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The below is a summary prepared by the United States Global Positioning System Industry Council (USGIC), which participated in the FCC Working Group and whose chairman, Charles S. Trimble, co-chaired the group:

Overview of the Final Report of the Working Group Established by the FCC to Study Overload/Desensitization Interference on GPS Receivers and GPS-Dependent Applications from LightSquared Terrestrial Broadband Operations

The following summarizes the findings of the Working Group (WG) that was established pursuant to the January 26, 2011 Order and Authorization of the FCC's International Bureau (the Bureau) in *LightSquared Subsidiary, LLC*, 26 FCC Rcd 566 (Int'l. Bur. 2011) (*LightSquared Order*). The WG was charged with examining the potential for overload interference/desensitization to Global Positioning System (GPS) receivers, systems, and networks from operation of LightSquared Subsidiary, LLC's (LightSquared's) planned deployment of a terrestrial broadband network in the mobile-satellite service (MSS) spectrum licensed to LightSquared in the 1525-1559 MHz and 1626.5-1660.5 MHz frequency bands. Based on the analysis performed, LightSquared should not be permitted to use the L-Band spectrum for a densely-deployed, non-integrated terrestrial-only network. Such a network would cause unacceptable interference to GPS operations, wiping out an installed base of over 500 million units used in a wide array of public safety, aviation, industrial and consumer applications. While mitigation techniques utilizing filters were discussed in theory, they could not be tested as part of the WG effort because filters do not exist, even in prototypes. No information considered by the WG demonstrated that any mitigation techniques – other than relocation of the proposed terrestrial network to an alternative band – would be successful.

These conclusions are consistent with those reached by third parties that have reported independent analyses of the impact of LightSquared's proposed operations. RTCA, Inc., a Federal Advisory Committee which evaluates aviation issues and issued a report upon which the Aviation Subgroup's report drew heavily, concluded that "The impact of a LightSquared upper channel spectrum deployment

is expected to be complete loss of GPS receiver function... 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.”^{1/} The National Public Safety Telecommunications Council (NPSTC) similarly issued a study concluding, “Theoretical analysis, organized, industry-wide and individual company laboratory testing, and fielded Live Sky testing has indicated that terrestrial use of L-band allocations near accepted and utilized Satellite Navigation allocations (1559-1610 MHz), including GPS, does diminish location accuracy and/or preclude, under certain circumstances, GPS service entirely.”^{2/}

Background

Following the Bureau’s decision in the *LightSquared Order*, LightSquared and the U.S. GPS Industry Council worked cooperatively to form the WG, establish guidelines for participation, and develop an 11-step Work Plan to guide the work that would go into conducting the testing and analysis to produce the report contemplated by the *LightSquared Order*. To perform the testing, the WG established the GPS Technical Working Group (TWG), which included representatives from a broad cross-section of constituencies using the positioning, navigation, and timing (PNT) information broadcast by GPS (and by the Global Navigation Satellite System (GNSS) and GPS augmentations in the radionavigation-satellite service (RNSS) and MSS frequency bands). The TWG was tasked to conduct a comprehensive evaluation of the interference effects of LightSquared’s planned terrestrial broadband service.

The TWG identified seven categories of receivers that are representative of the non-military use of GPS in the United States: aviation, cellular, general location/navigation (including public safety, and commercial and maritime safety-of-life-at-sea receivers), high precision, timing, networks, and space-based receivers. The TWG initially created seven sub-teams, one focused on each of the categories of receivers and each with active participation from representatives of LightSquared and the GPS community. The High Precision, Timing, and Network sub-teams subsequently combined their efforts to achieve efficiency in their test program. The sub-teams each developed test plans and procedures, and investigated and determined the effects on GPS receivers and devices due to interference from LightSquared’s planned terrestrial broadband base station transmitters in the 1525-1559 MHz band and from LightSquared’s planned terrestrial broadband user equipment in the 1626.5-1660.5 MHz band. Among the five remaining sub-teams, a total of 130 different GPS receivers and devices were selected to represent an appropriate range of manufacturers and operationally relevant scenarios. Given the short amount of time available for actual testing, not all proposed receivers were tested. Those that were tested were subject to rigorous batteries of tests and analyses using state-of-the-art laboratory testing facilities from across the country. TWG participants collectively put in thousands of hours to design and perform the testing, and to collate and analyze the results.

^{1/} RTCA, Inc., *Assessment of the LightSquared Ancillary Terrestrial Component Radio Frequency Interference Impact on GNSS L1 Band Airborne Receiver Operations*, at ix (June 3, 2011) (RTCA Report).

^{2/} NPSTC, *NPSTC Discussion and Concerns Regarding Interference to GPS Services Due to Terrestrial LTE Operations on Adjacent L-Band Allocations*, at 9 (June 15, 2011) (NPSTC Report).

The TWG Final Report consists of the reports and records of the seven sub-teams.³ Each report is presented in its own annex (with the reports from the High-Precision, Timing, and Networks sub-teams consolidated into a single annex). A separate annex includes the LightSquared deployment plans and system characteristics that were evaluated during the testing and analysis processes.

Key Results and Findings from the WG Report:

1. The LightSquared Terrestrial Broadband Service Will Cause Harmful Interference to Nearly All GPS Receivers and GPS-Dependent Applications

All seven TWG sub-teams reported that LightSquared’s proposed terrestrial broadband service will cause harmful interference to nearly all GPS receivers and devices tested. It did not matter which of LightSquared’s announced deployment phases were used; there were findings of harmful interference when LightSquared operations were tested using a 5 MHz or 10 MHz 4G LTE configuration with channels in the upper/higher portion of the 1525-1559 MHz mobile-satellite service/ancillary terrestrial component (MSS/ATC) (i.e., spectrum in the 1545.2-1555.2 MHz range) alone, as well as when LightSquared operations were tested using a 4G LTE configuration with channels in the upper portion of the MSS/ATC range together with channels in the lower portion of the MSS/ATC range (i.e., spectrum in the 1526-1536 MHz range).

Excerpts from several of the sub-team reports follow:

The Aviation Sub-Team report stated:

“[T]he Aviation Sub-team concluded that all three phases of the currently proposed LightSquared deployment plan are incompatible with aviation GPS operations absent significant mitigation, and would result in a complete loss of GPS operations below 2000 feet above ground level (AGL) over a large radius from the metro deployment center. For the originally defined LightSquared spectrum deployment scenarios, GPS-based operations are expected to be unavailable over entire regions of the country at any normal operational aircraft altitude.” (TWG Final Report at 15, 27.)

The Cellular Sub-Team report stated that: “[E]nough test data was available to demonstrate that LightSquared signals in the higher 5 MHz and 10 MHz band (1545.2 to 1555.2 MHz) caused GPS failure for a significant number of the tested devices.” (TWG Final Report at 16-17, 54-55.)

The General Location/Navigation Sub-Team report stated that: “[t]he General Location/Navigation sub-team has concluded that all phases of the LightSquared deployment plan will result in widespread harmful interference to GPS signals and service and that mitigation is not possible.” (TWG Final Report at 18, 122.)

³ The TWG Final Report is available at http://licensing.fcc.gov/myibfs/download.do?attachment_key=900848.

The High-Precision, Timing, and Networks Sub-Teams' report stated that "[t]he LightSquared Base Station 4G LTE signals harmfully interfere with High Precision, Timing, and Network GPS receivers over long ranges." (TWG Final Report at 22, 180.)

The Space-based Sub-Team report stated that:

"In NASA's view, the interference to space-based GPS receivers used for [Radiooccultation measurements] would be severely disruptive to NASA's science missions based on the test and analysis conducted in the TWG. Space-based GPS receivers used for navigation and precise orbit determination would receive a lesser amount of interference, though interference would occur. Therefore, mitigation of the interference to space-based GPS receivers is necessary in NASA's view." (TWG Final Report at 25, 300.)

The National Public Safety Telecommunications Council (NPSTC) Report similarly concluded:

"It has been shown that strong RF emissions located in frequency bands near the radiolocation allocation of 1559 – 1610 MHz; with the US GPS system centered at 1575.42 MHz, can impact the availability, acquisition and accuracy of GPS services."^{4/}

Conclusion:

As indicated in the TWG Final Report, all sub-teams concluded that widespread harmful interference would be caused by LightSquared's signals. As a result, the FCC cannot conclude, as the *LightSquared Order* requires (in ¶ 43), "that the harmful interference concerns have been resolved"

2. Limited Testing of LightSquared Terrestrial Broadband Operations in the "Lower" 4G LTE Channel Does Not Eliminate Harmful Interference to GPS Receivers and GPS-Dependent Applications.

In response to a request LightSquared made late in the testing and analysis processes, all sub-teams were able to briefly examine a possible alternative LightSquared deployment configuration that would limit LightSquared 4G LTE operations to a single 5 MHz or 10 MHz channel in the lower portion of the MSS/ATC band (1526-1536 MHz). In this configuration, some reduction in the interference effects on GPS receivers and GPS-dependent applications was both expected and observed. There is no question, however, that many types of GPS receivers and GPS-dependent applications will suffer harmful interference from LightSquared's operations in the lower channel, even when transmission power is limited to one-tenth the authorized limit that was used in the testing.

The General Location/Navigation Sub-Team report contains the following statement:

"Another proposed mitigation would be to permanently eliminate the upper channel and deploy only on the lower 10 MHz channel. . . . [t]his mitigation strategy was discussed at length in the General Location /Navigation sub - team. In fact, the

^{4/} NPSTC Report at 3.

sub - team even altered its test plan after testing had commenced in order to accommodate LightSquared's interest in this mitigation strategy. Lab testing revealed that many devices suffered from harmful interference from the lower 10 MHz channel; specifically, 20 out of 29 devices experienced harmful interference."^{5/}

The Aviation Sub-Team report indicated that a LightSquared configuration "using only a lower 5 MHz channel likely would be compatible with aviation GPS operations provided that ATC transmissions are kept at or below proposed levels of 32 dBW EIRP." (TWG Final Report at 15, 28.) This prediction did not extend to a lower 10 MHz channel at 1526-1536 MHz, however, even if ATC transmissions are kept at or below 32 dBW EIRP. The Aviation Sub-Team noted that there was disagreement as to whether or not initial acquisition could be supported in this configuration, and concluded instead that "[c]ompatibility of aviation GPS operations with a single lower 10 MHz channel could not be determined definitively without additional study." (TWG Final Report at 15, 28.)

The Space-based Sub-Team report notes that some limited testing was conducted on space-based non-high precision receivers using the lower 10 MHz channel. The sub-team concluded that while the potential mitigation option "showed promise for one type of space-based receiver, there was minimal improvement for the second space-based receiver tested." (TWG Final Report at 26, 301.)

The High Precision, Networks and Timing report notes harmful interference in all modes tested:

"The LightSquared Base Station 4G LTE signals harmfully interfere with High Precision, Timing, and Network GPS receivers over long ranges. . . .

"The LightSquared Base Station signals cause harmful co-channel interference with the FCC licensed StarFire and OmniSTAR augmentation systems. . . .

"In the lower 10 MHz channel configuration, 31 of 33 High Precision and Network GPS receivers tested experienced harmful interference within the range of power levels that would be seen inside the network (Fig 84). High precision receivers fielded today would experience harmful

^{5/} TWG Final Report at 19, 177. In the General Location/Navigation Sub-Team's report, LightSquared rejects the sub-team's decision to interpret the test results using the characterization of harmful interference as a 1 dB change (20% loss) in C/N_0 that is included in the International Telecommunication Union (ITU) recommendations on GPS/RNSS, and disputes use of a free-space propagation model. Instead, LightSquared attempts to redefine harmful interference as a 6 dB change (75% loss) in C/N_0 and prefers that the sub-group use a probabilistic propagation model. LightSquared provides no external validation, references to established benchmarks, or other accepted industry definitions of interference in support of its 6db criterion. The GPS participants on the sub-team concluded that LightSquared's approach leaves General Location/Navigation receivers (including public safety and commercial/maritime safety-of-life-at-sea devices) exposed to a serious risk of harmful interference as defined in the FCC's rules and the ITU Radio Regulations. Notably, by LightSquared's own assessment, its self-generated criteria would still result in harmful interference to tested devices under either the planned deployment configurations or the lower-channel-only configuration.

interference at up to 5km from a single LightSquared base station.” (TWG Final Report at 22, 180.)

In the presence of the single lower 10 MHz channel, interference to all high precision GPS receivers was observed and 31 of 33 units tested suffered interference so severe that they were unable to provide a high accuracy position at power levels that would be seen inside the network. Interfering signals of up to 800 billion times the GPS signal were recorded on the ground in Las Vegas and these overload the high quality state-of-the-art filters used in high precision GPS receivers, even in the lower 10 MHz block mode.

GPS receivers in cell phones do not produce high accuracy and are very low cost, and they typically only use a 2 MHz part of the 32 MHz GPS signal- 6% of the GPS band. This means that they can use the other 94% as protection from interference from LightSquared. Higher performance GPS receivers use the full GPS signal so do not have this extra protection. Even so, data from the cellular sub-group report clearly shows that 6 out of the 39 cellphone GPS receivers tested failed the defined interference tests^{6/} at power levels that would be observed inside the network^{7/}, even in the lower 10 MHz block only, raising serious doubts about claims that “99%” of GPS receivers are unaffected when LightSquared emits high powered signals in the lower channel adjacent to GPS.

Conclusion:

Not one of the sub-groups concluded that operation in the lower 10 MHz channel is a viable mitigation possibility. The high-precision, general location/navigation, and space-based receivers all showed extensive harmful interference with lower-channel operation. The aviation sub-group concluded that “the use of the lower 10 MHz channel cannot be determined to be compatible with aviation GPS operations without additional study” due to interference with aircraft GPS initial acquisition. (TWG Final Report at 50.) A significant number of devices tested showed harmful interference during LightSquared’s operations using only the lower 10 MHz 4G LTE channel, potentially causing interference to millions of users. The available test results do not show that the potential mitigation technique of restricting LightSquared 4G LTE operation to the lower band segment is appropriate or feasible.

3. Increasing Filtering on GPS Receivers Is Not an Available Mitigation Technique.

One of the biggest areas of disagreement between LightSquared representatives and GPS industry representatives in the TWG was over the appropriateness and feasibility of increased filtering in GPS receivers as a technique to mitigate the harmful interference to GPS receivers and GPS-dependent applications. LightSquared asserted in several sub-team reports that adding filtering is feasible.

In fact, increasing filtering on GPS receivers is nothing more than a theoretical mitigation possibility, and even if filters did exist that could provide GPS receivers with the necessary levels of rejection of the terrestrial broadband signals using higher channel and/or lower channel LightSquared configurations,

^{6/} TWG Final Report, Figure 3.2.2.

^{7/} TWG Final Report at 276, Figure 58.

use of these filters would result in performance penalties for GPS receivers and GPS-dependent applications. Such a mitigation approach could not possibly be implemented industry wide on any kind of time table that would allow LightSquared to meet its FCC-imposed service obligations.

a) No Suitable Filters Exist

While LightSquared claims that filters are a “proven technology,” the filters it supports exist only in PowerPoint presentations and on component-makers’ drawing boards. The TWG did not test any filtering options because no equipment exists today.

The Aviation Sub-Team report includes the following statement:

“The Aviation Sub-team also studied the potential for improvements in GPS receiver selectivity using new filter technology. Such improvements could not be tested because the new filter technology is not available at this time. This mitigation strategy could take many years to design, obtain FAA airworthiness certification, and install new airborne equipment in a manner consistent with FAA requirements. The aviation representatives on the sub-team believe, based on past experience with programs for modification of certified systems with safety or operational benefits, that this process would take at least 8-10 years.” (TWG Final Report at 16, 28.)

The General Location/Navigation Sub-Team report states that “[s]everal simulated filters were proposed as options for GPS receivers; however, no testing could be performed since these filters do not exist, not even in prototype form.” (TWG Final Report at 123.)

In the High-Precision, Timing, and Networks Sub-Teams’ report, the GPS manufacturers state that there is “no currently available receiver, filter, antenna or other mitigation technology that would enable the construction of future wideband High Precision, Timing, or Network GPS receivers and augmentation systems that are compatible with the Phase 0, 1, or 2 LightSquared rollout plans.” (TWG Final Report at 22, 181.)

b) Even if Filters Were Available, They Have Undesirable Performance Impacts on GPS Receivers That Have Not Been Evaluated.

Many of the filtering proposals made by LightSquared only allow use of about 2 MHz of the GPS signal, which is the minimum bandwidth required to track the GPS signal. The GPS signal actually uses 32 MHz, so these proposed filters reject much of the GPS signal along with the LightSquared signal. Many GPS receivers incorporate sophisticated processing techniques that require the use of bandwidths larger than 2 MHz to improve measurement accuracy. Use of such narrow filters will amount to a huge step backwards in technology and will degrade the accuracy of many receivers. There are many design trade-offs that must be made when improving the ability of a receiver to reject out-of-band signals; receiver bandwidth is just one of these. Many, if not all, of these trade-offs reduce the performance of the receiver in ways that are similar to the effects of harmful interference.

The WG Final Report clearly reveals that filtering is not a magic bullet for resolving the harmful interference that LightSquared's 4G LTE transmissions would cause to GPS receivers and GPS-dependent applications. Even assuming that filters will be available at some point in the future and would be effective at resolving the desensitization issues at that time, substantial shortcomings would remain.

The General Location/Navigation Sub-Team report contains the following statement:

Many variables must be weighed carefully in the design process to ensure that GPS performance is not compromised. As indicated previously, these include, but are not limited to, insertion loss, bandwidth, stop-band rejection, group delay, pass-band ripple, temperature stability, manufacturing variation, physical size (in relation to available space on the PCB), and cost. The filter design process almost always takes many months and even years. Once a suitable filter has been realized, it can take several more years to integrate it into an actual product. (TWG Final Report at 178.)

In assessing a filter presentation, the Aviation Sub-Team noted that the filter described in the proposal would provide greater rejection, "but also requires more input power than is currently provided by fielded GPS receivers." (TWG Final Report at 53.)

The Cellular Sub-Team observed, with respect to filtering, that "[e]ffects on device design (battery life, size and operating performance within a cellular network) must be determined and tested prior to being deemed commercially acceptable." (TWG Final Report at 120.)

The Aviation Sub-Team discussed the possibility of improving selectivity by the use of a passive inline cavity filter. It concluded that:

"This mitigation is not desirable to the aviation community because it increases the number of subassemblies that need to be securely mounted in the aircraft and may not be possible in smaller aircraft. Since this filter would be installed after the active antenna, there is still a potential for interference effects in the antenna caused by 3rd order intermodulation products of the upper and lower ATC channels." (TWG Final Report at 53.)

The NPSTC Report addressed the impact of filters on portable devices used by the public safety community:

"While it is possible to improve the performance and protection of the GPS receiver through re-designs of antenna to incorporate additional filtering and gain stages, upgrading units already in the field is not practical. Even if such antennas were designed, portable devices are power drain-sensitive. Any improved antenna design will consume more power from the portable device yielding a shorter battery life ... Denial-of-GPS-Service to portable devices represents perhaps the largest concern to the Public Safety market. Officers rely on 'Man-Down' signaling for immediate response under life

and death situations. In certain circumstances, an officer may be unable to voice their location; GPS tracking is the only backup they may have for rescue or aid.”^{8/}

c) Increased Filtering Does Not Mitigate Interference to Hundreds of Millions of GPS Users in the Installed Base.

Whatever filtering may be able to do down the road for future GPS receivers and GPS-dependent applications, there is nothing that can be done to cure the harmful interference that would be produced to the 500 million GPS receivers in use. This is even more problematic than it might be in other contexts because the TWG deliberations revealed that the GPS receivers are typically used for many years after they are purchased.

The General Location/Navigation Sub-Team observed in this regard that “[t]here is no filter or proposed filter simulation available today that can suppress the LightSquared transmission adequately; however, even if there were, it would take years to bring it to market and much longer to replace the existing user base.” (TWG Final Report at 178-79.)

The Cellular Sub-Team included the following statement in its report:

“As a final point, even assuming the capability to incorporate adequate filtering in future devices, the large embedded volume of existing devices will remain active in the field for at least several years. Experience demonstrates that it takes years for the embedded device base to turn over. Aside from the lower 10 MHz scenario, it is reasonable to expect that a significant number of mobile devices would be vulnerable to interference from LightSquared’s upper band operations until new filters are available and other mitigation techniques are developed and implemented.” (TWG Final Report at 120.)

The GPS manufacturers in the High Precision, Timing, and Networks Sub-Team noted that “Many users maintain their current receivers and systems for up to 15 years (and occasionally longer) to achieve an economic return on investment.” (TWG Final Report at 23, 181.)

The General Location/Navigation Sub-Team also addressed the installed user base impact. The report includes the following statement:

“[T]he majority of GPS devices are not user serviceable or capable of being retrofitted even if a filter did someday exist. This fact should not be taken lightly, given that the existing user base for GPS receivers exceeds 1 billion (1,000,000,000) users world-wide. Even if any mitigation were suggested, it would need to address the feasibility of retrofitting such a substantial user base.” (TWG Final Report at 177.)

^{8/} NPSTC Report at 5-6.

Conclusion:

Filtering is clearly not a viable mitigation technique. No filter solutions were available for testing by the TWG sub-teams, so there is no objective, verifiable data regarding the feasibility or appropriateness of this technique. Increased filtering, even if effective at rejecting LightSquared interference, comes with performance penalties and economic consequences that may prove insurmountable. A diminution in measurement accuracy caused by ineffective filters – a GPS key performance indicator in many applications – would be a serious degradation to GPS service and recognized as harmful interference under the FCC’s rules.^{9/} Therefore, ineffective filtering -- which reduces the utility of GPS -- must be rejected as a solution. Finally, and even if all other deficiencies and shortcomings with filtering could be overcome, there would remain the fact that hundreds of millions of GPS users in the installed base would be exposed to harmful interference. Product life cycles are long for GPS and the devices in which GPS capabilities are embedded, and several sub-teams concluded that it could be many years before all fielded products vulnerable to LightSquared interference would be rotated out of service.

Filtering and GPS-receiver mitigation options were not identified by the TWG and the WG Final Report as appropriate and feasible for any GPS receiver or GPS-dependent application. These mitigation possibilities remain theoretical.

4. The Only Feasible Solution to the Harmful Interference Effects LightSquared’s Proposed 4G LTE Terrestrial Broadband Service Will Cause to GPS Receivers and GPS-Dependent Applications Is to Relocate the LightSquared Service to Spectrum that is Not Adjacent to GPS/RNSS, outside of the L-Band.

Based on the work of the TWG sub teams, there appears to be only one mitigation technique capable of assuring that LightSquared’s proposed 4G LTE terrestrial broadband service does not cause harmful interference to GPS receivers and GPS-dependent applications – relocation of LightSquared’s high power terrestrial operations to a frequency band that is not adjacent to a frequency band used by GPS or other low-power RNSS systems.

The Space-based Sub-Team report includes the following statement:

“NASA notes that one mitigation technique that would resolve interference to both space-based and terrestrial high precision GPS receivers is to relocate high power terrestrial operations to a different frequency band. ” (TWG Final Report at 26, 302.)

The Aviation Sub-Team observed in its report that “a shift in the LightSquared ATC frequency to spectrum that is not adjacent to the GPS band could eliminate all interference concerns for aviation GPS.” (TWG Final Report at 16, 28.)

The General Location/Navigation Sub-Team’s report included the following assessment:

^{9/} 47 C.F.R. 1.2 (2010).

“One proposed mitigation would be to shift the LightSquared base station transmissions to another frequency band outside of the MSS L-band. This might potentially eliminate all interference effects with GPS receivers and allow both existing and future devices to coexist peacefully with LightSquared transmissions.” (TWG Final Report at 176.)

Conclusion:

Based on the overwhelming evidence of incompatibility between LightSquared’s proposed 4G LTE terrestrial broadband service and GPS receivers and GPS-dependent applications in the adjacent band, the only feasible option is relocation of LightSquared’s terrestrial operations from a satellite spectrum neighborhood to one that is better suited for terrestrial operations, while allowing LightSquared to operate its satellite services in the MSS L-Band. Such a move would recognize that principles of spectrum management require grouping of like-kind applications and services, and potentially allow the FCC and LightSquared to achieve an expansion of broadband capability in the United States, but not at the expense of the national GPS utility and its millions of users.

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