



- A certain company (Ligado) has License for transmitting Satellite to Ground for Communications in the very quiet MSS Band - very close to the Main GPS frequency
- ***But the received power was very low and did not support a large Data Rate***

But, in 2010, Ligado saw a great opportunity

- Convert the License to high power terrestrial transmissions (Asked for 15.8 Kw)
 - Tower Spacing at about $\frac{1}{4}$ mile
 - Would support broadband – sending movies etc. = 5G?
 - **Spectrum Value would jump: \$2B → \$12B+**
- Tried to get the FCC to slip this through just before Thanksgiving 2010 – while everyone was digesting turkey
- PNT community found out and realized this would do grave harm to GPS civil receivers- We helped slow the process down. Over \$60B per year in productivity benefits were at risk...
- But*But apparently a predecessor Lxxx company had already known there was a significant Clash with GPS...
 - Ligado claimed no knowledge
 - According to Harbinger lawsuit this was not true

Bottom Lines Up Front

- Ligado proposal was extensively tested by DOT
- Ligado now proposes 9.8 watt transmitters. (Company could receive a windfall profit of over \$10B)
 - Unknown, but probably very close tower spacing
- Even at this reduced level, at 300m transmitter spacing, over half the High Precision GPS receivers would be degraded over more than 10% of the operating Region, with many degraded over 100% of the Region (Based on DOT extensive ABC Testing)
- Many other organizations have filed opposition
- The PNTAB strongly recommends disapproval of this proposal

At Stake: High-Precision = High-Productivity Applications

Partial List - Green particularly at risk

Aviation and Space

- Area and Enroute Navigation

- *Approach to Airport*
- *Landing to Cat III*
- *NextGen & ADS-B*
- *UAV Guidance (Drones)*
- *Space Launch Guidance*

Agriculture

- Auto Farming
- Crop Spraying
- Precision Cultivating
- Yield assessment

Robotics and Machine Control

- *Construction Vehicle Guidance*
- *Mining Vehicle Guidance*

Scientific

- International Time Standard
- Earth Crustal Movement
- Earth's Shape and Rotation Rate
- *Weather Probes*

Commercial Timing

- Power Grid Synchronization
- Cellular Network Synchronization
- Banking
- Stock Trading

Survey and Mapping

- Geodetic and Cadastral
- *Roads and Bridges*
- *Site Layout and Survey*
- *Geographic Information Systems (GIS)*

High Productivity: In harm's way ... Apt to be much less than 400 meters away from Transmitter Construction/Infrastructure Scenarios

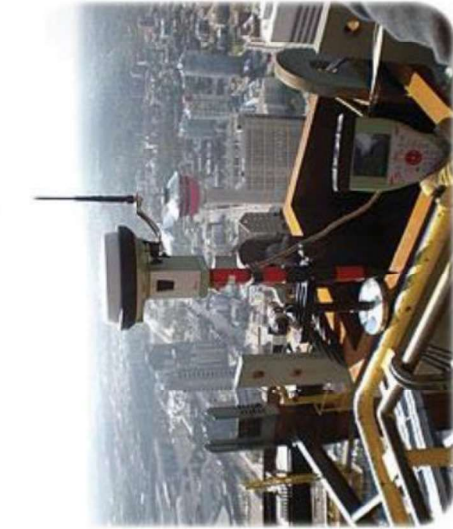


Photo courtesy of WSP Canada Inc

GPS HPR receiver used in construction/surveying



Photo courtesy ThinkStock

10/22/2019 GPS HPR receiver used in construction guidance

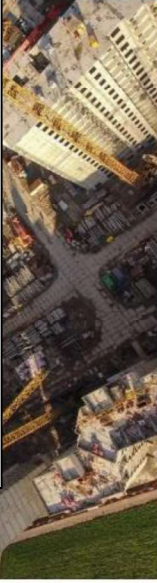
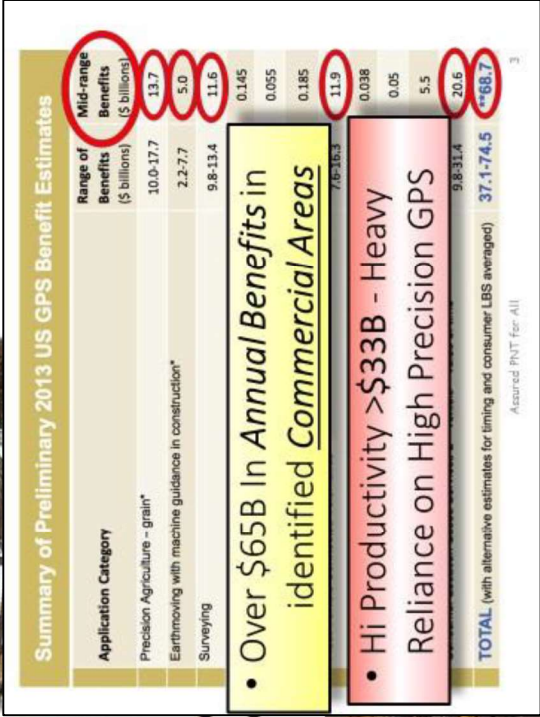
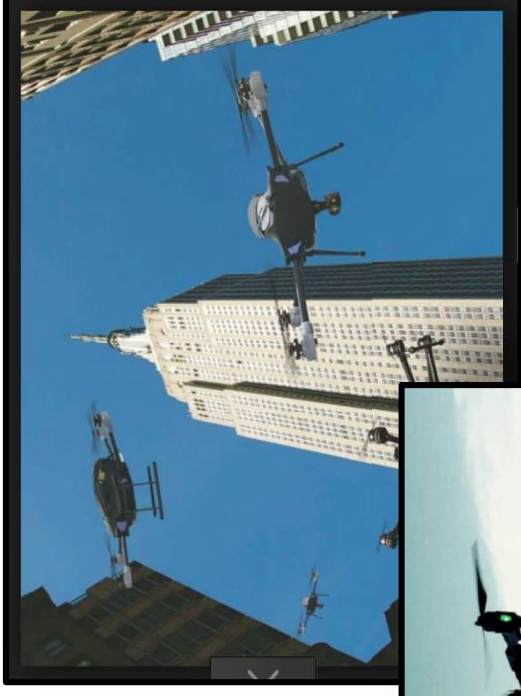
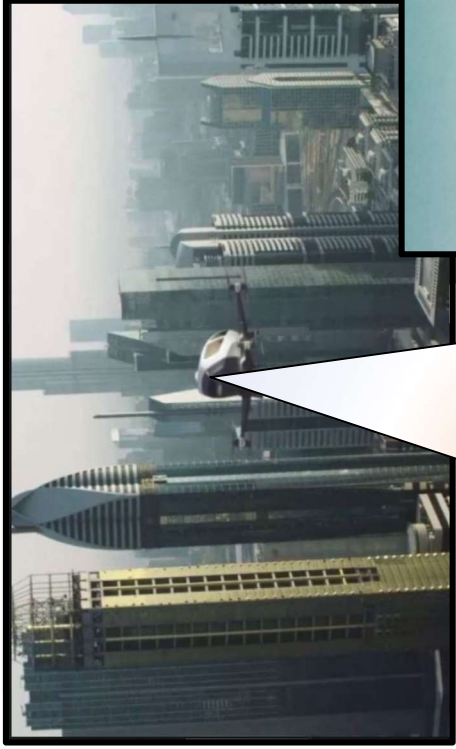


Photo courtesy Medvedkov/ThinkStock

Construction/Surveying

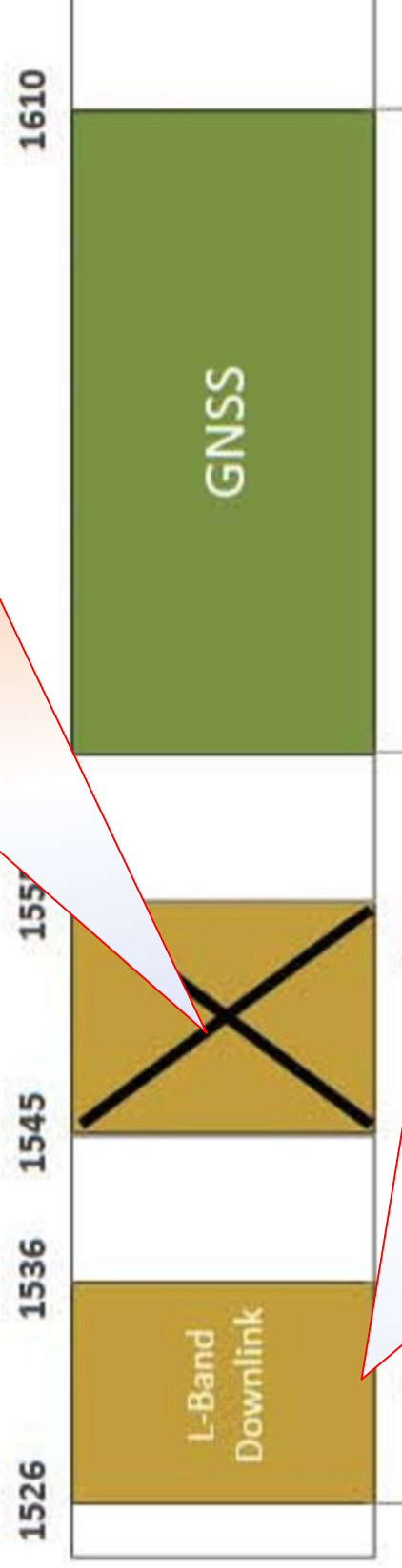
Also In Harm's Way: Rapidly growing RPV/UAV applications



Both RPV Control and Air Traffic Monitoring depend on GPS – probable paths less than 400 Meters to Transmitter sites Apt to be Directly in Main Beam

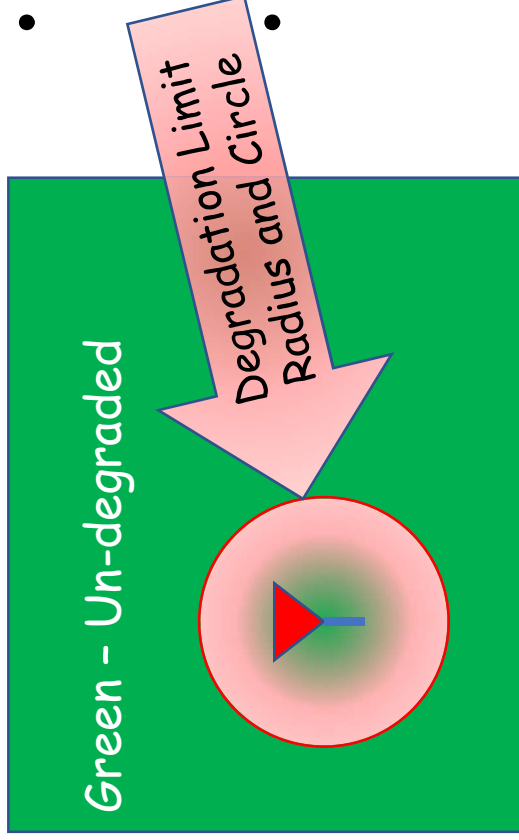
Adjacent band interference concern

“Upper” band is apparently off the table. Is this forever?



“Lower” band Power reduced to 9.8 Watts. Spacing not specified but original was ~400 meters. To meet 5G requirements it probably will be less. Perhaps about 100 to 200 meters.

Extensive DOT GPS testing helped define A "Degradation Radius"



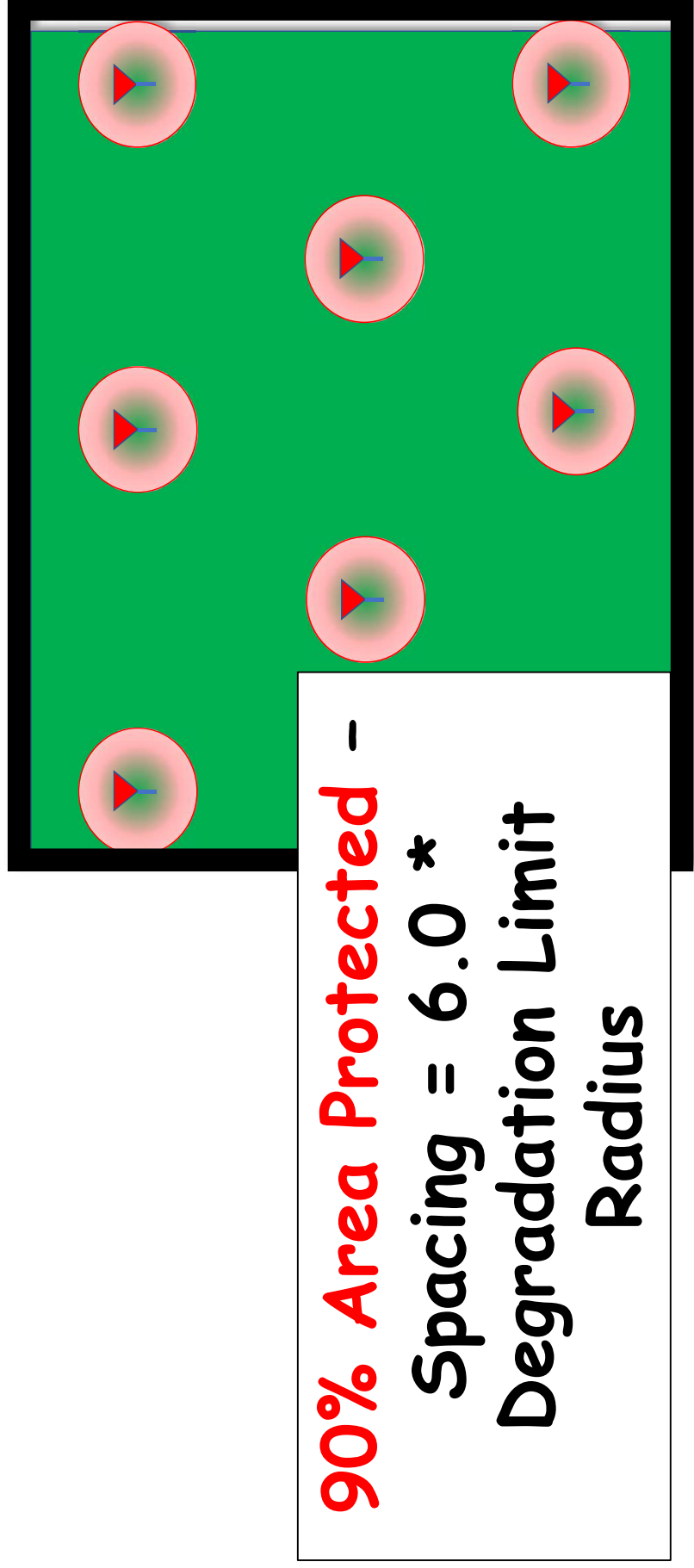
- Within that radius, GPS begins to experience ^{*} degraded accuracy
- Reasonable to insist that Interfering transmitters blanket less than 10% of a region

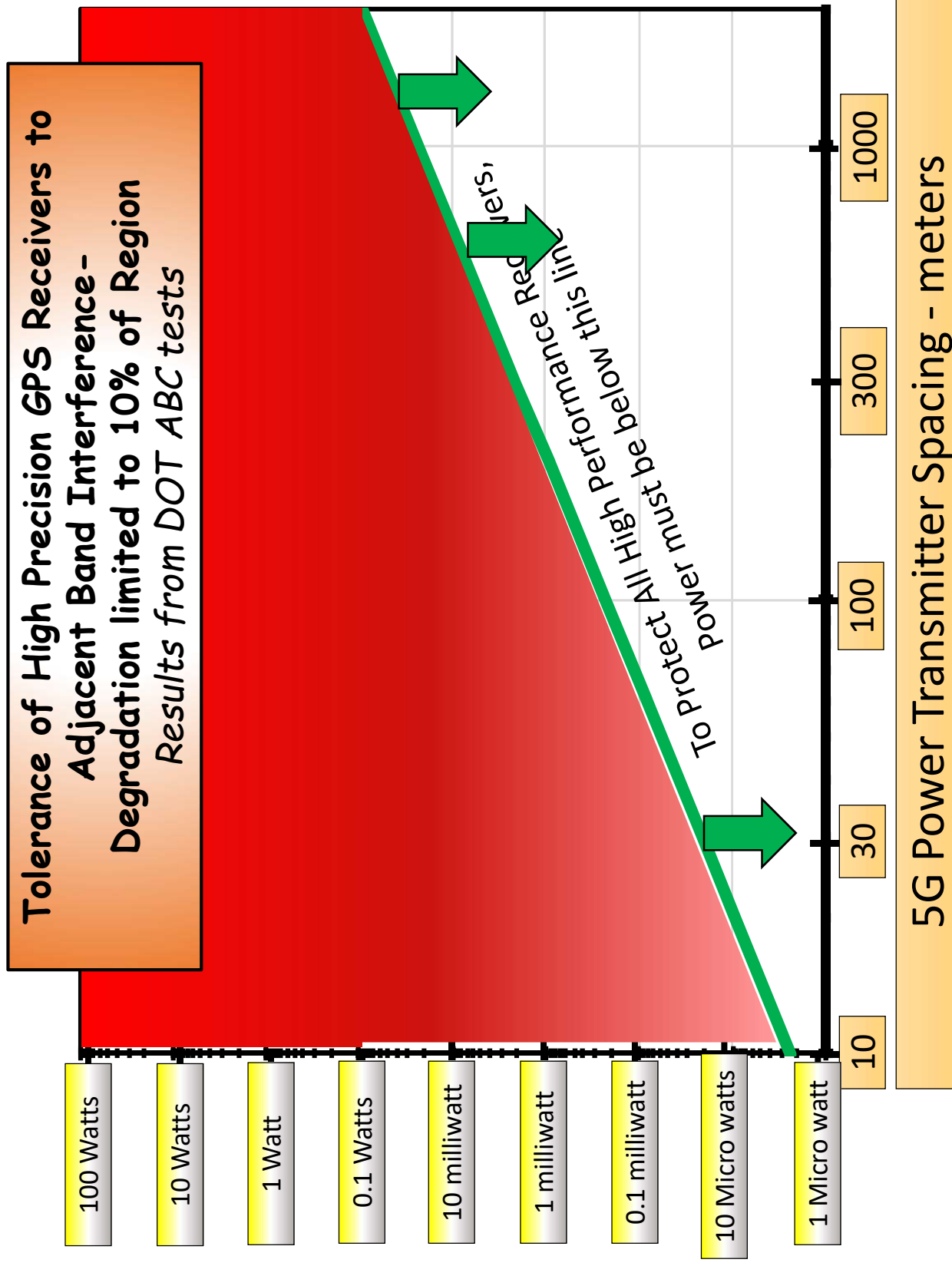
Adjacent Band transmitters can achieve compatibility (acceptable-degradation) by either:

- Reducing Power
- Increasing Spacing between transmitters

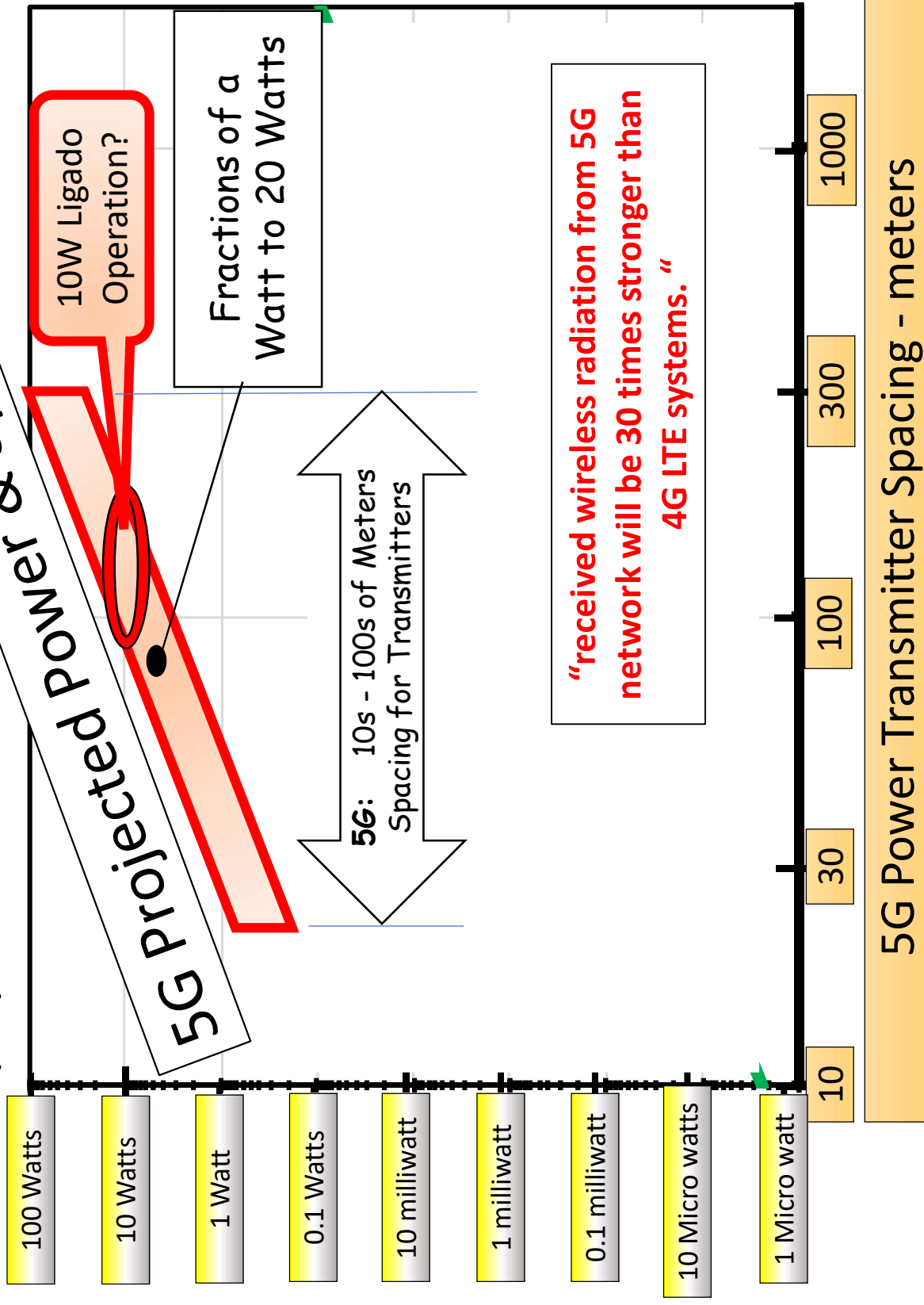
^{*} Degradation begins when interfering power exceeds 25% of the natural Background Radio Noise – (called the *1 dB interference power criterion*)

So the Absolute
Minimum Spacing/Maximum Power
combination looks like:



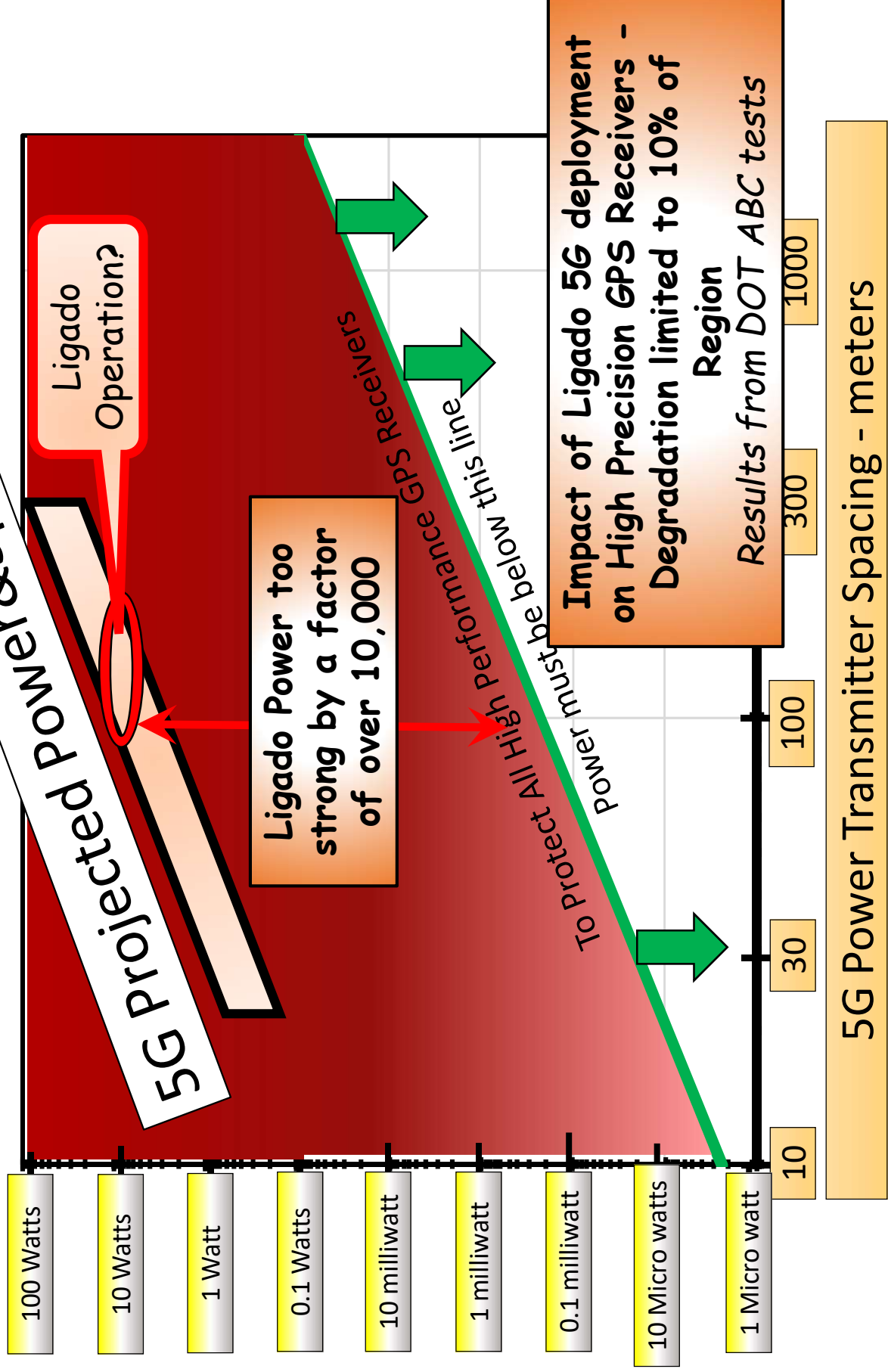


5G Deployment Plans...



Fundamental Incompatibility

5G Projected Power & Spacing



To protect all High Performance
GPS receivers, at 9.8 Watts:
*tower spacing must exceed
20km -*
far greater (100 times) than the
~200 meters for 5G

*What about the other
classes of GPS receivers?*

Using the ABC Degradation Radii -Calculation of
minimum Ligado 10W separation for various GPS Classes
Note: Ligado 5G spacing is probably 100 to 300 meters

Class of GPS Receiver	Bounding Degradation Radius for Receiver Class with 10W Transmitter (from ABC report – Appendix I)	Minimum Separation Between Ligado 10 Watt Transmitters
		90 % <u>Region Protected</u>
High Performance/ High Productivity (HPR)	3400 meters	20.5 km
Emergency Vehicles and General Navigation (GLN)	1045 meters	6.3 km
General Aviation and Helicopters (GAV)	1040 meters	6.2 km
Timing (TIM)	293 meters	1.7 km
Cell (CEL)	9.5 meters	57 m



90% is the minimum Area
 Protection Criterion
 (maximum 10% degradation)

It may be worse – not included in analysis...

- Multiple transmit towers contribute additive noise
- Reflections from ground and buildings can increase normal $1/R^2$ models by factors of over 10 (Factors of 15 measured in Las Vegas tests)
- The newer GNSS signals have wider RF bandwidths for greater accuracy and A/J, but the receivers also may have greater sensitivity to the adjacent band power. In ABC tests, the Galileo E1 signal was equally sensitive for HPRs.
- The new military signal deliberately pushes energy away from the center frequency, closer to Ligado power.

Agreement: Virtually all known *Precision and Scientific user Groups* of *GPS oppose Ligado Filing* because *Validated Scientific and Technical Tests Consistently Confirm severe problems*

- All Valid testing (AF/DOT - 2011 and 2016) has confirmed Ligado proposal will do severe harm - even at greatly reduced power levels
 - Company sponsored tests met none of the six essential criterion
- Opposition to Proposal to repurpose spectrum:
 - Virtually all involved in the Aircraft Industry including RTCA
 - Advanced applications such as RPVs and self-driving cars
 - Current and previous Generals commanding Air Force Space Command (GPS developers and operators)
 - An earlier PNT EXCOM, in spite of extreme administration pressure to approve
 - The USAF GPS Program office

Partial List: Groups filing opposition to the latest Ligado Filing

- AccuWeather
- Civil Aviation Aerospace Industries Association
- Operations and Safety Airlines for America
- ALERT Users Group
- American Geophysical Union
- American Meteorological Society
- American Weather and Climate Industry Association
- Aviation Spectrum Resources, Inc.
- DTN (formerly Schneider Electric)
- General Aviation Manufacturers Association
- Gogo Business Aviation
- International Air Transport Association
- Iridium Communications, Inc.
- Lockheed Martin
- Microcom Design, Inc.
- Narayan Strategy
- National Air Transportation Association
- National Emergency Number Association
- National Hydrologic Warning Council
- National Weather Association
- Resilient Navigation & Timing Foundation
- Rockwell Collins Inc.
- Satelles Inc.
- University of North Florida
- University of Wisconsin, Space Science and Engineering Center
- Idaho Geospatial Information Office
- Idaho Geospatial Council Executive Commit
- Boeing
- Air Line Pilots Association, International
- Airborne Public Safety Association
- Aircraft Owners and Pilots Association
- Airlines for America
- Association of Air Medical Services
- Helicopter Association International
- Helicopter Safety Advisory Conference
- National Business Aviation Association
- National EMS Pilots Association
- Professional Helicopter Pilots Association
- Users and Stakeholders of Hydrometeorological Information and Technology