June 27, 2011

VIA ELECTRONIC FILING

Marlene H. Dortch, Esquire
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: Notification of Ex Parte Presentation in LightSquared Subsidiary LLC, Application for Modification of Authority for Ancillary Terrestrial Component (File No. SAT-MOD-2010111-00239)

Dear Ms. Dortch:

This is to advise you, in accordance with Section 1.1206 of the FCC's rules, that on June 23, 2011, the representatives of the GPS community listed on Attachment A met with the individuals from the Commission listed on Attachment B. Among the FCC representatives, Messrs. Knapp and Repasi participated by telephone.

At the meeting, the following documents were provided:

1. Written testimony of Philip Straub, Vice President, Aviation Engineering, Garmin International, Inc., before the Transportation and Infrastructure Subcommittees on Aviation and Coast Guard and Maritime Transportation, United States House of Representatives, June 23, 2011 (“Straub Testimony”);

2. Assessment of LightSquared Terrestrial Broadband Systems Effects on GPS Receivers and GPS-dependent Applications, prepared by National Space-Based Positioning, Navigation and Timing Systems Engineering Forum (NPEF);

3. Letter of Roberto Kobeh González, President of the Council, and Raymond Benjamin, Secretary General, International Civil Aviation Organization, to Mr. Julius Genachowski, June 13, 2011; and


Just prior to the meeting, Mr. Knapp received these documents electronically. The other individuals received them at the meeting. In addition, the email to Mr. Knapp also included the “Statement of Margaret T. Jenny, President, RTCA, Inc., before a Joint Hearing of the U.S. House of Representatives Committee on Transportation and Infrastructure, Subcommittees on
Aviation and Coast Guard and Maritime Transportation,” June 23, 2011 (“Jenny Testimony”). A copy of this document is attached to the copy of this filing being sent to the other FCC participants who did not receive it when Mr. Knapp did. (We assume that Mr. Knapp provided the documents that he received to Mr. Repasi.) These documents, particularly the substance of the Straub Testimony and the Jenny Testimony, were discussed in the meeting.

Chris Hegarty of MITRE, one of the GPS industry representatives, is the co-chair of RTCA, Inc.’s (“RTCA’s”) Special Committee 159, which studied LightSquared’s proposals for a broadband terrestrial network and issued a report on June 3, 2011. RTCA, at the request of the Federal Aviation Administration, studied the issue of compatibility between operation of the LightSquared proposals and GPS receivers on board aircraft. At the meeting, Dr. Hegarty first addressed the latest technical proposal announced by LightSquared on June 20, 2011,¹ as he understood it to have been modified that morning at the joint hearing in testimony by the LightSquared witness. Dr. Hegarty said that RTCA looked at that specific proposal and could not conclude that it was compatible with, or acceptable for, civil aviation.

Dr. Hegarty described the results of the report that RTCA proposed, as summarized at pages 2-3 and 5-7 of the Jenny Testimony. Mr. Knapp commented that RTCA should make sure its report is included in the FCC record of this proceeding.

Dr. Hegarty noted, as discussed at pages 5-6 of the Jenny Testimony, that the report’s conclusions were based upon specific assumptions about LightSquared operation, and worse impacts would result if the LightSquared network was operated at the limits allowed in the FCC authorization. The specific assumptions involved (i) geographical distribution of base stations; (ii) base station transmission frequencies; and (iii) base station transmit power levels which are lower than those in the current FCC authorization. For example, the RTCA study assumed LightSquared base station towers at 1.6 kW per channel per sector, whereas the FCC license permits up to 16 kW per sector. The number of base stations per unit area was also limited under the model LightSquared provided for the study, whereas the FCC license does not limit the density. Dr. Hegarty said the RTCA study was done at an “historic pace” and emphasized further study was needed for additional reasons, including the fact that it did not look at all altitudes. Dr. Hegarty also discussed the history of the relevant RTCA standards as discussed on page 4 of the Jenny Testimony.

Philip Straub of Garmin discussed the challenges involved in designing GPS receivers and noted that any filters contemplated for GPS receivers would have to address constraints unique to aviation, such as vibration and extreme variations in temperature. (See pages 14-16 of Straub Testimony.) Dr. Hegarty commented that it is important that further analysis take these factors into account. Clay Barber of Garmin also stressed the challenges involved in designing filters for GPS receivers for aviation and retrofitting the existing fleet if filters could be designed.

All these individuals stressed that clarity is needed in LightSquared’s proposed technical parameters. Dr. Hegarty ended by noting that all relevant FAA standards need to be harmonized with international standards set by the International Civil Aviation Organization.

If you have questions about this submission, please contact me.

Very truly yours,

M. Anne Swanson

Attachments
cc w/RTCA testimony only (by email):
FCC Participants on Attachment B
Attachment A – GPS Community Representatives

Mr. Philip Straub
Vice President, Aviation Engineering, Garmin International, Inc.

Mr. Clayton Barber
Principal Engineer, Garmin International, Inc.

Dr. Chris Hegarty
Director for Communications, Navigation and Surveillance Engineering & Spectrum, MITRE Corporation (representing RTCA, Inc.)

M. Anne Swanson, Esquire
Dow Lohnes PLLC
Attachment B – FCC Participants

Mr. Julius Knapp
Chief, Office of Engineering and Technology

Mr. Ron Repasi
Deputy Chief, Office of Engineering and Technology

Mr. Walter Johnston
Chief, Electromagnetic Compatibility Division, Office of Engineering and Technology

Mr. Robert Weller
Chief, Technical Analysis Branch, Electromagnetic Compatibility Division, Office of Engineering and Technology

Mr. Mark Settle
Deputy Chief, Policy and Rules Division, Office of Engineering and Technology

Mr. Michael Ha
Office of Engineering and Technology

Mr. Paul Murray
Assistant Chief/Chief Counsel, Wireless Telecommunications Bureau

Mr. Robert Nelson
Chief, Satellite Division, International Bureau

Mr. Sankar Persaud
Electronics Engineer, Engineering Branch, Satellite Division, International Bureau
My name is Philip Straub, and I am Vice President, Aviation Engineering, for Garmin International, Inc. (“Garmin”). Today, I would like to address the serious threats to the aviation and maritime industries’ use of the Global Positioning System (“GPS”) posed by the proposal of LightSquared Subsidiary LLC (“LightSquared”) to offer a nationwide terrestrial broadband network. Garmin is not opposed to the roll-out of improved broadband service in this country. We just believe it should be done in other ways that will not eviscerate GPS service.

I. For Two Decades, Garmin Has Been Designing and Manufacturing Reliable GPS-Enabled Aviation and Maritime Products

Garmin is the leading manufacturer of GPS products for the general aviation industry in the United States and is a leading supplier of GPS-enabled products for the maritime market. It has been manufacturing GPS-enabled navigation devices since 1991.

Over the past two decades, Garmin’s aviation business has grown, and today Garmin has a larger installed user base of GPS equipment than all other manufacturers combined. Garmin provides a full suite of avionics for General Aviation aircraft, helicopters, and Part 25 business aircraft, including:

- Fully integrated “Flight Decks,” like the popular G1000, which provide pilots with instrumentation, navigation, weather, terrain, traffic, and engine data on large-format, high-resolution displays;
- GPS navigation/communication devices, like the GNS 400 and 500 product lines that have been the General Aviation standard since 1998 (over 115,000 sold) and their successors, the recently certified GTN 650 and 750. These aid pilots with high-resolution terrain mapping, graphical flight planning, geo-referenced charting, traffic display, and satellite weather;
- Mode S transponders which feature the extended squitter broadcast that enables the transponders to automatically transmit more accurate, and more useful, traffic surveillance data to support Automatic Dependent Surveillance-Broadcast (“ADS-B”), including aircraft flight identification, position, altitude, velocity, climb/descent, and heading information; and
Many other GPS devices that assist pilots in monitoring every element of their flight conditions.

Garmin also manufactures a broad line of GPS-enabled products for the marine market. These include Chartplotters, Sounders, Fishfinders, RADAR, Autopilots, Marine VHF Communications, Automatic Identification System (“AIS”) transceivers, products utilizing XM® signals, and Cellular Data Link products.

II. GPS-Enabled Aviation Products Have Revolutionized Aviation Safety, Particularly for the General Aviation Market

It is unquestioned that the introduction and use of GPS-enabled devices, like Garmin’s, have brought important advances in aviation safety, particularly for the General Aviation market. GPS has become ubiquitous and indispensable in the years since Garmin introduced its first aviation GPS receiver. Virtually all types of aircraft utilize GPS for navigation and approaches. Some 190,000 General Aviation aircraft are equipped with GPS, which represents over eighty percent of the active U.S. fleet. For the majority of these aircraft, GPS is the primary means of navigation. Almost eighty percent of air carriers’ planes utilize GPS. Nearly all military aircraft include GPS for navigation, weapon system integration, or command and control. Most foreign aircraft that enter U.S. airspace are fitted with GPS.

The position information computed by GPS receivers provides pilots with a reliable and accurate navigation source. When it is integrated with other systems in the cockpit, GPS enables a multitude of capabilities that enhance safety and improve operating efficiency. As the Aviation Subcommittee knows, GPS is the foundation for the Federal Aviation Administration’s (“FAA’s”) new NextGen System. The existing uses of GPS that are described below have made critical differences in the ability of pilots to ensure safety of life in the skies; proposed improvements in future devices will only enhance these benefits.

GPS provides pilots with the ability to fly point-to-point instead of following ground-based radio navigation aids that require longer flight paths between airports. GPS also gives pilots the ability to immediately orient where an aircraft is located relative to terrain or obstacle features when the GPS position is paired with map details. This combination provides “instant” orientation without the mental gymnastics that were necessary before GPS was introduced into the cockpit. This is a significant safety enhancement because it frees the pilot to concentrate on flying the airplane instead of working to stay oriented. During in-flight emergencies, GPS systems can provide immediate navigation to the closest airport, even in areas where there are no ground-based navigation aids.

GPS-based instrument approach procedures, both standalone and those enhanced by the Wide Area Augmentation System (“WAAS”) or Ground-Based Augmentation System (“GBAS”), allow aircraft to land safely at airports throughout the country. GPS approaches require substantially less ground infrastructure than those approaches utilizing ground-based

1 There were 223,877 total active General Aviation aircraft as of 2009. See http://www.faa.gov/data_research/aviation_data_statistics/general_aviation/CY2009/, Table 1.1 (last visited June 20, 2011).
availability, integrity, and accuracy are all necessary for GPS to function as a primary means of navigation and to ensure aviation safety. When weather is poor and a pilot cannot see outside the aircraft beyond the tips of the wings, he or she must rely on the plane’s navigation system to keep the aircraft in safe airspace. During an approach, the pilot works hard to follow the FAA-prescribed flight path to the runway and must be able to rely on the GPS and have confidence in the system. Improperly executed instrument approach accidents are consistently among the most common causes of lethal descent and approach accidents. The loss of the GPS signal during this critical time is clearly a hazard to safety. Without it, pilots have to scramble to stay ahead of the airplane by tuning to the frequencies of alternate navigation equipment and shifting their mindset to alternate navigation methods instead of relying on GPS.

The federal government has recognized the extensive benefits GPS brings to aviation safety. The FAA is in the process of implementing the NextGen program, which uses airborne GPS as an enabling technology for a new Air Traffic Control system. ADS-B equipment broadcasts GPS-derived position reports to other aircraft in the vicinity and to Air Traffic Control centers on the ground. ADS-B will enable increased safety, precision, capacity, and capability for Air Traffic Control with a reduced cost of operation since it is not dependent on ground-based radar systems. The FAA has mandated that all aircraft operating in class A, B, or C airspace be equipped with ADS-B by 2020.

GPS is also used as an input to many traffic awareness systems, particularly those derived from ADS-B. These systems can enhance safety by providing pilots with timely alerts of potential collisions with other aircraft so that they can be avoided. Additionally, GPS supplies position, altitude, and velocity information to many terrain awareness systems. Such systems greatly reduce the likelihood of controlled-flight-into-terrain incidents by providing the pilot with audible alerts of potential terrain and obstacle conflicts along the flight path and a picture of
the aircraft’s position relative to the surrounding terrain and obstacles. GPS also enables synthetic vision systems to display external topography from the perspective of the flight deck, enhancing situational awareness when pilots are flying in instrument conditions.

Many aircraft are equipped with electronic multi-function displays that depict the aircraft’s location on a map. GPS is a primary source of position data for these displays, which reduce pilot workload by improving situational awareness through pictures that show an aircraft’s position on a map that can be overlaid with weather radar and traffic information while airborne. Other GPS-enabled map displays, such as Garmin’s SafeTaxi®, provide the flight crew with a detailed picture of the runway and taxiway environment while on the ground to prevent runway incursions. When visibility is poor, it is difficult to remain oriented when taxiing. SafeTaxi®’s moving map display makes it easy.

In General Aviation aircraft, GPS is also used in conjunction with low cost inertial sensors to provide reliable, inexpensive, and lightweight attitude and heading systems. These devices replace spinning-mass gyroscopic instruments that have notoriously poor reliability and that otherwise would provide a pilot’s primary means for determining attitude and heading during instrument flight.

Finally, GPS is a crucial technology for airborne search and rescue operators. GPS allows search and rescue aircraft to fly precise, predetermined search patterns at any location, day or night, under all weather conditions. Accurate GPS position reports allow rescue personnel to quickly reach the correct location once the victim is found.

I use GPS in the personal and business sector and have become highly dependent upon the system. Our business uses many types of aircraft, from single-engine to light jet aircraft, to facilitate a broad range of business endeavors. These aircraft are predominantly utilized by working-level professionals and often carry these individuals to areas not well served by the airlines and locations lacking sophisticated infrastructure. To be valuable business tools, we expect these aircraft to complete their mission under a wide range of weather and operational conditions. GPS enables these aircraft to reach remote destinations under adverse weather conditions while enabling GPS-dependent safety technologies such as enhanced flight vision systems displays, terrain awareness and warning, runway incursion prevention and next generation traffic awareness systems. My personal single-engine airplane is based at an airport served only by a World War II era non-directional beacon (“NDB”) circling approach. The GPS overlay capability for this approach provides incalculable safety enhancements over flying that approach with only an NDB receiver. My experience as a pilot is very typical.

III. GPS-Enabled Marine Products Have Brought Similar Improvements in Boating Safety

The introduction and use of GPS-enabled devices have similarly enhanced safety in the operation of all types of watercraft. The United States Coast Guard mandates that most boats have on board a VHF radio that is enabled with Digital Selective Calling (“DSC”). DSC depends on GPS to send accurate position information over VHF frequencies in emergencies such as capsize, piracy, overboard loss of passengers, and numerous other situations. These
devices replace the need for boaters to rely on rough estimates of their position transmitted verbally over a radio.

GPS-enabled devices have become even more critical for marine safety with the United States Coast Guard’s termination on February 8, 2010 of the Loran-C system, a low-frequency hyperbolic radionavigation system.\(^4\) Established in 1957, the Loran-C system provided navigation, location, and timing services for both civil and military marine users. In decommissioning Loran-C service, the Department of Homeland Security and the Coast Guard noted that technological advancements and the emergence of GPS had rendered the system unnecessary.\(^5\)

Like avionics, modern marine electronics, through GPS, are also able to expand a boater’s situational awareness beyond knowledge of just the basics of a boat’s location to provide additional information about its position relative to fixed hazards like rocks or shoreline. Dynamic weather overlays also provide information necessary to avoid hazardous situations, and GPS-enabled equipment informs the boater where he or she is relative to such disturbances.

When visibility is low, marine surface radar overlays on charts allow boaters to differentiate between fixed (charted) obstacles and other vessels. Marine collision avoidance systems such as the marine Automated Identification System (“AIS”) further enhance situational awareness and incorporate alerts that help prevent accidents when two vessels come within close proximity. To operate, these systems require the accurate position, speed, and course information that GPS provides.

As with aviation, GPS is also a crucial technology in facilitating rescue operations at sea, allowing rescue personnel to reach endangered craft and their passengers quickly. The Global Maritime Distress Safety System (“GMDSS”) relies heavily on GPS position information as a primary feature in many of its component systems, including Emergency Position-Indicating Radio Beacons (EPIRBs), DSC, and AIS.

In addition to collision avoidance, marine AIS facilitates the tracking and management of large international shipping vessels when they enter United States coastal waters. Any degradation to the GPS signals on which this system relies poses a serious threat not only to the safety of the vessels in question, but also to the nation’s border security.

IV. **Given the Technical Characteristics of GPS Signals, Receivers Are Extremely Sensitive**

The GPS signals used by civilian receivers are transmitted in the GPS L1 Band, located at 1559-1610 MHz. This band is directly adjacent to the L-Band frequencies LightSquared is


proposing to use at 1525-1559 MHz. Both of these bands historically have been reserved for space-to-earth signal transmissions.

Space-to-earth transmissions need a very quiet interference environment because the signals reach earth at extremely low power levels. The only means of powering GPS signals from satellites is via solar panels, and GPS signals are sent out from satellites using 50 or fewer watts, about the same wattage it takes to power a light bulb. The GPS signal then travels 12,600 miles before being received. GPS receivers must be designed to be very sensitive in order to pick up these weak signals, in some instances using a wide bandwidth to improve measurement accuracy. For example, FAA-certified GPS/WAAS equipment is allowed to receive satellite signals across 20 MHz of bandwidth.6

GPS receivers are extremely sensitive to strong signals operating on nearby frequencies. The GPS receivers are “listening” very hard for relatively weak GPS signals, so strong signals overload their capacity to “hear” those signals the same way that standing next to a lawnmower makes it impossible to hear someone whispering in your ear. LightSquared’s proposal essentially is to start a lawnmower in a library. At ground level, GPS signals have a minimum guaranteed strength of -128.5 dBm; LightSquared signals, on the other hand, are authorized at +72 dBm, although LightSquared initially plans a power level of +62 dBm. Earlier this week, LightSquared proposed a fifty percent (3 dB) reduction in its authorized transmitter power limit, lowering it from +72 dBm to +69 dBm; however, such a proposed reduction is immaterial as it does not affect the proposed deployed power level of +62 dBm, which has been conclusively shown to cause harmful interference for many GPS receivers.7 At 800 meters from its transmitters, LightSquared’s power is predicted to be 96 dB higher than GPS. That translates to a LightSquared signal that is four billion times stronger than a GPS signal. GPS receivers of all types are not designed to exclude such strong signals, something never contemplated before LightSquared sought its waiver to offer its new terrestrial broadband service in an area of the spectrum historically reserved for weak space-to-earth signals.

V. LightSquared’s Threat to GPS

A. For Years, the Terrestrial Component of MSS Has Been Both Ancillary to and Integrated with MSS Operations

As Garmin’s lawyers have explained to me, the Federal Communications Commission (“FCC”) International Bureau’s January 26, 2011 decision granting LightSquared a waiver to offer a widespread terrestrial broadband service represented a fundamental change in FCC policy. LightSquared proposes to operate its high-power terrestrial broadband network in spectrum historically allocated to the Mobile Satellite Service (“MSS”), which is located at 1525-1559 MHz and 1626.5-1660.5 MHz. These frequency ranges in the “L-Band” are adjacent

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6 RTCA/DO-229D, Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment, December 13, 2006, sections 2.1.4.5.1 and 2.1.4.5.2.

to or near the frequency band used for low-power GPS signals. MSS carriers provide satellite communications services that are interconnected to the public switched telephone network in rural areas unserved by terrestrial commercial wireless telephone services. MSS signals are characterized by very low power at ground level, which makes them entirely compatible with other satellite services like GPS that operate in an adjacent spectrum. The low-power MSS signals, however, typically make the service unsuitable for voice communications in densely populated urban areas that are the most profitable to serve.

In 2003, the FCC sought to make offering MSS in underserved areas more attractive by permitting MSS carriers to use L-Band frequencies to provide an “Ancillary Terrestrial Component” (“ATC”) to their satellite service that would “fill-in” gaps in geographic areas where the satellite service would not work. The FCC made clear that it was not seeking to reallocate MSS to terrestrial service. Instead, it was trying to strengthen MSS by allowing add-on terrestrial service in limited areas. The FCC explicitly stated in this 2003 action that “[w]e do not intend, nor will we permit, the terrestrial component to become a stand-alone service.”

To ensure that the ATC portion of the service remained truly “ancillary,” the FCC adopted what is known as the Integrated Service Rule, requiring any MSS carrier offering ATC service to do so only by offering “an integrated service of MSS and MSS ATC.” In other words, if an MSS operator offers a service plan that includes ATC service, the FCC’s rules require that plan to include satellite service as well. To make absolutely clear what this integrated service requirement meant, the FCC adopted a “safe-harbor” rule providing that the integrated service requirement would be satisfied if the MSS used a “dual-mode” receiver capable of communicating using both the satellite and ATC components of the service.

As a final warning to service providers who might see the ATC component as a back-door way of providing competitive terrestrial wireless service, the Commission stated that:

[W]e intend to authorize ATC only as an ancillary service to the provision of the principal service, MSS. We have established a number of gating requirements to ensure that ATC may only operate after the provision of MSS has commenced and during the period in which MSS continues to operate. . . . 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.”

No one read these unequivocal FCC statements as anything other than assurances to operators in the L-Band and adjacent bands that the agency was committed to maintaining a spectrum environment hospitable to low-power satellite services like MSS and GPS.

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9 Id. at 1965 & n.5.
In 2005, the FCC reiterated that “ancillary” must remain “ancillary”:

The purpose of ATC is to enhance MSS coverage, enabling MSS operators to extend service into areas that they were previously unable to serve, such as the interiors of buildings and high-traffic density urban areas. We will not permit MSS/ATC operators to offer ATC-only subscriptions, because ATC systems would then be terrestrial mobile systems separate from their MSS systems.10

In the same order, the Commission again explicitly stated that MSS ATC operators were required to “control self-interference sufficiently to maintain satellite service.”11

Given this history and the underlying rules, other users of the MSS and adjacent spectrum, such as GPS providers, had every reason to expect that ATC operations would enhance – not interfere with – MSS operations. The Integrated Service Rule assured that any ATC service provider would, through its use of dual-mode or integrated handsets, protect against “self-interference” to the integrated MSS component. GPS providers reasonably concluded that any power levels or filtering of the ATC service that was sufficient to protect the MSS component from interference would likewise be sufficient to protect GPS signals in the adjacent spectrum band.

B. LightSquared’s Terrestrial Proposal Is Anything But Ancillary

On November 18, 2010, LightSquared filed a letter with the FCC that fundamentally undercut these expectations. In its filing, LightSquared informed the FCC that it had developed a new business plan that would involve offering ATC service on a wholesale basis to retail wireless providers. LightSquared’s proposed network would operate from 40,000 terrestrial transmitters located nationwide. Most importantly, LightSquared would no longer commit to satisfying the Integrated Service Rule by offering service only for use with “dual mode” handsets. Instead, it contended that it would be offering an “integrated service” merely because it would continue to offer MSS in the rural and sparsely populated areas where its ATC service would be unavailable.

Without the provision of “dual mode” handsets, LightSquared would no longer need to avoid self-interference, a crucial requirement basic to the GPS industry’s willingness on several prior occasions to work with MSS applicants to ensure their ATC service did not result in harmful out-of-band emissions. LightSquared’s November 2010 filing transformed its proposed service into an offering that would severely degrade GPS service for the millions of individuals, businesses, and government agencies that rely upon it.

10 Flexibility for Delivery of Communications by Mobile Satellite Service Providers in the 2 GHz Band, the L-Band, and the 1.6/2.4 GHz Band, Memorandum Opinion and Order and Second Order on Reconsideration, 20 FCC Rcd 4616, 4628, ¶ 33 (2005).

11 Id. at 4633, ¶ 46.
C. The FCC Rushed To Allow LightSquared’s Proposed New Service Without Evaluating Interference Concerns and Ignored Evidence of Interference and Numerous Objections, Including Those From Key Federal Offices

The FCC’s International Bureau responded to LightSquared’s November 2010 letter by deeming it an application for a change in LightSquared’s authorization, but the agency did not treat the letter according to the Commission’s typical application processing policies. In place of the thirty days usually allowed for public comment and petitions to deny, followed by additional periods for oppositions and replies to those oppositions, the Bureau merely gave the public ten days to submit initial comments and an additional seven days for reply.12 The Bureau surprisingly put the letter on public notice the very day after it was filed, meaning that, in this case, the comment period included the Thanksgiving holiday weekend. Ultimately, the Commission granted a very brief, three-day extension of the comment period, but the period was still much shorter than normal for an application of this consequence.13

Despite the truncated deadlines, a wide range of parties, including the U.S. GPS Industry Council, Verizon Wireless, AT&T, and CTIA-The Wireless Association filed comments discussing the massive problems that would be caused by LightSquared’s proposed operations and arguing that such a wholesale rule change, as LightSquared was requesting, should more appropriately be handled in a broader rulemaking proceeding allowing opportunity for wide notice and comment. Following the comment deadline, oppositions continued to pour in from both individual GPS users and organizations representing them.

On January 12, 2011, the National Telecommunications and Information Administration (“NTIA”) wrote the FCC, informing it that the Departments of Defense, Transportation, and Homeland Security had expressed concerns about LightSquared’s impact on GPS and wanted the FCC to defer action on modifying LightSquared’s authorization until the FCC evaluated the scope of the problem.14 Attached to NTIA’s letter was another letter from the Department of Defense requesting that NTIA oppose grant of LightSquared’s request and suggesting that the FCC defer action until a rulemaking proceeding could be conducted. Rather than follow the Defense Department’s recommendation, however, NTIA told the FCC Chairman that if the FCC intended to grant LightSquared’s requested modification, it should simultaneously establish a process for analyzing the scope of the potential interference and establishing solutions before allowing LightSquared to commerce operations.

On January 20, 2011, the U.S. GPS Industry Council filed test data compiled by Garmin demonstrating that LightSquared’s proposed operations would cause harmful interference to GPS devices. In experimental testing using the technical details of the proposed LightSquared system, an FAA-certified Garmin aviation receiver experienced harmful interference at power

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14 Letter from Lawrence E. Strickling, Assistant Secretary of Commerce for Communications and Information, to FCC Chairman Julius Genachowski, dated Jan. 12, 2011.
levels expected at a range of 13.8 miles and entirely lost its position at an estimated 5.6 miles from a LightSquared transmitter.

Despite this evidence and the growing opposition from private and government parties, the FCC’s International Bureau granted LightSquared’s request on January 26, 2011, subject to the condition that LightSquared engage in a process with interested parties to identify the scope of anticipated interference and propose solutions for mitigating it.\(^{15}\) The Bureau directed LightSquared, as chair of the group, to make periodic reports to the Bureau on its progress, with a final report due by June 15, 2011. In essence, the FCC delegated its core function – expert interference analysis for purposes of spectrum allocation – to a LightSquared-led non-governmental group. Moreover, the Bureau’s order did not require that GPS interference be solved before LightSquared begins offering service; it merely required that LightSquared complete the “process for addressing interference concerns related to GPS.”\(^ {16}\) The Bureau left itself the option of allowing LightSquared to commence service even if it turned out that GPS interference could not be remediated. In the view of Garmin and many other parties, this unprecedented action amounted to an abdication of the FCC’s responsibilities to police interfering uses of spectrum.

Following the decision, numerous parties, including Garmin, asked the full FCC to review the Bureau’s order. On March 25, 2011, the Departments of Defense and Transportation also wrote FCC Chairman Genachowski objecting to the lack of inclusion of federal agencies in the LightSquared-led working group process and advising that a comprehensive study of “all the potential interference to GPS is needed.”\(^ {17}\)

At today’s hearing, Garmin fully expected to be able to discuss with the Subcommittees the final working group report to the FCC. Unfortunately, on the day the report was due, LightSquared sought and was granted an extension of time until July 1, 2011 to file the report, despite the GPS Industry Council’s comments, on the part of its members who had been actively involved for months in the working group process, that the group’s technical report was final and ready for submission.\(^ {18}\)

This month, both the International Civil Aviation Organization (“ICAO”) and the International Air Transport Association (“IATA”) have notified the FCC Chairman that they have serious concerns about LightSquared’s proposed service. IATA expressed “strong opposition” to any waiver of the Integrated Service Rule for LightSquared, particularly because


\(^{16}\) \textit{Id.} at 588, ¶ 48.

\(^{17}\) Letter from William J. Lynn III, Deputy Secretary of Defense, and John D. Porcari, Deputy Secretary of Transportation, to FCC Chairman Julius Genachowski, dated Mar. 25, 2011.

of the threat it creates for NextGen.\textsuperscript{19} ICAO, terming its concern “grave,” discussed the “far-reaching impact on current and future aviation operations” caused by the LightSquared proposal and urged that the United States government’s long-standing commitment to provide GPS Standard Positioning Service for aviation throughout the world not be “jeopardized by the introduction of the LightSquared system and the ensuing impact on GPS use by aviation.”\textsuperscript{20}

VI. Testing Conducted on Aviation GPS Equipment Conclusively Demonstrates Serious Problems

Given the potentially devastating consequences that the LightSquared system poses for the aviation industry, multiple groups have conducted tests -- besides those done by the LightSquared-led working group -- to assess the true impact. All of the testing performed to date confirms that the LightSquared system, as currently proposed, will result in a widespread degradation of GPS receiver performance and severely limit the GPS utility as we now know it.

At the request of the FAA, RTCA, Inc. (“RTCA”), a standards setting body for the aviation community, performed tests and analysis to assess the impact of the LightSquared system on aviation GPS operations. The results of this effort were published on June 3 as RTCA/DO-327\textsuperscript{21} and showed a severe impact to aviation GPS operations. The tests included a set of four aviation receivers from both the General Aviation and Air Transport sectors. All of the tested receivers experienced significant degradation when exposed to the LightSquared signals. Every receiver was significantly degraded at interfering signal levels that will be seen within 1.1 kilometer of a single LightSquared transmitter, but some receivers were impacted at interfering signal levels corresponding to ranges of 6.2 or 25.8 kilometers. Several of the tested receivers experienced a loss of satellite tracking in the presence of LightSquared signal levels that would be expected during routine low altitude operations such as during instrument approaches to landing. The RTCA analysis considered the effects of multiple LightSquared transmitters and showed that significant degradation would be experienced at aircraft altitudes below 18,000 feet over large regions of the country where LightSquared plans to deploy. In light of these findings, the RTCA report concluded that use of the upper LightSquared channel is incompatible with aviation GPS operations. Until this week, all of the proposed LightSquared deployment phases included the use of the upper channel. While the RTCA report stated that the operation of a single lower 5 MHz channel might be compatible with aviation GPS operations, the statement was based on an assumption that LightSquared would operate at 1/10\textsuperscript{th} of its authorized power limit. RTCA did not reach any conclusion on the compatibility of a single lower 10 MHz channel with aviation use; it said further study was needed.

\textsuperscript{19} Letter from Giovanni Bisignani, Director General and CEO of the International Air Transport Association, to FCC Chairman Julius Genachowski, dated June 5, 2011.

\textsuperscript{20} Letter from Raymond Benjamin, Secretary General, and Robert Kobeh González, President of the Council, International Civil Aviation Organization, to FCC Chairman Julius Genachowski, dated June 13, 2011.

Separate from the RTCA effort, the Department of Defense coordinated two sets of tests to assess the LightSquared impacts. The first of these was a series of laboratory tests conducted at White Sands Missile Range, New Mexico, from April 4 to April 7. Simulated LightSquared signals were broadcast to the GPS receivers being tested in an anechoic chamber, which is specially designed to eliminate reflecting signals. The tests included filters on the broadcast signal that were provided by LightSquared. LightSquared’s engineers were present to assess the test setup, and they concurred that it was appropriate. These tests included FAA-certified aviation receivers, all of which demonstrated a complete loss of function with interfering signal levels that would typically be seen in airborne operations.

The White Sands testing was followed by open-air tests at Holloman Air Force Base in New Mexico from April 14 to April 17. As with the White Sands tests, LightSquared was an active participant; it provided representative LightSquared transmitter equipment, and its engineers were on site to support the tests.

The data from these two Defense-coordinated tests, along with the results from RTCA, were analyzed by the National Space-Based Positioning, Navigation, and Timing Systems Engineering Forum (“NPEF”), which recently released its own assessment of the LightSquared effects on GPS. The data showed that significant degradation of aviation GPS performance will occur at distances up to 27.2 kilometers from a single LightSquared base station and that a complete loss of service can be expected at distances up to 12.2 kilometers. As shown in Figure 1 below, when the data are superimposed against a proposed deployment in the greater District of Columbia metropolitan area, they show a denial of aviation GPS service over the entire area.

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The NPEF report looked at potential mitigations that might allow GPS to coexist with the LightSquared system. The addition of filtering was considered and was determined to be excessively costly and likely to sacrifice the levels of performance achieved by existing GPS equipment. The report stated that, for many applications of GPS that require the use of a wide pass-band, a practical receiver design with sufficient filtering will not be possible. The potential for mitigation by limiting LightSquared to operations using a single 5 MHz or 10 MHz in the lower portion of the LightSquared band was also evaluated. The NPEF noted that while some applications such as aviation may be compatible with this strategy, it will not work universally across the wider range of GPS applications. The only mitigation strategy that the NPEF identified as compatible with all GPS applications was the relocation of LightSquared to another band more suitable for high power terrestrial operations (i.e., not the MSS band).

Based on these findings the NPEF made the following recommendations to the National Executive Committee for Space-Based Positioning, Navigation, and Timing (“PNT”):

1. Move to rescind the FCC conditional waiver (FCC Order DA 11-133) of January 26, 2011 authorizing terrestrial only ATC operation in the Mobile Satellite Service (MSS) 1525 - 1559 MHz Band.
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.

3. Based on testing of representative ATC equipment which became available for the first time during this NPEF evaluation, it strongly recommended the FCC revisit and readdress the effects of the 2003-2010 ATC authorizations within the MSS L-Band spectrum on GPS applications.

These recommendations, made by the U.S. government’s own experts on GPS and its critical importance to the nation’s infrastructure, clearly show that LightSquared poses a dangerous threat to the continued operation of GPS.

VII. The Concept of Mitigation Cannot Be Supported

The aviation and GPS communities themselves have invested a significant amount of time, effort, and money not only in testing the effect of LightSquared’s proposed service but investigating potential mitigations that might allow GPS to coexist with LightSquared transmissions in the MSS L-Band. They have found that the concept of mitigation cannot be supported.

LightSquared has suggested that filters might effectively protect GPS receivers from its transmissions. There are no filters in existence that would protect aviation GPS receivers from LightSquared’s proposed transmissions. Since no filters exist – not even prototypes – the aviation community has not been able to test this mitigation proposal; however, as filter proposals surface, it is important to evaluate them in light of the stringent requirements imposed on products installed in aircraft. In addition to the challenging filter selectivity constraints required to reject LightSquared signals adjacent to the GPS band, aviation filters must reliably preserve the GPS spectrum, be able to withstand extreme temperature variations, endure the rigors of intense vibration, survive electrostatic discharge and lightning events, and meet strict size and weight limitations. To achieve the high level of rejection required to eliminate the high power LightSquared transmissions from the GPS receiver, any potential filter must necessarily reject some of the GPS signal as well. Improving out-of-band signal rejection comes at the cost of other performance requirements that are critical to the operation of the GPS receiver.

LightSquared has stated that there are companies willing to build filters that meet the aforementioned constraints. The aviation and GPS communities have only received one proposal thus far. The proposal was comprised of two facets; it was evaluated carefully and found to be completely infeasible. First, this proposal suggested the use of an in-line cavity filter. The insertion loss of this cavity filter is much too large for use as an antenna preselect filter, and it does not provide sufficient protection against 3rd order intermodulation when installed in-line after the antenna module. In addition, the size and weight of the cavity filter present serious challenges for airframe certification. Second, this proposal suggested an unconventional antenna module with an up-conversion approach to reduce the filter size. This approach requires converting GPS signals to another frequency, filtering them, and then
converting them back to the GPS frequency. It would significantly increase the complexity of the antenna design with an unconventional approach that may not be well suited to the stringent operational requirements described above. It also would fail to address the 3rd order intermodulation concerns. In addition, it draws significantly more power than conventional aviation antenna modules and would, therefore, require a re-design and re-certification of the GPS receiver in addition to the antenna.

The filters needed to protect GPS from LightSquared do not exist. There are no commercially available parts that will work. We have yet to even see a prototype. Furthermore, many of the proposals that have surfaced reject a large portion of the GPS signal in order to sufficiently attenuate LightSquared’s powerful signal. Meanwhile, LightSquared continues to make claims that GPS receivers “look into its spectrum.” Essentially, LightSquared is instead proposing that the GPS community add filtering to GPS receivers that would restrict them to using only a fraction of the frequency band allocated to GPS. These proposed filters actually filter out much of the desired GPS signals. This is hardly an acceptable compromise.

Even if a suitable filter could be developed, it would take many years to obtain all of the necessary certifications and approvals. Furthermore, the task of retrofitting the entire fleet of GPS-enabled aircraft in the United States would take years. Any aircraft from other countries flying to U.S. destinations would also need to be retrofitted. Equally important, there is no one-size-fits-all solution to this problem, so numerous filters would be required to meet the needs of various aviation GPS receivers.

In summary, there are numerous obstacles to filter-based mitigations that lead Garmin to conclude that such a proposal is completely impractical. Specifically, these obstacles are:

Technical obstacles:

1. Appropriate filters do not exist. All discussions in the FCC-mandated technical working group process have focused on proposals derived from simulations.
2. Proposed filters reject portions of the GPS signal in addition to the LightSquared signal.

23 Joint Planning and Development Office, NextGen Avionics Roadmap, Version 1.2, September 21, 2010) at 3 (under heading “System Safety – Avionics Constraints: Historical Communication Navigation and Surveillance (CNS) Lead-Times” states “it is important to highlight that many past efforts involving avionics system upgrades have spanned long periods (15-25 years with an average of 18 Years - as shown in the figure below”), http://www.jpdo.gov/library/20101008_ARM_v_1.2.pdf.

24 For example, the FAA’s ADS–B Out Performance Requirements to Support Air Traffic Control Service Discussion of the Final Rule, Section II.N.1 includes the following statement: “[a]fter reviewing all the comments, the FAA finds that a 2020 compliance date remains appropriate because [National Airspace System (“NAS”)] . . . users need time to equip to the requirements of the rule.” Automatic Dependent Surveillance – Broadcast (ADS-B) Out Performance Requirements to Support Air Traffic Control (ATC) Service, 75 Fed. Reg. 30176 (May 28, 2010).
3. The physics of filter design make it virtually impossible to reject a signal four billion times stronger than and closely proximate to the very weak GPS signal without harming the GPS signal to some degree.

4. Proposed filters are considerably larger than existing ones, making any retrofitting of existing receivers virtually impossible.

5. Handheld units would have to be scrapped because the antenna is integral to the unit.

6. The proposed filters do not address third-order intermodulation issues.

7. Proposed filters would require a different power design than presently exists, requiring new receiver designs to power the filter and antenna.

8. It is impossible to design one filter that will address all of the diverse requirements of the existing GPS user base.

**Cost and time obstacles:**

1. The time and expense of developing numerous filters to meet the needs of different aviation receivers.

2. The time required to obtain necessary certifications and approvals.

3. The time, expense, and feasibility of retrofitting the entire fleet of aircraft in the U.S. and aircraft flying here from other nations.

4. The loss of revenue and impact on jobs while aircraft are out of service for the installation and retrofit.

5. The difficulty in determining who would be responsible for funding the extensive development and retrofit costs when the changes offer no improved benefit or greater operational capabilities.

The remaining mitigation discussions with LightSquared focused on modifications to its deployment plans that would move it to spectrum further away from the GPS band. One proposal discussed the possibility of LightSquared only utilizing its lower 10 MHz channel, centered at 1531 MHz. RTCA has concluded that not enough information exists today to decide whether this option is viable and that more study is needed.

Earlier this week, LightSquared issued a press release setting forth what it termed a “comprehensive solution” to the problem of interference with GPS receivers. While the details remain vague, this solution involves initially limiting LightSquared to using the lower 10 MHz channel, along with, as noted above, a 3 dB (50%) reduction in its maximum authorized transmit power of 42 dBW. This proposal is no solution at all, given that the RTCA analysis was unable to show that the lower 10 MHz channel is compatible with aviation GPS operations due to a negative margin for initial GPS signal acquisition. The proposed reduction in power is an illogical conclusion given that the RTCA analysis was based on LightSquared’s previously stated plan to limit base station transmissions to 1/10th (32 dBW) of its authorized transmit power. LightSquared’s latest proposal would allow it to transmit at five times the power levels assumed in the RTCA analysis. Moreover, this “comprehensive solution” conveniently ignores much of the existing user base, especially users of high precision GPS equipment.

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The only fail-safe mitigation strategy proposed to date is for LightSquared to move to entirely different frequencies outside of the MSS L-band, away from GPS.

VIII. Allowing LightSquared To Proceed Will Have Profound Consequences for Aviation and Marine Safety, As Well As Harmful Economic and International Implications

Aviation Safety of Life. Given the way that GPS-enabled aviation products have revolutionized aviation safety, it is not an understatement to say that allowing the LightSquared proposal to proceed, in any form within the identified spectrum, will have serious implications for aviation safety of life. To ensure their products consistently meet safety objectives, Garmin and others in the industry design their devices to not only meet minimum requirements but also include margins, redundancy, and other backup design elements. Any threatened erosion of these critical elements, as would occur with LightSquared’s proposed operation, would produce extremely serious consequences for integrity and availability of GPS service. Not only is NextGen likely to be seriously delayed, if not compromised entirely by any roll-out of LightSquared’s proposed network, the possibilities in individual circumstances are alarming:

1) NextGen would be slowed or stopped completely if the GPS signal does not meet the availability and integrity requirements of the National Airspace System. NextGen programs at risk include ADS-B, Required Navigation Performance (“RNP”) / Area Navigation (“RNAV”), WAAS, GBAS, and Cockpit Display of Traffic Information (“CDTI”). These programs already have proven extremely beneficial to aircraft operators because of the GPS-based capabilities bring improved safety and airspace/airport capacity and reduced passenger delays, carbon emissions, and noise impact.

2) Losing GPS while on approach would be more than an inconvenience; it would cause significant distraction and require pilots to revert to a less precise ground-based navigation system that has few of the capabilities of GPS. Furthermore, loss of GPS would deny approach coverage at hundreds of airports and heliports that previously had no instrument approach because they were not in proximity to a ground-based navigation aid and could not afford to purchase a standalone instrument approach system of their own.

3) The inability of GPS to acquire position while on the ground would prevent the functioning of SafeTaxi® and similar applications, increasing the probability of runway incursions.

4) Without GPS, the Terrain Awareness and Warning System (“TAWS”) will not work for General Aviation, and Air Transport TAWS effectiveness will be degraded, increasing the likelihood of controlled flight into terrain.

5) Loss of GPS means that, for General Aviation, cockpit displays of aircraft position would be gone, and, therefore, a pilot would lose the very valuable situational awareness associated with a moving map display and a relative display of weather and traffic.

6) Loss of GPS would disable a synthetic vision system’s ability to display external topography from the perspective of the flight deck, thus reducing a pilot’s situational awareness.
7) Poor GPS availability would preclude low cost AHRS systems and promote the return to spinning mass gyroscope instruments with their notoriously poor reliability and safety record.

8) Without GPS, pilots would lose the ability to fly precise predetermined search patterns at any location night or day under all weather conditions.

9) Loss of GPS would mean rescue personnel could not determine a precise location for rendering emergency help and would greatly delay their ability to save lives.

**Marine Safety of Life.** Equally concerning is the effect that impairment of GPS service would have on safety of operations on the nation’s lakes and waterways and along its coasts. Any degradation or interruption of GPS signals would erode the integrity and availability of critical positional information. Again, the possibilities are alarming:

1) Losing GPS-enabled DSC service would mean boaters would have to return to reliance on rough estimates of location conveyed verbally over a radio.

2) Without GPS, boaters who depend on marine surface radar overlays with their GPS components to supply information on hazards instead would have to rely simply on visual identification, which becomes impossible at night or in fog.

3) Loss of GPS would render boaters unable to make the decisions necessary to avoid weather squalls based on marine weather information geo-located via GPS.

4) Without GPS, marine collision avoidance systems such as DSC and AIS (Class B) for small vessels, and AIS (Class A) for large vessels would be rendered useless.

5) Loss of GPS would cripple GMDSS component systems (e.g. EPIRB, DSC, and AIS) and make marine search and rescue efforts much less likely to reach emergency locations and stranded individuals or vessels.

6) Without GPS, marine AIS (Class A) used to track large international shipping vessels would be unavailable, affecting national security.

**Other Serious Implications.** Disruption of GPS has profound economic and international implications. The GPS community, the aviation industry, and numerous other business sectors have already spent significant resources over the last half year to analyze LightSquared’s proposed broadband terrestrial network to compensate for the FCC’s failure to do so prior to its issuance of the LightSquared waiver on January 26, 2011. The distraction from the business of developing, designing, and implementing new products has diminished economic competitiveness. In the event that any aspect of LightSquared’s proposal is allowed to proceed, these businesses will be forced to expend critical resources continuing to study this issue while facing diminishing profit margins due to degradation in GPS receiver performance. The cumulative effect is a massive delay in the development of new GPS technology beneficial to consumers, businesses, governments, and the safety of life. Some parties have even begun to harbor concerns that, because of LightSquared, GPS users in the U.S. may actually find it more cost effective to switch to other global navigation systems, such as Russia’s GLONASS, given
the different frequencies that system uses, further eroding American leadership in space-based navigation and timing.

Moreover, any FCC decision that allows or promotes GPS degradation will affect foreign aircraft operating in affected U.S. airspace. If LightSquared is allowed to proceed, these aircraft will require the same costly retrofit (if adequate mitigation is technically possible) with whatever new system U.S. aircraft will be forced to employ to retain GPS functionality. Complex U.S.-based standards for GPS-enabled aviation devices are harmonized with other countries and through international organizations, like ICAO, and accepted abroad. Any necessary modification of U.S. standards for GPS-enabled avionics means that the whole system of worldwide standards would need to be revised.

Similar problems will occur in the marine context. Marine GPS receivers used in safety-of-life applications such as AIS are required to undergo international GPS receiver certification per International Electrotechnical Commission (“IEC”) 61108-1.26 Furthermore, many agencies, including the US Coast Guard and the FCC, rely on international standards written by the Radio Technical Commission for Maritime Services (“RTCM”) to regulate GPS performance as it relates to AIS, DSC, and EPIRB, to name a few. Modification of these standards due to harmful interference from LightSquared would have far reaching international consequences for other countries that adopt these same standards.

IX. Conclusion

Garmin’s experience based on its participation in the GPS industry’s review of LightSquared’s operations over the past half year confirms what its original tests in January 2011 showed: operation of LightSquared’s proposed broadband terrestrial network will cause catastrophic harm to GPS service, and this potential harm cannot be mitigated in any practical manner. Garmin and numerous other companies have cooperated in good faith to evaluate these concerns, spending millions of dollars that should have been more productively directed toward increasing jobs and advancing their own business goals and objectives. At this point, Congress should put an end to this dysfunctional exercise and, as NPEF recommended, work to ensure the FCC’s rescission of LightSquared’s conditional waiver and an overall review of the effects of Ancillary Terrestrial Component operations in L-Band spectrum. At a minimum, LightSquared’s proposed operations should be moved to entirely different frequencies outside of the MSS L-Band, away from GPS.

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26 IEC 61108-1 Ed. 2.0 en: 2003, Maritime navigation and radiocommunication equipment and systems - Global navigation satellite systems (GNSS) - Part 1: Global positioning system (GPS) - Receiver equipment - Performance standards, methods of testing and required test results.
Assessment of LightSquared Terrestrial Broadband

System Effects on GPS Receivers and

GPS-dependent Applications

Prepared By:

National Space-Based Positioning, Navigation, and Timing Systems Engineering Forum (NPEF)
Executive Summary

The Executive Steering Group (ESG) of the National Executive Committee (EXCOM) for Space-Based Positioning, Navigation, and Timing (PNT) directed the National Space-Based PNT Systems Engineering Forum (NPEF) to conduct an assessment of the effects of LightSquared’s planned deployment of a terrestrial broadband network to Global Positioning System (GPS) receivers and GPS-dependent systems and networks. The NPEF was tasked to engage with the LightSquared Working Group established at the direction of the Federal Communications Commission (FCC), and the GPS manufacturing and applications communities through relevant industry bodies (e.g., the U.S. GPS Industry Council and RTCA, Inc.). The NPEF investigated and determined effects due to interference from LightSquared Ancillary Terrestrial Component (ATC) transmitters operating in the 1525-1559 MHz frequency band to a selected set of GPS receivers based on operationally relevant scenarios. While the NPEF tasks were conducted in coordination with all involved entities to the extent possible, the NPEF report is considered to be an independent assessment. The contents of this Report consist of a compilation of findings from nine subtasks along with appendices that include summaries of all of the detailed test data and results collected over the last four months via a series of laboratory and field environment testing of GPS receivers. This Report is a summary of the work conducted during this effort and includes specific recommendations and responses to questions as requested by the EXCOM.

Based on analysis described in the main body of this Report, the NPEF has developed the following recommendations for ESG consideration.

Recommendation 1: Move to rescind the FCC conditional waiver (FCC Order DA 11-133) of January 26, 2011 authorizing terrestrial only ATC operation in the Mobile Satellite Service (MSS) 1525 - 1559 MHz Band.

Test results of the LightSquared Phase 0, Phase 1, and Phase 2 deployments of ATC transmitters utilizing the MSS band (1550.2 – 1555.2 MHz for Phase 0, 1526.3 – 1531.3/1550.2-1555.2 MHz for Phase 1, and 1526-1536/1545.2 – 1555.2 MHz for Phase 2) have demonstrated there are significant detrimental impacts to all GPS applications assessed as part of this NPEF effort. These impacts encompassed both US Government and commercial GPS applications. The potential degradation of GPS operation due to LightSquared emissions was further characterized via simulation that showed that completion of the network of high-powered base stations envisioned by LightSquared would result in degradation or loss of GPS function (ranging, position) at standoff distances of a few kilometers extending to space operations. Possible mitigations for GPS applications were identified and evaluated but were deemed impractical as they would require significant modification or complete redesign and replacement of currently fielded GPS equipment. The timeline to field new GPS receivers for some applications, from initial concept development through production, can take 10-15 years. Finally, there remain certain applications that even with modification or complete redesign would still not be able to perform their current mission in the presence of such Network broadcasting directly adjacent to the GPS L1 band.
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.

Initial test results demonstrated that some applications (e.g. aviation) were able to operate with little to no degradation when only a 5 or 10 MHz channel (1526.3 – 1531.3 MHz or 1526 – 1536 MHz) in the lower portion of the MSS spectrum was utilized for the LightSquared broadcast. However, for other applications, GPS loss of function still occurs at unacceptable distances to LightSquared towers. Use of only the lower portion of the L-band MSS spectrum is not one of the planned Phases for the LightSquared Network evolution so only limited testing has been conducted under this scenario. Additionally, no tests on LightSquared handset (or user terminal) transmissions were conducted as part of this NPEF study, due to non-availability of hardware. LightSquared handsets will transmit in the band 1620.5-1660.5 MHz and the potential for interference to GPS receivers given the very close proximity to an arbitrary number of LightSquared users remains to be evaluated. Evaluation of the LightSquared emissions effects on timing receivers was not thoroughly addressed during the course of this NPEF investigation. An additional evaluation period of at least six months would enable completion of a thorough assessment of the LightSquared Network and should be conducted to allow the EXCOM to make informed decisions on impacts, mitigations, and the way forward for all GPS users. Note, however, it is not clear that LightSquared can provide its planned 4G LTE services levels using only the lower 5 MHz or even 10 MHz channel location.

Recommendation 3: Based on testing of representative ATC equipment which became available for the first time during this NPEF evaluation, we strongly recommend the FCC revisit and readdress the effects of the 2003-2010 ATC authorizations within the MSS L-Band spectrum on GPS applications.

At the conclusion of this NPEF effort significant concerns remain that operation of an ATC integrated service as originally envisioned by the FCC cannot successfully coexist with GPS. Until the FCC granted a conditional waiver to LightSquared in January 2011, operation of terrestrial services under the MSS ATC regime had been coupled with the MSS satellite service so that the MSS L-band remained primarily a limited power space service downlink band that ensured compatibility with adjacent band space services such as GPS. Rigorous analysis of systems compatibility had also been impossible prior to now due to non-availability of relevant commercial ATC equipment. As with recommendation #2, this recommendation suggests there’s need for additional assessment of previous rulemaking to determine if authorized ATC architectures in the MSS L-band could be tolerated by GPS applications in any form.
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Background

U.S. Space-Based Positioning, Navigation, and Timing Policy states that a “fundamental goal of this policy is to ensure that the United States maintains space-based positioning, navigation, and timing services, augmentation, back-up, and service denial capabilities that: (1) provide uninterrupted availability of positioning, navigation, and timing services; (2) meet growing national, homeland, economic security, and civil requirements, and scientific and commercial demands; (3) remain the pre-eminent military space-based positioning, navigation, and timing services; (4) continue to provide civil services that exceed or are competitive with foreign civil space-based positioning, navigation, and timing services.”

GPS modernization includes new signals and capabilities required to be compatible with the use of existing GPS receivers designed in compliance with specifications and standards in existence at the time of the receiver design. Compatibility with federal augmentation system (Wide Area Augmentation System [WAAS], Local Area Augmentation System [LAAS], Nationwide Differential GPS [NDGPS], and Maritime DGPS [MDGPS]) receivers in accordance with the specifications of these systems is also required.

Further, in 2004, the U.S. signed an agreement with the European Union establishing cooperation between GPS and the European Galileo system. The Agreement specifically 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 harmonized use of spectrum on a global basis, notably at the ITU.”

In 2007, the U.S. Federal Aviation Administration (FAA) submitted a letter to the International Civil Aviation Organization (ICAO), in lieu of an agreement, which “reaffirms the United States Government’s commitment to provide the Global Positioning System (GPS) Standard Positioning Service (SPS) for aviation throughout the world. Further, the United States commits to provide the Wide-Area Augmentation System (WAAS) service within its prescribed service volume.” The letter goes on to state that “The U.S. Government plans to take all necessary measures for the foreseeable future to maintain the integrity, reliability and availability of the GPS SPS and WAAS service and expects to provide at least six years’ notice prior to any termination of such operations or elimination of such services.”

On 9 Feb 2011, the Executive Steering Group (ESG), via the National Coordination Office (NCO) of the National Executive Committee (EXCOM) for Space-Based Positioning, Navigation, and Timing (PNT), directed the National Space-Based PNT Systems Engineering Forum (NPEF) to conduct an assessment of the effects of LightSquared’s planned deployment of terrestrial broadband systems to GPS receivers and GPS-dependent systems and networks (see Appendix A).

This Report is a summary of the work conducted on this Task (see Appendix B) and includes specific Recommendations as requested by the EXCOM. Department of Defense (DoD) findings for the Task are captured separately given their security classification.
Summary of Task Findings

The following material is a summary of the various subtasks performed in response to the EXCOM NPEF request. Detailed reports for each of the subtasks performed by the NPEF are included in Appendix B and contain additional data and information.

Task 1: Signal Specifications & Characteristics

The relevant technical information on LightSquared specifications and GPS applications were investigated and documented. Details of the LightSquared signal include intended LightSquared channel configurations, antenna characteristics, out of band emissions, tower density and handset technical parameters. Figure 1 depicts the LightSquared plans for three spectrum deployment phases (though the L1 identified in this Figure represents only the main lobe of the C/A portion of the GPS L1 signals).

- Phase 0: One 5 MHz channel: 1550.2 MHz- 1555.2 MHz, 62 dBm effective isotropic radiated power (EIRP) per 5 MHz channel, per base station sector.
- Phase 1: Two 5 MHz channels: 1526.3 MHz -1531.3 MHz & 1550.2 MHz - 1555.2 MHz, 62 dBm EIRP per 5 MHz channel, per sector.
- Phase 2: Two 10 MHz channels: 1526 MHz -1536 MHz & 1545.2 MHz - 1555.2 MHz, 62 dBm EIRP per 10 MHz channel, per sector.

Figure 1. LightSquared Signal Spectral Occupancy
LightSquared will utilize the prevalent fourth-generation cellular standard, known as Long Term Evolution (LTE), for their terrestrial network and has stated their intention to always operate ATCs at least 4 MHz separated from the start of the GPS L1 band (1559 MHz). It should be noted however, there is no regulatory requirement to maintain this guardband nor does LightSquared’s MSS ATC authorization impose such a restriction. In addition, the FCC authorization permits use of ATC power levels as much as 10 dB in excess of what LightSquared intends to use and, as a consequence, tests could not be conducted at the maximum allowable ATC levels. At these allowable higher levels there may be additional deleterious effects, such as intermodulation products caused by ATC emissions that are as yet unobserved but can be confirmed with additional testing.

GPS application requirements obtained for this evaluation vary greatly in specificity, with very detailed requirements identified for aviation to much less information for other classes of GPS users. GPS application requirements were obtained primarily from the Technical Working Group (TWG) which reports to the LightSquared Working Group established at the direction of the Federal Communications Commission (FCC). The TWG categorized GPS applications under the following classes: aviation, cellular, general position/navigation, high precision, networks, and space. Key requirements for these categories of applications are contained in the Task 1 detailed report in Appendix B.

Task 2: Model Characterization of the Terrestrial Broadband Network

The ATC locations of sites planned for the initial deployment by LightSquared were provided to the NPEF. The separation distance between these base stations depends on type of morphology around each site as well as capacity and coverage considerations. The maximum number of LightSquared Network handsets a single ATC tower can support depends on the demand and service profile of each mobile device/handset. A typical site with the Phase 2 construct using two 10 MHz channels can support 1200 users in active state and a much higher number in dormant state. For the LightSquared Network deployment of base stations by 2015, LightSquared expects that the distance between base stations would typically be:

- Dense urban environment: 0.4-0.8 km
- Urban environment: 1-2 km
- Suburban environment: 2-4 km
- Rural environment: 5-8 km

Tower locations provided by LightSquared for their initial deployments were used in Task 6 as part of the aviation and space simulation scenarios.

Task 3: RF Interference in Operational Scenarios

The NPEF utilized the operational scenarios developed in the TWG and RTCA forums. TWG scenarios were developed for each of the receiver categories mentioned in Task 1. The scenarios considered most relevant to the NPEF test effort were those for aviation, space, and scientific applications. The aviation scenarios covered en Route, terminal and approach, and surface operations. The spaceborne scenario investigated radio occultation (RO) applications where the
GPS receiver antenna is directed towards the Earth limb in order to measure properties of the atmosphere and typical navigation applications.

**Task 4: Receiver Performance Metrics**

The NPEF documented several metrics useful to assess performance of a GPS receiver under interference conditions. These metrics include carrier to noise density ratio (C/N₀), pseudorange and carrier phase measurement quality, carrier phase measurement continuity, automatic gain control characteristics, and position/time quality. Additionally some applications measured the ability to acquire or reacquire the GPS L1 signal. While all these metrics have utility in evaluating performance effects, due to the time constraint for this effort receiver characterization under LightSquared interference conditions concentrated on C/N₀ and loss of position/time quality. Loss of position/time quality was referred to as loss of satellite tracking. For NASA, loss of tracking meant no data, rather than poorer quality data, was produced by the unit under test.

**Task 5: Expected and Potential Effects on GPS Users**

GPS susceptibility tests were conducted using various LightSquared signals and test environments. Conducted emissions testing was accomplished in laboratory environments, radiated emissions testing was performed in an anechoic chamber, and ‘nominal’ operations testing utilized the ‘live sky’ environments provided by the current GPS constellation. Test results were obtained from several different types of receivers with applications ranging from aviation to survey to space.

Tables 1 and 2 provide summaries of the standoff distances where civil receivers indicated a 1 dB degradation in C/N₀ and when satellite tracking was disrupted (loss of lock) in the presence of LightSquared emissions. The 1 dB degradation point (approximately 25% loss in effective signal power) is not necessarily a tolerable level of degradation from LightSquared emissions but is useful to highlight the onset of severity associated with these emissions. For example, some tested aviation receivers could not meet their WAAS word error rate requirements in the presence of LightSquared interference that caused a 1 dB degradation in C/No. These results are for a single LightSquared base station and do not address aggregate power from multiple base station scenarios (see Task 6 for specific applications). In lieu of listing specific receiver results, the Tables categorize receivers into functional areas and then provide ranges to cover the degradation observed for these receivers against each specific LightSquared signal type. (Note that the separation distances in these Tables are used to compare the relative sensitivity of different classes of receivers and are based on free space propagation path loss where the receiver is in the main beam of the LightSquared base station transmission.) In addition to the LightSquared-proposed spectrum deployment phases, results for a single 10 MHz Low channel are also provided in these Tables since there was initial exploratory evaluation of a modified LightSquared spectrum deployment that might prove viable as a mitigation approach for some GPS applications.

Results in these Tables demonstrate that for all GPS applications assessed during this NPEF effort, the LightSquared signal caused degradation at distances of approximately one kilometer to several hundred kilometers for LightSquared Phase 0, 1 and 2 configurations. These distances are in excess of the planned spacing between base stations for all but the most rural areas. Further, as shown in the Task 6 assessments, there is also an aggregate effect that compounds the
degradations experienced from such emanations, i.e., the impacted area outside of a region of
dense base station deployment will typically be much larger than the impacted area around a
single station. For the 10 MHz Low channel, several receivers were found to operate very well
while others demonstrated performance degradation at several hundred kilometers.

Additionally, the ability to acquire or reacquire GPS in the presence of LightSquared ATC was
measured for some users. Analysis showed the distance from the LightSquared transmitter to
acquire or reacquire GPS signals was always greater than the distance where loss of GPS L1
tracking itself occurred. Testing indicated that loss of the ability to acquire or reacquire GPS
signals occurred at distances anywhere between 2 and 4 times greater than initial loss of GPS L1
solution.

It should also be noted that for some applications detailed receiver outputs could not be obtained.
E911 and Bureau of Land Management are examples where their reporting from live sky testing
at Holloman AFB was simply that at a given standoff distance the receivers stopped functioning
or an erroneous position was output.

One final point concluded from these test efforts was confirmation that, for the LightSquared
power levels tested, the LightSquared filters were able to satisfy their stated emission mask and
constrain out of band LightSquared emissions to less than -100 dBW/MHz at 1559 MHz and
above. Thus, for the LightSquared power levels tested, out-of-band emissions by LightSquared
ATCs into the GPS band have been determined to not represent a significant interference source.
Laboratory, anechoic chamber, and live sky testing confirmed that the primary sources of GPS
receiver degradation are receiver front end overload and intermodulation interference generated
in the antenna assembly or receiver that causes 3rd order intermodulation products to be formed
in the GPS L1 band (for details see Task 5 in Appendix B).
**Table 1.** Distance in Kilometers for 1 dB Degradation Caused by a Single LightSquared Base Station

<table>
<thead>
<tr>
<th>Application</th>
<th>Phase 0</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>10 MHz Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviation</td>
<td>24.3 – 1.1</td>
<td>27.2 – 1.2</td>
<td>19.3 – 0.9</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>Maritime</td>
<td>NM</td>
<td>NM</td>
<td>NM</td>
<td>NM</td>
</tr>
<tr>
<td>High Precision**</td>
<td>TBR – 0.5</td>
<td>TBR – 6.8</td>
<td>TBR – 3.8</td>
<td>TBR -- &lt; 0.1</td>
</tr>
<tr>
<td>(Survey, Agriculture, Science)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timing</td>
<td>NM</td>
<td>10.8</td>
<td>NM</td>
<td>NM</td>
</tr>
<tr>
<td>Space</td>
<td>121.6</td>
<td>305.5 – 19.3</td>
<td>NM</td>
<td>NM</td>
</tr>
</tbody>
</table>

**Data still being analyzed**

**Table 2.** Distance in Kilometers for Loss of Satellite Tracking Caused by a Single LightSquared Base Station

<table>
<thead>
<tr>
<th>Application</th>
<th>Phase 0</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>10 MHz Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviation</td>
<td>10.8 – 0.4</td>
<td>12.2 – 0.5</td>
<td>8.6 – 0.3</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>Maritime</td>
<td>0.6-2</td>
<td>1.6-4</td>
<td>1.0-3</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>High Precision**</td>
<td>2.2 – 0.2</td>
<td>7.7 – 2.1</td>
<td>6.1 – 1.7</td>
<td>0.4 -- &lt; 0.1</td>
</tr>
<tr>
<td>(Survey, Agriculture, Science)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timing</td>
<td>NM</td>
<td>&lt; 0.1</td>
<td>NM</td>
<td>NM</td>
</tr>
<tr>
<td>Space</td>
<td>24.3</td>
<td>61.0 – 2.7</td>
<td>NM</td>
<td>NM</td>
</tr>
</tbody>
</table>

*NM- Not measured

**Task 6: Simulation Activities**

Simulation activities utilized the planned initial LightSquared network documented in Task 2, scenarios from Task 3, and susceptibility results from Task 5 to evaluate impacts to aviation and space applications.

An aviation impact assessment was undertaken using the initial LightSquared base station locations located in four markets. Assuming a maximum EIRP of 62 dBm per sector per carrier, the assessment indicated that aircraft avionics will experience interference levels over very large regions of the United States and some portions of Canada and Mexico for the Phase 0, Phase 1,
and Phase 2 spectrum deployments that exceed the levels that the equipment is certified to
tolerate. Of the subset of certified airborne GPS receivers tested, all appeared to demonstrate a
tolerance to interference at the LightSquared frequencies that exceeds the applicable FAA and
International Civil Aviation Organization (ICAO) standards by some amount. However, even
when utilizing the measured interference tolerance of this small subset of equipment, the NPEF
assessment indicates that the LightSquared Network initial deployment would cause severe
operational impact over significant regions of the United States. For instance, Figure 2 depicts
two contours where GPS would be unusable for an aircraft operating at 500 feet above the
ground for two representative receivers subjected to the LightSquared Phase 0 and Phase 1
signals. A common airborne receiver used on transport-category aircraft would be unable to track
any GPS satellites in the orange region, while both this receiver and a very popular general
aviation airborne receiver would be unable to track any GPS satellites in the red region. Both
receivers would be significantly degraded over much larger regions than depicted on the map.
Additional analyses are contained in the RTCA LightSquared Report (DO-327).  

Figure 2. Upper Channel Received Power Levels 500 feet Above the Ground in the Baltimore-
Washington Area for the Example LightSquared Network Deployment for Phase 0 or Phase 1.

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1 Assessment of the LightSquared Ancillary Terrestrial Component Radio Frequency Interference Impact on GNSS
L1 Band Airborne Receiver Operations, RTCA/DO-327, 3 June 2011
Simulation and analysis for space-based receivers was performed based on testing performed at JPL on current and future generations of space-based GPS receivers. Analysis was conducted to determine the percentage of time that space-based occultation measurements would be disrupted within a 10-day simulation. Results indicated that, depending on the spacecraft orbit (orbits assumed were 400 and 800 kilometer orbits inclined at 72 degrees) and on assumed parameters for the LightSquared base stations, the percentage of time occultation measurements could be disrupted was on the order of 5-10% for the power levels planned for use by LightSquared, to as high as 12% if FCC authorized levels of transmit power are assumed. Note that these are outage percentages based on a 10-day period and that the outage percentages based only on when the spacecraft is in view of the United States would be significantly higher per satellite pass. Such degradation would represent a severe disruption of space-based GPS receivers for radio occultation measurement of the Earth’s atmosphere and other science purposes. GPS receivers used for typical spacecraft navigation purposes with zenith pointed antennas are affected to a lesser degree (< 3% degradation for the worst case).

For high-precision GPS receivers used for Earth sciences and other applications requiring precise measurements, analysis was conducted to determine the required minimum separation distance between a terrestrial high-precision GPS receiver and a single LightSquared base station where there would be no discernible effect on received C/No. Results of the analysis showed that separation distances for the two receivers tested, assuming several different propagation models, ranged from approximately 1.5 to 4 kilometers for one receiver type to approximately 3 to12 kilometers for the other receiver model tested. Both models tested are used in the International GNSS Service (IGS) network. Given the ATC deployment density anticipated with the LightSquared terrestrial network, it is unlikely that such separation distances could be assured.

High-precision receivers are also used in many state and local networks. The National Geodetic Survey (NGS), an office of NOAA's National Ocean Service, manages a network of Continuously Operating Reference Stations (CORS) that provide Global Navigation Satellite System (GNSS) data consisting of carrier phase and code range measurements in support of three dimensional positioning, meteorology, space weather, and geophysical applications throughout the United States, its territories, and a few foreign countries. The sites are independently owned and operated. Each agency shares their data with NGS and NGS in turn analyzes and distributes the data free of charge. As of May 2010, the CORS network contains over 1,450 stations, contributed by over 200 different organizations, and the network continues to expand (See Error! Reference source not found.).

Figure 3. U.S. CORS Station Locations
Task 7: Work Plan, Test Planning & Field Test Activities

The testing discussed in Task 5 included participation by LightSquared personnel to observe and comment on test conduct. LightSquared visited both Zeta Associates Inc., who performed FAA sponsored aviation receiver tests, and JPL, who performed NASA sponsored space-based receiver testing. LightSquared visited White Sands Missile Range to observe chamber test conditions and also provided and operated a representative ATC base station in support of open-air (‘live sky’) testing conducted at Holloman Air Force Base. To ensure a high fidelity test, actual LightSquared filters with representative antennas and equipment were used to transmit the LightSquared signal. LightSquared did not identify or voice any concerns regarding any of the above described test configurations.

Task 8: Mitigation Measures Applicable to GPS Users

Four possible mitigation measures applicable to GPS were identified and assessed. These included:

- Additional filtering – adding filtering to GPS user equipment to suppress the LightSquared signals.
- Adaptive antennas – using adaptive array antennas to spatially suppress the LightSquared signals.
- GPS changes – increasing GPS and WAAS broadcast signal strength to compensate for the signal-to-noise degradation caused by the LightSquared Network.
- Operational solutions – keeping GPS users separated from LightSquared base stations and mobile subscriber handsets.

Of these measures, adding additional filtering was found to be the most viable but would most likely be costly where it could be applied and cannot be applied to all GPS users. Many fielded GPS receivers are self-contained or integrated into other products (e.g., mobile phones). For such equipment, it is likely to be more cost-effective to replace the equipment rather than modify a given unit. Some fielded GPS equipment that utilizes external antennas may be able to satisfactorily function with the addition of in-line filtering or a replacement antenna with additional self contained filtering. However, such add-on filtering solutions are not viable for a significant fraction of fielded equipment due to considerations such as performance (signal attenuation, increased thermal noise floor, phase and group delay variations with temperature and between frequencies, loss of narrow correlator benefits), cost, size, and weight. Further, in the case of the aviation application, the equipment and its installation procedure would also need to be recertified following the inclusion of an in-line filter.

For a new product, many additional degrees of freedom are opened for mitigation techniques. In this case, the entire receiver and antenna design could be optimized to meet an overarching set of requirements that included the need to tolerate high levels of out of band interference at the LightSquared frequencies. In addition to adding to the filtering distributed along the RF front-end signal path, there are other design modifications that may be necessary to facilitate coexistence with the proposed LightSquared network. These include the careful control of the unit’s oscillator phase noise and spurs that may lead to reciprocal mixing problems, and the need to ensure that the signal path components do not saturate in the presence of the high-powered...
LightSquared emissions. Unfortunately, redesign is not likely to result in the same level of performance provided by current receivers, especially those employing wide RF front-end passbands. Such receivers are expected to increase in usage and importance in the near future as GLONASS, Galileo, and Compass satellite navigation constellations plan to be interoperable with GPS.

Given the wide variety of operational uses for GPS, however, the design requirements on receiving equipment also varies widely and there are some applications for which a practical receiver design will NOT be possible once the added constraint of coexistence with 34,000 high-powered base stations broadcasting signals 20 MHz away from the L1 carrier is applied. High-precision equipment is among the most difficult to protect against the LightSquared emissions since these receivers typically process wideband GPS signals that require a wideband receiver passband and such equipment usually also has severe differential group delay requirements. For these types of receivers, filtering can typically significantly degrade or even destroy the very information required for the most demanding scientific and precision applications.

Task 9: Mitigation Measures Applicable to LightSquared

The NPEF examined several possible mitigation measures that could be implemented by LightSquared to reduce potential interference to GPS receivers while still providing a viable nationwide terrestrial broadband service as required by the FCC. Five possible mitigation measures were examined: 1) increasing the frequency separation of LightSquared’s transmitted signal relative to the lower edge of the RNSS allocated band at 1559-1610 MHz (e.g., by using only the lower of the two proposed LightSquared channels); 2) reducing the transmitted power to reduce the magnitude of the interfering signal; 3) modifying the base station antenna (either by narrowing the vertical beamwidth or increasing the antenna tilt so that less area is covered by each transmitting antenna); 4) using exclusion zones to maintain a minimum separation distance where the installation is fixed; and 5) relocating the proposed LightSquared network operating frequencies to a band more suitable for high power terrestrial operations.

Of these possible mitigation techniques applicable to LightSquared, the two involving increased frequency separation present the most promise for the widest communities of GPS users. The mitigation technique that offers the greatest long-term benefit to the GPS community is the relocation of LightSquared’s terrestrial operations to a band more suitable for such applications and less disruptive to adjacent band space services such as GPS.

Another approach examined involves limiting the LightSquared transmissions to the lower 5 or 10 MHz channel of their planned deployment. However, while this approach would protect a limited number of GPS applications other applications would still be susceptible to interference. Using this approach it may be possible to protect classes of GPS receivers, primarily those with

\[2\] The 15 May 2011 report of the FCC Technical Working Group noted that their tests did not reflect the planned LightSquared power levels. In single frequency mode, the test sites operated at power levels of approximately 59 dBm EIRP per channel as opposed to the 62 dBm EIRP per channel currently planned for the initial commercial deployment. For two carrier tests, the MIMO gain will not be present, reducing the EIRP a further 3 dB per channel to approximately 56 dBm EIRP. It is not adequate to merely adjust the standoff distances to account for greater power because this does not account for intermodulation products which might be introduced at the highest radiated power. The effects shown with respect to GPS may have to be adjusted in further tests to reflect planned operating conditions.
greater receiver selectivity. However, some classes of GPS receivers would still not be protected under this mitigation technique. Receivers having wider RF front-end characteristics, such as those used for scientific and commercial uses requiring high precision measurements, and some receivers capable of receiving multiple signals from different GNSS systems (e.g., GLONASS) would remain susceptible. Additionally, the use of only the lower LightSquared channel would provide only a temporary solution to the existing interference problems as 4G LTE levels of service may not be possible. Thus, even if allowed, the FCC’s objectives and service conditions on the LightSquared license would not be met.
Recommendations

Based on analysis described in the main body of this Report, the NPEF has developed the following recommendations for ESG consideration.

**Recommendation 1:** Move to rescind the FCC conditional waiver (FCC Order DA 11-133) of January 26, 2011 authorizing terrestrial only ATC operation in the Mobile Satellite Service (MSS) 1525 - 1559 MHz Band.

Test results of the LightSquared Phase 0, Phase 1, and Phase 2 deployments of ATC transmitters utilizing the MSS band (1550.2 – 1555.2 MHz for Phase 0, 1526.3 – 1531.3/1550.2-1555.2 MHz for Phase 1, and 1526-1536/1545.2 – 1555.2 MHz for Phase 2) have demonstrated there are significant detrimental impacts to all GPS applications assessed as part of this NPEF effort. These impacts encompassed both US Government and commercial GPS applications. The potential degradation of GPS operation due to LightSquared emissions was further characterized via simulation that showed that completion of the network of high-powered base stations envisioned by LightSquared would result in degradation or loss of GPS function (ranging, position) at standoff distances of a few kilometers extending to space operations. Possible mitigations for GPS applications were identified and evaluated but were deemed impractical as they would require significant modification or complete redesign and replacement of currently fielded GPS equipment. The timeline to field new GPS receivers for some applications, from initial concept development through production, can take 10-15 years. Finally, there remain certain applications that even with modification or complete redesign would still not be able to perform their current mission in the presence of such Network broadcasting directly adjacent to the GPS L1 band.

**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.

Initial test results demonstrated that some applications (e.g. aviation) were able to operate with little to no degradation when only a 5 or 10 MHz channel (1526.3 – 1531.3 MHz or 1526 – 1536 MHz) in the lower portion of the MSS spectrum was utilized for the LightSquared broadcast. However, for other applications, GPS loss of function still occurs at unacceptable distances to LightSquared towers. Use of only the lower portion of the L-band MSS spectrum is not one of the planned Phases for the LightSquared Network evolution so only limited testing has been conducted under this scenario. Additionally, no tests on LightSquared handset (or user terminal) transmissions were conducted as part of this NPEF study, due to non-availability of hardware. LightSquared handsets will transmit in the band 1620.5-1660.5 MHz and the potential for interference to GPS receivers given the very close proximity to an arbitrary number of LightSquared users remains to be evaluated. Evaluation of the LightSquared emissions effects on timing receivers was not thoroughly addressed during the course of this NPEF investigation. An additional evaluation period of at least six months would enable completion of a thorough assessment of the LightSquared Network and should be conducted to allow the EXCOM to make informed decisions on impacts, mitigations, and the way forward for all GPS users. Note,
however, it is not clear that LightSquared can provide its planned 4G LTE services levels using only the lower 5 MHz or even 10 MHz channel location.

**Recommendation 3:** Based on testing of representative ATC equipment which became available for the first time during this NPEF evaluation, we strongly recommend the FCC revisit and readdress the effects of the 2003-2010 ATC authorizations within the MSS L-Band spectrum on GPS applications.

At the conclusion of this NPEF effort significant concerns remain that operation of an ATC integrated service as originally envisioned by the FCC cannot successfully coexist with GPS. Until the FCC granted a conditional waiver to LightSquared in January 2011, operation of terrestrial services under the MSS ATC regime had been coupled with the MSS satellite service so that the MSS L-band remained primarily a limited power space service downlink band that ensured compatibility with adjacent band space services such as GPS. Rigorous analysis of systems compatibility had also been impossible prior to now due to non-availability of relevant commercial ATC equipment. As with recommendation #2, this recommendation suggests there’s need for additional assessment of previous rulemaking to determine if authorized ATC architectures in the MSS L-band could be tolerated by GPS applications in any form.
Appendix A: Assessment of LightSquared Terrestrial Broadband System Effects on Civil GPS Receivers and GPS-dependent Civil Government Applications

Task Statement

Assessment of LightSquared Terrestrial Broadband System Effects on Civil GPS Receivers and GPS-dependent Civil Government Applications

Scope

At the direction of the Executive Steering Group (ESG) of the National Executive Committee for Space-Based Positioning, Navigation, and Timing, herein referred to as the EXCOM, and with facilitation by the National Coordination Office (NCO), the National Space-Based PNT Systems Engineering Forum (NPEF) is tasked to conduct an assessment of the effects of LightSquared’s planned deployment of terrestrial broadband systems to Global Positioning System (GPS) receivers and GPS-dependent systems and networks. The NPEF should engage with: 1) The LightSquared Working Group established at the direction of the Federal Communications Commission (FCC) and 2) GPS manufacturing and applications communities through relevant industry bodies (e.g. the U.S. GPS Industry Council and RTCA, Inc.). The NPEF is to investigate, assess, and determine the range of effects to GPS use based on operationally relevant scenarios that represent the current installed user base. While the NPEF tasks are to be conducted in cooperation with all involved entities to the extent possible, the NPEF is requested to produce an independent report to the ESG and EXCOM.

Background


Methodology and Assessment

1. Document LightSquared’s Ancillary Terrestrial Component (ATC) and related user equipment signals and antenna specifications and characteristics, GPS receiver specifications and characteristics (e.g., Radionavigation-Satellite Service (RNSS) receiver characteristics submitted to the International Telecommunication Union (ITU)), and future spectrum environment considerations.
2. In cooperation with the LightSquared Working Group, develop a baseline model characterization of the planned initial and fully deployed broadband network, including ATC locations and siting assumptions/limitations. Identify user handset planning assumptions as appropriate.

3. In conjunction with federal and commercial GPS technical experts, develop operational scenarios representative of the full range of anticipated effects to GPS receiver use (including characterization by existing GPS receiver categories where possible) as well as deployed federal and commercial GPS-dependent systems or networks. The scenarios assessed shall consider federal and state government and commercial communities’ current and planned use of GPS and GPS applications.

4. Develop appropriate metrics to quantitatively and qualitatively assess performance degradations from both technical and operational perspectives.

5. Analyze the expected and potential effects on GPS use for each of the developed scenarios including both current and future spectrum environment (e.g. 2025) considerations.

6. Coordinate simulation activities to further assess effects on GPS usage under various scenarios.

7. Coordinate work plan, test planning, and field test activities with the FCC, LightSquared, NTIA and the EXCOM departments and agencies to measure emissions and determine representative technical and operational GPS receiver effects as a function of distance from a LightSquared terrestrial base station.

8. Assess potential mitigation techniques and their expected effectiveness/costs for various representative GPS receivers in each of the selected scenarios. Assessments should include analysis, simulation, and prototype testing (as practical).

9. Assess and recommend potential mitigation measures or techniques that are applicable to the LightSquared system based on the representative GPS receivers and the operational scenarios developed above including, for example, potential variations in emitted power, antenna gain pattern, and operating spectrum for the ATC base stations and mobile handsets.

Schedule and Deliverable
The NPEF is to complete the work under this Task Statement by May 31, 2011. An interim update will be provided to the ESG/EXCOM through the NCO Director by March 31, 2011. The final deliverable report will be produced in a publicly releasable version and For Official Use Only version as appropriate. The reports will detail the planned broadband system effects on GPS use and include details on potential technical and operational mitigation options for interoperability between the planned LightSquared network and federal and commercial GPS-dependent users, systems and networks. The report will include field measurements from the LightSquared ATC stations and mobile handset and an analysis of representative GPS receiver performance. Any classified concerns will be briefed to the NCO and ESG for discussion in an appropriate forum and venue. Issues of proprietary data will be handled on a case-by-case basis.
Appendix B: NPEF Tasks

**See companion pdf document.**
Ref: AN 7/5 - CNS41541 13 June 2011

Mr. Julius Genachowski
Chairman
Federal Communications Commission (FCC)
445 12th Street, SW
Washington, DC 20554
United States

Dear Mr. Genachowski,

We are writing to you about an issue of grave concern to the international civil aviation community, in connection with Federal Communications Commission (FCC) Order and Authorization DA 11-133, adopted on 26 January 2011.

As you are aware, the Order granted LightSquared Subsidiary LLC a conditional waiver of FCC rules, enabling the company to use terrestrial-only devices in a band adjacent to that in which the global positioning system (GPS) operates.

Subsequent to the Order being issued, studies have shown that LightSquared transmissions would have a dramatic impact on aviation GPS receivers. Specifically, the conclusion reached by an authoritative aviation industry body (RTCA, Inc.), after an exhaustive technical investigation, is that the proposed LightSquared operation would be incompatible with the current aviation use of GPS.

The safety and efficiency of aviation operations today are already, to a substantial extent, reliant on the invaluable position, navigation and timing service provided by GPS. Ongoing aviation developments, such as those being undertaken in the framework of United States NextGen programme and the European SESAR programme, will place even more emphasis on the central role of GPS and other satellite navigation systems in aviation operations.

Therefore, the potential disruption to aviation use of GPS caused by the LightSquared system would have a far-reaching impact on current and future aviation operations. The impact would not only be limited to the United States. The international aircraft fleet flying into the United States would be directly affected and also similar developments could arise elsewhere and propagate the disruption beyond their borders.
In September 2007, the United States Government reaffirmed its commitment to provide the GPS Standard Positioning Service (SPS) for aviation throughout the world.

This commitment, first expressed in 1994, was the foundation for the development of key GPS aircraft navigation applications, based on ICAO international standards and procedures, which today support safer and more efficient aviation operations worldwide.

We urge you to ensure that this vital commitment is not unintentionally jeopardized by the introduction of the LightSquared system and the ensuing impact on GPS use by aviation.

Yours sincerely,

[Signatures]

Roberto Kobeh González
President of the Council

Raymond Benjamin
Secretary General

cc: Mr. Raymond H. LaHood
United States Secretary of Transportation
U.S. Department of Transportation

Mr. J. Randolph Babbitt
Administrator
Federal Aviation Administration (FAA)

Representative of the United States
on the Council of ICAO
5 June 2011

The Honorable Julius Genachowski
Chairman
Federal Communications Commission
445 12th Street, SW
Washington, D.C. 20554
United States of America

Dear Mr. Chairman,

On behalf of the 230 member airlines of the International Air Transport Association (IATA), I am writing to express our strong opposition to the waiver of the "integrated service" rule granted to LightSquared Subsidiary LLC (LightSquared) for its Mobile Satellite Service license in the L Band.

Specifically, we are concerned that interference from the proposed LightSquared system will impact Global Positioning System (GPS) frequencies, which are used by airline operations around the world for critical navigation, communication, and surveillance services that are essential for aviation safety.

We are particularly alarmed that interference to GPS signals will directly impact the U.S. Next Generation Air Transportation System (NextGen), an air traffic modernization effort strongly endorsed by the Obama Administration, which uses the GPS as the basis of its technology.

IATA is a strong proponent of NextGen and endorses its implementation to improve safety, increase efficiency, and reduce aviation's environmental footprint. We urge the Commission to take all necessary steps to ensure that GPS service provision is not compromised in any way by the LightSquared system.

Sincerely,

Giovanni Bisignani
Director General & CEO
STATEMENT OF
MARGARET T. JENNY
PRESIDENT, RTCA, INC.

Before a Joint Hearing of the

U. S. HOUSE OF REPRESENTATIVES
COMMITTEE ON TRANSPORTATION AND INFRASTRUCTURE
SUBCOMMITTEES ON AVIATION
and
COAST GUARD AND MARITIME TRANSPORTATION
on
GPS RELIABILITY: A REVIEW OF AVIATION INDUSTRY PERFORMANCE,
SAFETY ISSUES, AND AVOIDING POTENTIAL NEW AND COSTLY
GOVERNMENT BURDENS

WASHINGTON, D.C.
June 23, 2011
INTRODUCTION
Good morning, Chairmen Petri and LoBiondo; Ranking members Costello and Larsen; and Members of the Subcommittees. My name is Margaret Jenny, President of RTCA, Inc. Thank you for inviting me to participate in today’s hearing on “GPS Reliability: A Review of Aviation Industry Performance, Safety Issues, and Avoiding Potential New and Costly Government Burdens.”

RTCA BACKGROUND
RTCA is a not-for-profit association founded in 1935 and utilized as a Federal advisory committee. We are the premier Public-Private Partnership venue for developing consensus among diverse, competing interests on critical aviation modernization issues in an increasingly global enterprise.

RTCA works closely with the Federal Aviation Administration (FAA) to develop comprehensive, industry-vetted and endorsed recommendations for the government on issues ranging from technical performance standards to policies for air transportation. Our deliberations are open to the public and our products are recommendations, developed by aviation community volunteers functioning in a consensus-based, collaborative, peer-reviewed environment.

RTCA provides two categories of recommendations to the government: (1) policy and investment priorities to facilitate implementation of air traffic management system improvements, and (2) minimum performance standards, reports, and guidance documents used by the FAA as a partial basis for the certification of equipment.

OVERVIEW
My testimony today will summarize the findings of a study conducted by RTCA on the impact of the proposed LightSquared terrestrial wireless broadband network on GPS receivers onboard aircraft. The RTCA report identified specific adverse effects on the use of GPS in aviation.

In my role as President of RTCA, I am here today to present the consensus findings of Special Committee 159 (SC-159), and not my views or even the views of individual members of the committee. The time-honored RTCA process is designed to welcome all views to the table, and work through to a consensus or, in cases where a consensus cannot be reached, to include a minority report. In the case of the LightSquared study, the committee, which included members from LightSquared, was able to make some compromises to reach a consensus and that consensus is what I will discuss today.
RTCA LIGHTSQUARED REPORT OVERVIEW

In a letter (Appendix A) dated March 3, 2011, from Robert A. Frazier, Acting Group Manager, Spectrum Engineering Services, FAA, RTCA was requested to conduct a study (Appendix B - Executive Summary) to address the issue of compatibility between operation of a terrestrial wireless broadband network in the bands 1525-1559/1626.5-1660.5 megahertz (MHz) by LightSquared, pursuant to its FCC Order and Authorization, DA 11-133, January 26, 2011, and GPS receivers onboard aircraft utilizing the GPS Link 1 (L1)\(^1\) signal centered on 1575.42 MHz for navigation and positioning within the National Airspace System.

This Tasking was assigned to RTCA SC-159, Global Positioning System, under the leadership of Co-Chairs Chris Hegarty, The MITRE Corporation, and George Ligler, Project Management Enterprises. The Special Committee, originally formed in 1985, has over two-decades of experience resolving issues associated with GPS and conducts its work in accordance with the requirements of the Federal Advisory Committee Act (FACA), which allows for an open, participatory process. During the months of March through June of this year, the members of SC-159 developed a document titled “Assessment of the LightSquared Ancillary Terrestrial Component Radio Frequency Interference Impact on GNSS L1 Band Airborne Receiver Operations.” The study was released on June 3, 2011 as RTCA Document 327 (DO-327). It concludes that the current LightSquared terrestrial authorization would be incompatible with the current aviation use of GPS; however, modifications could be made to allow the LightSquared system to co-exist with aviation use of GPS. As previously mentioned, the committee welcomed new members from LightSquared to participate in the development of this report, and they are a part of the final consensus documented in the report.

Adhering to the scope of the request from the FAA, the report addresses the issue of compatibility between the proposed operation of a terrestrial wireless broadband network in the bands 1525-1559/1626.5-1660.5 MHz by LightSquared, pursuant to its Federal Communication Commission (FCC) license, and GPS receivers onboard aircraft. The report addresses the issues analytically, based on existing domestic and international standards and incorporates the test results of four certified aircraft GPS receivers.

The RTCA study assumed the spectrum deployment plan illustrated below for the base stations within the proposed LightSquared terrestrial wireless broadband network. In the first spectrum deployment phase, Phase 0, the base stations would transmit within a 5 MHz channel from 1550.2-1555.2 MHz. Phase 1 would add to Phase 0 a second 5 MHz channel from 1526.3-1531.3

\(^1\) The L1 center frequency is 1575.42 MHz.
MHz. During Phase 2, the two channels would be broadened from 5 MHz each to 10 MHz each, spanning 1526-1536 MHz for the lower channel and 1545.2-1555.2 MHz for the upper channel. These base station transmissions are in a frequency band just below the frequency band that contains the L1 frequency used by Civil Aviation and the base station transmissions are planned\(^2\) to be at a radiated power level of 1.6 kilowatts per channel per base station sector. Importantly, the RTCA assessment was based strictly upon LightSquared’s deployment plans as provided to RTCA by LightSquared representatives who participated in the consensus development of DO-327. As outlined in Section 2.4 of the report, the FCC authorization permits higher power levels, which would make the results far worse if they were considered.

As the LightSquared participants on the committee explained the plans, LightSquared is planning to deploy approximately 36,000 base stations throughout the United States, covering hundreds of millions of people, and an important component of the RTCA study was to assess the aggregate LightSquared signal power that would be seen from all visible base stations by a GPS receiver on an aircraft in various typical operational scenarios. These scenarios included high altitude cruise, low altitude cruise, precision approach, and airport surface operations. The received power assessment was conducted using data provided by LightSquared regarding the technical characteristics of their base station antennae and the densities of base stations to be deployed in urban, suburban, and rural environments.

\(^2\) The FCC license allows up to 16 kW per sector.
To evaluate the impact of the LightSquared base station transmissions on GPS avionics, the aggregate received power levels were compared to allowable interference limits, which were derived from: (1) applicable domestic and international regulations, including RTCA Minimum Operational Performance Standards (MOPS) referenced below, and (2) standard spectrum management practices. In 1991, RTCA completed GPS MOPS for avionics to support the introduction of GPS into civil aviation which was declared an operational capability for civil aviation in 1993. The FAA has invoked these MOPS in various Technical Standard Orders (TSOs) that are used as a basis for equipment certification. The latest suite of GPS MOPS includes RTCA/DO-316 for stand-alone GPS avionics, RTCA/DO-229D for GPS avionics augmented by the Wide Area Augmentation System (WAAS)\textsuperscript{3}, and RTCA/DO-253C for GPS avionics augmented by the Local Area Augmentation System (LAAS)\textsuperscript{4}.

All three of these MOPS include the same requirements for receiver interference susceptibility, and are harmonized with the requirement levied within the International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPs). The ICAO SARPs are used by numerous foreign civil aviation authorities as a basis for equipment certification. These global standards help ensure that the same receiver onboard an aircraft will work in flight anywhere around the globe. These interference requirements, as applicable to the LightSquared base station transmissions, have not changed materially since they were first published in 1996 in the initial issuance of RTCA/DO-229. GPS avionics have been certified using the DO-229 interference requirements (with performance requirements from earlier MOPS) since 1997, and the first-generation of airborne equipment built in complete conformance with the DO-229 MOPS certified by the FAA in 2002.

The MOPS interference requirements dictate that certified equipment must meet all applicable performance requirements, as demonstrated through testing, in the presence of specified interference power levels. These power levels generally become larger for interference center frequencies that are further removed from the GPS L1 frequency. Since the interference power level that can be tolerated by a MOPS-compliant receiver is greater as the center frequency of the interference becomes further away from L1, the receiver will be more susceptible to disruption from channels which are closer to the L1 frequency.

\textsuperscript{3} WAAS is a navigation aid introduced by the FAA to augment GPS with the goal of improving its accuracy, integrity, and availability.

\textsuperscript{4} LAAS is an all-weather landing system based on GPS that improves integrity and accuracy of the signal in the vicinity of an airport, enabling precision approaches.
Importantly, the implication of these requirements is that airborne GPS receivers are expected to be more susceptible to disruption from the upper LightSquared channels than the lower LightSquared channels.

Aviation spectrum management practices aim to ensure that GPS avionics never experience interference from transmissions that are right at the maximum power level for which the GPS receivers have been tested. Consistent with this practice (see, e.g., the International Telecommunication Union Radiocommunication Sector [ITU-R]’s Recommendation M.1477), the RTCA study used interference power limits that were the MOPS test levels adjusted by a standard safety margin.

**REPORT CONCLUSIONS**

The study concludes that all three spectrum deployment phases described above for the planned LightSquared terrestrial are incompatible with the current aviation use of GPS. However, use of a single 5 MHz lower channel could allow the LightSquared system to co-exist with aviation’s use of GPS.

The impact of a LightSquared upper channel spectrum deployment is expected to be complete loss of GPS receiver function. The LightSquared upper channel interference from Phase 0 deployment exceeds the GPS receiver MOPS-related environmental limit by a factor ranging from 18,000 to 380,000, depending upon the operational scenario involved. Because of the size of the single-city station deployment, GPS-based operations below about 2000 feet will be unavailable over a large radius from the metro deployment center (assuming no other metro deployments are nearby). This means that, since the GPS receiver will not be able to provide a position with any sort of continuity (if at all), GPS-based operations cannot be undertaken. Given the situation in the high altitude U.S. East Coast scenario, GPS-based operations will likely be unavailable over a whole region at any altitude at which aircraft normally fly.

The results of this study indicate that terrestrial base station operation at the lower 5 MHz-wide channel (1526.3-1531.3 MHz) is compatible with aviation GPS operations for all the representative scenarios (including both signal tracking and initial acquisition). Initial acquisition is acquiring enough satellites in the constellation to provide an initial GPS-based position, and signal tracking generally refers to tracking GPS satellites as they and the aircraft move to continue to be able to provide a GPS-based position for the aircraft.

The study indicates that for terrestrial base stations using only the lower 10 MHz channel at 1526-1536 MHz, there is a small positive margin for GPS tracking (but not necessarily initial acquisition) in the presence of mean aggregate terrestrial network interference. As noted
above, these conclusions are based upon specific assumptions about LightSquared operation and worse impacts would result if the LightSquared network was operated at the limits allowed per the FCC authorization. The specific assumptions include geographical distribution of base stations, base station transmission frequencies, and base station transmit power levels which are below those in the current FCC authorization. Two examples: The study assumed LightSquared base station towers at 1.6 kW per channel per sector, whereas the FCC license allows up to 16 kW per sector. Also, the number of base stations per unit area was limited per the model provided by LightSquared for this study, whereas the FCC license does not limit the density.

EVALUATION OF POSSIBLE MITIGATION
Unlike the receivers used for many non-aviation GPS applications, the airborne GPS receivers typically use multiple separate filters (for example, there are generally two filters in the antenna) and are generally considered quite robust to out-of-band interference. But, they still are adversely affected by emissions in the LightSquared band. Should LightSquared deploy as planned, many aviation receivers would be completely inoperable over very large swaths of airspace meaning that, in general, the receivers would be unable to provide a GPS position.

Airborne GPS receiver mitigations were also explored in the report, but the findings indicate that the only viable option is through invocation of more stringent performance requirements for the GPS antenna/receiver combination that would require the manufacturers to optimally layer filtering throughout the receiver front-end. This approach would take many years to get installed on the entire fleet of aircraft, since it would require new standards to be developed, new TSOs to be issued by the FAA, new receivers to be built and certified to the new standard, and finally installed within the fleet of aircraft that operate within U.S. airspace. This would be extremely disruptive to NextGen implementation, since it would cost billions of dollars and likely 7-10 years to retrofit the aircraft fleet after several additional years to develop new standards.

Thus, no viable short-term options based on changes to GPS receivers or antennae were identified in the report.

REPORT RECOMMENDATIONS
The main recommendations from this aviation GPS receiver operational assessment are:

1. From an aviation perspective, LightSquared upper channel operation should not be allowed.
2. Further study is recommended to more carefully determine a refined terrestrial base station power versus frequency limit to verify the conclusions for a LightSquared deployment scenario that involves only the lower 10 MHz channel at 1526-1536 MHz.

On this last point, the study indicated that terrestrial base station operations at the lower 5 MHz wide channel (1526.3-1531.3 MHz) is compatible with aviation GPS operations for all the representative scenarios (including both signal tracking and initial acquisition).

CONCLUSION

On behalf of the hard working and committed volunteers of SC-159, thank you for the opportunity to testify on this important topic. As the President of RTCA, I am gratified by the trust the FAA places in our committees to forge consensus on such challenging and critical aviation issues. The work of this committee, conducted in a very short three months, determined that the proposed LightSquared terrestrial wireless broadband network would have adverse effects on GPS receivers onboard aircraft.

I’d be pleased to respond to your questions.

REFERENCES


Dear Ms. Jenny:

The 1525-1559 MHz and 1626.5-1660.5 MHz bands have been allocated for many years for mobile satellite service (MSS) communications (e.g., Inmarsat).

A few years ago a United States satellite company “LightSquared” (previously called Mobile Satellite Ventures (MSV), then SkyTerra) started a process with the Federal Communications Commission (FCC) to also allow terrestrial communications in the 1525-1559 MHz band. These “ancillary terrestrial components”, or ATC\(^1\), were terminals that were an integral part of the MSS network. The stated intent was to act as “gap fillers” to allow the company to service users in areas where the satellite signals had difficulty reaching (e.g., cities and “urban canyons” where buildings caused blockages of the satellite signals). After considerable study that approach was approved, and in fact was recently updated based on agreements between LightSquared and Inmarsat.

In November 18, 2010, LightSquared requested to the FCC to amend their license to allow them to service terminals that are not combined MSS/terrestrial, rather are simply just purely terrestrial terminals. In the longer term that capability could be leased-out by LightSquared making it impossible for the ATC portion to be an “integral part of the satellite network”, rather it would simply become another cellular-type service. This raised the concern that the number of such terminals will increase. In fact, the current projection is that the number of these terminals will explode to an order of magnitude more than previously proposed. This presents a potential interference threat to the aviation community which is increasingly relying on Global Positioning System (GPS) L1 for navigation for not only approach and landing, but for enroute (automatic dependent surveillance broadcast) and surface navigation on airport tarmac.

The Federal Aviation Administration (FAA) believes that studies using the new assumptions need to be undertaken to ensure protection of the GPS. These studies should include

\(^1\) For this document ATC in italics refers to ancillary terrestrial component and not air traffic control. Due to confusion on the topic some have started writing the acronym as ATCt and the international term for ATC is complementary ground component (CPG).
receiver vulnerability, as well as scenario studies including aggregate effects of LightSquared transmissions on GPS receivers used in aircraft.

After reviewing the current terms of reference, we have determined that the evaluation of this potential interference is already within the scope of Special Committee 159. Therefore, I would like to add this issue to those already being addressed by SC 159. In order to provide timely input to the FAA, this evaluation will need to be completed quickly. LightSquared is required by the FCC to help organize and fully participate in a working group that includes the GPS community and federal agencies to study the potential for overload to GPS devices and to identify any measures necessary to prevent harmful interference to GPS. LightSquared will submit a final report by June 15 to the FCC. The RTCA evaluation should proceed in parallel, with a deliverable to the FAA by June 3.

Please let me know as soon as possible your response to this request at (202) 267-9722 or by e-mail at robert.frazier@faa.gov.

Sincerely,

Robert A. Frazier
Acting Group Manager, Spectrum Engineering Services
Executive Summary

This report documents a study conducted by RTCA Special Committee 159 in response to a request from the Federal Aviation Administration to address the issue of compatibility between the operation of a terrestrial wireless broadband network in the bands 1525-1559/1626.5-1660.5 MHz by LightSquared, pursuant to its FCC license, and GPS receivers onboard aircraft. The report addresses the issues analytically based on existing domestic and international standards and includes results of tests of four certified aircraft GPS receivers.

The study concludes that the current LightSquared terrestrial authorization would be incompatible with the current aviation use of GPS, however modifications could be made to allow the LightSquared system to co-exist with aviation use of GPS. The study’s conclusions and recommendations are strictly based on an assumed set of operational parameters for the LightSquared system and identified source mitigations. These operational parameters would produce less Radio Frequency Interference (RFI) than if LightSquared were to operate at its fully-authorized limits.

In addition, the analysis is based upon the assumption that all equipment is minimally compliant with the interference rejection requirements in harmonized domestic and international standards. Additionally since GPS is an aviation safety service, the analysis includes a 6 dB safety margin as is standard practice. Results from the four receivers tested show that these receiver models are significantly more resilient to interference from the LightSquared terrestrial base stations than limits derived from the standards.

The impact of a LightSquared upper channel spectrum deployment is expected to be complete loss of GPS receiver function. Because of the size of the single-city station deployment, GPS-based operations below about 2000 feet will be unavailable over a large radius from the metro deployment center (assuming no other metro deployments are nearby). Given the situation in the high altitude U.S. East Coast scenario, GPS-based operations will likely be unavailable over a whole region at any normal aircraft altitude.

The results of this study indicate that terrestrial base station operation at the lower 5 MHz wide channel (1526.3 – 1531.3 MHz) is compatible with aviation GPS operations for all the representative scenarios (including both signal tracking and initial acquisition). The study indicates that for terrestrial base stations using only the lower 10 MHz channel at 1526-1536 MHz, there is a small positive margin for GPS tracking (but not necessarily initial acquisition) in the presence of mean aggregate terrestrial network interference. As noted above, these conclusions are based upon specific assumptions about LightSquared operation.

The main recommendations from this aviation GPS receiver operational assessment are:

1. From an aviation perspective, LightSquared upper channel operation should not be allowed.
2. Further study is recommended to more carefully determine a refined terrestrial base station power versus frequency limit considering:
   a. determination of the lowest path loss for the low altitude enroute scenario,
   b. confirmation of acceptable receiver susceptibility for GPS initial acquisition and signal tracking in the presence of the 10 MHz bandwidth terrestrial network interference,
   c. computation of the cumulative probability distribution function for the aggregate path loss.