

Purpose of US PNTAB:

Assuring PNT for all -

and

Exploiting GNSS for Future Applications

*FACA Representing 100s of millions of diverse users
and many scores of applications*

Adm. Thad Allen (Chairman), Booz Allen Hamilton

Hon. John Stenbit (Deputy Chairman), former Assistant Secretary of
Defense

Dr. Bradford Parkinson (1st Vice Chair), Stanford University

Governor James E. Geringer (2nd Vice Chair), Environmental Systems
Research Institute (ESRI)

To Assure Availability of PNT - "PTA"

Take specific steps to:

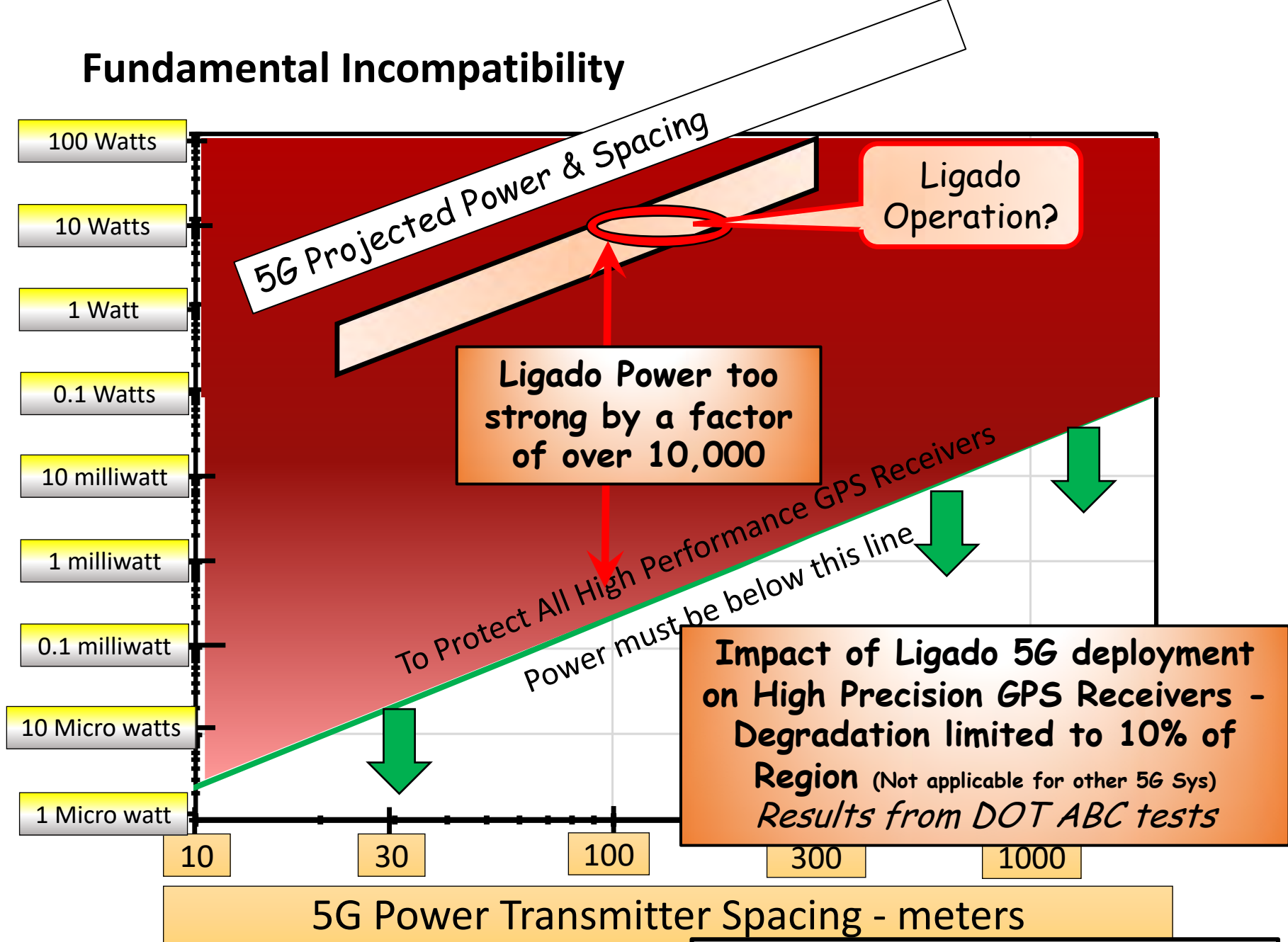
- Protect Clear and Truthful Reception
- Toughen System and User's Receivers
- Augment or substitute PNT sources

Extract from Plenary Talk to Admiral Ellis and UAG - Advisors to VP Pence's National Space Council:

Update on Protect:

*Threat of **Ligado Proposal to FCC***

Fundamental Incompatibility



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
		<u>90 % of Region Protected</u>
High Performance/ High Productivity (HPR)	3400 meters	20.5 km/12.6 miles
Emergency Vehicles and General Navigation (GLN)	1045 meters	6.3 km/3.8 miles
General Aviation and Helicopters (GAV)	1040 meters	6.2 km/3.8 miles
Timing (TIM)	293 meters	1.7 km/1.1 miles
Cell (CEL)	9.5 meters	57 m/ 62 yards

Extract from Plenary Talk to UAG -

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

Spectrum Issues: Application to UAG of National Space Council

- A Majority of Space-based systems rely on relatively weak radio signals from space
- Most are placed in radio bands of "like-use"
- Commercial pressure on many bands comes from desire for greater (*terrestrial*) data bandwidth - e.g. hi-def movies
 - Temptation is to reduce adjacent-band restrictions
- Vigilance is needed - once band use is allowed, it is not apt to be reversed

What is important for
PNT users now?



Feedstock for the Current and Future
PNT Advisory Board Meetings

What are possible criteria for "Important"?

- Should Preserve/Enhance current and/or future PNT and Applications
 - Robustness
 - Safety
 - Productivity
 - Convenience
- EXCOM/PNTAB should have potential leverage
 - Remove Barriers
 - Create Enablers

An Initial List of Important Things??

"Protect"

- P1. Protecting spectrum - both Ligado repurposing and recurrence of 2001 Wide-band problem
- P2. Need for a National System to monitor, locate and shutdown jammers and spoofers?

"Toughen"

- T1. Publicize latest threat model & techniques/counters to GNSS Spoofing/Jamming
- T2. Understanding the Galileo outage - any lessons for other GNSS?
- T3. Vulnerabilities and solutions for GPS cybersecurity

"Augment"

- A1. What additional augmentation to GPS are being or should be pursued?
- A2. What are FAA plans to include Galileo and others in WAAS monitoring system?

"Future Applications and Capabilities"

- F1. Defining power of 2nd (and 3rd) GPS satellite signal lobe for SSV
- F2. Progress and prospects of Intelligent Highways Program
- F3. Progress on fielding Autonomous Vehicles - especially large interstate trucks
- F4. What are Air Traffic Plans to handle the UAS challenges?
- F5. Results of initial testing of GPSIII (L1C, L5 etc.)

A1. Augmentations have been under study for years - "The cruelest form of Denial"

- Ongoing Dialogue
- Central Contenders
 - Residual VOR/DME (FAA plan)
 - Enhanced Loran (eLoran)
 - LEO Communications Satellites
 - Inertial Systems (Cost/performance tradeoffs)
 - (Also should consider Digital multi-element antennas)
- Army has a new Mounted Assured PNT System or MAPS program
 - to replacing multiple hand-held DAGRs with a single receiver, thereby reducing SWAP

A2. The FCC has now officially “authorized” most of the Galileo signals to be received.

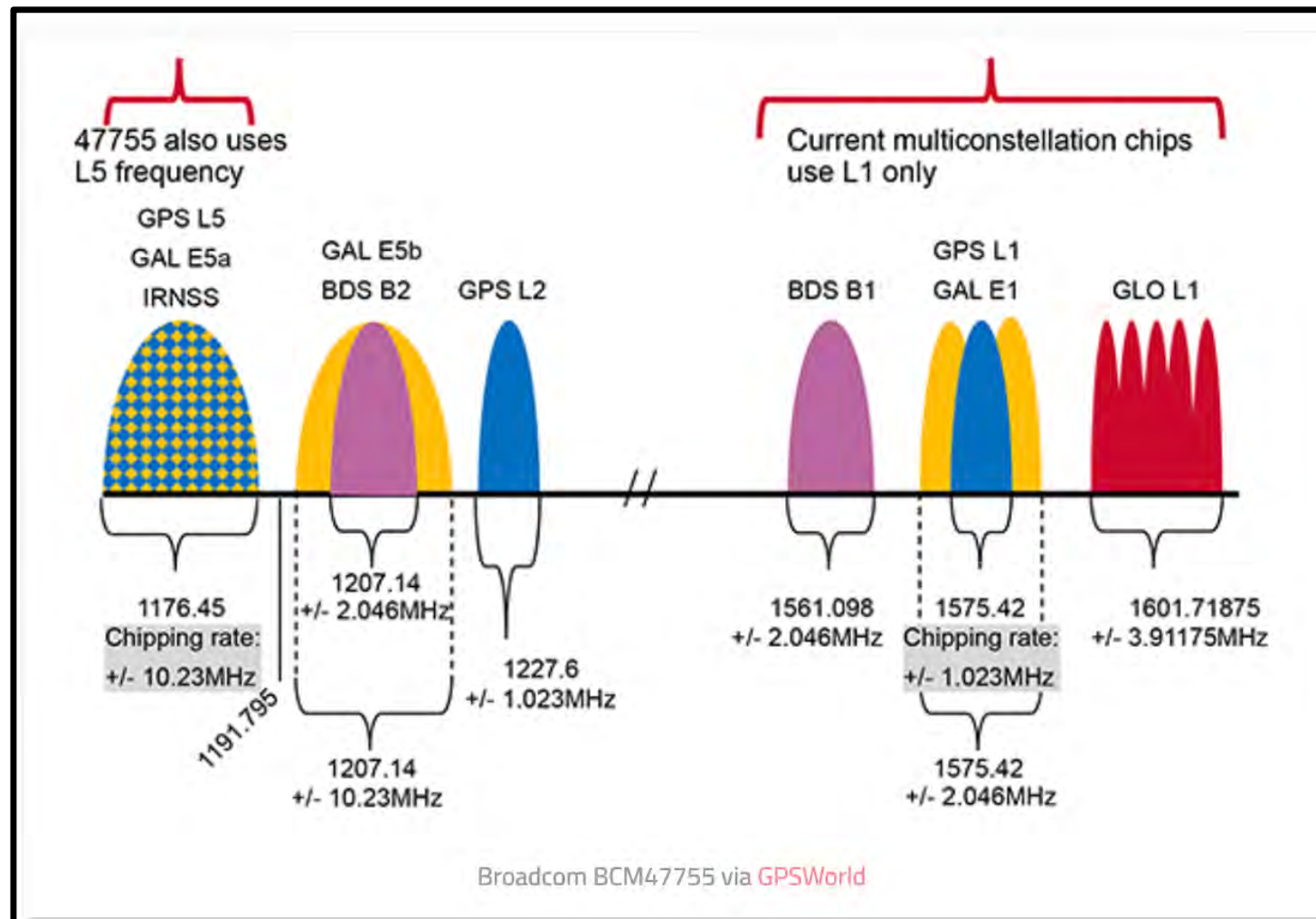
2. As described in detail below, we grant the requested waivers for non-Federal receiver operations with two of the Galileo signals, E1 and E5, which are transmitted in the same Radionavigation-Satellite Service (RNSS) bands where GPS transmits its L1, L5, and L2 signals, and deny the requested waiver for the Galileo E6 signal. Subject to the Commission’s rules not otherwise waived and the

- High performance receivers have been using GLONASS for years
- FAA development of a new monitoring receiver to include Galileo has been announced
- New cell phone chips multi-constellation and dual frequency...

How do we ascertain Integrity for other GNSS?

Dual Frequency Cell Phone chips - Major Market disruptor ?

When will WAAS include other GNSS, operationally ?



F3. Status and enablers for Autonomous Road Vehicles - specially Semi's

- “The Freightliner”
- Daimler-Benz Prototype
- GNSS plus
- Stereo Camera Reads Lanes
- Short and Long Range Radars

- The World's First Self-Driving Semi-Truck Hits the Road (May 2015)



- Including: V2V
Vehicle to Vehicle
Communications - What are
adjacent vehicles doing?

What are minimum Cybersecurity requirements for the PNT on self-driving long-haul trucks

F4. UAS are found in all rural and city regions

Example: BVLOS operation not yet authorized - most UASs are not so equipped - one issue is PNT assurance



Both UAS Control and Air Traffic Monitoring will depend on GNSS/GPS –



“[no BVLOS] hinders the full value and benefits that the UAS industry has to offer.” *Brian Wynne, AUVSI president and CEO*

What non-UAS Applications spend time flying close to the ground?

(Where collisions with UASs are most probable)

- Wildfire Tankers/Helicopters
- Law Enforcement Helicopters
- Commercial Airplanes during takeoff and landing

And Coming:

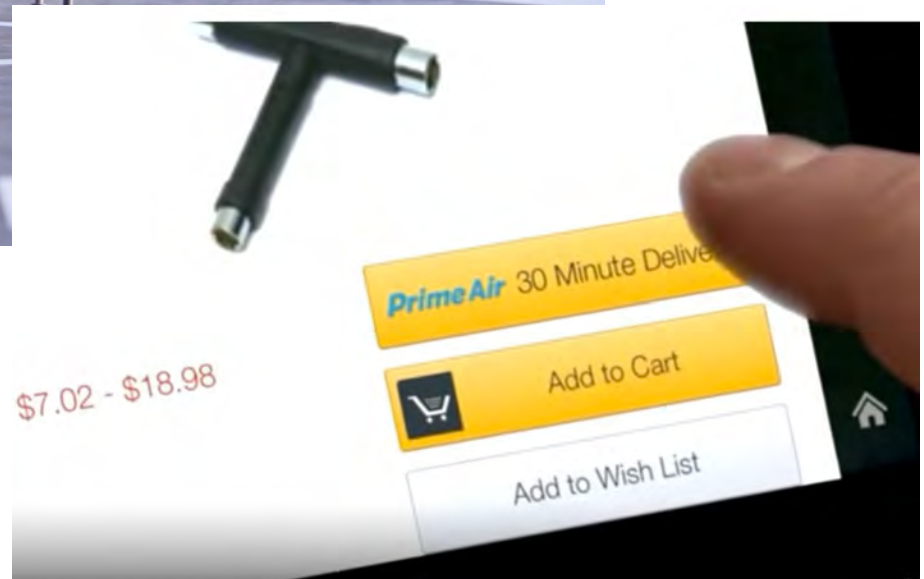
- Amazon Delivery "PrimeAir"
- Un-piloted Air Taxis

Firefighting Aircraft are significant users of low-altitude airspace

14 Firefighting Aircraft Grounded by Drone, Operator Faces 14 Felony Charges



PrimeAir Coming to a house near you?



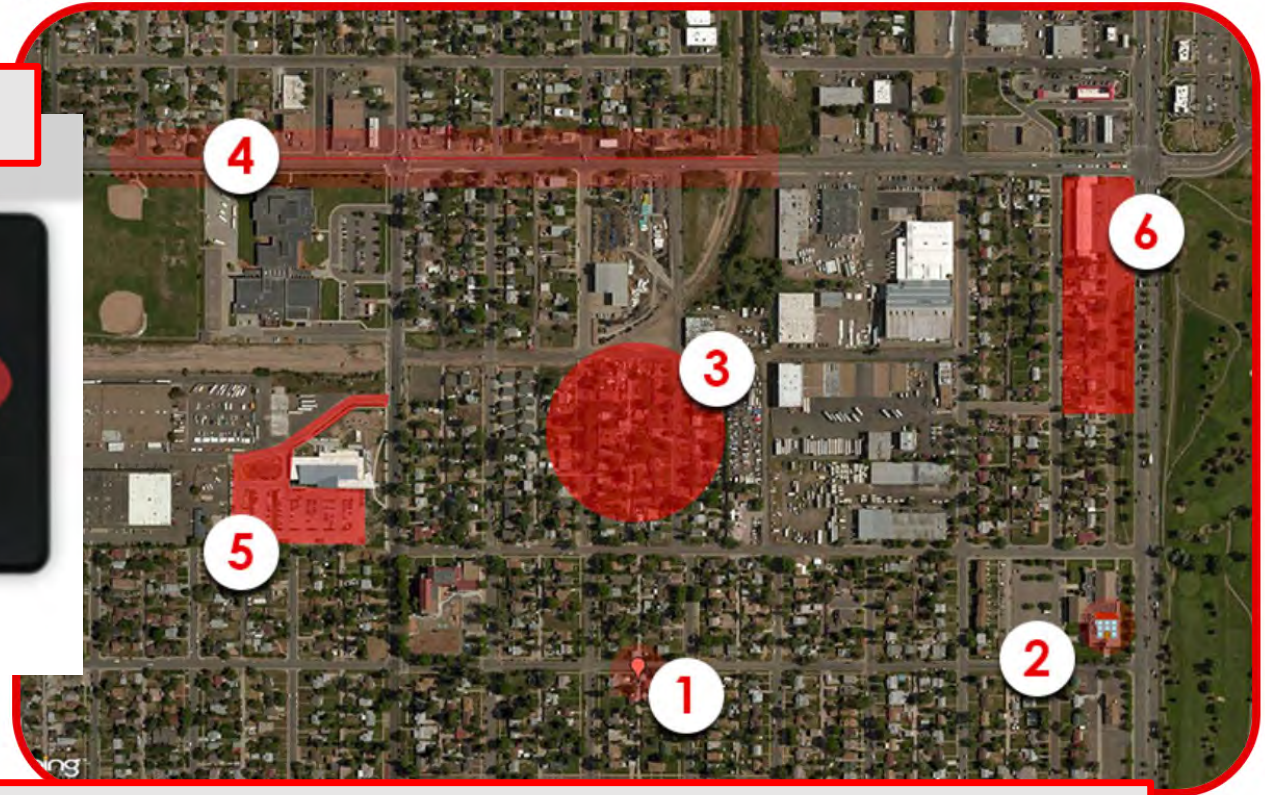
UAS regulation by FAA is evolving - amid safety and security concerns

- No simple answers but PNT is at the heart of the problem and any possible solution
- BVLOS not authorized, but certainly feasible and desirable for civil applications
- "Geofencing" has well established products and systems for fleet management
 - Adaptation to UAS?
 - Static and dynamic fences?
 - Feasibility of fail safe UAS control?

Geofencing - commercial products already available

GPS Satellite View

~ 3 inches



Need 3D and rapid exclusion assignment - enforcement?

F5. How do we exploit new signals, and new messaging capability?

GPS III

- All civil signals
- Better Clock
- Retroreflectors in later versions



L5:

- Improved signal structure for enhanced performance
- Higher transmitted power than L1/L2 signal (~3 dB, or 2× as powerful)
- Wider bandwidth provides a 10× [processing gain](#), provides sharper autocorrelation and requires a higher sampling rate at receiver.
- Longer spreading codes (10× longer than C/A)
- Uses the Aeronautical Radionavigation Services band (ARNS)
- Can include near-real time messaging capability

Requested Help at SCPNT Symposium

- What else is "Important" for PNTAB ?
- What are your top 5? Ordered #1 to #5.

Example straw vote:

#1 A1 5 points

#2 P1 4 Points

#3 F4 3 Points

etc.

etc.

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Conclusions for what is important: Actionable Recommendations for EXCOM

- Removing Barriers
- Creating Enablers

Possible Examples

Removing Barriers

- ITAR prevents commercial development of known, highly effective AJ/AS receivers
- Foreign GNSS do not have the integrity assurance that WAAS gives to GPS
- NRC study to examine issues and solution to burgeoning UAS population

Creating Enablers -

- Assigning Department responsibility and Funding to field a system that will identify, locate, and shut down AJ and AS sources
 - EU has issued an RFP for such capability
- Publicize a Threat/Risk assessment for PNT
 - Give Equipment manufacturers yardsticks for their offerings
- Oppose any expansion of wideband frequency allocations
- ???

So what is missing?

What should be eliminated?

Which are most important?

Thanks for your help...

We have lost two GPS heroes in the
last six months.

Both were superb Engineers

Jim Spilker- August 4, 1933 - September 24, 2019

A Father of the GPS signal - Major contributor to Stanford University



- Worked at Lockheed and Philco Ford
- Founder of Stanford Telecommunications
- Fellow of ION, Life Fellow IEEE
- **Inventor of the Delay Lock Loop**
- Co Editor and author of GPS Global Positioning System: Theory and Applications won the AIAA Sommerfield Best Book Medal.
- Member of the GPS IRT
- Recognized with many awards, including the Kepler and Burka of ION
- Recipient with three others of the QEII Prize for Engineering

Remembering Ron Hatch - A true GPS "Hero" (December 1938 to September 2019)



- Member of the US PNTAB
- Worked at APL, Boeing, and Magnavox
- Started NavCom Technology Inc. with Jim Litton et. al.
- Fellow of ION {President in 2001 }
- **Inventor of the Hatch Filter**
- Challenged Einstein's Theories with 1992 Book: **Escape from Einstein**
(A Lorentzian Alternative)
- Recognized with Kepler and Thurlow Awards of ION