transmissions from LightSquared base stations would unavoidably jam the reception of weaker MSS signals used by the high precision GPS receivers. Thus when talking about receiver bandwidths, it is not enough to receive just the GPS signal itself, 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.

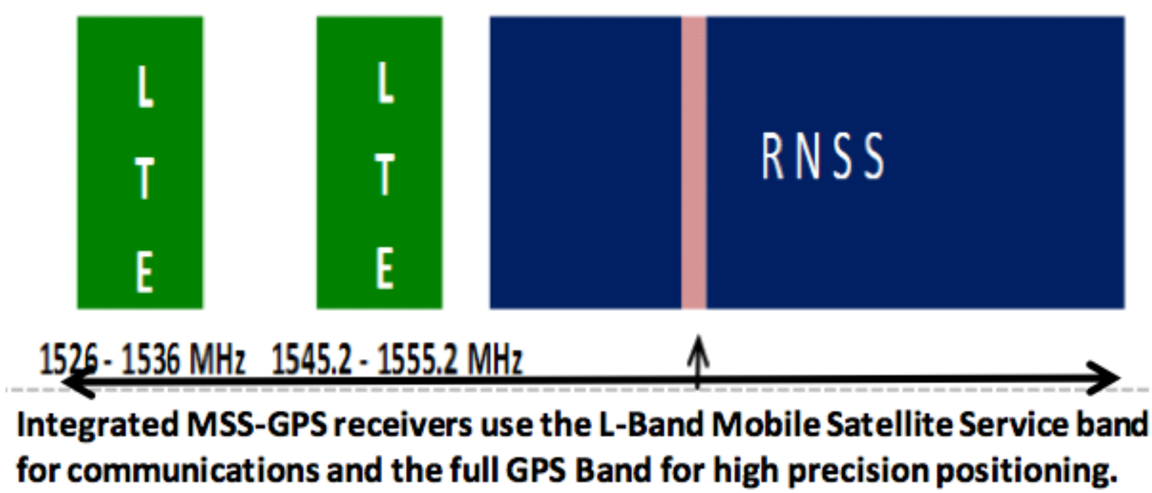

Figure 3 – The Highest Precision Receivers are Augmented Wideband Receivers

In addition to the federal science agencies, the university scientific community is concerned with the LightSquared network. I serve on the board of the Universities Space Research Association, a non-profit organization of 105 Ph.D.-granting universities conducting space and aeronautics-related research. In January of this year, prior to the FCC granting the requested waiver of the satellite requirement, the CEO of USRA wrote:

> … USRA member universities are very engaged in research on all aspect of GPS use and testing. This includes development of the impending Federal Aviation Administration's transition to a satellite based navigation system, known as NextGen…. Satellite data used by universities involving GPS tracking and geodetic networks across the United States could also be impacted. These applications range from global environmental monitoring, weather prediction, and earthquake monitoring to advanced concepts such as training for space systems engineers. All of these have the potential to be adversely effected by the LightSquared proposal unless rigorous measures are implemented to mitigate interference to the reception of GPS signals."

International Concerns

While LightSquared is currently a domestic issue, it has attracted international notice and concern. The Japan GPS Council (JGPSC) is the non-profit association composed of the major firms and organizations of the civil GPS applications and users in Japan. On May 27, they provided a letter to the FCC docket stating:

> GPS receivers are properly designed to operate in the "satellite" neighborhood that exists in the domestic and international tables of frequency allocations in the 1525-1660.5 MHz range. There are no unaccounted for high-power terrestrial signals anywhere in the world that pose the threat of harmful interference to GPS

> and other RNSS users. At least there were none until LightSquared's new owners opportunistically decided to try to convert what has always been an ATC-enhanced satellite band into a new home for high-power terrestrial mobile broadband signals. The physics is clear; LightSquared cannot provide 4G LTE service in the satellite neighborhood without causing harmful interference.

> (The) US and Japan have worked in close cooperation at the domestic level as well as in international fora to protect and preserve spectrum for GPS in order to safeguard national security applications as well as maintaining flexibility and opportunity for continued commercial innovation and critical public infrastructure….

> Any threat to the integrity or availability of GPS in US markets would undermine and devalue the substantial investment that Japanese firms have made to serve users and customers in the US. Japanese firms provide products and equipment for high-precision applications to US customers, …

> Any policy which would allow degradation of GPS service in the US would also raise question as to the integrity of the stated US commitment to maintain GPS as a stable and reliable global standard for positioning, navigation and timing.

The European Commission expressed similar concerns in a July 19th letter to the FCC docket. This letter cited technical concerns raised by the European Space Agency and concerns about impacts to Galileo, which is to be interoperable with GPS:

> The band immediately below 1559MHz, allocated by the Radio Regulations to the mobile-satellite service (MSS), has been used for satellite based transmissions for many years and has proved to be broadly compatible with RNSS systems above 1559MHz. The LightSquared proposal for a terrestrial network deployment in MSS spectrum would completely change the nature of radio transmissions in the band…
>
> Analysis carried out in Europe, including by our own technical partner the European Space Agency, has shown that transmissions from LightSquared base-stations do indeed have considerable potential to cause harmful interference to Galileo receivers operating in the United States. Interference effects have been determined to occur in the range 100m to almost 1,000km, depending on the type of receiver being used. This obviously presents a grave threat to the viability of providing a Galileo service covering US territory - a service which many studies have shown will not only benefit Galileo users, but those of GPS too as the two systems will be interoperable through a common signal design providing significantly improved coverage and accuracy in urban environments.

Europe and Japan are major international partners in every area of scientific cooperation. Harmful interference to GPS and other GNSS systems in the United States would undermine that cooperation. It would also undermine the long-standing international commitment the United States has made to protection of RNSS spectrum, not just GPS, from harmful interference. This, in turn, calls into question the ability of the United States to be a leader at a time when other systems from Europe, Japan, Russia, China, and India are being deployed. Ironically, if LightSquared were deployed in a way that caused harmful interference to GPS, a major beneficiary would likely be the Russian GLONASS system. Its operating frequencies are located farther away from the LightSquared base station frequencies. Damaging GPS and driving users to a Russian space system are not desirable outcomes for the United States.

The Technical Working Group Final Report Shows GPS Interference

The TWG Final Report documents issues associated with the interference threat to GPS receivers and GPS-dependent applications resulting from LightSquared's proposal to deploy a high-power terrestrial broadband system in the 1525-1559 MHz and 1626.5-1660.5 MHz bands on either side of the 1559-1610 MHz band used by GPS, GLONASS, and other satellite navigation systems. These bands were licensed to LightSquared for mobile-satellite service and ancillary terrestrial component use, prior to the Bureau's January 2011 decision to conditionally waive the satellite "gating" requirement.

The final report is over 1,000 pages long and detailed summaries are available from the participating companies and government agency observers. LightSquared also participated in the testing and contributed to the final report. A key strength of the TWG report is that it used multiple approaches to characterizing interference. Paper calculations of potential interference were made, along with testing in controlled environments (e.g., anechoic chambers), and finally realistic operational scenarios were defined for specific categories of users and "live sky" field tests were conducted on government-controlled ranges. This reflects a best practice for interference studies when national security or public safety applications are at risk – no one approach is to be trusted but all are done to see if consistent results are achieved.

Consistent results were achieved, supporting the expectations of early analytical estimates. Specifically, the planned LightSquared deployment would create harmful or significant interference for all categories of GPS receivers. There were three categories of interference that were examined. The first was "out of band emissions" from LightSquared into the GPS band. The observed emissions were in compliance with MSS ATC limits set in 2005 and were not a source of harmful interference. The second was "receiver overload" or "receiver desensitization" due to the powerful terrestrial transmissions exceeding the GPS receiver's normal tolerances with the MSS bands. The third was an effect known as "intermodulation" in which separate LightSquared signals interact to produce a composite signal in a different part of the spectrum. In this case, intermodulation products were observed on and near the center frequency of the primary GPS signal known as L1.

Figure 4 shows a snapshot from testing conducted in New Mexico earlier this year. The two large peaks are the expected LightSquared terrestrial signals and the smaller peak to the right is the observed intermodulation effect that lies at the same location as the GPS L1 signal.

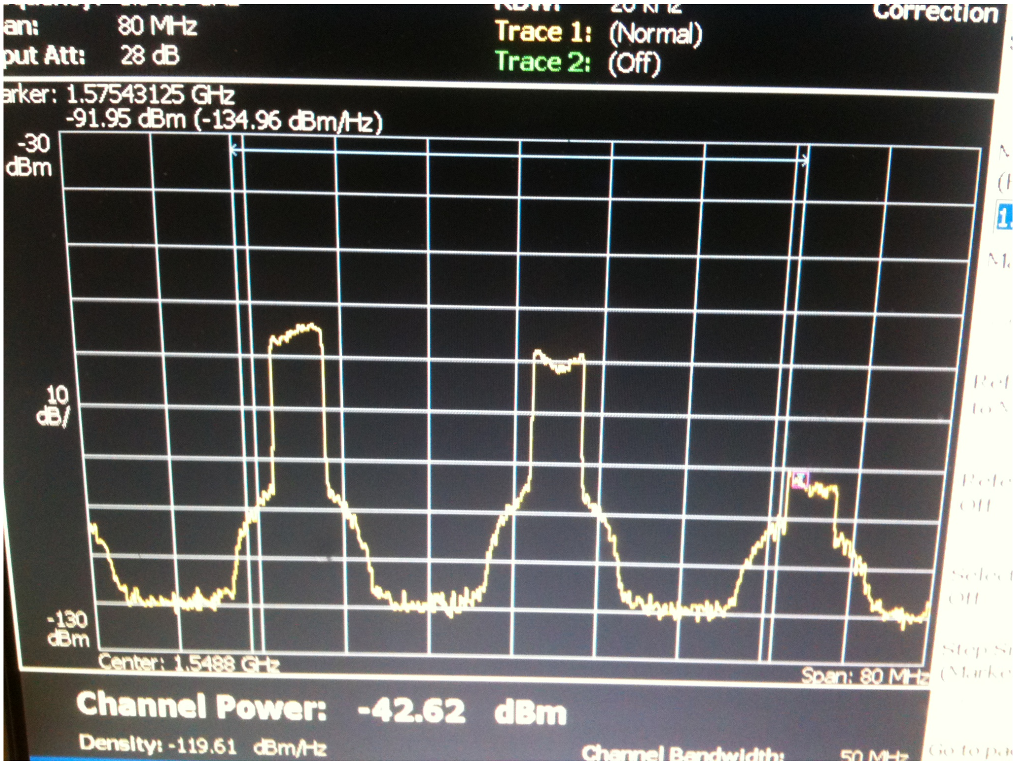

Figure 4 – Screenshot of Third Order Intermodulation Effect at GPS L1

The operational impact of interference effects for scientific applications can be inferred from impacts to high precision receivers, networks of high precision receivers, and space applications. Virtually all tested precision receivers, those used by scientists and deployed in networks around the world, were harmfully impacted. In the TWG report, the GPS community concluded that 31 of 33 high precision receivers tested were significantly affected in the testing. This is an unavoidable and natural consequence of taking in as much of the GPS signal as possible using a wideband receiver. It is a natural consequence of accessing multiple radionavigation satellite systems that share the same RNSS band as GPS. Giving up access to the best GPS signals available or access to other RNSS satellite systems is not a solution for scientific users.

In addition to direct effects on the receipt of GPS signals, the LightSquared signals create co-channel interference to MSS signals in the 1525-1559 MHz band where they operate. This blocks the receipt of those signals by GPS receivers that use them to create "differential corrections" to augment the accuracy of the basic GPS receiver. The FCC has licensed commercial firms such as Starfire and OmniSTAR to provide augmentation services that scientific, agricultural, and other users rely on today across the country.

Due to the large distances involved, GPS receivers used for navigation on spacecraft may not suffer harmful interference from the LightSquared network. However, GPS receivers looking at the Earth would be affected. Such receivers are used to understand the ionosphere and atmosphere by looking at the behavior of the GPS signal as it passes through them. This enables great improvements to weather forecasts, tracking hurricanes and typhoons, and establishing precise climate benchmarks to allow actual measurements of climate change.

In addition to scientific research, 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.

The Government's NPEF Report is Consistent with TWG Report Results

The National PNT Engineering Forum (NPEF) report contains the results of testing by federal agencies, including the science agencies, and had technical results consistent with those of the TWG effort. As with the TWG, multiple approaches were taken to ensure theoretical and experimental results agreed with each other. A summary of the TWG report is available from the National Coordination Office and in other testimony. I would like to therefore highlight the two recommendations made by the NPEF:

Recommendation 1: *LightSquared should not commence commercial services per its planned deployment for terrestrial operations in the 1525 – 1559 MHz Mobile-Satellite Service (MSS) Band due to harmful interference to GPS operations.*

Recommendation 2: *The U.S. Government should conduct more thorough studies on the operational, economic and safety impacts of operating the LightSquared Network; to include additional ATC signal configurations not currently in LightSquared planned spectrum phases, effects on timing receivers, as well as transmissions from LightSquared handsets. As part of these studies the compatibility of ATC architectures in the MSS L-Band with GPS applications should be reassessed.*

The two recommendations underscore the infeasibility of operating the LightSquared network as proposed without harmful interference to GPS. The recommendations also note areas where testing was incomplete, raising deeper questions about the feasibility of operating even previously approved MSS ATC networks in the band, never mind a broadband terrestrial network. The MSS ATC networks approved earlier had never been deployed and realistic equipment was not available to verify the regulatory limits truly prevented harm to GPS. Given the discovery of intermodulation products, a reexamination of the feasibility of "traditional" ATC would be prudent.

LightSquared's Proposed Solution is Not Sufficient

LightSquared has proposed to change the *order* in which they would deploy the same frequencies in the band adjacent to GPS. There are two channels of spectrum in the band adjacent to GPS, which they originally planned to deploy in a certain order. They now propose to suspend, for what is implied to be a short time, use of the upper 10 MHz channel and begin with the lower 10 MHz channel. This would potentially result in impacting high precision scientific users first and other users, such as aviation, later.

The company has also proposed reducing the power of the terrestrial base stations by 50% from allowable levels. Unfortunately, that does not help, as cell site transmitter providers do not even supply equipment at the very high 15.8-kilowatt level the FCC proposes to allow. All testing was done with equipment that was available, that is, at roughly 10% of the maximum allowable level.

Even if it was considered acceptable to sacrifice high precision GPS users, the "lower 10 MHz" approach could be solution only if it was a complete solution. Unfortunately, it is not. LightSquared has been consistently clear that a commercially viable network would require more spectrum, preferably close to where they would already be operating.

Deployment in the lower block alone has not been concluded to be compatible with GPS and would likely require around 15 years prior to commencement for new technology to be developed and existing user equipment to be replaced. However, without a *permanent* restriction on use of additional spectrum for terrestrial operations in other parts of the band, this approach merely shifts the burden of mitigation to the existing GPS users.

Section 25.255 of the FCC's rules makes the obligation of resolving harmful interference to other services that is caused by MSS ATC operations the sole responsibility of the ATC operator.[1] Nominally, at least, even under the *LightSquared* order, LightSquared is still an ATC operator subject to Section 25.255. It cannot require authorized users of another service take measures – especially measures deemed infeasible or inappropriate by a substantial majority of the TWG – to mitigate the harmful interference. This obligation is LightSquared's alone.

There is no viable or verifiable technological solution that has been identified to date 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,

[1] 47 C.F.R. § 25.255.

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.

There is one possible solution available today that I am aware of. LightSquared could operate the satellite part of its network, serving rural and public safety users outside of cellular coverage areas, in the L-band adjacent to GPS while developing its new high-powered terrestrial portion of its network in a different band, where it would be compatible with adjacent uses. Possible locations include the S-Band (above 2 GHz) or the 700 MHz bands already allocated to terrestrial 4G wireless services. The MSS satellite part of the LightSquared network is compatible with neighboring GPS uses and thus can coexist with all GPS services, applications and existing user equipment. The terrestrial component of the LightSquared network has not yet been built therefore it is at least technically feasible to move to a different band from the outset, thus avoiding large scale disruption to GPS users across the United States.

Competing National Policy Objectives Need to be Reconciled

On June 28, 2010 the Administration released two major policy statements. The first was aimed at expanding spectrum for wireless broadband use.[2] The Memorandum from the President called for collaboration between the FCC and the National Telecommunications and Information Administration 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

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

account the need to ensure no loss of critical existing and planned Federal, State, local, and tribal government capabilities....”[3]

On the same day, the White House also released a new National Space Policy that specifically referred to GPS as a form of space-based positioning, navigation, and timing.[4] In the policy, 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.”

Considering the objectives of both policies, there seem to be four options for consideration by the FCC, Administration and Congress:

1. Accept the most recent LightSquared proposal to begin deployment in the lower 10 MHz of the 1525-1559 MHz band. Additional testing to define mitigation measures should be required as a condition of approval.
2. Rescind the LightSquared waiver and bar commercial operations even in the lower 10 MHz pending completion of further testing and demonstration of specific mitigation measures by LightSquared to preclude harmful interference to GPS.
3. Assist LightSquared in finding alternative spectrum for its terrestrial network outside the L-band. The FCC would have to explore legal and regulatory challenges in aiding such as move that may or may not be economically feasible for the company.

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[3] *op cit*

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

4. Conclude that the terms of the LightSquared conditional waiver have not been met and withdraw LightSquared license to deploy a terrestrial network in the 1525-1559 MHz band.

In my judgment, the safest and most fact-based course of action is #4. It is the only approach fully consistent with the terms of both the National Space Policy and the Broadband Memorandum as well as the FCC's own regulations.

Conclusion

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 20MHz 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.

If allowed to operate in either its original or modified form, the LightSquared terrestrial network would create unacceptable harmful interference to GPS users and high precision scientific users in particular. Such operations would be contrary to the technical facts established by independent testing; they would improperly place burdens on the victim service, in this case GPS, undermine the international credibility the United States has built for GPS, and would be contrary the National Space Policy and the terms of the President's own broadband initiative.

The last twenty years have seen continuous improvement in the ability to use GPS for measurements of the Earth, the atmosphere, and the biosphere via precise positioning, navigation, and timing. If the LightSquared terrestrial network is allowed to operate as proposed, it will mark a permanent decline in the beneficial capabilities GPS has afforded scientific users in the United States. It would create new, additional, and unforeseen, costs for federal science agencies as well as State and local governments who rely on high precision GPS-derived data.

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

ATTACHMENT 1 - HISTORICAL NOTES ON MSS ATC AT L-BAND

August 17, 2001: Notice of Proposed Rulemaking (NPRM) on MSS ATC Released

- Based on applications of ICO and Motient MSS systems
- Included consideration of out-of-band emission limits to protect GPS

July 25, 2002, Agreement between MSV and US GPS Industry Council

- Parties reach agreement on a -100 dBW/MHz limit for MSS ATC base stations in order to protect GPS/RNSS in the 1559-1610 MHz band.
- Predicated on the assumption that ATC use remained tied to satellites and that the service would be relatively low-density fill-in.

February 10, 2003: First Report and Order and NPRM on MSS ATC Released

- FCC makes clear that MSS ATC is to augment satellite service:

  Para. 1: "We do not intend, nor will we permit, the terrestrial component to become a stand-alone service."

  Footnote 5: "While it is impossible to anticipate or imagine every possible way in which it might be possible to "game" our rules by providing ATC without also simultaneously providing MSS and while we do not expect our licensees to make such attempts, we do not intend to allow such "gaming." For example, even if an MSS licensee were to enter an agreement to lease some or all of the access to its authorized MSS spectrum to a terrestrial licensee such spectrum could only be used if its usage met the requirements to ensure it remained ancillary to MSS and were used in conjunction with MSS operations, i.e., that it met all of our gating requirements. The purpose of our grant of ATC authority is to provide satellite licensees flexibility in providing satellite services that will benefit consumers, not to allow licensees to profit by selling access to their spectrum for a terrestrial-only service."

- Adopts "Gating Criteria" (FCC Part 25.149(b)(4)) to limit terrestrial deployment to that which is ancillary to the satellite component of the network. Effectively prohibits ATC-only or stand-alone terrestrial services.

- Declined to adopt limits on emissions into the RNSS band (1559-1610 MHz) more stringent than GMPCS rules (-70 dBW/MHz) for BS and METs and mentioned possible rulemaking on GPS protection in a future proceeding.

- Number of base stations limited to 1725.

- EIRP limited to 14.1 dBW (~ 25 watts) towards the horizon and maximum EIRP of 23.9 dBW (~245 watts) per sector (derived from limit on per-carrier EIRP of 19.1 dBW and the number of carriers per sector limited to three).

November 8, 2004: MSV Order and Authorization Released

- MSV commits to meeting a -100 dBW/MHz limit in 1559-1610 MHz RNSS band, which FCC imposes as a condition of the authorization (noting these limits are more stringent than FCC rules require).

- Limit of 1725 base stations increased to 2415.

- Gating criteria in 25.149(b)(4) retained…retaining the prohibition against stand-alone terrestrial services.

- Overhead gain suppression relaxed to permit base-station antenna gain of up to 27 dB below the maximum directional gain in vertical angles from 30° to 55° and up to 30 dB below the maximum directional gain in vertical angles from 55° to 145°, as requested."

- Aggregate EIRP increased (subject to some restrictions) to 26.9 dBW toward the physical horizon and 31.9 dBW in other directions.

February 25, 2005: Memorandum Opinion and Order (MO&O) Released.

- Limit on number of base stations eliminated in favor of delta T/T limit of 6% to protect Inmarsat MSS in the L-band.

- Aggregate EIRP increased by rule (beyond just waiver granted to MSV) to 31.9 dBW (~1550 watts) generally and 26.9 dBW (~490 watts) per base station sector toward the horizon, representing an 8 dB increase over the previous power limits that apply when three carriers are used within an antenna sector.

- Gating criteria in 25.149(b)(4) retained…retaining the prohibition against stand-alone terrestrial services.

- No L-band MSS ATC network or equipment deployed.

Note: Order includes extensive testing and analysis of Inmarsat terminals and interference from MSV ATC network.

December 21, 2007: Inmarsat-MSV Spectrum Sharing Agreement.

- According to *Satellite Today* (January 2008): The agreement was defined in two phases. Phase one, from December 2007 to September 2011, gives the companies an 18 to 30 month period to transition to the modified band plan, including "modification of certain of Inmarsat's network and end user devices and a shift in frequencies between the MSV parties and Inmarsat," according to the U.S. Securities and Exchange Commission report. MSV will be allocated 28 MHz of L-band spectrum and will pay Inmarsat $250 million in cash and $87.5 million in equity for additional spectrum. During phase two, from January 2010 to January 2013, Inmarsat will be able to modify the amount of spectrum it uses over North

America and make that bandwidth available to MSV for rental use. MSV will pay $115 million for this additional spectrum.

- No L-band MSS ATC network or equipment yet deployed.

March 26, 2010: FCC Issues Order on Harbinger Acquisition of SkyTerra;

- Relevant Milestones:

  March 27, 2009: Harbinger begins acquisition of SkyTerra with filing to FCC for transfer and control of SkyTerra to Harbinger Capital Partners, Ltd.

  November 24, 2009: FCC issues Protective Order allowing submissions by Harbinger and SkyTerra to be handled as proprietary and confidential material upon request.

  February 26, 2010: Harbinger submits information on its business model, including the planned build-out of an extensive terrestrial network, and requests it be treated as proprietary and confidential information as allowed by the Protective Order. The new business model (including the proposed building of an extensive terrestrial network) is not coordinated with the IRAC and Federal agencies.

  March 26, 2010: FCC issues a Memorandum Opinion and Order and Declaratory Ruling finalizing the acquisition of SkyTerra (to be renamed LightSquared) by Harbinger.

  March 26, 2010: Harbinger files a letter with the FCC on the same day the Harbinger Order is released, making available information on its business plans (including the building of an extensive terrestrial network) that was filed under a request for confidential treatment on February 26, 2010.

  April 1, 2010: Verizon files Petition for Partial Reconsideration of the Harbinger Order, alleging various process fouls and irregularities in the proceeding. (Believed to be still pending)

  April 2, 2010: AT&T files Petition for Reconsideration of the Harbinger Order, alleging various process fouls and irregularities in the proceeding. (Believed to be still pending)

  April 15, 2010: Harbinger withdraws its request that the February 26, 2010 information on its business plans be treated as confidential material.

March 26, 2010: FCC Releases Order and Authorization to modify SkyTerra ATC license.

- Aggregate EIRP increased to 42 dBW (~15.85 kilowatts) per sector.

- No change to gating requirement and tying of ATC to satellites.

- Power density limits relaxed near airports and waterways subject to Inmarsat making its terminals less susceptible to receiver overload interference (see paragraphs 35, 36):

- Increased protection for GPS from femtocells added to SkyTerra authorization: PSD of emissions in the 1559-1605 MHz band limited to -114.7 dBW/MHz and that PC data cards transmitting to such femtocells should limit the PSD of emissions in the 1559-1605 MHz band to -111.7 dBW/MHz.

- No L-band MSS ATC network or equipment yet deployed.

November 2010: FCC Initiates LightSquared Waiver Proceeding

- *November 18, 2010*: LightSquared Files Report to FCC on its MSS ATC Plans and notes that if the plans are not in conformance with the "gating criteria" in FCC's rules, request that the requirement be waived.

- *November 19, 2010*: FCC initiates proceeding on LSQ waiver request by placing the application on Public Notice and inviting public comment. By a separate Order on November 26, FCC extended comment deadline to December 2, 2010, with reply comments due December 9, 2010.

- No L-band MSS ATC network or equipment yet deployed.

January 26, 2011: FCC Grants LightSquared Waiver of Gating Criteria

- Federal agencies object to granting the gating waiver prior to completion of technical studies establishing whether GPS would be protected. The Department of Defense separately expresses its opposition to the FCC Chairman.

- While noting agency objections and the creation of a "new interference environment" NTIA does not formally block the FCC waiver proposal.

- On January 26, 2011, FCC granted a waiver to LightSquared of FCC rule 25.149(b)(4), permitting stand-alone terrestrial use for the first time.

- Establishes Technical Working Group (TWG) to examine potential interference to GPS.

- Report from the TWG due to FCC on June 15, 2011. The FCC later granted a two-week extension to *June 30, 2011* at the request of LightSquared.

- No L-band MSS ATC network or equipment deployed. First base station equipment provided for testing in April 2011

June 30, 2011: FCC places TWG Report on docket for Public Comment

- Period for comments closes July 30, 2011. Period for reply comments closes August 15, 2011

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.