

Assuring PNT for all

US PNT Advisory Board

*("PNTAB"-major defender of
current and future PNT techniques/capabilities)*

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Primary PNTAB Objective:

Meet the Obligation of

Assured PNT for all Users

- Therefore our Focus is PTA Program
 - Protect the radio spectrum + identify + prosecute interferers
 - Toughen GPS receivers against natural and human interference
 - Augment with additional GNSS/PNT sources and Techniques
- We Advocate Three Foundational GNSS Principles:
 - Transparency - System and Signal definition, FMEA, *Timely* insight into Operations, Development, Deployment and Threats
 - System Performance Commitments: A Clearly written and officially published - Satellite numbers and geometry, Accuracy, Inherent System Integrity etc.
 - Integrity Establishing methods for independent and timely user notifications of integrity breach

Why are we concerned about any potential threat to accuracy, availability or integrity of GPS?-

- The "Stealth Utility", is of enormous value to US economy
 - Now a largely hidden foundation of our US infrastructure
 - Economic value to selected Commercial users only over \$60B

Initial assessment is clearly Under-estimated:
Recent UK "Value" study, extrapolated to US, suggests
total value is well over 1 Trillion \$ per year

Summary of Preliminary 2013 US GPS Benefit Estimates

Application Category	Range of Benefits (\$ billions)	Mid-range Benefits (\$ billions)
Precision Agriculture – grain*	10.0-17.7	13.7
Earthmoving with machine guidance in construction*	2.2-7.7	5.0
Surveying	9.8-13.4	11.6
		0.145
		0.055
		0.185
	7.6-16.3	11.9
		0.038
		0.05
		5.5
Consumer Location Based Services 2 – Vehicle – Value of time	9.8-31.4	20.6
TOTAL (with alternative estimates for timing and consumer LBS averaged)	37.1-74.5	**68.7

• Over \$65B In Annual Benefits in identified Commercial Areas

• Hi Productivity - Heavy Reliance on High Precision GPS receivers

Underestimate Examples -(Not in the Initial Economic Analysis) - Applications with insufficient quantified benefit information, which includes:

- Non-vehicle LBS - Location Based Services
 - asset tracking, people, and value
- Maritime navigation and Safety
- GIS applications except for surveying - global GIS market estimated at \$10.6 billion
- Value of GPS as a timing standard and GPS timing use in several sectors
- Construction other than earth moving
- Open pit mining
- Also: Forestry, Health, Education, Weather, Science, Space

And Initial Economic Benefit analysis
does not include difficult to quantify benefits.

- Safety-of-life
- Environment
- Disaster assessment and relief
- Induced Benefits
- International benefits -
- Future benefits - new Applications

**Clearly the US has an enormous stake in Preserving
the Current and Future GPS Capabilities**

First Action Area of PTA - Protect, Toughen, Augment

- Protect the Clear & Truthful Signal - 7 steps
 - Pre-actions - even before interference occurs - FCC/Legal/Law Enforcement/
 - 1. Protect Spectrum/ 2. Enact strong Penalties/ 3. suppress Jammer sales
 - Re-actions when interference/spoofing occurs -
 - 4. Quick Knowledge of Jamming Area/
5. Pinpoint Location/ 6. Apprehend Perpetrator/
7. Prosecute as Appropriate

Adjacent band interference concern

“Upper” band is apparently off the table, but not officially rescinded



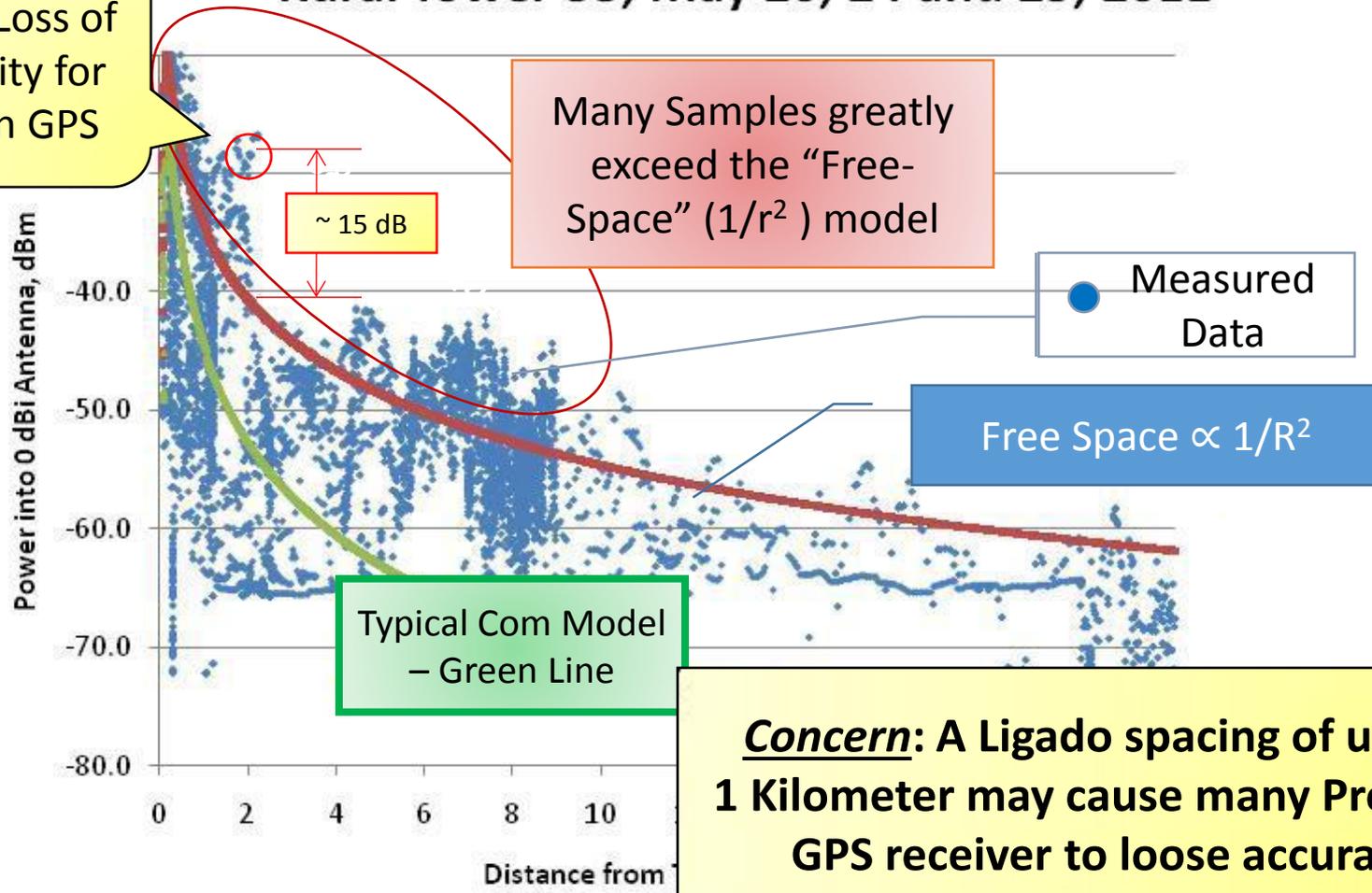
***Original proposal: Convert to terrestrial & transmit 15 kW+ ,
Tested in 2011 – Lesser Power- Transmit 1.58 kW –***

Example then Considered: With a minimum tower spacing of 1320' (most, impacted area **must be far less than 660'** or else impacted area could be, e.g., city-wide)

Models for Assured Communications and Positioning Interference have a substantial disagreement: Example from **Real Data - One Azimuth in Las Vegas**

Rural Tower 53, May 20, 24 and 25, 2011

Massive Loss of Availability for Precision GPS



Potential Interference Testing

- Sponsored by Ligado
 - Roberson
 - NASTCN (NIST?)
 - PNTAB found major Omissions- sent written suggestions
- DOT Adjacent Band Compatibility (ABC) Testing
 - Considered all Applications
 - Examined Acquisition/Reacquisition/Tracking
 - Considered receivers designed to track newer signals, including other GNSS

Interpretation of Results:

- Loss of accuracy occurs at much lower interference power levels
 - 1 dB Criterion guards against onset of accuracy loss
 - Realistic evaluation must include multiple transmitter and reflective environments

So What?

- What PNT applications would be close to Ground Transmitters?

Public Safety. In harm's way ... Apt to be much less than 200 meters enroute to Emergency
Emergency Services Scenarios



Photo courtesy Tiero/ThinkStock
**Drone/Emergency
Response/Disasters**



Photo courtesy StockSolutions/ThinkStock
**Ankle Bracelet
Monitoring**



Photo courtesy Mokee81/ThinkStock
**Police/Emergency
Response/Resource Tracking**



Photo courtesy Mrdoomits/ThinkStock
**Emergency Response/
Resource Tracking**



Photo courtesy ThinkStock
**Drone/Emergency
Response/Disasters**

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 of WSP Canada Inc

GPS HPR receiver used in construction/surveying



Photo courtesy ThinkStock

GPS HPR receiver used in construction guidance



Photo courtesy Medvedkov/ThinkStock

Construction/Surveying

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



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

UAVs are requiring centimeter-level positioning (RTK)

- Used for Precision aerial survey
- High Productivity Gains
- Very Apt to be within 400 meters of proposed transmitters
- Represents a major class of future applications that must be evaluated
- Also apt to be in main beam of Adjacent-band Transmitter



"Since our training, we've flown multiple missions and demos for customers. These systems have been very positively received. We demonstrated them for a construction company and they came back and told us that the deliverables were ten times better than they achieved with a competitor's product."

STEVE RICHTER, VICE PRESIDENT
Sales and Marketing, Frontier Precision

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NO GROUND CONTROL POINTS,* LESS SIDELAP, MORE PRODUCTIVITY.
Ask about the mdMapper1000DG. It's equipped with a Trimble APX-15 module featuring a survey-grade GNSS receiver and a precisely calibrated IMU from Applanix, built specifically for Direct Georeferencing (DG).



Answer to So What?

(What PNT applications (Called *Proximity Operations*) would be within proximity of a Ground Transmitter?)

Answer: Many - particularly involving Emergency Providers and High Precision and Productivity.

Recent Spectrum Allocation Developments

- **Ligado Proposal Still on Table** (update today)
 - Letters to FCC (Ex Parte)
 - Ligado invited to present at this PNTAB (modified proposal?)
- Study of Testing "Gaps" by PNT Engineering Forum
 - To be briefed at a later PNTAB
- Air Force assessment of DOT (ABC) study will be briefed at this meeting

Board Technical Evaluation: Would the latest Ligado proposal do no harm to any of the current and future signals and applications?

PNTAB has Requested Ligado Talk include

- Detailed *Proposed Final Operating Configuration*
(Spacing/Density, Antenna types, Power levels, Proposed Propagation models incl. reflections etc.)
- *Impacts and Mitigation* for:
 - All Current and Future GNSS signals (US L1M, L1 P/Y, Galileo etc.)
 - All Modes of PNT Operation (e.g. acq and reacq, moving vehicles etc.)
 - All Current/Future PNT Applications - *Especially the "Proximity Operations" apt to be within 1/10th of a mile or less of Transmitters*
 - *En-Route Emergency/First Providers - e.g. Police/Fire/Ambulance*
 - *Precision Timing and Survey*
 - *Autonomous vehicles; e.g. UAVs and RPVs both tracking and control*
 - *Helicopters*
 - *Military, Commercial and General Aviation*
- Proposed "Open Air" verification of critical cases

PNTAB view: Minimum Criteria for Testing/Evaluation of Interference Potential of High Power terrestrial transmitters in repurposed radio bands

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.