?

What is important for PNT users now?

Brad Parkinson

Feedstock for the PNT Advisory Board

Outline

- Update on PNTAB
- What is Important now?
  - With extract from BP presentation to UAG
- Views of Attendees
- Memories of yet another lost GPS Warrior

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

Thad Allen (Chairman), Booz Allen Hamilton

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

Bradford Parkinson (1st Vice Chair), Stanford University

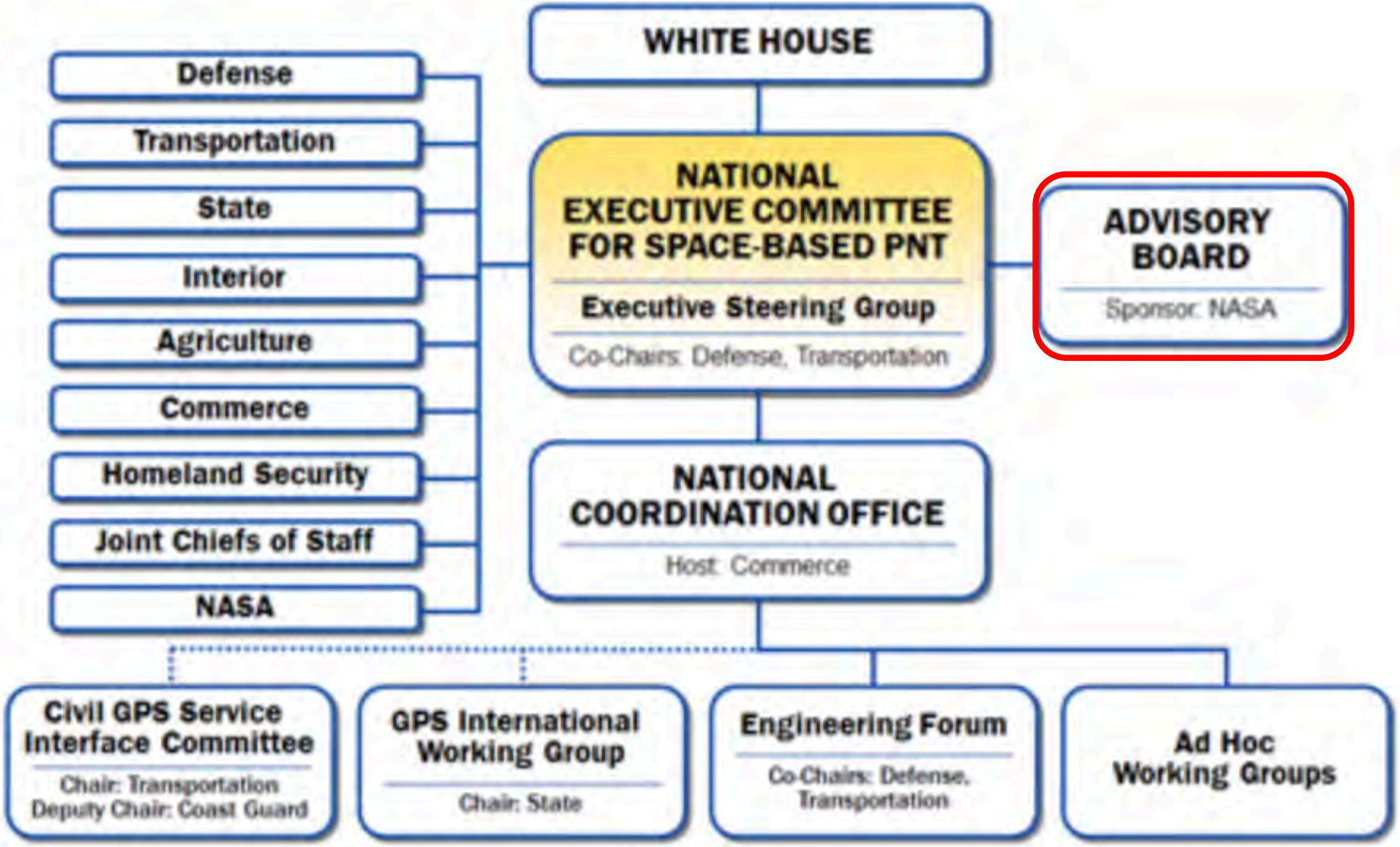
James E. Geringer (2nd Vice Chair), Environmental Systems Research Institute (ESRI)

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

Organizational Structure



PNTAB Membership Over 450 Years of PNT experience - Balanced US and International

- FACA since 2004
  - SGEs and Representatives
- The Advisory Board consists of GPS experts from outside the U.S. government.
- Currently, there are 25 members representing U.S. industry, academia, including (5) international members.
- The Chairman of the Advisory Board is Admiral (Ret.) Thad W. Allen. (former USCG Commandant)
- Administered by NASA under James Miller

What is "Important"?

- Should Preserve/Enhance *current* and/or *future* PNT and Applications
  - Robustness
  - Safety
  - Productivity
  - Convenience
- PNTAB should have potential leverage
- Non-classified for PNTAB

An Initial List of Important Things??

"Protect"

P1. Status of ongoing Ligado Interference Situation and recurrence of Wide-band problem

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T1. Latest on counters to GNSS Spoofing/Jamming

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F1. Defining power of 2nd (and 3rd) GPS satellite signal lobe for SSV

F2. Intelligent Highways latest progress and prospects

F3. Autonomous Road Vehicles - specially semi's

F4. What are Air Traffic Plans to handle the UAV challenges?

F5. Results of initial testing of GPSIII

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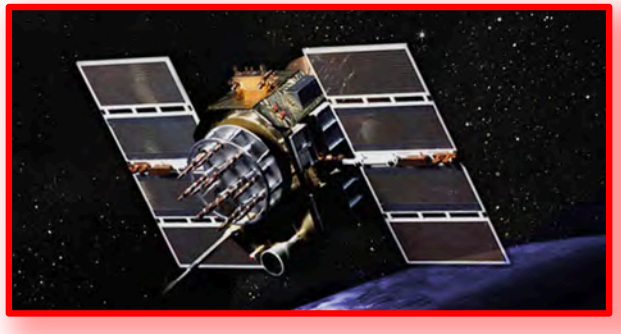
Extract from Plenary Talk to UAG – Advisors to VP Pence's National Space Council:

Update on Ligado Proposal to FCC

Extract from Plenary Talk to UAG –

GPS – 24/7, worldwide

(Accuracies to fractions of an inch



- Received signal *weaker than a millionth of a billionth of a watt*
- Over 3 ***Billion*** receivers in Use across planet
- ***Taken for granted world wide – literally 100s of applications***
- Economic value greatly exceeds $65B/year
- **An essential part of US infrastructure (DHS)**

Extract from Plenary Talk to UAG –

An Example of PNTAB Activities –

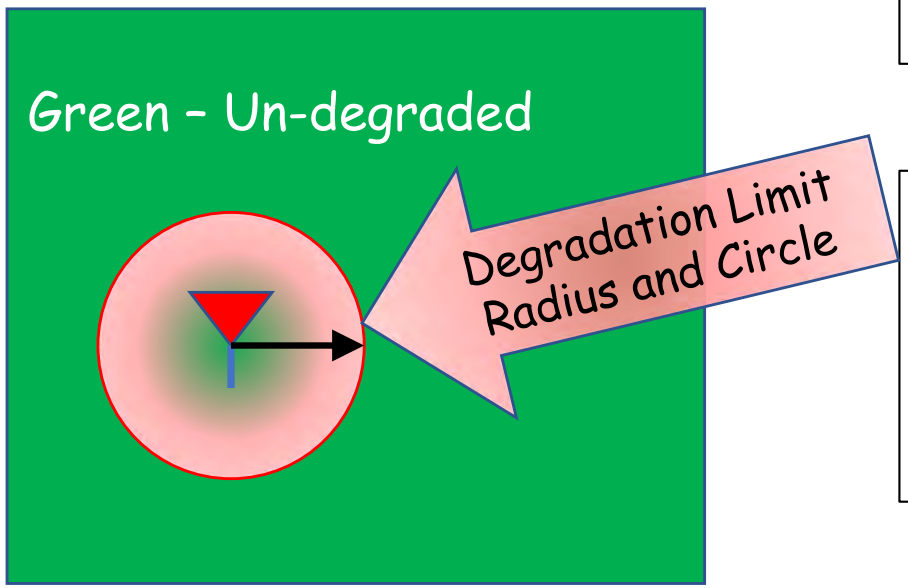
Countering A Grave threat to GPS

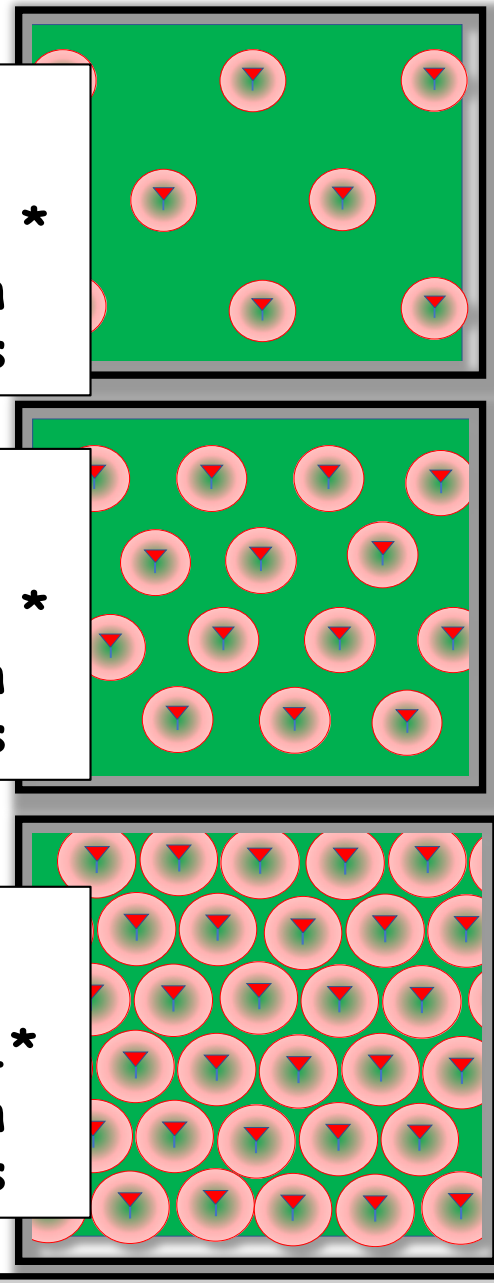
for FAA, DOT, NASA, DOD
and
other High-Precision Users

A visual Example:

To insure additional GPS interference noise does not exceed 25% International Standard either:

- **Limit minimum Transmitter Spacing** for a given power
  Or
- **Constrain Power** for a given spacing (Reduce Degradation Radius)



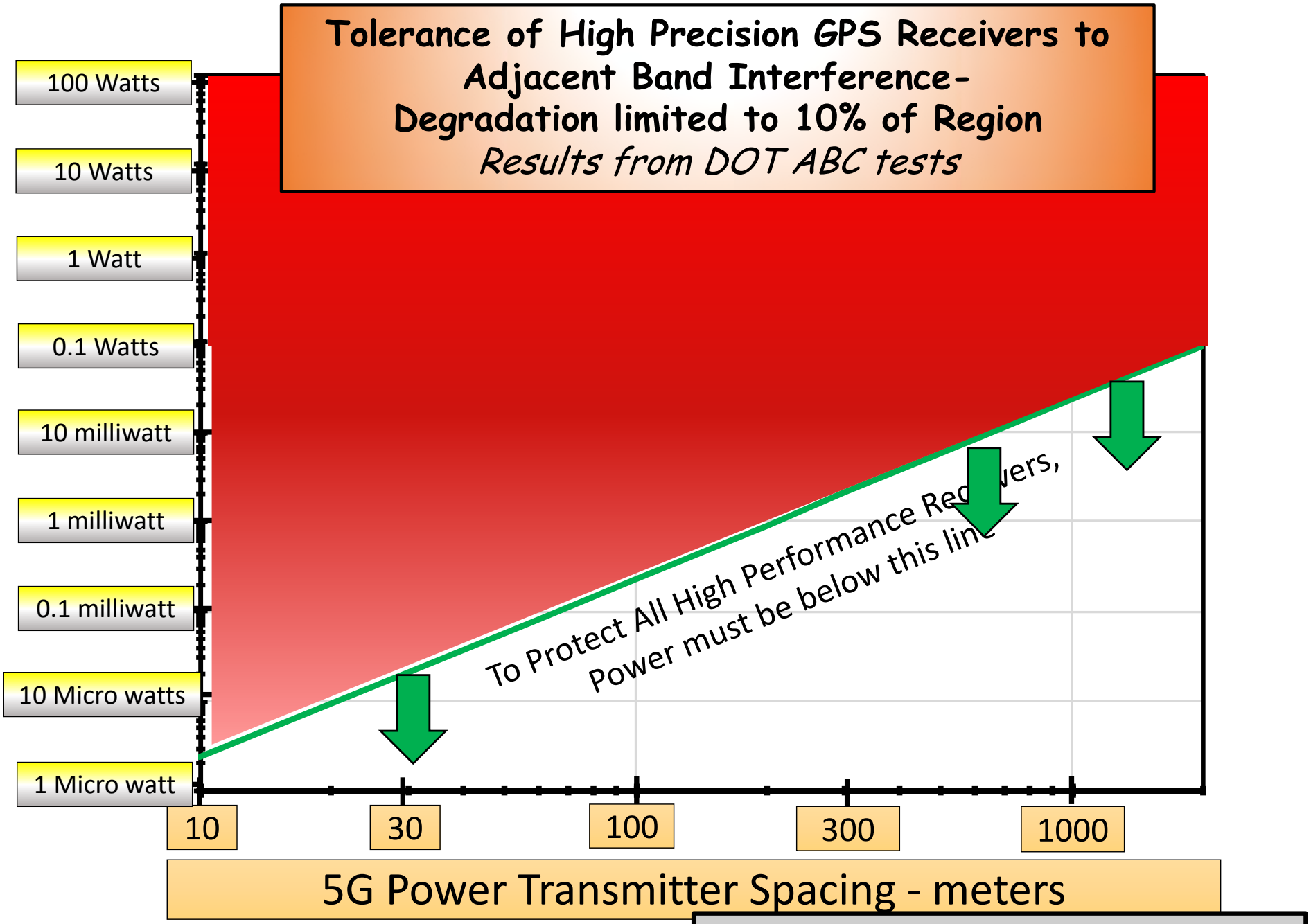


90% Area Protected – spacing = 6.0 * Degradation Limit Radius

50% Area Protected – spacing = 2.4 * Degradation Limit Radius

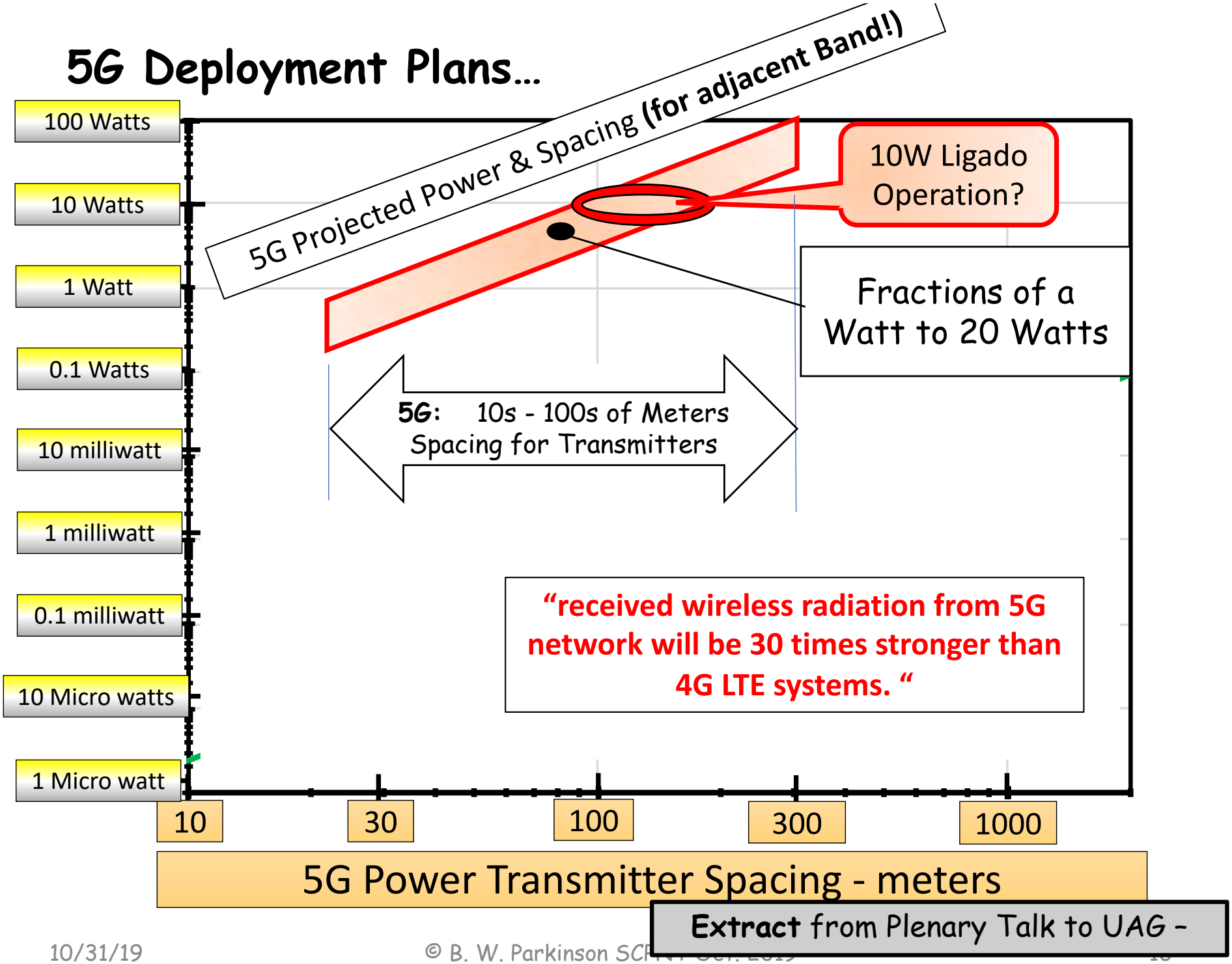
20% Area Protected – spacing = 2.1* Degradation Limit Radius

Extract from Plenary Talk to UAG –



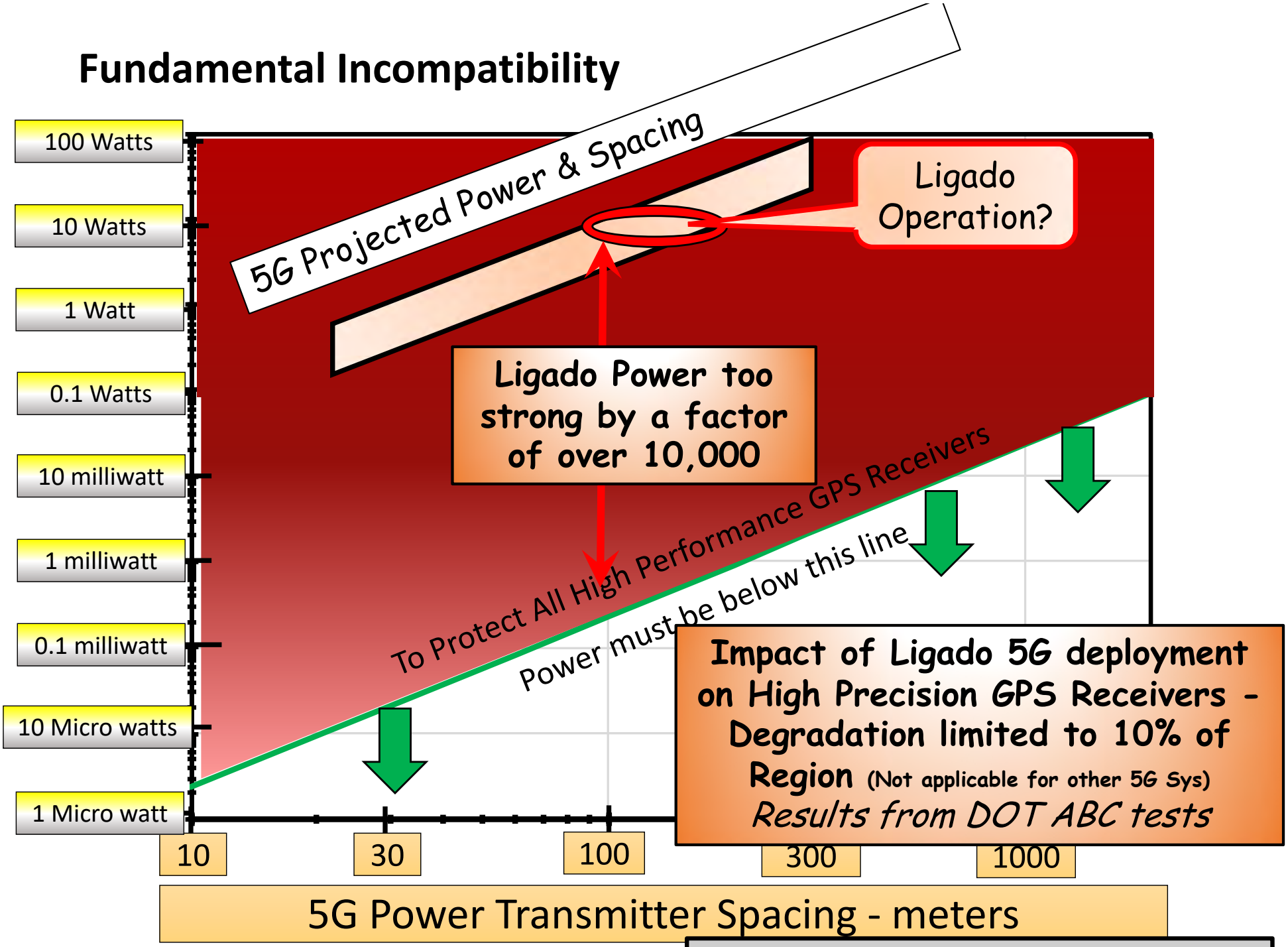
Extract from Plenary Talk to UAG –

5G Deployment Plans…



Extract from Plenary Talk to UAG –

Fundamental Incompatibility



Impact of Ligado 5G deployment on High Precision GPS Receivers - Degradation limited to 10% of Region (Not applicable for other 5G Sys)
Results from DOT ABC tests

Extract from Plenary Talk to UAG –

Extract from Plenary Talk to UAG –

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 % *Region Protected*
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**

Extract from Plenary Talk to UAG –

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

Extract from Plenary Talk to UAG –

So we requested USG support for PNTAB Recommendations:

- Reject latest Ligado 10 watt proposal
  - Does not meet PNT EXCOM January 2012 goal to protect "existing and evolving uses of space-based PNT services"
  - Not even close to acceptable
- Apply PNT EXCOM Adjacent Band Compatibility (ABC) methodology to any future proposals

But ultra-wide band communications has re-emerged as an interference threat

FCC issued its Original Report and Order in 2002.

Extract from Plenary Talk to UAG –

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

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EU RFP: What is the US equivalent?

Request for proposals to be issued:

The Official Journal of the European Union (EU) will publish a funding opportunity in the near future for a GNSS "Advanced Interference Detection and Robustness Capabilities System," according to officials familiar with the project.

What about crowdsourcing with cell phones?

Crowdsourcing GNSS jamming detection and localization

Luka Strizic, *University of Colorado Boulder & Luleå University of Technology*
Dennis M. Akos, *University of Colorado Boulder & Stanford University*
Sherman Lo, *Stanford University*

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GSA Offers 3M Euro Funding for Anti-Spoofing Receiver Designs

The European GNSS Agency (GSA) has opened a call for proposals for implementation of Open Service Navigation Message Authentication (OS-NMA) and/or Integrity Navigation Message (I/NAV) features in close-to-market receivers and/or GNSS user terminals. The deadline for submissions is October 31, 2019.

By Inside GNSS Read More >

- Need a comprehensive manual on anti-spoofing techniques. New cellphone chips offer some great new potentials.
- Exploit cm/sec velocity and Multiple or dual antennas

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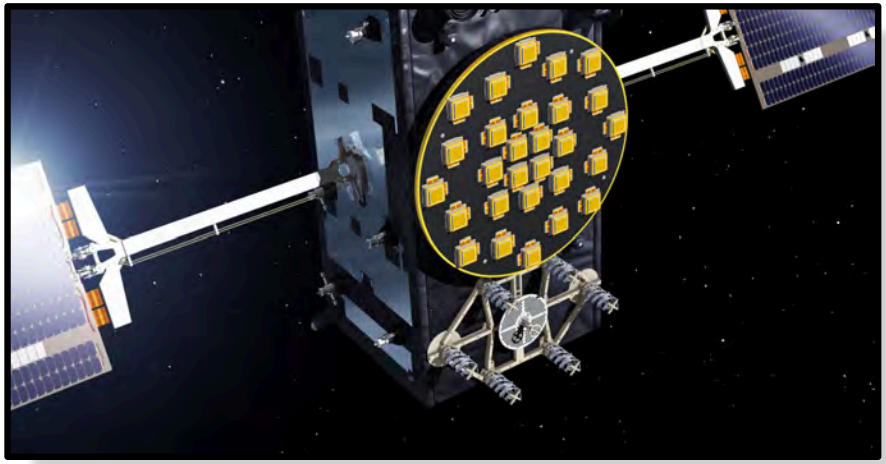
T2. What do we know about the Galileo outage – any lessons for other GNSS?

- Out for about one week

  (11 to 16 July)
- Cause is obscure
- Difficult to get information



"part of what makes GPS "golden" is the high trust level invested in the system by users—due in no small part to the transparency and alacrity with which the U.S. Air Force and Coast Guard Navigation Center respond to such incidents." – *Glen Gibbons Inside GNSS*

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A1. What additional augmentation to GPS are being or should be pursued?

- Ongoing Dialogue
- Central Contenders
  - Residual VOR/DME (FAA plan)
  - Enhanced Loran (eLoran)
  - 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

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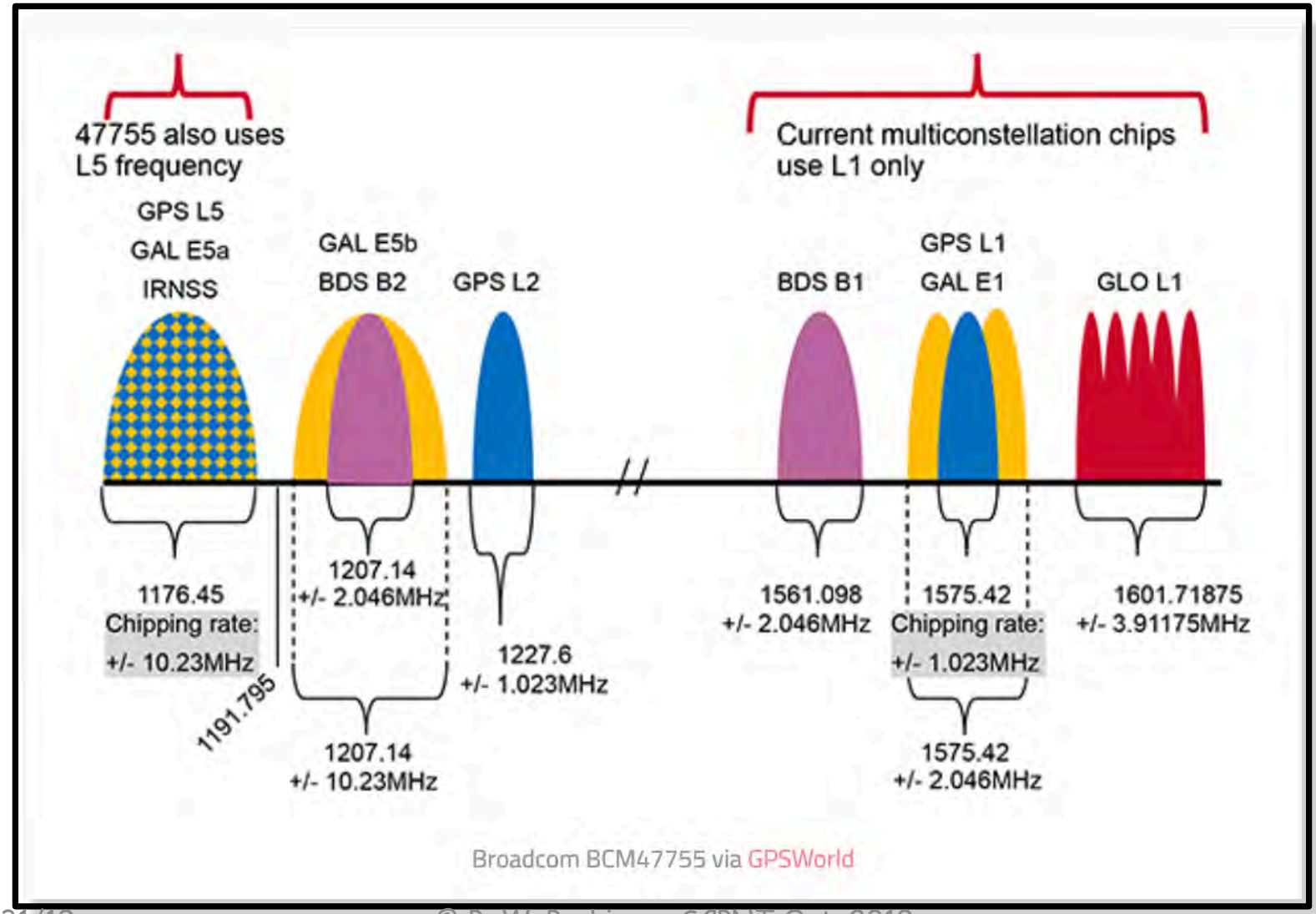
A2. What are FAA plans to include Galileo and others in WAAS monitoring system?

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 developing a new monitoring receiver to include Galileo has been announced
- New cell phone chips multi-constellation and dual frequency…

Dual Frequency Cell Phone chips – Major Market disruptor ?
When will WAAS include operationally ?



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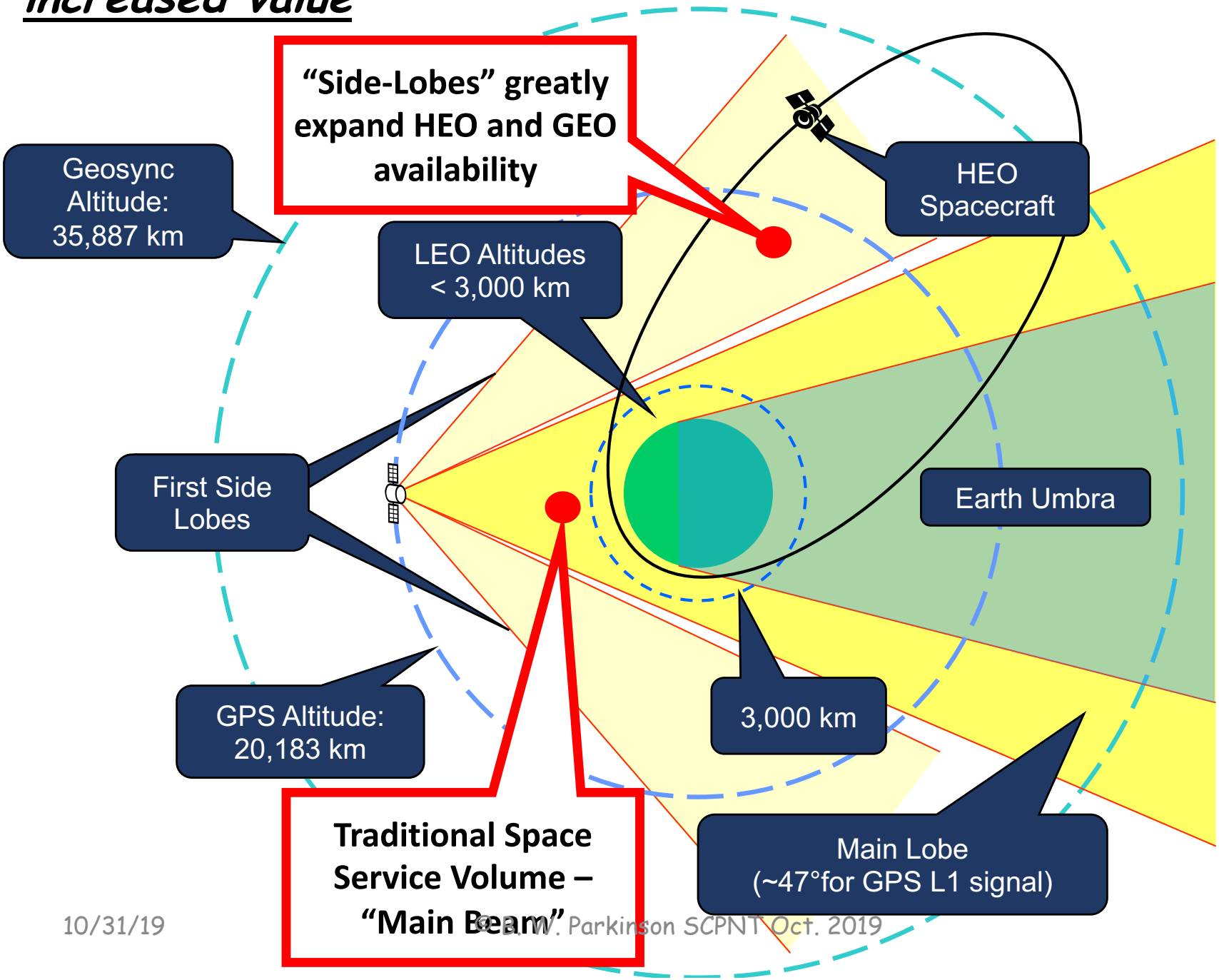
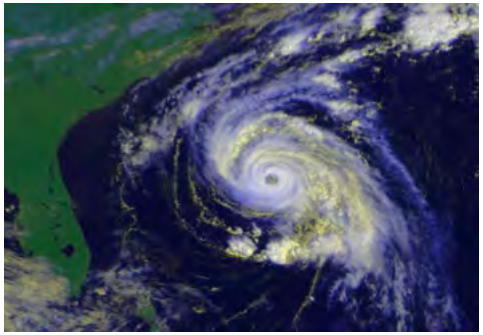
Space Service Volume: *New techniques have greatly increased value*



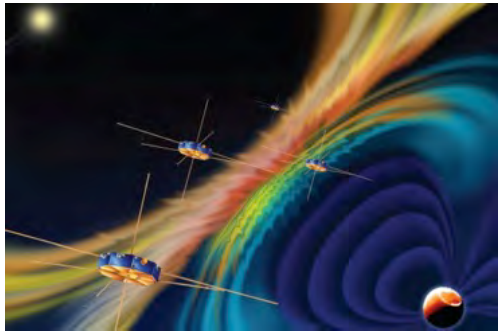
GPS for Real-Time Navigation in Space Service Volume

Benefits of GPS use in SSV:

- Significantly **improves real-time navigation performance** (from: km-class to: meter-class)
- Supports **quick trajectory maneuver recovery** (from: 5-10 hours to: minutes)
- GPS timing **reduces need for expensive on-board clocks** (from: $100sK-1M to: $15K–50K)
- Supports **increased satellite autonomy**, lowering mission operations costs (savings up to $500-750K/year)
- Enables new/enhanced capabilities and better performance for **High Earth Orbit (HEO)** and **Geosynchronous Orbit (GEO) missions,** including:



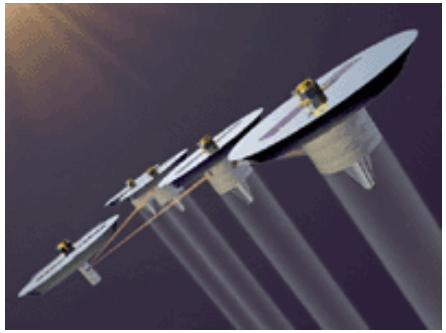
Earth Weather Prediction using Advanced Weather Satellites



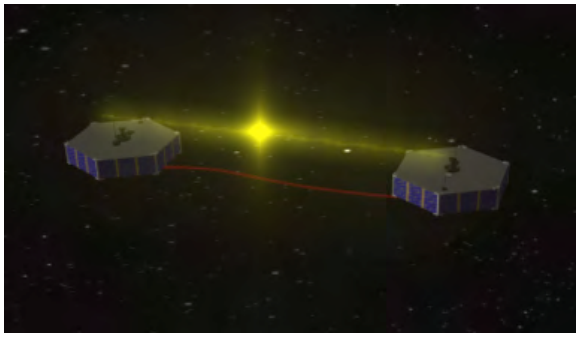
Space Weather Observations

Precise Relative Positioning

Launch Vehicle Upper Stages & Beyond-GEO applications



Formation Flying, Space Situational Awareness (SSA), Proximity Operations



Precise Position Knowledge & Control at GEO

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- FAST Act continues the ITS program, which provides for
- the research, development, and operational testing of Intelligent Transportation Systems (ITS)
  - aimed at solving congestion and safety problems,
  - improving operating efficiencies in transit and commercial vehicles, and
  - reducing the environmental impact of growing travel demand.
- GPS and V to V are critical parts
- What are status and schedule?

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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?

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

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

"hinders the full value and benefits that the UAS industry has to offer." *Brian Wynne, AUVSI president and CEO*

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GPS III
- All civil signals
- Better Clock

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)

Requesting Help

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

Example straw vote:

#1 A1
#2 P1
#3 F4
etc.

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Thanks for your help…

We will remember a founder of this Symposium, Jim Spilker at the end of our afternoon.

Without detracting from that in any way, I would like to recall another recent loss

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

- Worked at APL, Boeing, and Magnavox
- Started NavCom Technology Inc. with Jim Litton et. al.
- Fellow of ION {President in 2001)
- **<u>Inventor of the Hatch Filter</u>**
- Challenged Einstein's Theories with 1992 Book: **Escape from Einstein**

  (A Lorentzian Alternative)
- Member of the US PNTAB
- Recognized with Kepler and Thurlow Awards of ION