Three Wishes
and
an elaboration

For Reception of

RESILIENT NAVIGATION and TIMING FOUNDATION

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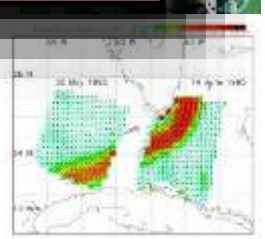
(these are my personal views)

Good News: World-wide dependency on GNSS – *PNT Taken for Granted – the "Stealth" Utility*

- Civil
  - Transportation
    - Aviation
  - Other
- Military





The ***Majority*** of these Applications were not part of the original "formal definition" of GPS

They resulted from:

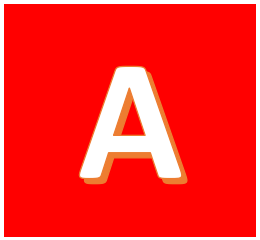
- Civil Creativity
- Plummeting cost of GPS receivers
- Virtually 100% Reliability and Availability

Primary PNTAB Objective:

Meet the ***Obligation*** of

Assured *PNT* for all Users

- Therefore 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



Wish 1: Begin deployment of eLoran Immediately

eLoran Characteristics

- **Unjammable** (virtually) **and adds Frequency Diversity**.
- **Regional –** Trial system in UK. Full US deployment would require 20 to 30 transmitters plus ~50 differential stations
- **Horizontal Only.** No third dimension –Baro can help
- **Accuracy over landmass adequate for backup.** Variable speed of signal – errors can be 0.1 mile (or perhaps more).
  - Issue is spatial and temporal decorrelation if differential techniques are used (ASF corrections are a form of differential and assume temporal decorrelation is negligible)
- **Can Achieve 10-15 meter accuracy in small areas** (within about 5-10 miles of calibration point) must use ~ *continuous updates* of Differential Accuracy for Integrity

eLoran is the most viable augmentation to GPS to provide PNT in times of stress and to deter deliberate jamming

Wish 1: Begin deployment of eLoran Immediately

- Consider Government Commercial partnership
- Develop and offer affordable eLoran timing and positioning receivers
- Start with US timing capability
- Add redundancy and positioning capability in hi-payoff areas
- Add eLoran differential capability where justified

Wish 2: That low-cost Very Jam-resistant GNSS receivers are Commercially available

Jam Resistance - the *"Nibbles"*

Improving Jamming Resistance Performance

Digital Technology is making beam steering and vector receivers much more affordable

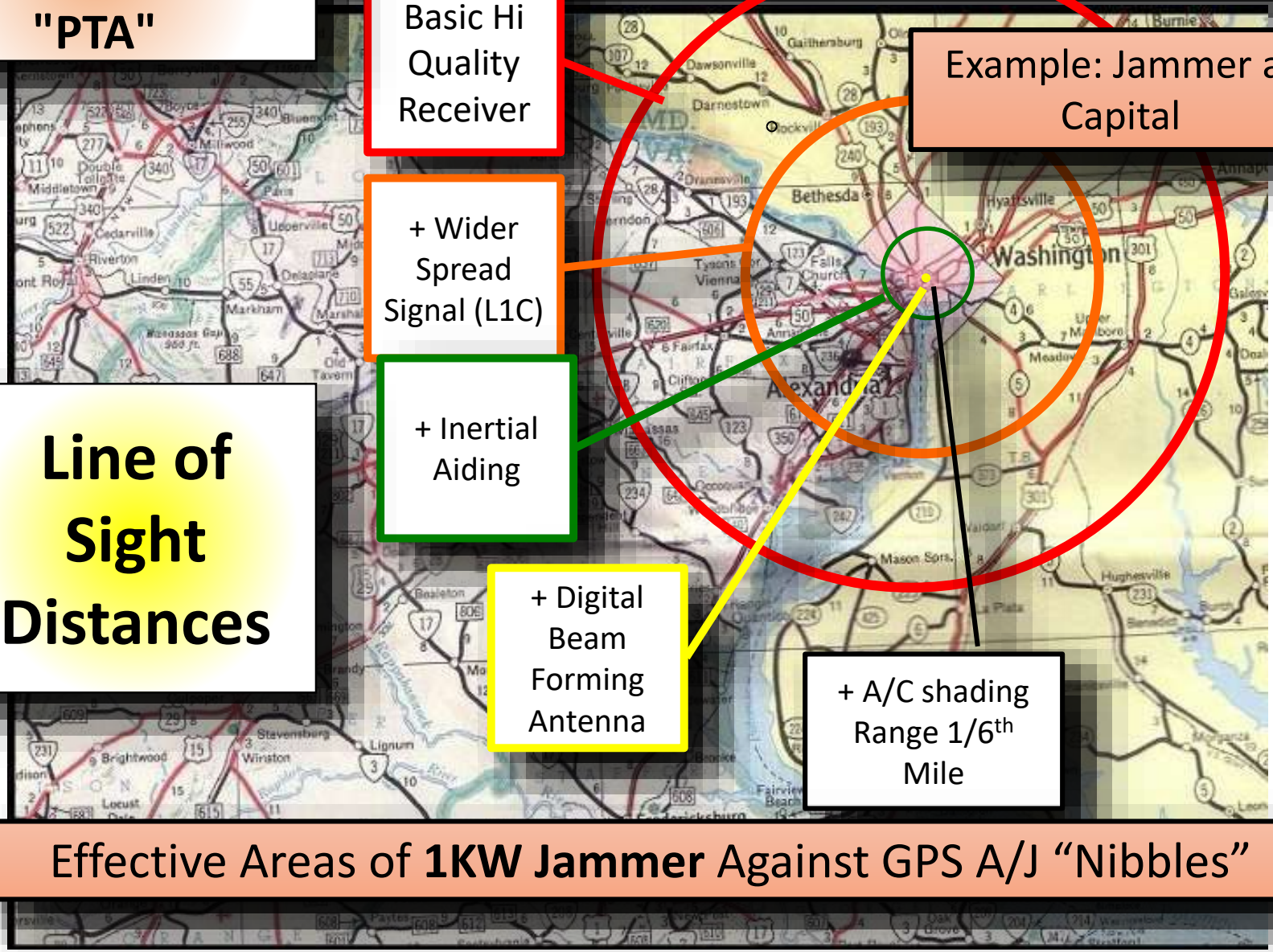
Believe This is a trend that will continue

Ine (MEM		
Wide Spreading GNSS Signal (e.g. L1C)	5 dB	32%
Digital Beam Forming Antenna	20-30 dB	1.0% - 0.1%
Aircraft Shading (commercial Aircraft)	5-10 dB	32% - 10%
"Spilker" Vector Receiver (A powerful form of frequency diversity)	Up to 10 dB	10%
Potential Total Improvement	**48 –67 dB**	**0.0016% - 0.00002%**

Require > 60,000 Jammers to cover Original Area

Assured Availability of PNT "PTA"

Toughening GPS Receivers



Effective Areas of **1KW Jammer** Against GPS A/J "Nibbles"

Wish 2: *That low-cost Very Jam-resistant GNSS receivers are Commercially available*

- Particularly Beam-steering digital antennas – 17 Elements large base perferred
- Specifications of Capability included in Commercial aircraft receivers
- For military remove incentive to add complex and expensive steerable arrays on satellites (Earliest full capability would be about 2035)

The #1 GPS/GNSS *Availability* Issue

Spectrum Interference -

Illegal jamming

and/or

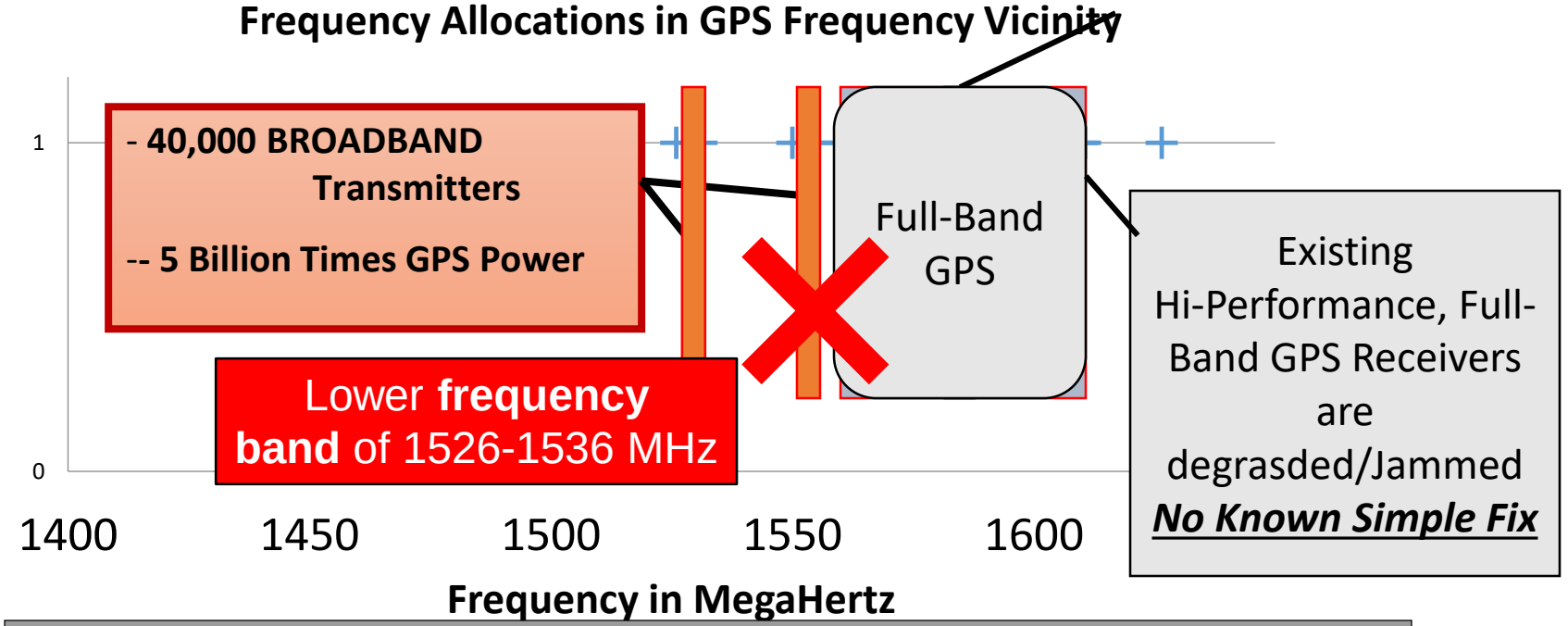
Licensed Intrusion

Adjacent band interference concern

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

Original proposal: transmit 15 kW+ ,
Tested in 2011 - Transmit 1.58 kW **– "**Ligado's proposed minimum tower spacing of 1420', impacted area must be far less than 710' or else impacted area could be, e.g., city-wide " (FAA report)

Existential Threat to GPS – FCC Re-allocation of Nearby Band to Higher Power *(Ligado Proposal)*



Problems:

Proximity (geographic and RF spectrum) and ***Power***

DepSecDef Carter and DepSecTrans Pocari ExCom Letter to Asst Sec Strickling 13 Jan 2012

". . . without affecting existing and evolving uses of space-based PNT services vital to economic, public safety, scientific, and national security needs."

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Wish 3: *FCC does not approve repurposing of Adjacent Spectrum until/unless proposal passes realistic evaluation of all current and future GNSS signals, applications and techniques*

The Fundamental Differences in Radio Communications and Radio Navigation must be Recognized

- Digital Radio Communications:
  - Incoming message is not known – finding it is the whole point
  - Must determine whether each signal "bit" is a one or a zero
  - Use sophisticated methods to correct errors
- Digital Radio Navigation:
  - Incoming signal sequence (ones and zeros) is totally known by user
  - The goal of the user is to precisely time the transition from one to zero (and zero to one)

In the face of interference, degradation of positioning accuracy occurs well before total loss of signal

Specific Issues (Near L1 C/A, P/Y, M, L1C, Galileo i.e. the 1575 mHz band)

- The New GNSS Signals
  - US (L1C and Lm)
  - Other GNSS (Galileo + Glonass and Beidou)
- Embracing the 1 dB criterion
- Antenna Patterns and Propagation Model
- Repurposed transmitter density and power
- Applications apt to be within Harms Way
  - Both Current and Emerging