

PNT Challenges: Space Weather and a Whole Lot More

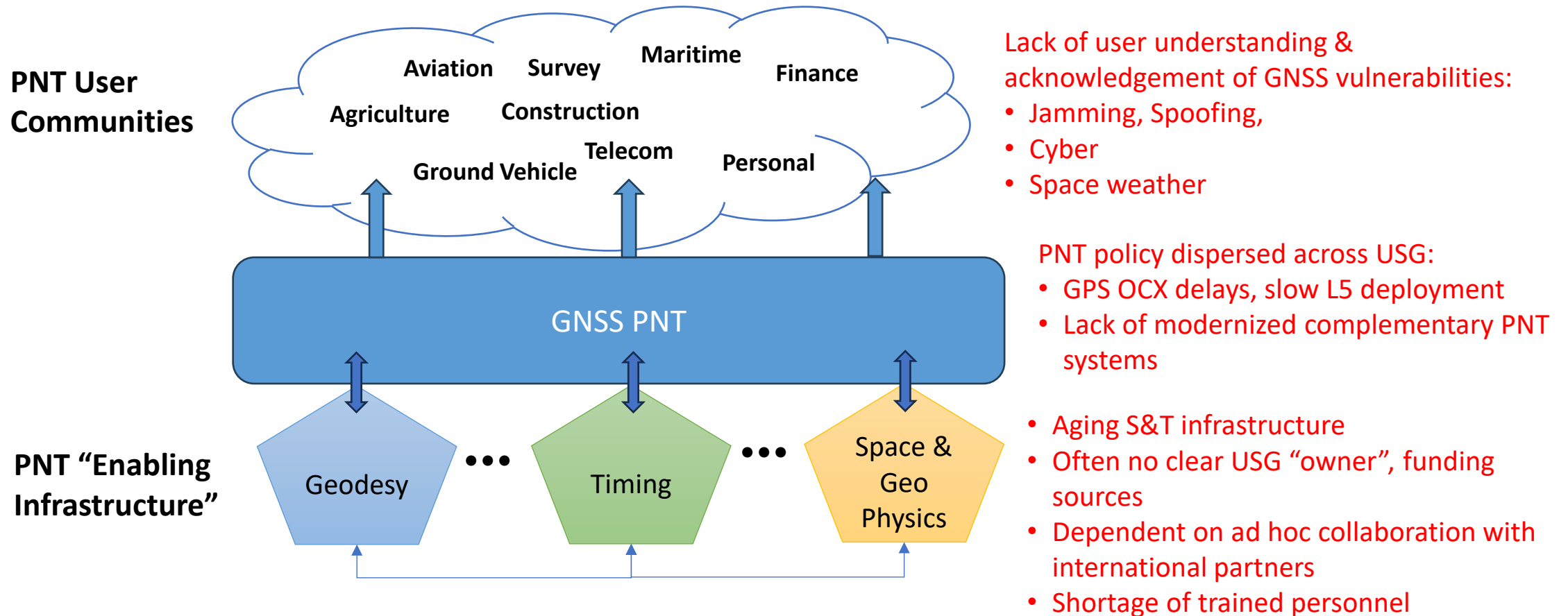
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NAS Space Weather Roundtable
February 5, 2025

Disclaimer:

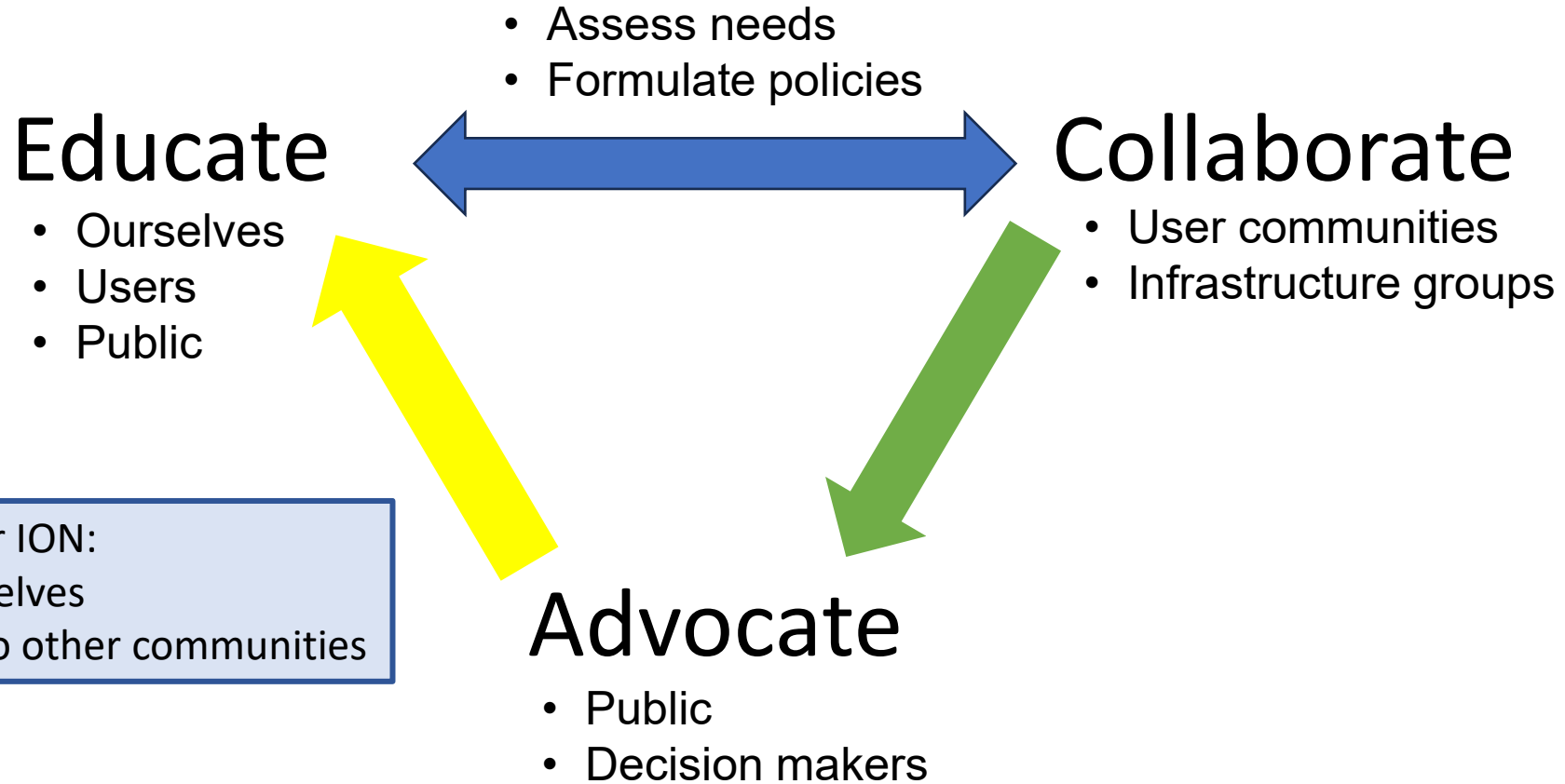
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BLUF: GPS/GNSS is Critically Threatened



There is a need for collaboration to advocate for PNT and enabling infrastructure

ION PNT Advocacy Initiative



Beginning steps for ION:

1. Educating ourselves
2. Reaching out to other communities

PNT Challenges: Overview

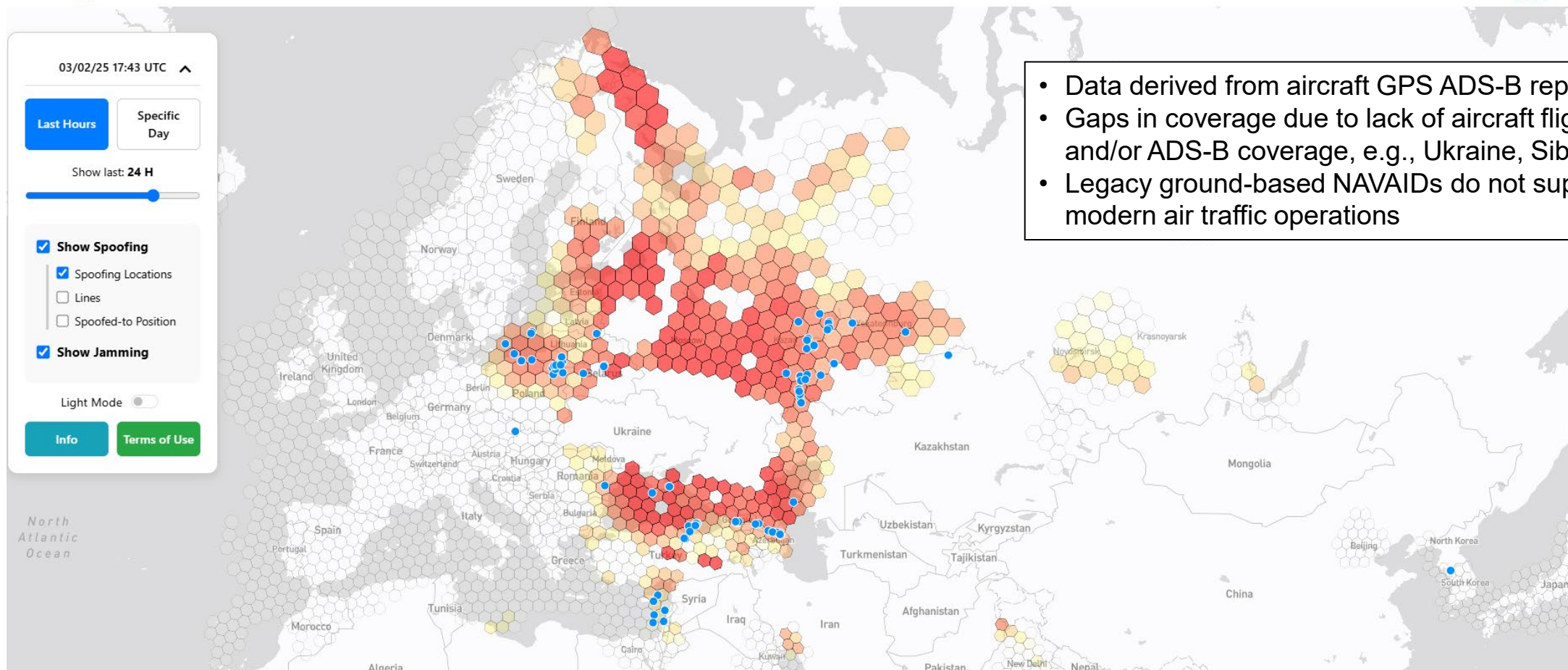
- GPS/GNSS PNT vital to national infrastructure, economy and public safety
- GNSS are vulnerable to:
 - Radio frequency interference: jamming & spoofing
 - Space weather
 - Underlying infrastructure is fragile
 - Complacency by governments and users
- Need to Protect, Toughen and Augment (PTA) GPS/GNSS
 - Complementary PNT sources are especially important to address space weather effects to GNSS
- Outreach, Education & Collaboration for PNT advocacy is needed

} Topics for remainder
of presentation

GNSS Jamming & Spoofing Now Widespread

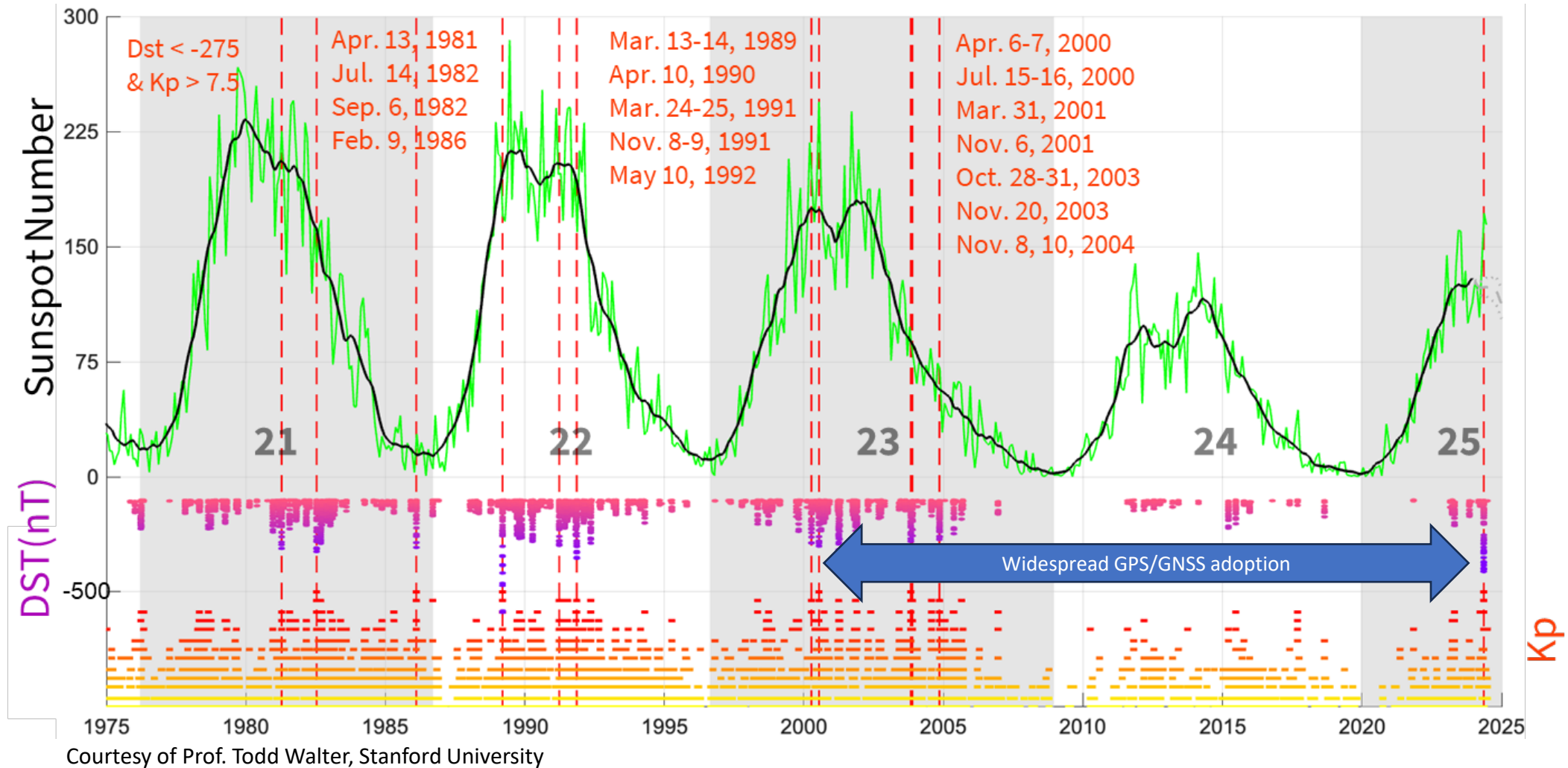


Live GPS Spoofing and Jamming Tracker Map



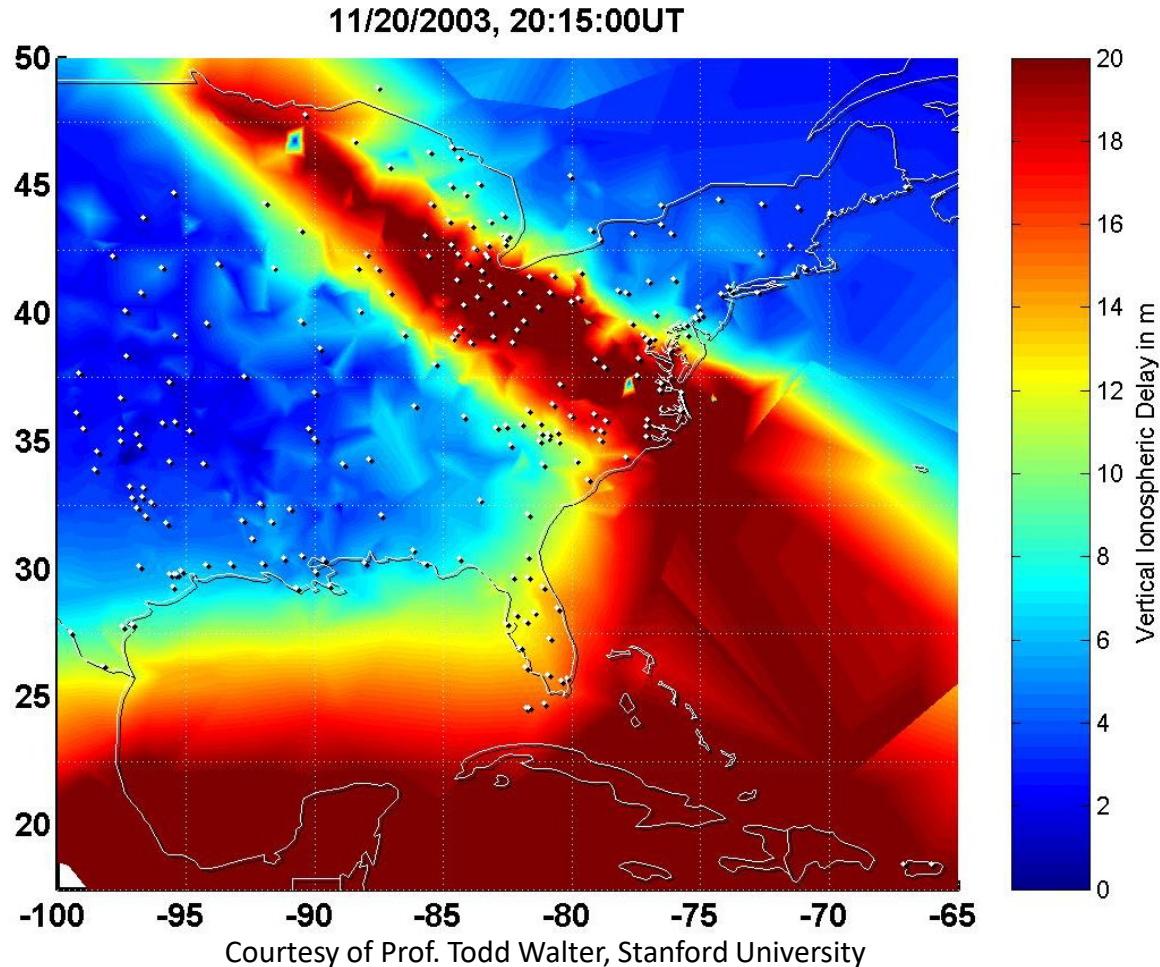
- Data derived from aircraft GPS ADS-B reports
- Gaps in coverage due to lack of aircraft flights and/or ADS-B coverage, e.g., Ukraine, Siberia
- Legacy ground-based NAVAIDs do not support modern air traffic operations

Recent Solar Cycles



Ionospheric Effects on GNSS Summary

Example Disturbed Ionosphere



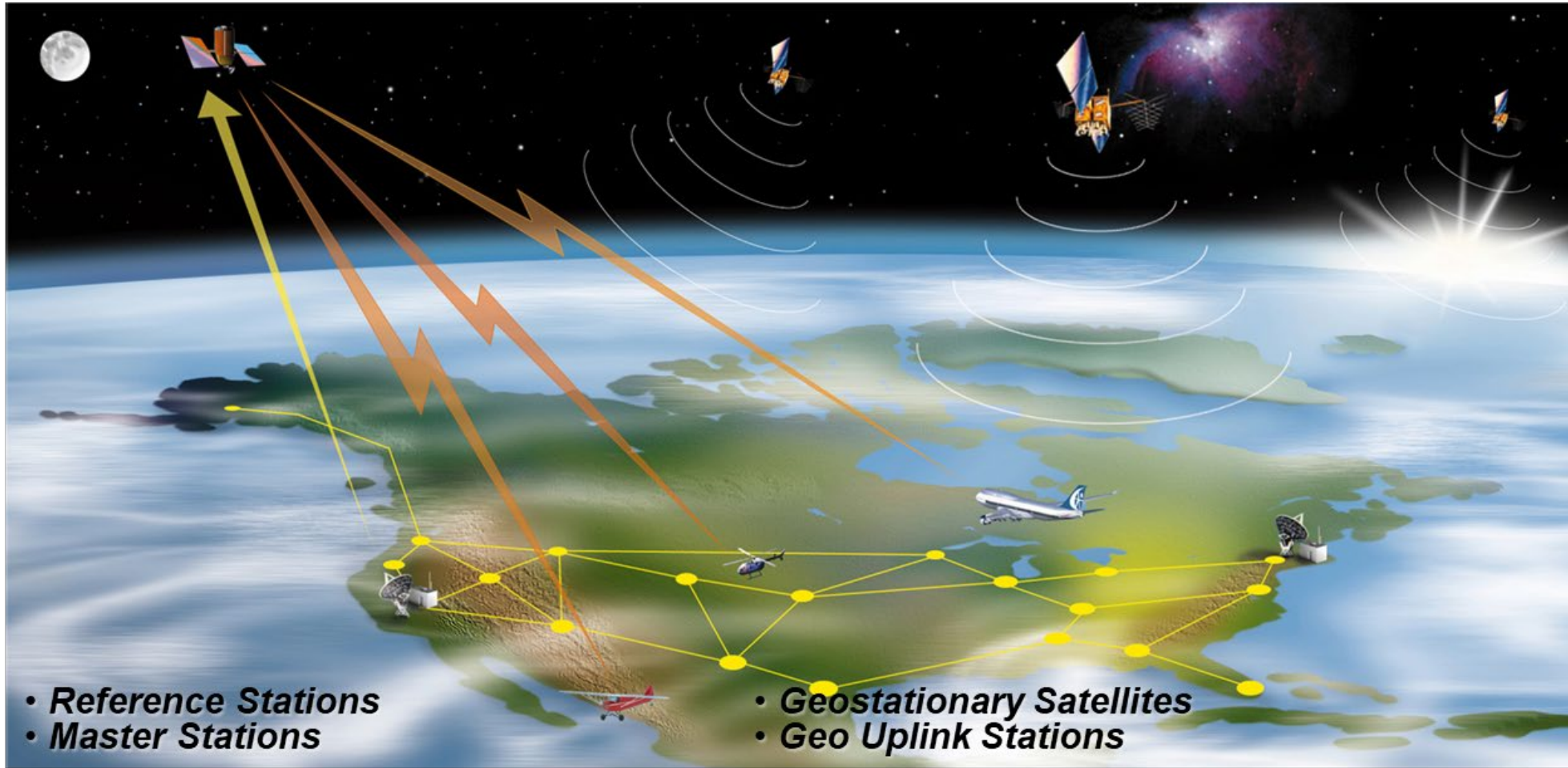
- Single frequency iono compensation models unreliable in disturbed conditions
- Spatial and temporal gradients affect augmentation systems
 - Local differential (e.g.: Ground Based Augmentation System-GBAS)
 - Regional differential (e.g.: Space Based Augmentation System-SBAS)
- Dual frequency GNSS much more robust but large gradients can still lead to ranging errors due to extreme refraction effects
- Scintillation can lead to loss of signal tracking – affecting continuity

Parameters Used to Evaluate PNT Performance for Safety of Life Applications

- **Accuracy:** characterizes typical system behavior in the presence of nominal errors
- **Integrity:** characterizes risk that abnormal behavior affects the system
 - Integrity risk
 - Maximum tolerable error
 - Time to alert (TTA)
- **Continuity:** risk of losing the service unexpectedly
- **Availability:** fraction of time that one has the accuracy, integrity, and continuity required to perform the desired operation
- **Coverage:** Geographic area where PNT service is available

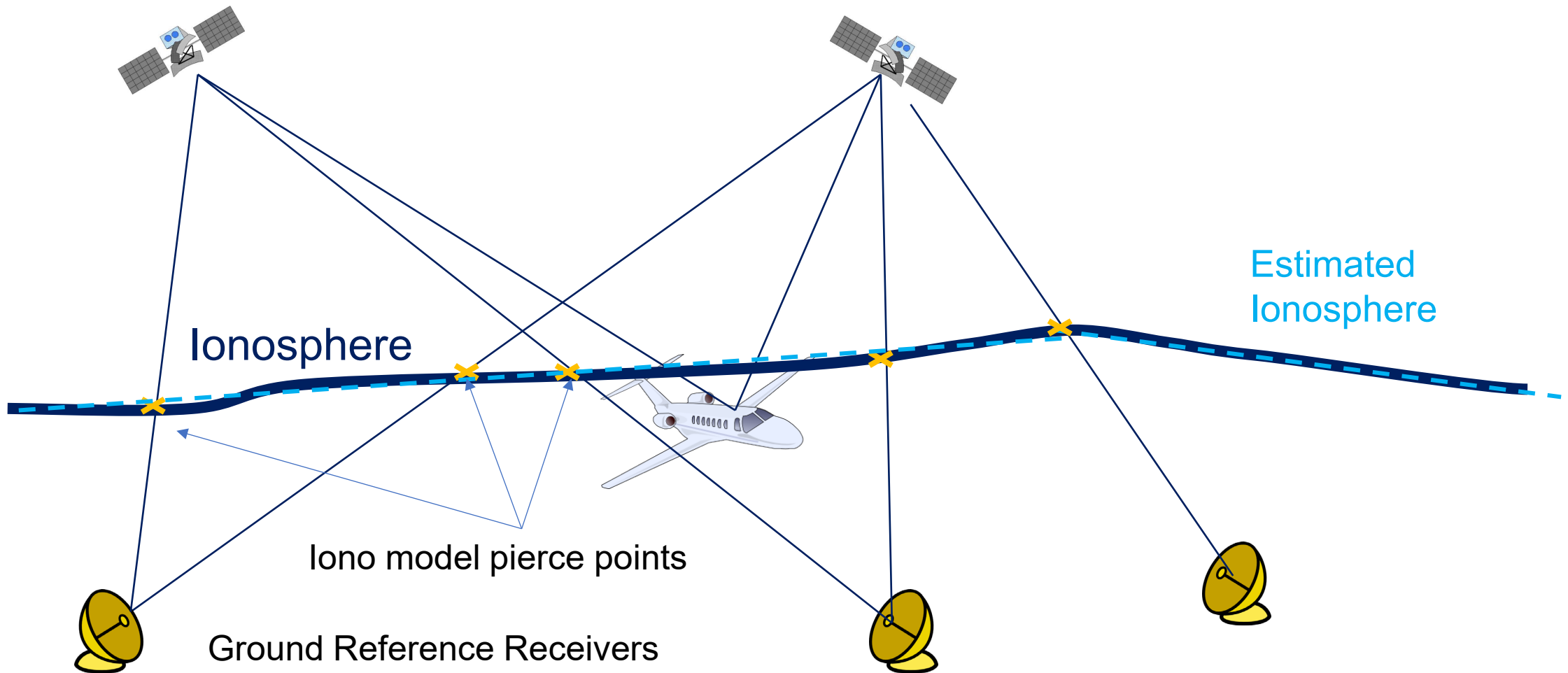
Space weather can impact all of these parameters for GNSS

Space Based Augmentation System (SBAS)

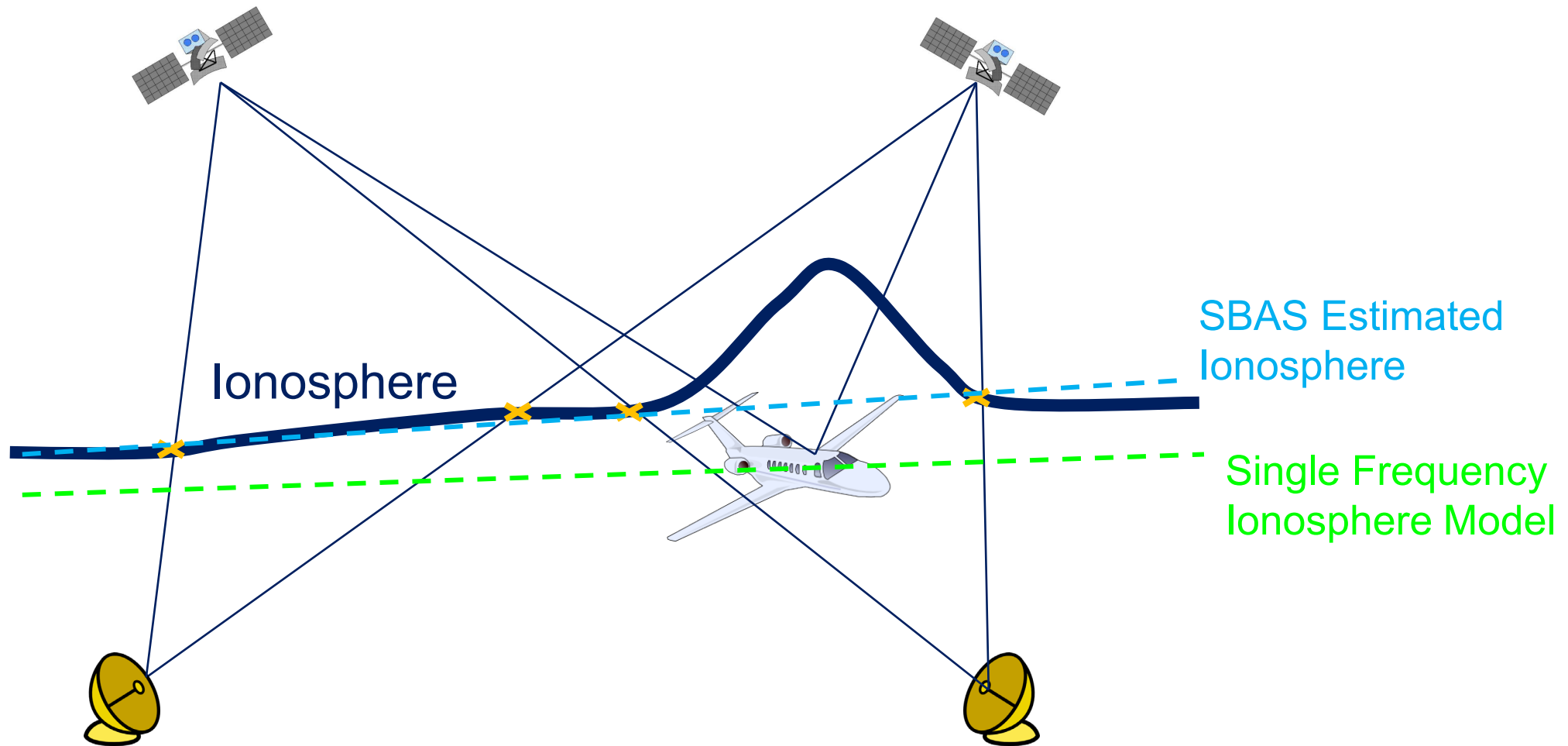


Courtesy of FAA

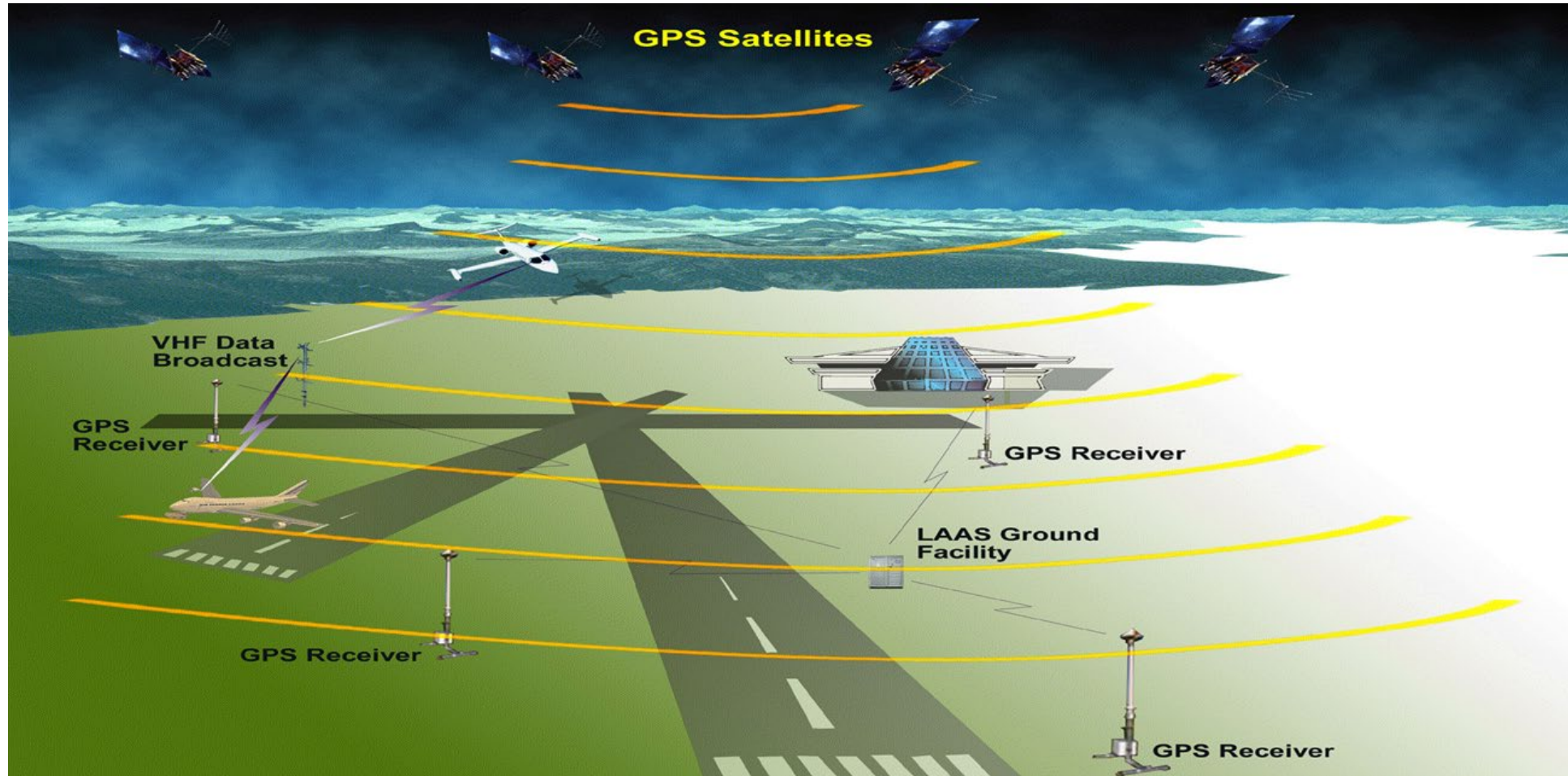
SBAS Models Ionospheric Delay on a Continental Scale



Disturbed Ionosphere Affects SBAS & Standalone Single Frequency Users

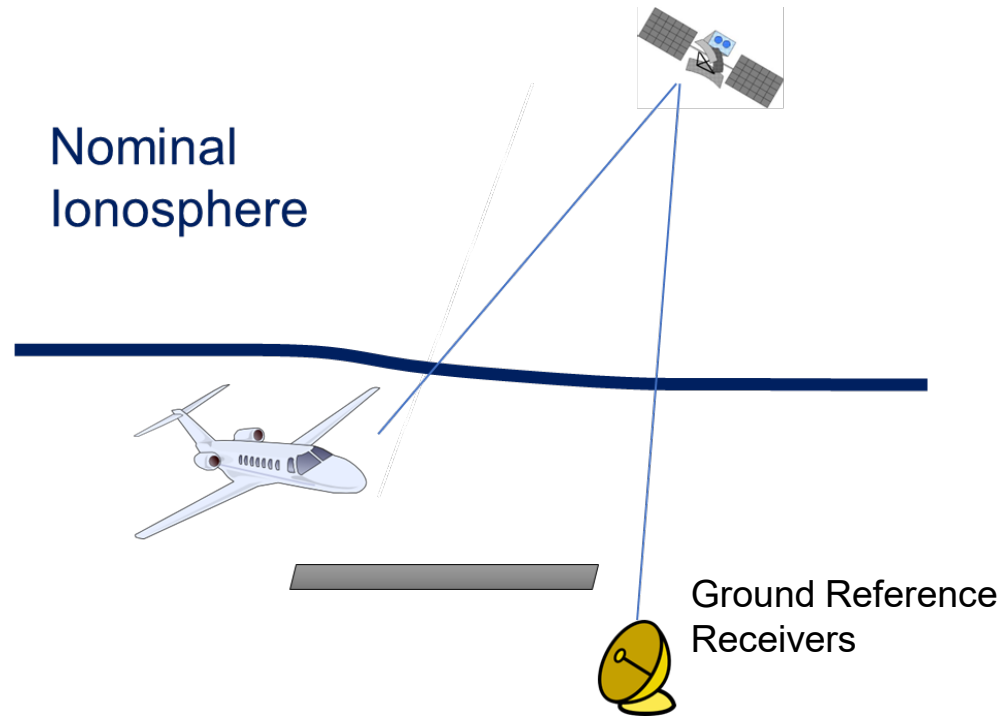


Ground Based Augmentation System (GBAS)

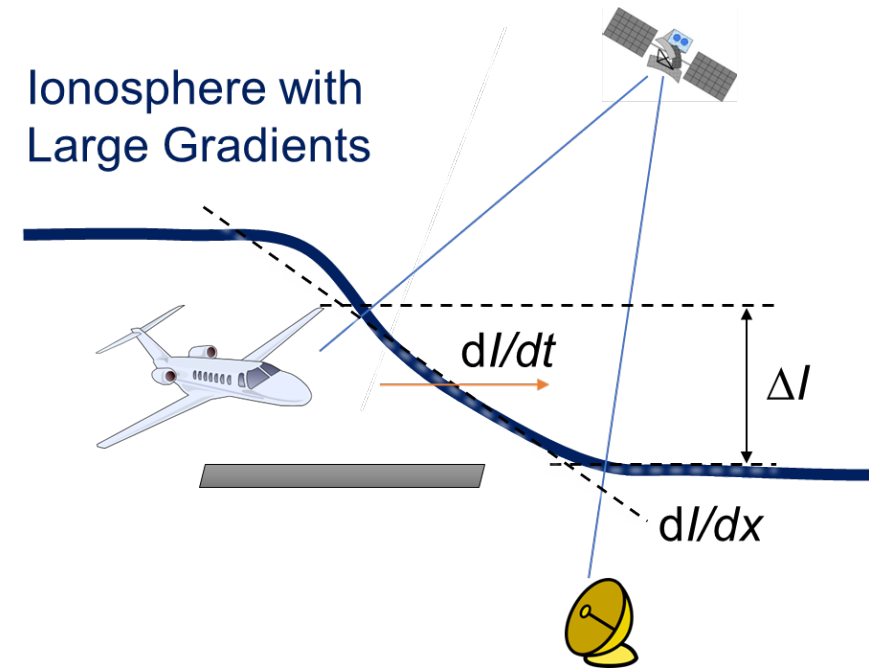


Courtesy of FAA

Local DGNSS Ionospheric Effects



- Air-ground ionosphere error approximately cancels for GBAS



- Air-ground ionosphere error, ΔI , is large and challenging to reliably detect
- Spatial & temporal gradients induce errors in single frequency carrier-smoothed code filters
- Coverage area for high accuracy & integrity shrinks

High-level PNT Recommendations for Aviation

