Assuring PNT-
A PTA program
and
Recommendations
of the US PNT Advisory Board

Brad Parkinson

Acting Chair US PNTAB

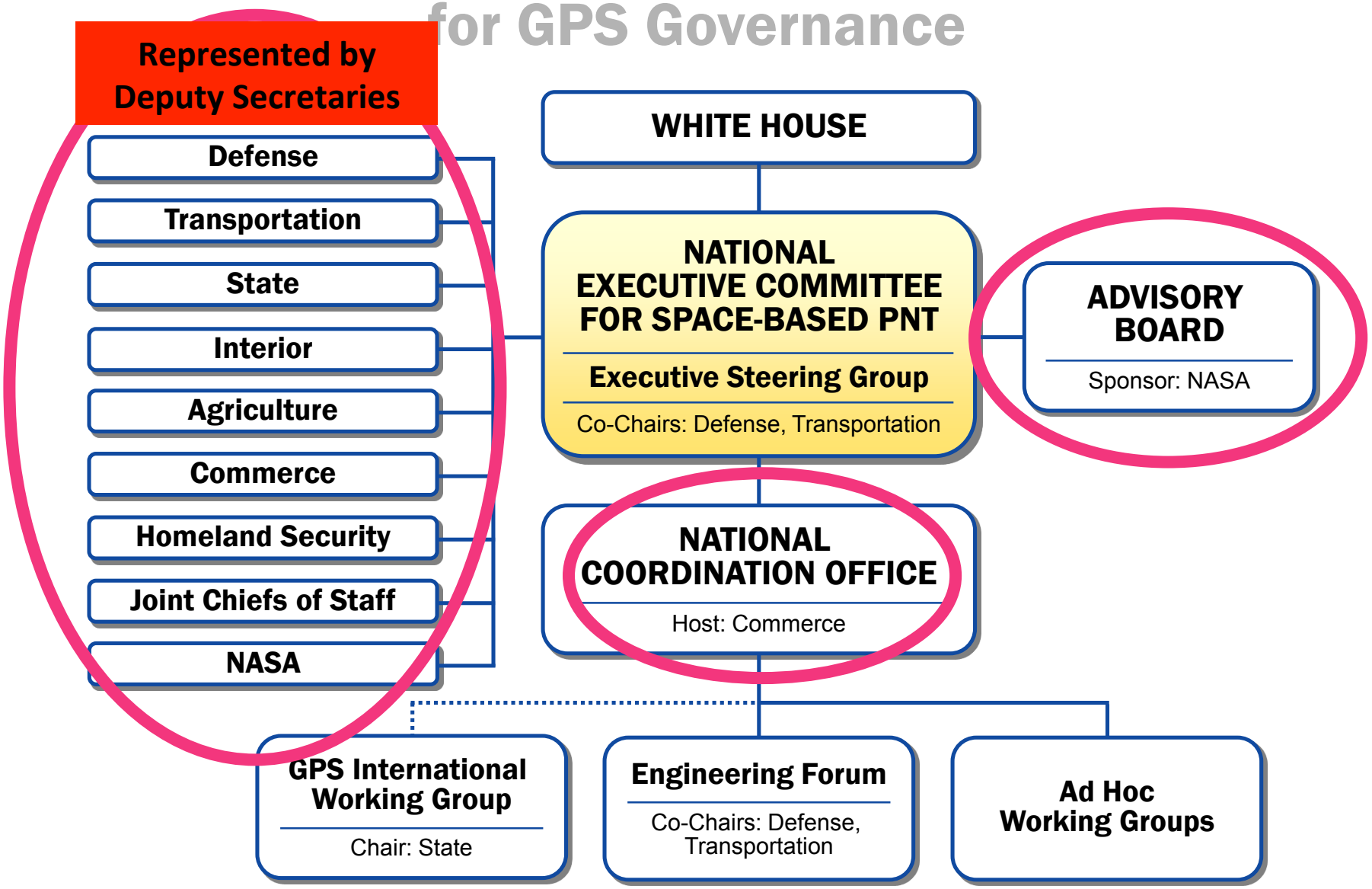
Supported by FAA, NASA, AND Aerospace Corp.

(All opinions are my own)

Outline of Talk

- Role of the PNTAB in the US Government
- The PTA - A Program to Assure PNT by *Protecting*, *Toughening* and *Augmenting* GNSS
- PNTAB recommendations – relationship to the PTA Program

U.S. Organizational Structure for GPS Governance



PNTAB Charter

The National, Space-Based, Positioning, Navigation, and Timing (PNT) Advisory Board (**PNTAB**) provides:

- ***Independent*** advice to the U.S. government on GPS-related
  - *policy,*
  - *planning,*
  - *program management, and*
  - *funding profiles*

In relation to the current state of national ***and international satellite navigation services***.

- Fundamental Purpose:

  Assured PNT **(At required availability, accuracy and integrity)**

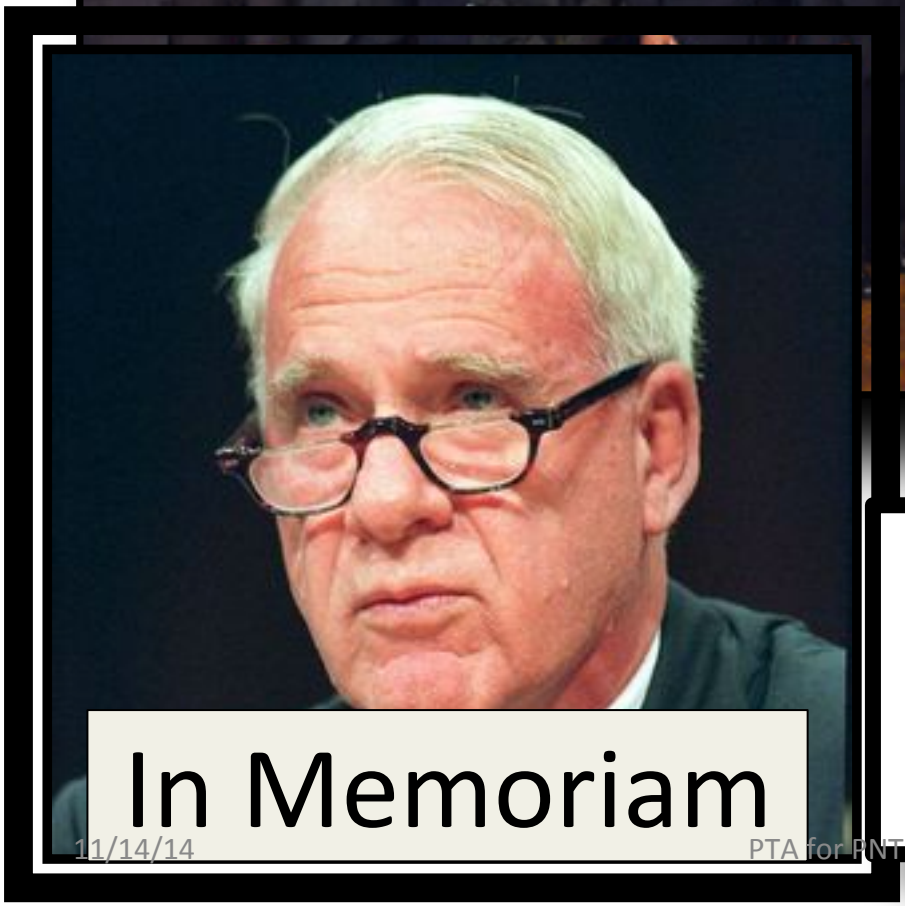
◆ PNTAB Generally meets 1 to 2 times per year.

PNTAB Advisors

- **Bradford Parkinson** (Acting Chair), Stanford University original GPS Program Director
- **Thad Allen**, Booz Allen Hamilton retired Commandant of the Coast Guard
- **Penina Axelrad**, University of Colorado, Chair of Department of Aerospace Engineering
- **John Betz**, MITRE, Former Chair Air Force Scientific Advisory Board
- **Dean Brenner**, Vice President, Government Affairs Qualcomm
- **Joseph D. Burns**, United Airlines, Former Chief Technical Pilot, United Airlines
- **Per K. Enge**, Stanford University, Head of Stanford Center for PNT
- **Martin C. Faga**, MITRE Retired CEO of Mitre
- **James E. Geringer**, ESRI Former Governor of Wyoming
- **Ronald R. Hatch**, consultant to John Deere, inventor of the GPS "Hatch" filter
- **Rajiv Khosla**, Colorado State University, Past President, International Soc. of Precision Agriculture
- **Peter Marquez**, Planetary Resources, Former White House National Security Space Policy
- **Terence J. McGurn**, private consultant, retired CIA analyst of Position, Navigation and Control
- **Timothy A. Murphy**, The Boeing Company, Technical Fellow with Boeing Commercial Airplane
- **Ruth Neilan**, Jet Propulsion Laboratory, vice chair, Global Geodetic Observing System
- **T. Russell Shields**, Ygomi, a founder of NavTeq
- **Ann Ciganer**, VP Trimble Navigation, Director of GPS Innovation Alliance
- **Gerhard Beutler**, Professor of Astronomy and Director of the Astronomical Institute, U. of Bern.
- **Elizabeth Cannon**, Canadian Aeronautics and Space Institute (Canada), President U of Calgary
- **Arve Dimmen**, Division Director Maritime Safety Norwegian Coastal Administration (Norway)
- **Matt Higgins**, President International GNSS Society (Australia)
- **Hiroshi Nishiguchi**, Chairman Japan GPS Council (Japan)
- **Rafaat M. Rashad**, Chairman Arab Institute of Navigation (Egypt)

◆ We take great pride in the inclusion of International members at all meetings

The PNT Advisory Board 2013-14



In Memoriam

Dr. James Schlesinger passed away on March 27, 2014, while serving his fourth term as chairman of the National Space-Based PNT Advisory Board.

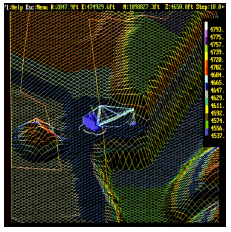
Good News: World-wide dependency on GNSS – *PNT Taken for Granted*

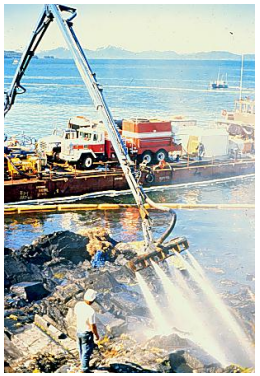
- Military
- Civil
  - Transportation
    - Aviation
    - Automobile
    - Maritime
    - Rail Control
  - Public Services
  - Timing & Frequency
  - Surveying
  - Surveillance
  - Machine Control
  - Other

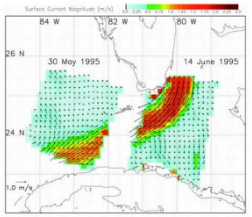










Progress in Quantifying GNSS Benefits: Economic Study under US PNTAB Now being Refined

	Annual GPS Equipment Spending ($ billion)	Estimated Annual Benefits ($ billion)
Precision agriculture (crop farming)	$0.5	$19.9 - $33.2
Engineering Construction (heavy & civil and surveying/mapping)	$1.1	$9.2 - $23.0
Transportation (commercial surface transportation)	$3.2	$10.3 - $15.1
Sub-total (3 industries examined)	$4.8	$39.4 - $71.3
Other commercial GPS users	$3.5	$28.2 - $51.1
Total commercial GPS users in the U.S.	**$8.3**	**$67.6 - $122.4**

Sou

- Over $65B In Annual Benefits in identified Commercial Areas

Conclusion :

PNT/GPS/(GNSS) – The "*Stealth*" Utility - A powerful, worldwide, enabler for Productivity and Safety

So what is the Problem?

- Some have publically stated: "GPS is much too vulnerable, we must ***replace*** it with new Inertials and Chip Scale Atomic Clocks"
- Indeed, GPS has a very weak signal, and also depends on Line of Sight to at least 4 satellites,

  But…
- **IMHO – *Better Statement* – the "PTA" solution:**

  "We must ***P***rotect, ***T***oughen, and ***A***ugment GPS/GNSS to ensure that it meets User's PNT needs"

Reminder: Prerequisites for GPS/GNSS contribution to **assured world-wide PNT** –

Clear and truthful Ranging to ≥ 4 Satellites

- Must have Line of Sight to GPS/ GNSS
  - **For sky-impaired, need densification**
    (GPS + Galileo + GLONASS + Beidou)
- Must be able to accurately measure range
  - **Overcome local interference**
- Must insure ***Integrity*** of received signals
  - **Self- integrity (RAIM/ARAIM)**
  - **External rapid-checking (e.g. WAAS, Egnos, MSAS)**
  - **+ (potentially) GDGPS**

"…it is recommended that a 30+ GPS satellite constellation be geometrically optimized"

"… eliminate Selective Availability (S/A) capabilities from GPS III"

"…Begin transmitting navigation message on L2C"

"…it is essential to implement laser retroreflectors on GPS III. "

Highlights in **Red** are PNTAB recommendations or Actions
Green – Done
Orange - Underway

PNTAB Actions to Assure PNT for all users

- **First** – Increase National Awareness of Value of GPS (and GNSS) and System Vulnerabilities

PNTAB is sponsoring "Economic Study of Value"

- **Initial result: GPS provides over $60B/yr of Benefits**
- **Refinement underway**

"Develop a Formal National Threat Model for PNT Applications in Critical Infrastructure:

The DoD routinely develops and updates threat models to GPS defense capabilities, and also prioritizes countermeasures to these threats. However, **public safety** GPS stakeholders, and other critical sectors, **do not have a validated threat model**."

- **Second** – Implement specific PTA steps to:
  - **Protect** Clear and Truthful Reception
  - **Toughen User's Receivers**
  - **Augment** or substitute PNT sources

Highlights in **Red** are PNTAB recommendations or Actions

Green – Done

Orange - Underway

Assured Availability of PNT - "PTA"

Three Action Areas:

PTA – **P**rotect, **T**oughen, **A**ugment

- ***P*rotect the Clear & Truthful Signal**-7 steps
  - **Pre-actions – even before interference occurs - Legal/Law Enforcement/FCC:**
    - **Protect Spectrum/Enact strong Penalties/suppress Jammer sales**
  - **Re-actions when interference/spoofing occurs –**
    - **Quick Knowledge of Jamming Area/Pinpoint Location/ Apprehend Perpetrator/Prosecute as Appropriate**

Selected Actions to ***P***rotect

Pre1. *Spectrum Protection*
- Avoid the "Legal Jammer"

- **Protect the bands adjacent to GNSS as "Quiet" neighborhoods**

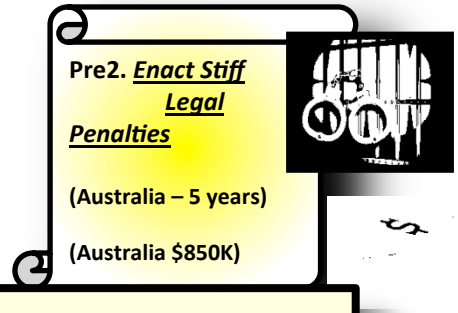
"Prevent the Proliferation of Licensed Emitters in GPS Frequency Bands: European Proposals by CEPT would license certain terrestrial transmitters, or "pseudolites," to operate in the primary GPS band (also known as GPS L1). This frequency band is designated as a Radionavigation Satellite Service (RNSS) and should be very carefully regulated."

- **Identify GPS as Critical Infrastructure** – identify and empower lead federal Official

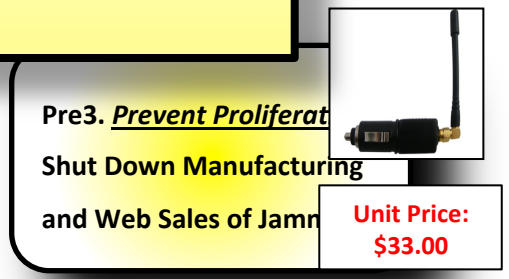
"Formally Designate GPS as a Critical Infrastructure Sector for the United States: Virtually every DHS-designated critical infrastructure sector is dependent on access to GPS for positioning, timing, or both. Specifically, these PNT services are pervasive elements in 14 of 16 critical U.S. sectors."

Selected Actions to *Protect*

- **Work with Lawmakers to increase legal penalties for interference**



"Shutting Down and Prosecuting Interferers – Legal and Law Enforcement actions. The National Executive Committee should examine whether or not they should sponsor Legislation in Congress that addresses interference to GPS that provides substantial fines and jail time for both possession and use of GPS jammers. "



Highlights in **Red** are PNTAB recommendations or Actions

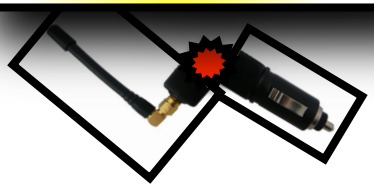
Assured Availability of PNT - "PTA"

Protect the Clear and Truthful Signal– The *Reactions* - "DIEP"

Re1. *Detection* – Rapid Location of Jammed Receivers

Re2. *Identification* & Location of Jammer within minutes

Re3. Physical *Elimination* of the Jammer



Re4. *Prosecution* of the Offender

Work with Communications and Enforcement to improve timeliness and accuracy of interference identification

(e.g. crowdsourcing, every cell phone a detector?)

"Develop means to detect, measure, locate, and mitigate radio interference or jamming in support of the National Security Infrastructure."

Assured Availability of PNT - "PTA"

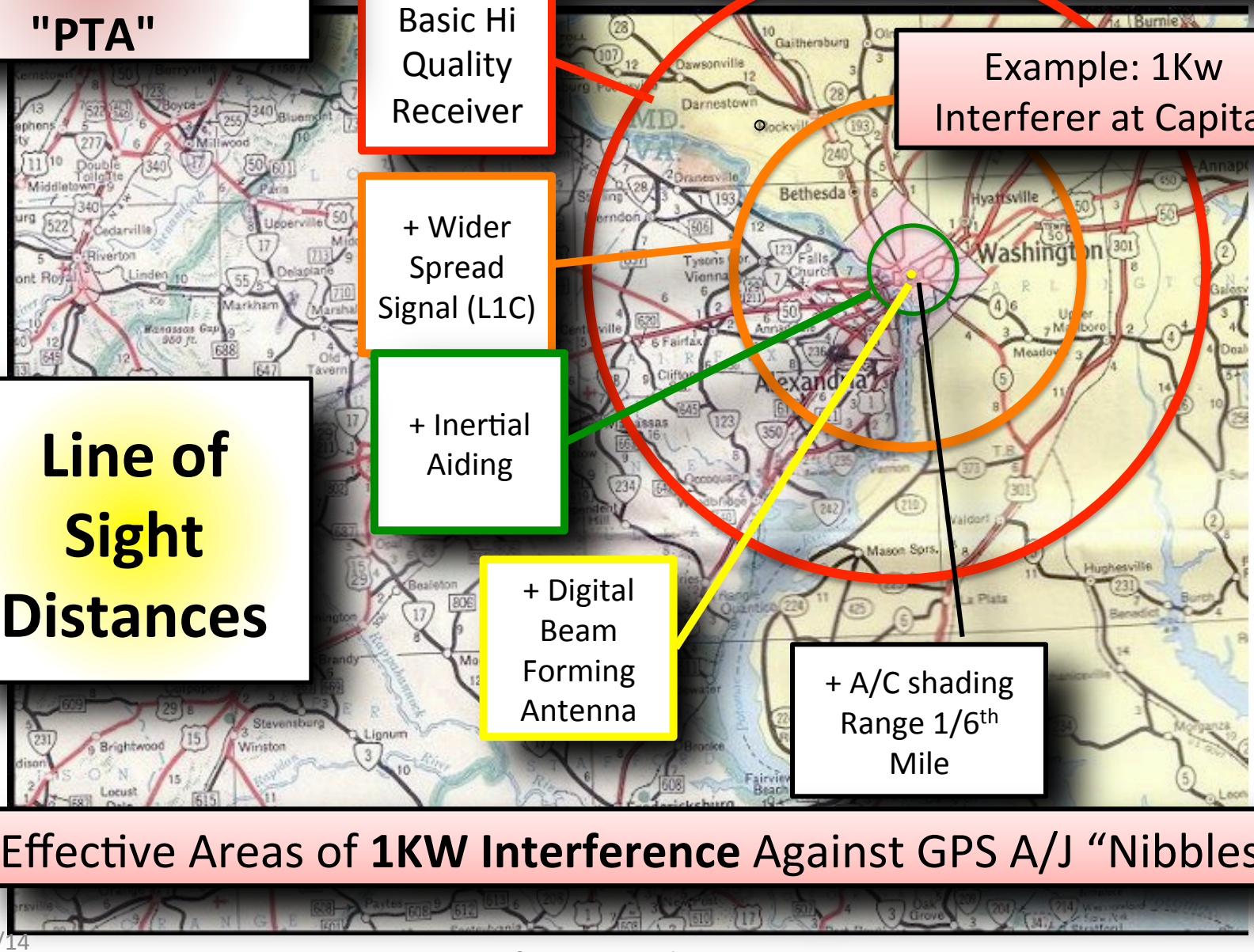
Three Action Areas:

PTA – **P**rotect, **T**oughen, **A**ugment

- ***T*oughen Users' Receivers to use GNSS**
  - **Increase Jam resistance – use well established techniques**
  - **Diversify -** *All GNSS signal* receivers (with vector feature)

Assured Availability of PNT "PTA"

2nd Action Area: Toughening GPS Receivers



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

Selected Actions to *T*oughen

- Develop Industry (ICAO?/RTCA/RTCM) standards for improving Interference resistance
  - Deep Inertial integration
  - Directional antennas
  - Vector Receivers (All GNSSs)
- Encourage users to move to tougher receivers

"Government should foster and help to stimulate Manufacturers to speed up the development and offering of interference resistant GPS receivers, especially for safety-of-life applications such as commercial air and maritime."

Assured Availability of PNT - "PTA"

Three Action Areas:

PTA – **P**rotect, **T**oughen, **A**ugment

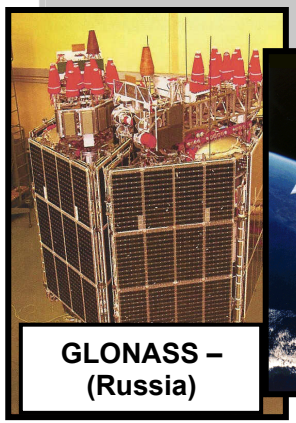
- ***A*ugment or substitute PNT sources**
  - **– Densify and Diversify satellites –**

    Signals/constellations
    - **Worldwide Integrity Monitoring**
  - **– Use Complementary PNT Sources –**

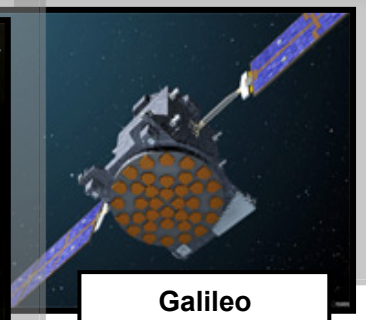
    e.g. DME, eLoran

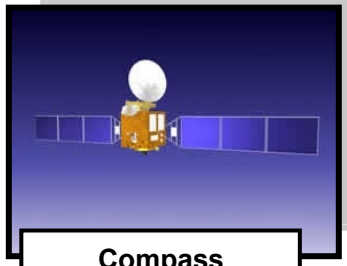
Assured Availability of PNT - "PTA"

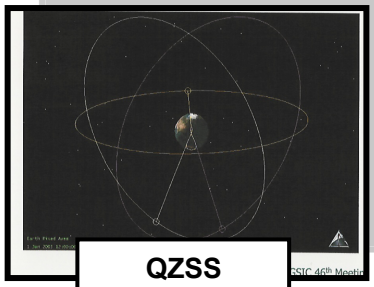
Augment or substitute PNT Sources


GLONASS – (Russia)


GPS (USA)


Galileo (European)


Compass *(Beidou* China)


QZSS (Japan)

GNSS Community – both Toughen and Augment PNT

Effectiveness driven by # of operational constellations, constellation size, *AND their Integrity*

Assured Availability of PNT - "PTA"

Augment or substitute PNT Sources

Augmentation using *all GNSS* promotes:

- Diversification (for GPS signal denied) and
- Densification (for sky-impaired)

- **Use of all GNSS must address integrity**
- **Note: Also improves GPS anti-jam (Toughens)**
- **Enables more capable ARAIM**

  (Advanced Receiver Autonomous Integrity Monitoring)

- **Best Technique: Interchangeability**

  (Any 4 will do – CARS – *C*ross *A*ugmentation *R*eference *S*ystem)

Need authorization to use Galileo/et.al.? in US

Emphasizing – *For many uses* *(e.g.* ***Aircraft and Safety of Life)***

Availability and Accuracy of the signals is insufficient

Integrity is also required for ***adoption***

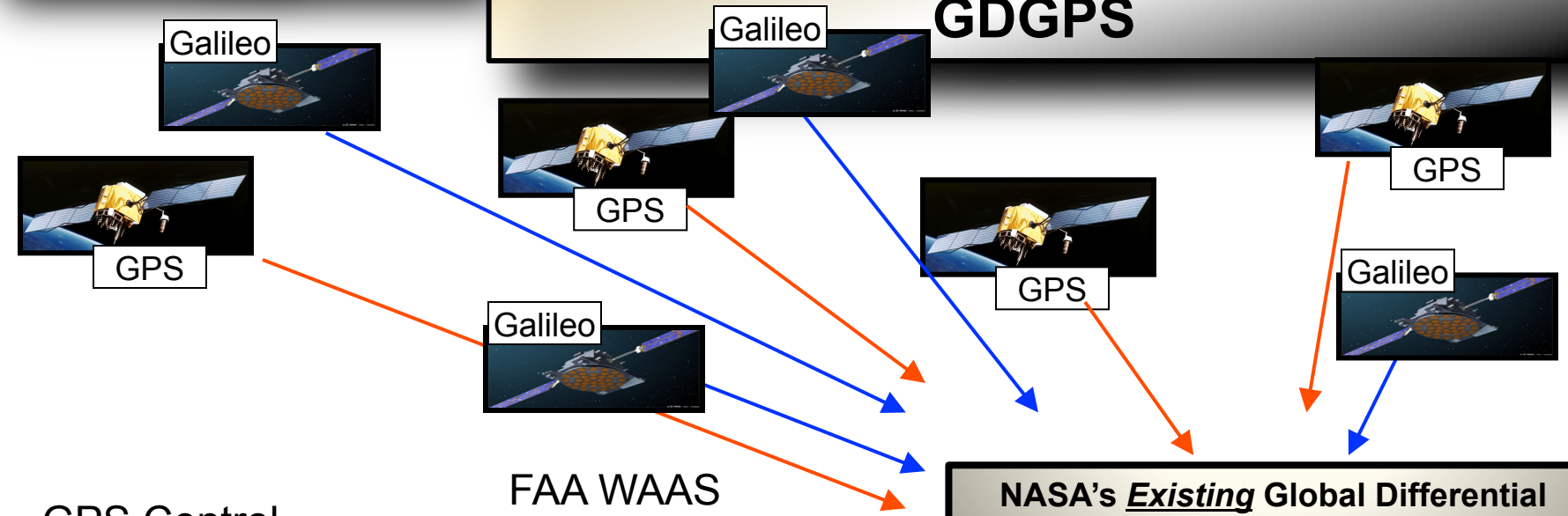
Required Integrity:

- **Probability that expected accuracy is not exceeded**
  - **[Example – Cat III Landing -No Hazardous or misleading information > 10^{-7}]**

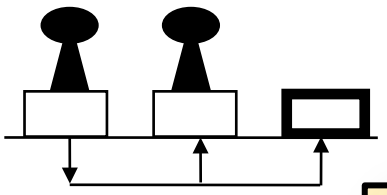
– "Continue to implement ARAIM & inertial for Integrity (+WAAS/EGNOS/MSAS + …)"

Assured Availability of PNT "PTA"

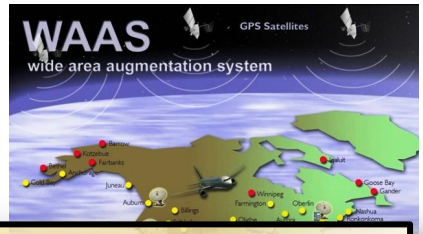
Augment
Monitoring All GNSS Civil Signals for Integrity and Accuracy with NASA's GDGPS



GPS Control Segment – **Military Signals Only**



FAA WAAS
North America Location
GPS L1 C/A Civil Signals Only



In Europe: Plus EGNOS
GPS L1 C/A and Galileo

NASA's *Existing* Global Differential GPS (GDGPS) System
All GPS Civil Signals Worldwide
Expandable to All GNSS

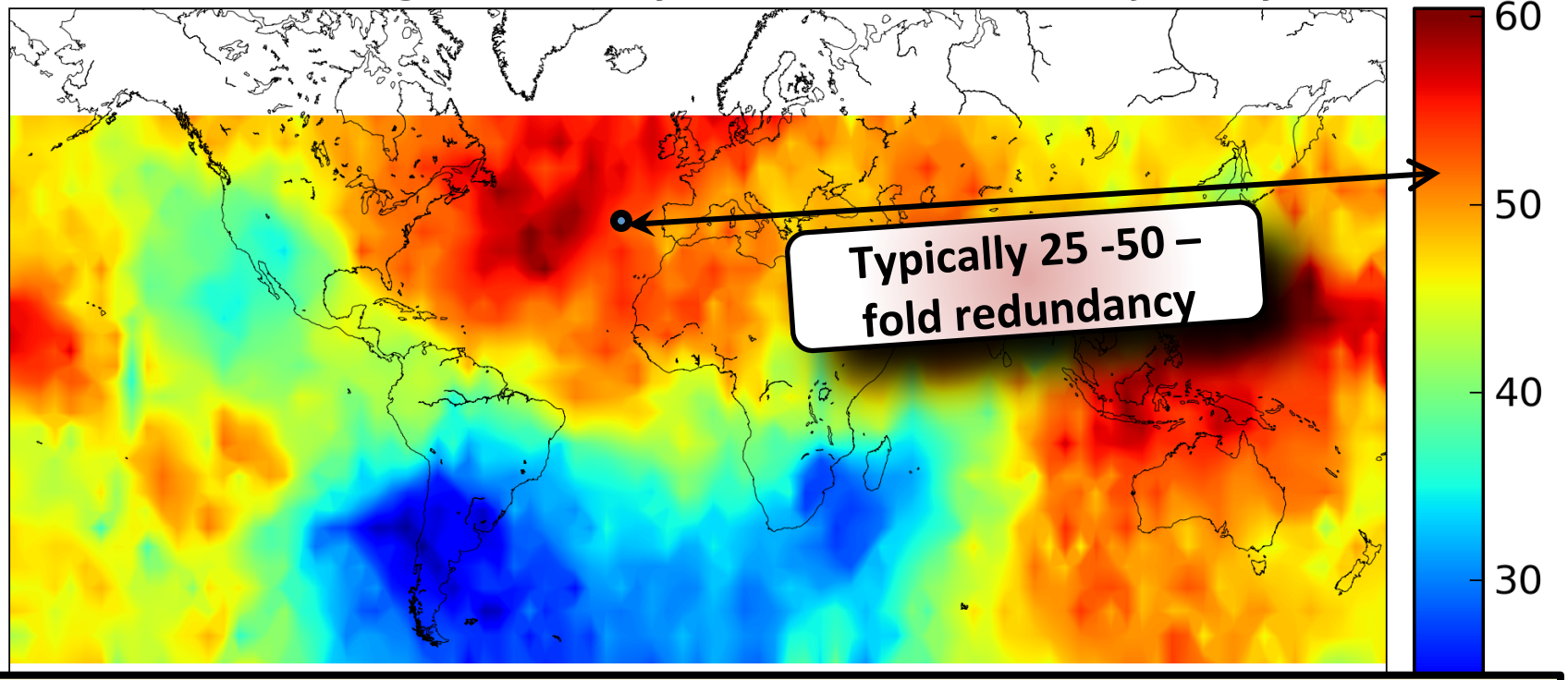
Real-Time Tracking Network
(200+ sites)

BUT: GDGPS is not currently a direct part of the GPS Control System

Assuring Integrity of the GDGPS Integrity System

Minimum **Simultaneous Tracking Redundancy for satellites located over various points (i.e. sub-nadir)**

GPS Satellite Tracking Redundancy with GDGPS Network (January 2014)



"Recommend GDGPS be considered for near-real time, worldwide Integrity Monitoring"

Assured Availability of PNT - "PTA"

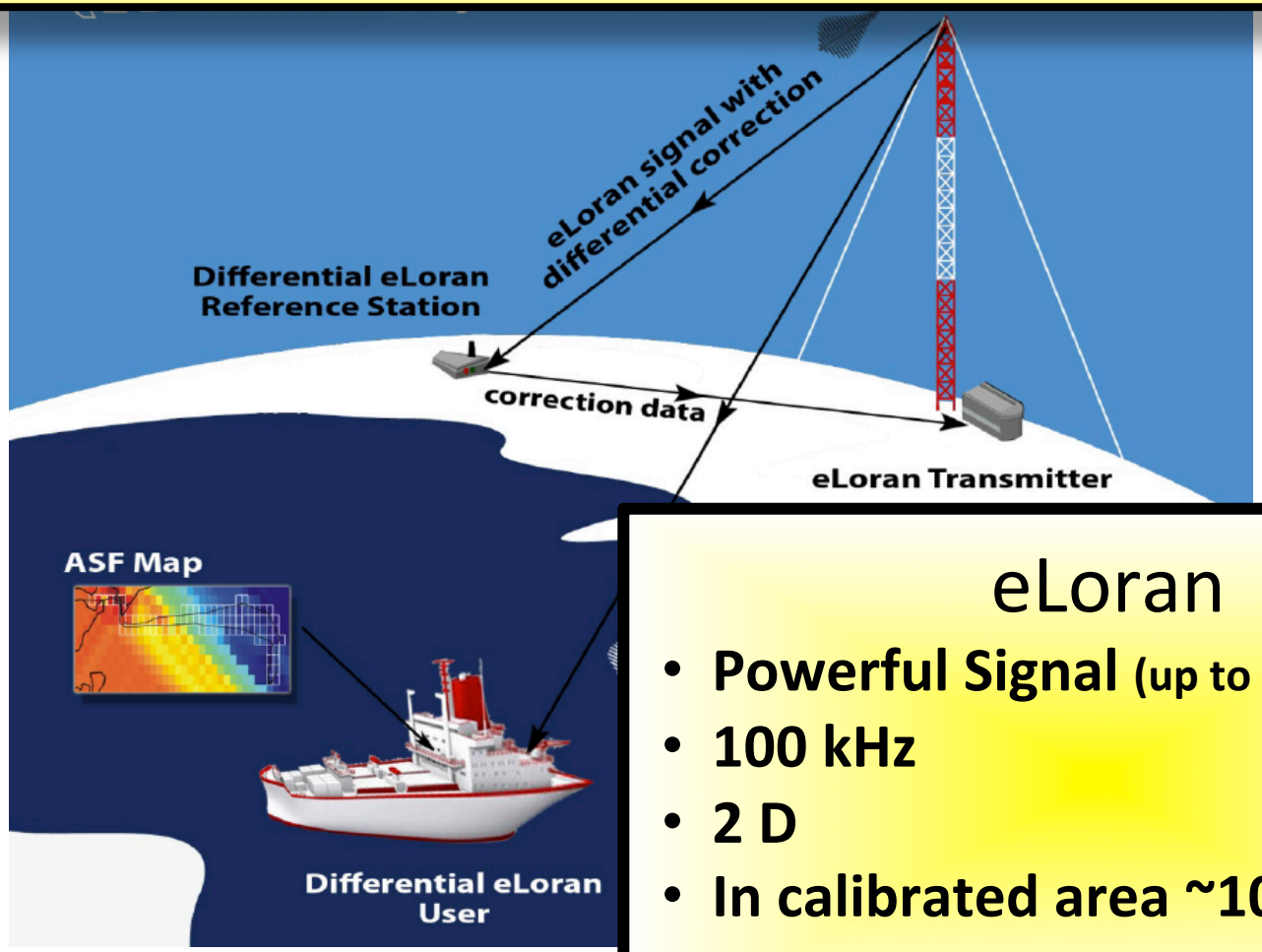
Augment or substitute PNT Sources

- **Ground Augmentations**
  - **Pseudolites *outside* GNSS frequencies for special, fixed situations**
- **Backup PNT Sources**

- **"We support the FAA's efforts to provide Alternate PNT options that can provide a robust backup to GPS and deter malicious interference."**

- **"We strongly recommend that the previously announced decision (to deploy eLoran as the primary Alternate PNT) should be reconfirmed and quickly implemented."**

Augment For Ground/Maritime Users



eLoran

- **Powerful Signal (up to 100kW)**
- **100 kHz**
- **2 D**
- **In calibrated area ~10m accuracy**

Strong IAT Recommendation (2006): Finish eLoran = "no cost solution"

- **US GPS PNT Advisory Board (2008):**
  - **Unanimous Recommendation – deploy eLoran**
- **PNT EXCOM, DOT and DHS supported this recommendation**
  - **Lack of appropriate funding forced cancellation of eLoran and dismantling of existing LORAN stations**
- **US Congress now appears to be taking action**
  - **Perception of need is increasing**

Who is responsible for **P**rotecting, **T**oughening and **A**ugmenting for assured ***PNT*** ?

To My Knowledge:

- Parts of PTA are being pursued (Need for clearer responsibility?)
- No ***single*** entity *(in the US – Europe?)* is identified that has the knowledge, breadth, will, and resources…

- Perhaps an International Focus Group
  (A separate working Group in ICG ?– Or assign to an existing Groups?)

Future Topics for PNTAB Consideration

(Next meeting in December, 2014)

- Anti-spoofing authentication codes
- Tracking the progress of eLoran deployment
- Updating the PNTAB Economic Benefits study
- Status of FCC Licensing use of non-US GNSS
- Explore state-of-the-art in commercially available Receiver toughening

Conclusion…

GNSS is the backbone of "Assured PNT"

[e.g. Availability, Accuracy, & Integrity]

- but -

To continue the PNT Revolution for all users,

- Let's Accelerate and Expand *PTA:*
  - **P**rotect – Legal and Law enforcement
  - **T**oughen – Maximize affordable Jam resistance
  - **A**ugment – Use all available sources of PNT

Thank You