Introduction

FCC has made a Grave Error in Authorizing a High-Power, Terrestrial Communication-Network in the Mobile Satellite Service (MSS) Radio Spectrum, Adjacent to GPS –

This is the radio band that the *FCC assured the GPS community* would exclusively be designated for faint radio signals coming from satellites

The Message **and** ***Nine Takeaways***

The PNTAB of the PNT EXCOM

Approved unanimously on 1 July 2020

The Message (1)

- *Re-purposing the Mobile Satellite Services (MSS) radio-spectrum is very high risk and brings virtually no near-term benefit to the United States*
- *Risks affect much more than DoD: High-value civil applications (and most others) also in jeopardy*
- *Such re-purposing should have been subject to Formal Rule-Making*

- Re-purposing will, *at most*, provide a small benefit to 5G deployment, because there are no hardware or 5G L-band standards available for immediate use. Thus, the FCC order *has little positive impact* on US competitive 5G posture with China, while it may actually damage GPS's reputation as the world's premier Positioning System.
- Per the 2000 Orbit Act, satellite spectrum cannot be auctioned. Therefore, FCC's action resulted in Ligado avoiding having to pay billions at auction as would normally be required of other wireless service providers for a terrestrial network .
- FCC's Ligado order announces the re-purposing of MSS L-band spectrum for a stand-alone terrestrial application. It bases such permission on a previously unannounced interference criterion. The PNTAB believes such fundamental change in spectrum policy should have been the subject of a more transparent rule- or policy-making proceeding, with an opportunity for affected parties to comment.

The Message (continued)–

- Extensive government and Ligado testing, **of the exact same 10-Watt case**, has shown that re-purposing degrades performance and jeopardizes virtually **every category of high-performance GPS user** – especially noteworthy are civil aviation and unmanned aerial vehicles (see box for more) – as even acknowledged by the FCC.
- No FCC independent analysis of the technical effects, nor the relative benefits and risks, has been made available for public scrutiny. There was no formal rule-making as prescribed by law.
- Contrary to statements by Ligado, and the FCC order, Major GPS manufacturers have filed opposition (Deere, Garmin, Trimble,). **There are no "co-existence" agreements with any of them that support the 10-Watt terrestrial service.**
- Most US applications now use ***all*** GNSS constellations at the common international frequency. The true "Gold Standard" is the combination. **All will be degraded since that is the same frequency as the main GPS signal.**

For benefit of the US, as a whole, this order should be immediately rescinded

GPS User Categories affected: Aviation, Emergency Services, Timing, Agriculture, Rescue, Recreational/Automotive, Tracking, Scientific, Military, Robotics/Machine Control

Nine Takeaways

PNTAB Draft for Discussion

1. Ligado's threat to the value of GPS greatly exceeds any of Ligado's benefits to US

- The value of GPS is extensive and keeps growing
  - Includes many applications, including airplanes, farm tractors, UAVs, banking, cellphone towers, etc.
  - GPS value to the US is likely larger than the $1B per day to the U.K. (per a British study), since the US is a much larger country
  - Military use of GPS in US is essential for training and Humanitarian Assistance
  - DHS notes that virtually every critical infrastructure in US is dependent on GPS
- The DOT Adjacent Band Compatibility tests clearly demonstrated great disruption by Ligado at 10-Watts (with transmitters at every other block corner and *GPS users typically 20 to 200 meters away from one)*
- Ligado's lower band contribution (1526-1536 MHz) is only 2.8% of the 10-350 MHz of new 5G spectrum
  - Ligado L-Band is not used internationally for 5G
  - Standards and Hardware do not exist to support for Ligado's frequencies
- **Future Applications** that will enhance safety and productivity may be particularly affected: e.g. control and monitoring of UAVs, and smart highways. All use GPS plus all other GNSS signals. The Gold standard is this ensemble of signals.

2. The FCC has followed an inadequate rule making process for over 10 years –

Major change in whole band architecture without required rulemaking review

- Given the potential impacts, the FCC should have had a fully transparent and open rulemaking process rather than burying important spectrum policy decisions within a licensing proceeding
- Re-purposing in the quiet MSS band started with initial permission for a predecessor of LightSquared to operate ground transmitters (Ancillary Terrestrial Components, or ATCs), and the 2003 MSS ATC rulemaking added: "We do not intend, nor will we permit, the terrestrial component to become a stand-alone service" [1]
- This was followed with the Thanksgiving 2010 proposal and the January 2011 Waiver to allow up to 40,000 1550-Watt ground transmitters ***independent of satellite services*** by waiver of MSS ATC "Integrated Service Rule"
- In the recent order, the FCC relied exclusively on Ligado-sponsored testing, and a novel use of "harmful interference" advocated by Ligado, to justify its license modification conclusion

1. *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 Bands; Review of the Spectrum Sharing Plan Among Non-Geostationary Satellite Orbit Mobile Satellite Service Systems in the 1.6/2.4 GHz Bands*, Report and Order and Notice of Proposed Rulemaking, FCC 03-15, 18 FCC Rcd 1962, 1965 (2003).

3. The FAA and major manufacturers do not support Ligado's position – contrary to the FCC order

- Ligado has been marketing a pitch that all manufacturers agree with the repurposing – clearly not supported by facts
- Therefore, the recent order resulted in additional **written protests** by Garmin[1], Trimble and many others
  - All continue to support the 25% maximum interference increase criteria (1 dB)
  - Protests had been filed earlier, but not taken into account by the FCC
- The new "Keep GPS Working Coalition" illustrates major degree of significant opposition to the FCC order
- ***FAA*** has also indicated its opposition to the latest Ligado proposal, as a signatory of the February 20, 2020 multi-agency IRAC letter included with NTIA's April 10, 2020 letter to FCC

1. An example: "Garmin states again for the record that it never entered into a coexistence agreement with Ligado. Instead, Garmin entered into a technical settlement agreement in 2015 to resolve ongoing litigation brought against it by Ligado. Nothing in the Settlement Agreement constitutes support for or an endorsement of Ligado or its proposed services or technologies. Garmin states again that it does not support or endorse Ligado's license modification applications. To the contrary, the Settlement Agreement captures Garmin's ongoing concern about its certified aviation devices, preserves its ability to petition the government for protection of these devices, and maintains its ability to advocate for the use of a standard based on a 1 dB decrease in the Carrier-to-Noise Power Density Ratio or C/N0 ("1 dB Standard") in evaluating harmful interference to all GPS devices."

4. FCC dismissed the well-accepted ("1 dB") interference criterion, but provided no meaningful alternative

- Traditional C/N_0 is related to all aspects of receiver performance[1]; it is the only well-defined, practical metric for acceptable interference
  - **1 dB** C/N_0 reduction is equivalent to a 25% increase in the noise floor, which preserves performance under simultaneous real-world stresses [1]
  - **1 dB** C/N_0 reduction is used internationally and by FCC in an an analogous situation: March 3, 2020, order protecting C-Band satellite downlinks from adjacent-band interference by terrestrial 5G broadband services (FCC 20-22)
- Instead, the FCC has dictated a new "harmful interference" criterion for "performance-based metrics"
  - There are no stated precedents for such criterion
  - It is undefined and arbitrary. No specific metrics or numerical criteria are given.
  - **It is unworkable. It potentially requires dozens of such metrics for different receiver classes operating in different modes.**
- The FCC provided no prior notice; and instead uncritically accepted Ligado's flawed assertions

1. Includes: ranging accuracy, acquisition time, ambiguity resolution, reacquisition time, and tolerance to vibration, multipath, and receiver dynamics

4. (cont.) Clarification on the function of the Interference Protection Criterion (IPC)

(IPC -Maximum Noise (C/N_0) increase limited to 25% - also called the 1 dB criterion)

- **IPC is not to protect signal *reception***
  - GPS can "receive" at higher levels of noise
- IPC **is to preserve *GPS performance*[1]*, including accuracy*** of timing/ranging, and therefore the accuracy of position under **all operating conditions**
- GPS could be further toughened by certain, relatively ***expensive*** techniques to mitigate jamming interference
- Most civil users cannot justify the cost of the additional hardware / software
  - Also, they had been promised by the FCC that repurposing would never be allowed to an all-terrestrial-transmitter system in this MSS band

1. Again, includes: ranging accuracy, acquisition time, ambiguity resolution, reacquisition time, and tolerance to vibration, multipath, and receiver dynamics

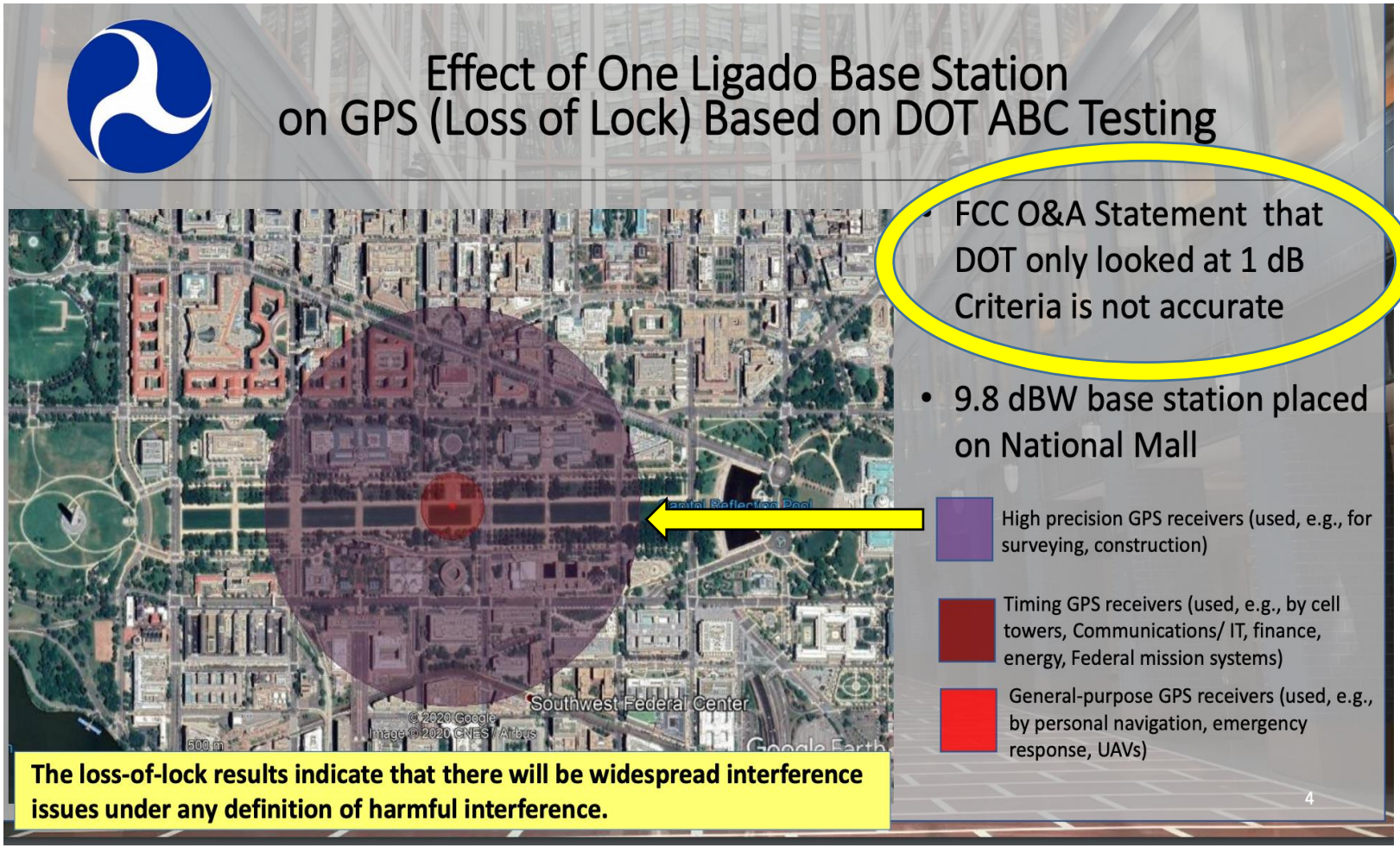
5. Ligado's testing was inadequate, while DOT's testing was comprehensive

- **Ligado's testing** was carefully reviewed by the PNTAB and determined to be inadequate. It only looked at 14 sets and, for example, did not include Real Time Kinematic performance.
  - Did not address full GPS operation – e.g. acquisition/reacquisition
  - The PNTAB provided 6 critical criteria to assess the validity, and none were met. Moreover, GPS subject matter experts were not involved in the tests.
  - Instead Ligado tried to "invent" new "performance" metric that would not consider all cases. This metric was rejected by all PNT groups.
- **DOT/ABC testing involved 80 different GPS receivers from all classes** – the report was published in 2018, which did include the 10-Watt power limit proposed by Ligado
  - DOT's testing met all six criteria (see backup slide), as judged by the NPEF
  - Clearly showed 10-Watt transmitters (with minimum 433 m separation, GPS users within 250 m of a transmitter) would degrade (1 dB) all classes except cell phones
  - At Ligado's proposed transmitter spacing, power would need to be reduced from 10-Watts to about one milliwatt (.001 Watt, which is a factor of 10,000) to protect all tested High-Performance receivers
- **FCC has misconstrued the testing and its results**
  - Contrary to the FCC's assertions, all testing performed to date has demonstrated harmful interference from the Ligado network that was authorized.
  - Only small fraction of GNSS receiver models have been tested. The effect on most models is unknown at this point.
  - Widespread effects will only be discovered through painful experience as the network is deployed

6. The Ligado signal is definitely not **"Low Power."** – contrary to the order

- The order does not appreciate the faint GPS signal – 1/10th of 1 millionth of one billionth of a Watt. This is less than 1/100th of background noise
  - The GPS signal power is 20 Watt when generated, and then travels over 20,000 km while spreading its power across half the earth
- At 10-Watt EIRP, and at a distance of 50-100 meters to the transmitter, ***Ligado signals are always 2 Billion times greater power <u>or more</u>*** compared to the GPS signal as received by the user
- GPS is in a quiet band (MSS) of space-to-ground frequencies to ensure no cross-interference
- **In context of this proposal, <u>*Ligado should be called "high power"*</u>**

From FAA ex-parte — Loss of lock due to single Ligado station – more severe than 1 dB noise increase



7. Ligado proposal is not only high-power, it is also high-density

- Configuration would have a transmitter at every other street corner
  - Consequence – All GPS sets would be within ~ 10 to 250 meters of a transmitter – about a city block away
- All classes would be degraded, except cell phones which have limited accuracy – **From the DOT ABC report**:

Distance from GPS Receiver to Transmitter	Maximum Tolerable Power without D		
	High Performance Receiver	General Lo and Naviga	
10 meters	0.00008 W		
100 meters	**0.008 W**	100 mW	1 W

Maximum tolerable interference is less than 1/10th of 1% of proposed 10 Watts

- Clearly, 10-Watt is unacceptable by many orders of magnitude
- European's Galileo (similar to GPS) is at the same, GPS frequency and ABC tests show it had the same degradations from

Ligado dropped power, but now all GPS sets in region will be within 250 meters – typically 50 to 100 meters

Effect of Many Ligado Base Stations on GPS (Loss of Lock) Based on DOT ABC Testing

The loss-of-lock results indicate that there will be widespread interference issues under any definition of harmful interference.

- FCC O&A Statement that DOT only looked at 1 dB Criteria is not accurate
- 9.8 dBW base stations separated by 433 m in hexagonal grid on National Mall

High precision GPS receivers (used, e.g., for surveying, construction)

Timing GPS receivers (used, e.g., by cell towers, Communications/ IT, finance, energy, Federal mission systems)

General-purpose GPS receivers (used, e.g., by personal navigation, emergency response, UAVs)

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8. FCC remedies are inadequate, unworkable, and ignore Ligado's effects on most GPS users

- Delegating Ligado to self-report interference from a transmitter is unworkable
  - GPS users are not equipped to recognize, nor attribute, Ligado-caused interference
  - It is inappropriate for Ligado to determine which reports are "credible"
- Remedies are limited to US Government -owned GPS receivers
  - It burdens agencies to determine possibility of harmful interference based on transmitter locations supplied by Ligado
  - Replacing a limited set of military user equipment would not work according to DoD and NTIA . **No other civil user (High Performance, Emergency Services, UAVs,…) has remedies in the order - Scientific users are largely ignored**
- **Example**: Commercial GPS aircraft equipment can cost up to $1M per set (installed), must be certified, and take up to seven years to replace in normal cycles of maintenance

9. Opposition to the FCC order is widespread and consistent

- Major GPS equipment manufacturers (Deere, Trimble, Garmin)
- All nine USG departments of the PNT EXCOM
- The PNT Advisory Board
- Virtually every group associated with the aircraft industries
- Et. Al.: Filings in opposition since the FCC order (there were even more before the order was announced):

1. Iridium
2. Air Line Pilots Association
3. The Aerospace Industries Association (“AIA”), the Aircraft Owners and Pilots Association (“AOPA”), Airlines For America (“A4A”), the Aviation Spectrum Resources, Inc., (“ASRI”), the Cargo Airline Association (“CAA”), the General Aviation Manufacturers Association (“GAMA”), the Helicopter Association International (“HAI”), the International Air Transport Association (“IATA”), the National Air Transportation Association (“NATA”), and the National Business Aviation Association (“NBAA”)
4. NTIA Petition for Reconsideration
5. NTIA Petition for Stay
6. Resilient Navigation and Timing Foundation
7. Lockheed
8. Garmin
9. THE ASSOCIATION OF EQUIPMENT MANUFACTURERS, THE AMERICAN FARM BUREAU FEDERATION, AND
10. THE AMERICAN ROAD & TRANSPORTATION BUILDERS ASSOCIATION
11. HASC Smith/Thornberry Letter
12. Trimble

Summary: What are the relative benefits & risks for the US citizens?

- **All** positioning (GPS) operations from aviation to emergency providers to cell phone towers (timing) are clearly at risk
- The Ligado low-band adds less than 3% to the available spectrum for 5G – and not even in the near term
- The costs to modify equipment would be borne by the GPS user, and ultimately by the US taxpayer
  - Taxpayers have already spent millions to measure the effects of Ligado
- The big beneficiary would be a single company, that apparently knew the proposal was deeply flawed before the first submittal – according to a group of disgruntled investors

The FCC should rescind this decision. If they wish to persist, at minimum, they should recognize the grave implications of a major change to the MSS band and use the required legal Rule-Making Procedure

Backups

Trimble submittal INRE FCC Order

Commission made several material errors and omissions in adopting the *Ligado Order*.

- *First*, it adopted the *Ligado Order* through an opaque process without engaging in a notice-and comment rulemaking and disregarding key inputs from the federal agencies with expertise in GPS gained from utilizing it as a critical utility in accomplishing their public missions. Instead, the FCC effectively outsourced its decision-making to experts hired by Ligado. In so doing, the Commission violated its obligations under Section 343 of the Communications Act ("Act").
- *Second*, the Commission failed to include a reasoned cost-benefit analysis – merely relying on promises and press releases from Ligado to establish the purported public interest benefits of Ligado's applications, while failing to systematically consider the costs and risks to GPS and the applications and critical activities that depend on it.
- *Third*, it erred by misunderstanding or mischaracterizing agreements between Ligado and a handful of GPS manufacturers to reach the false conclusion that they "concurred" with or supported Ligado's applications.
- *Fourth*, the Commission dramatically underestimated the potential for interference to GPS devices by relying on a vague legal standard of harmful interference and *ad hoc*, limited analyses of Key Performance Indicators ("KPIs") as opposed to the readily measurable and well-established 1 dB metric for measuring interference to GPS devices.
- *Fifth*, even though it acknowledged that an unknown number of the nearly 900 million existing GPS receivers will suffer interference, the FCC's "stringent conditions" intended to mitigate and address incidents of interference are entirely unworkable, especially because the Commission has outsourced the job of policing interference to Ligado itself.

Expanding an additional point: FCC has misconstrued the testing and its results

- Contrary to the FCC's assertions, all testing performed to date has demonstrated harmful interference from the Ligado network that was authorized (Note, this includes the DOT ABC test results, which looked at loss of lock and acquisition times as well as degradation to C/N_0, but were ignored by the FCC)
- Only a small fraction of GNSS receiver models have been tested. So the effect on most receiver models is unknown at this point.
- The widespread effects will only be found out through painful experience as the network is deployed
- The resulting impacts on state and local government, commercial, and consumer users of GNSS are completely unknown at this point

NPEF (and PNTAB) Evaluation Criteria – No Ligado Test Met them…

#	PNTAB Criteria
1	Accept and strictly apply the 1 dB degradation Interference Protection Criterion (IPC) for worst case conditions. (This is the accepted, world-wide standard for PNT and many other radio-communication applications.)
2	Verify interference for all classes of GPS receivers is less than criteria, especially precision (Real time Kinematic – requires both user and reference station to be interference-free) and timing receivers (economically these two classes are the highest payoff applications – many $B/year)
3	Test and verify interference for receivers in all operating modes is less than criteria, particularly acquisition and reacquisition of GNSS signals under difficult conditions (see attachment of representative interference cases)
4	Focus analysis on worst cases: use maximum authorized transmitted interference powers and smallest-attenuation propagation models (antennas and space losses) that do not underrepresent the maximum power of the interfering signal (including multiple transmitters).
5	Ensure interference to emerging Global Navigation Satellite System (GNSS) signals (particularly wider bandwidth GPS L1C – Galileo, GLONASS), is less than criteria
6	All testing must include GNSS expertise and be open to public comment and scrutiny.