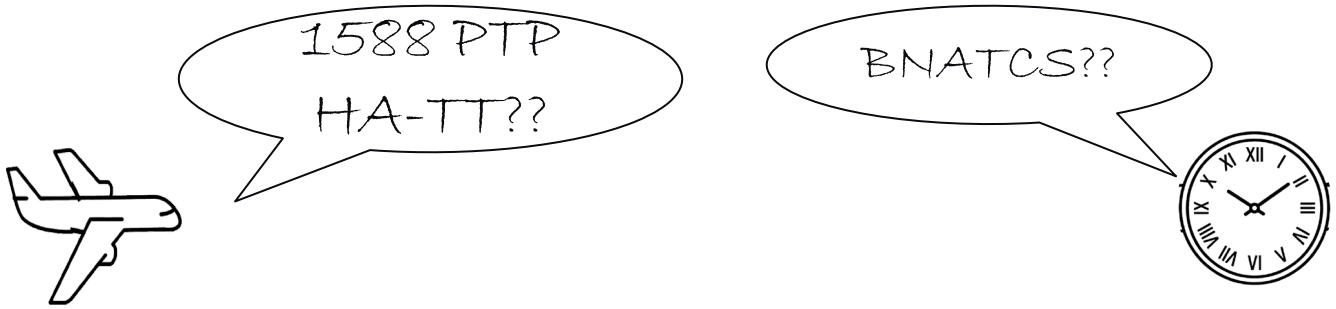


Time Flies – The Role of Precise Frequency and Time in Air Traffic Control

MICROCHIP

A Leading Provider of Smart, Connected and Secure Embedded Control Solutions

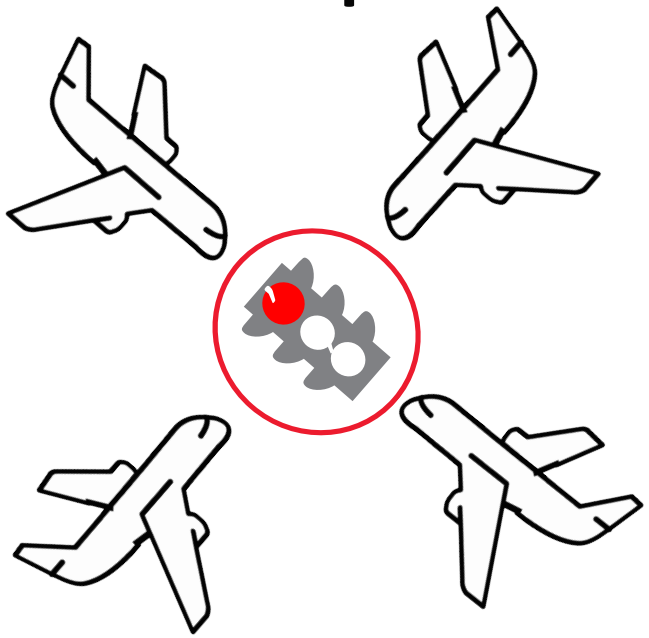
SMART | CONNECTED | SECURE

David Chandler, Senior Product Line Manager

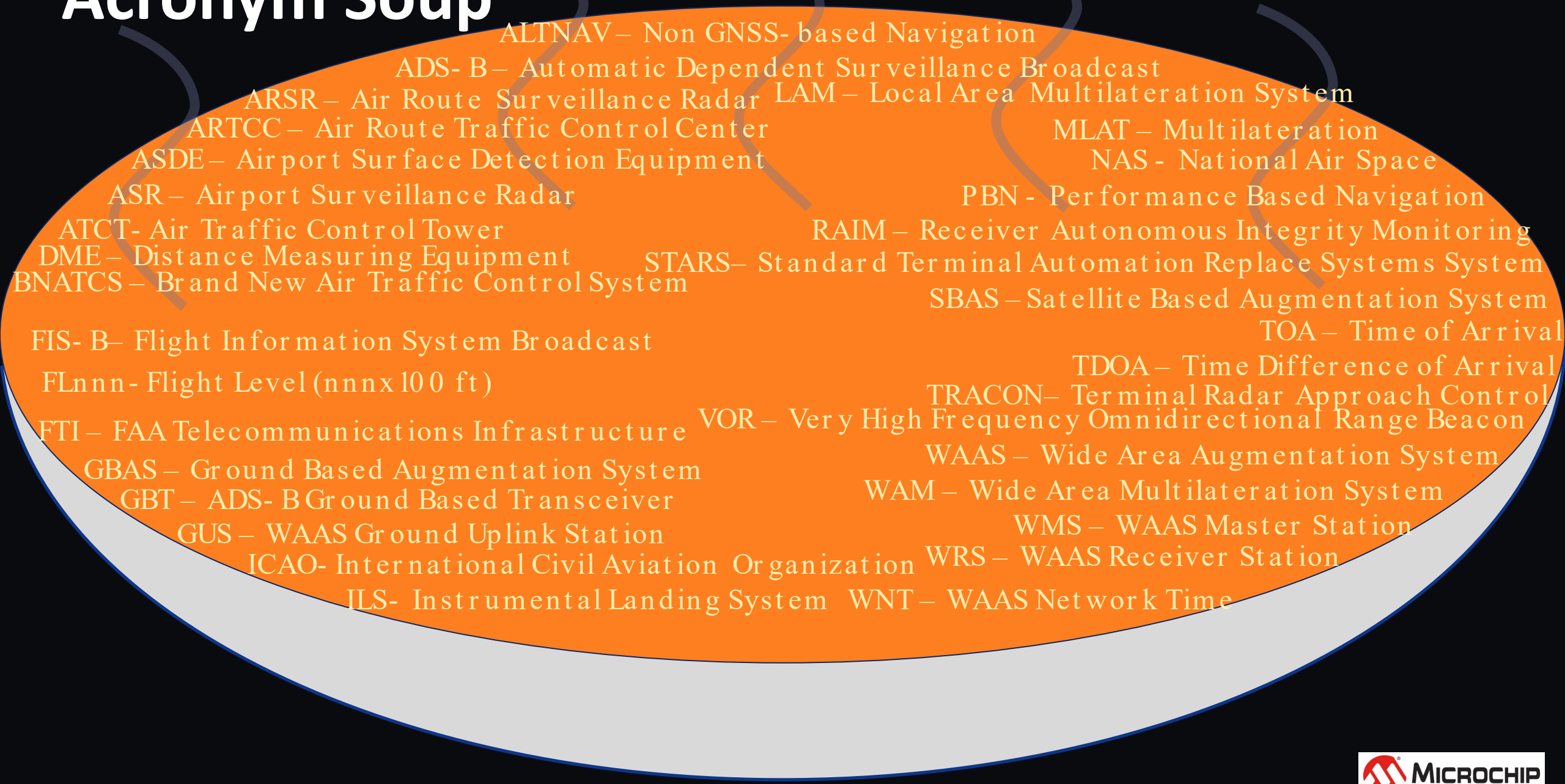
May 5, 2026

Agenda

- Focus on time and navigation
- Current status of national airspace and air traffic
- Position and navigation requirements
- Air traffic control systems and equipment
- Timing implications (what do we actually need?)
- Recommendations for GNSS time independence



Acronym Soup



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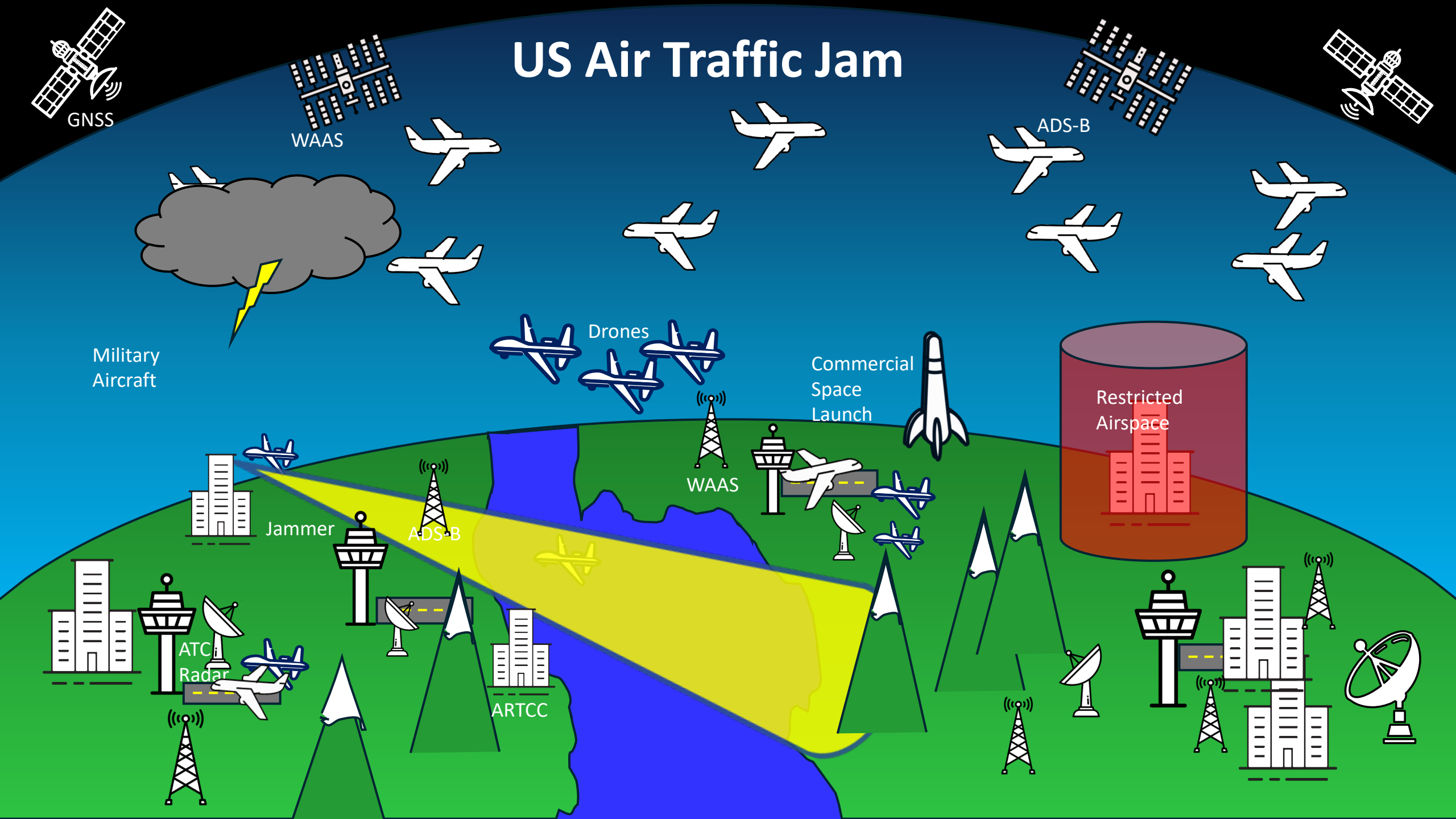
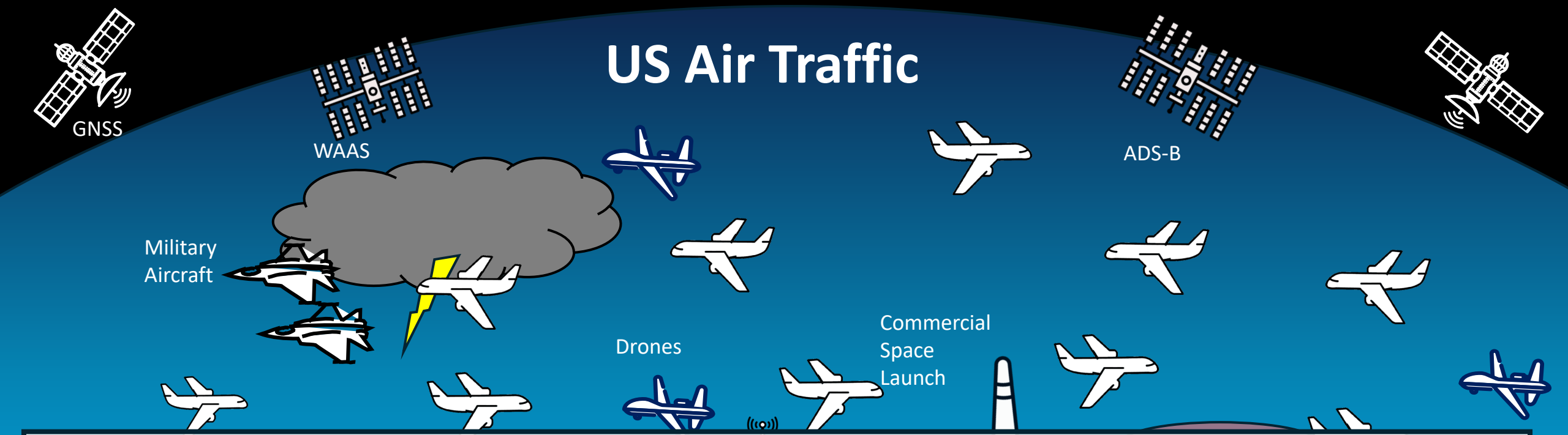

US Air Traffic Jam
GNSS
WAAS
ADS-B
Military Aircraft
Drones
Commercial Space Launch
Restricted Airspace
WAAS
Jammer
ADS-B
ATC Radar
ARTCC

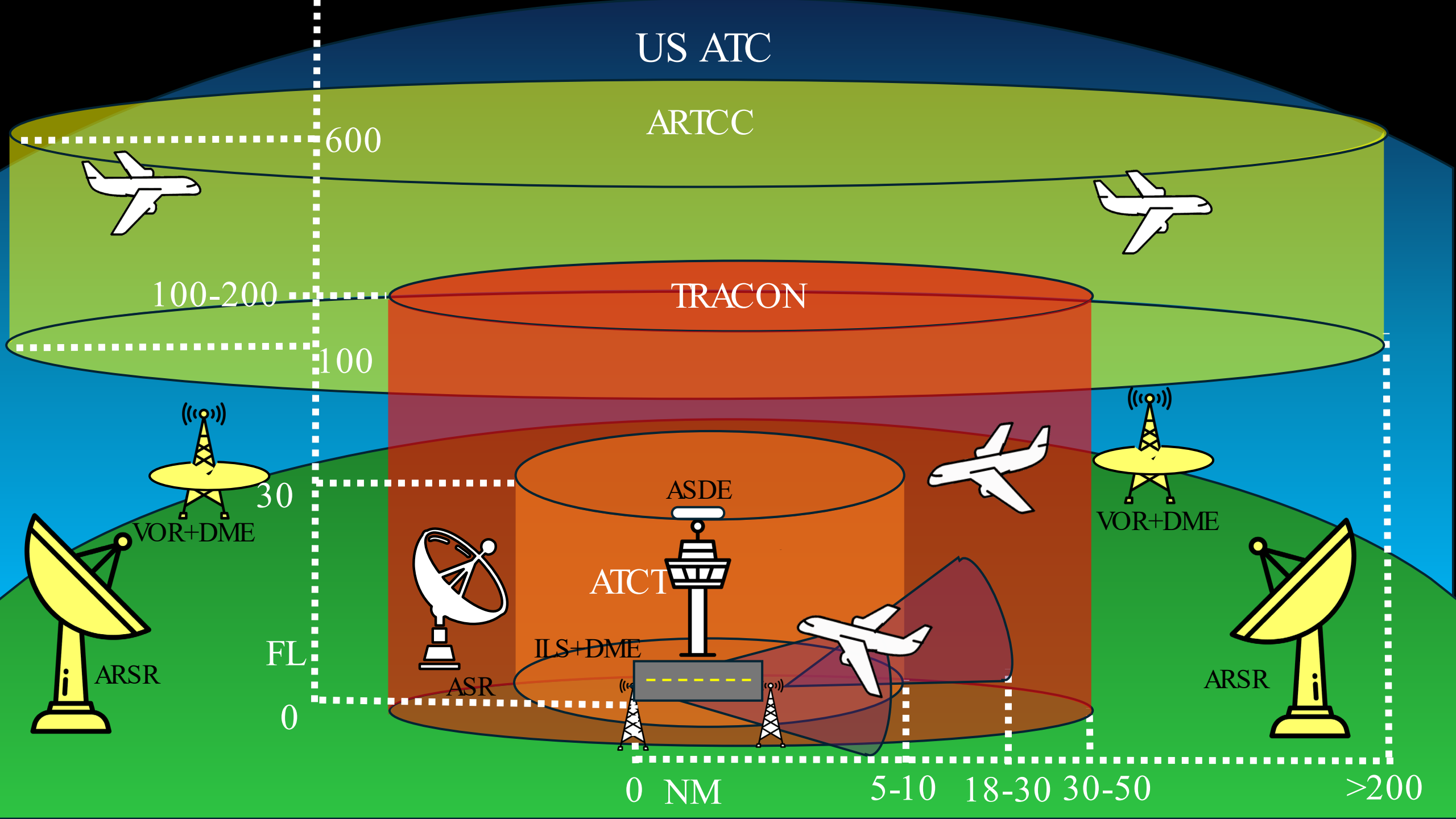
US Air Traffic



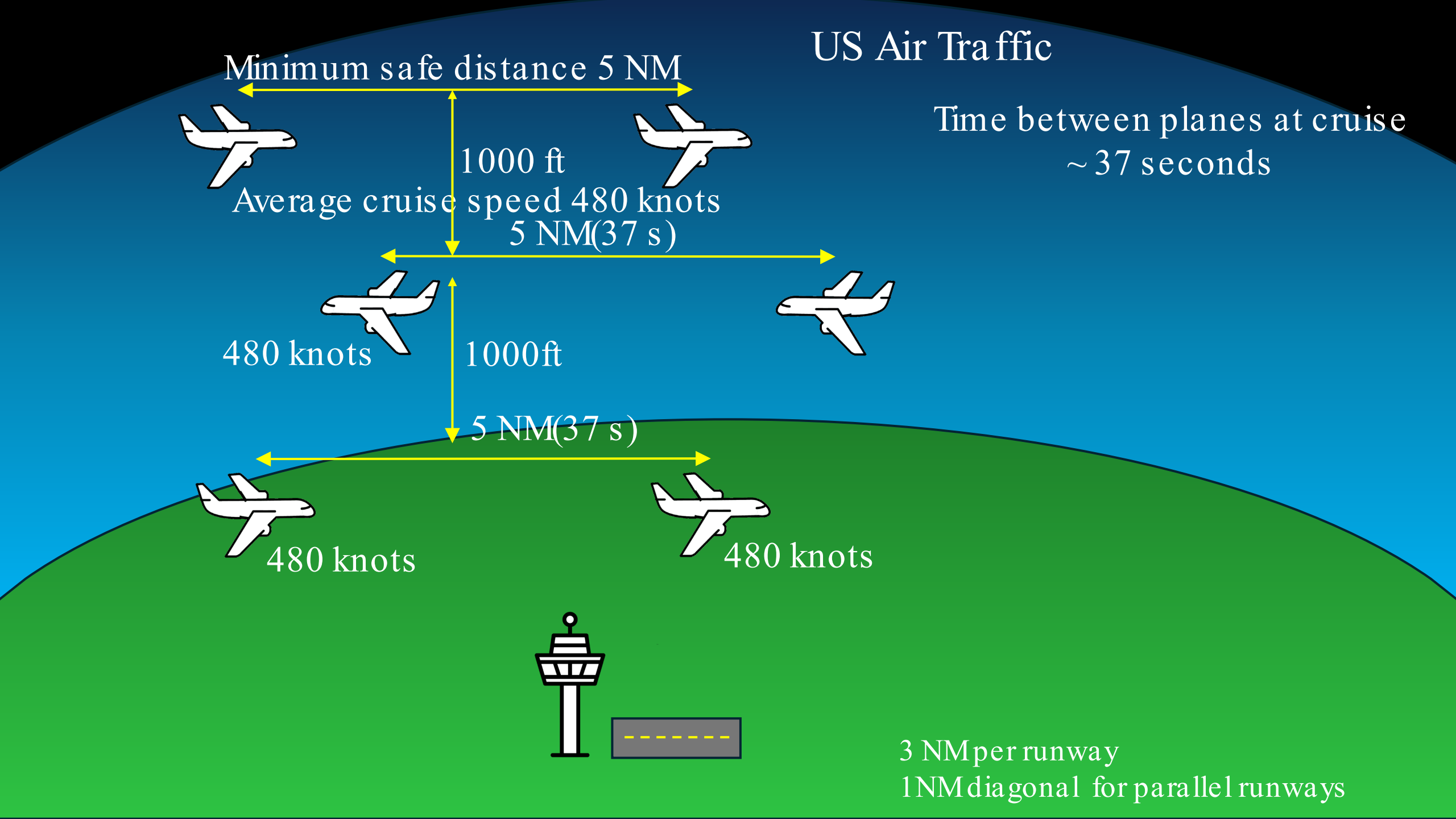
FY 24 data from FAA

- Number of planes per day average: 45,000
- Number of plane simultaneously in air at peak operation: 5,500
- Average time between landings and take offs at busiest airport: ATL 16 s
- Commercial space launches per year: 157
- Total area of NAS (land only): 5,300,000 sq mi
- Average density at peak: 963 sq mi/aircraft

https://www.faa.gov/air_traffic/by_the_numbers/air-traffic-by-the-numbers-FY2024.pdf


US ATC
ARTCC
600
TRACON
100-200
100
30
FL
0
ASDE
ATCT
ILS+DME
ASR
VOR+DME
VOR+DME
ARSR
ARSR
0 NM
5-10
18-30
30-50
>200

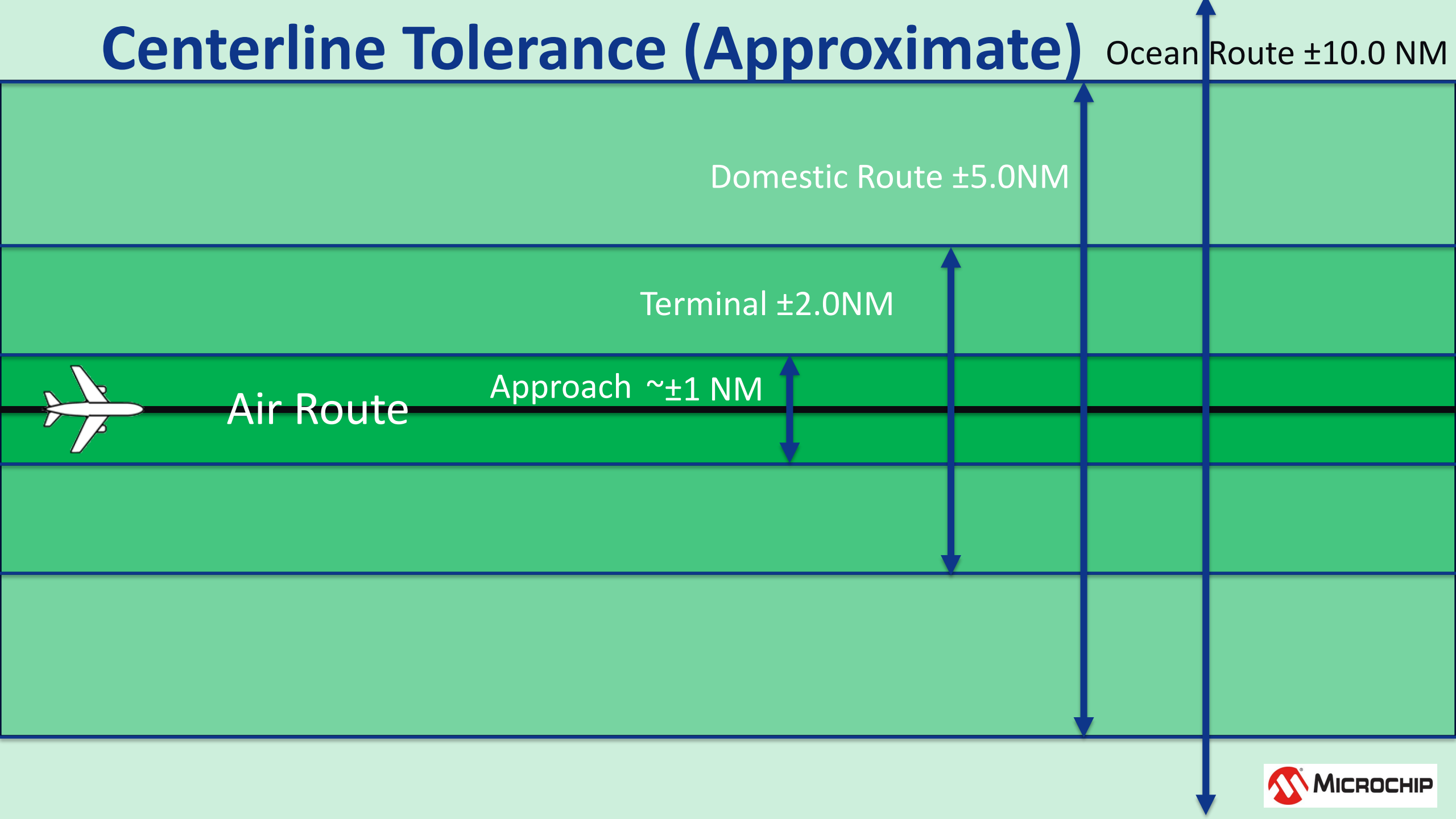
US Air Traffic



Time between planes at cruise
~ 37 seconds

3 NM per runway
1NM diagonal for parallel runways

Centerline Tolerance (Approximate)



National Airspace System (NAS) 2/20/2026

https://www.flightradar24.com/37.22,-102.53/5

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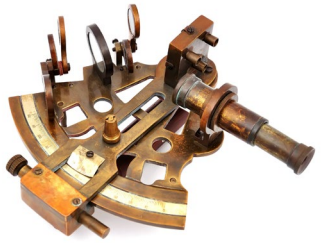
Radars in Air Traffic Control System
"Good Old Times"

Region	Radar	Quantity Deployed in NAS	Seconds Between Updates	Typical Aircraft Speed (knots)	Typical Distance Traveled Between Updates (NM)	Safe Distance (NM)	Fraction Of Safe Distance	Center Line (±NM)	Fraction Of Centerline Tolerance
Route (ARTCC)	ARSR	~150	12	480	1.60	5.00	0.32	5.00	0.32
Terminal (TRACON)	ASR	~350	5	220	0.31	3.00	0.10	2.00	0.15
Approach (ATCT)	ASR/Visual	~350	5	150	0.21	3.00	0.07	1.00	0.21
Ground (ATCT)	ASDE	35	1	NA	NA	NA	NA	NA	NA

- Radars only synchronized to UTC +/- 1 second
- Monostatic radars
- System synchronization not demanding by today's requirements

Over ocean – get out your sextant



More on radar frequency requirements

https://wsts-atisorg.s3.us-east-1.amazonaws.com/2025/tutorials/videos/WSTS25_FundamentalsofTimeandFrequencyinAerospaceandDefense_Chandler.mp4

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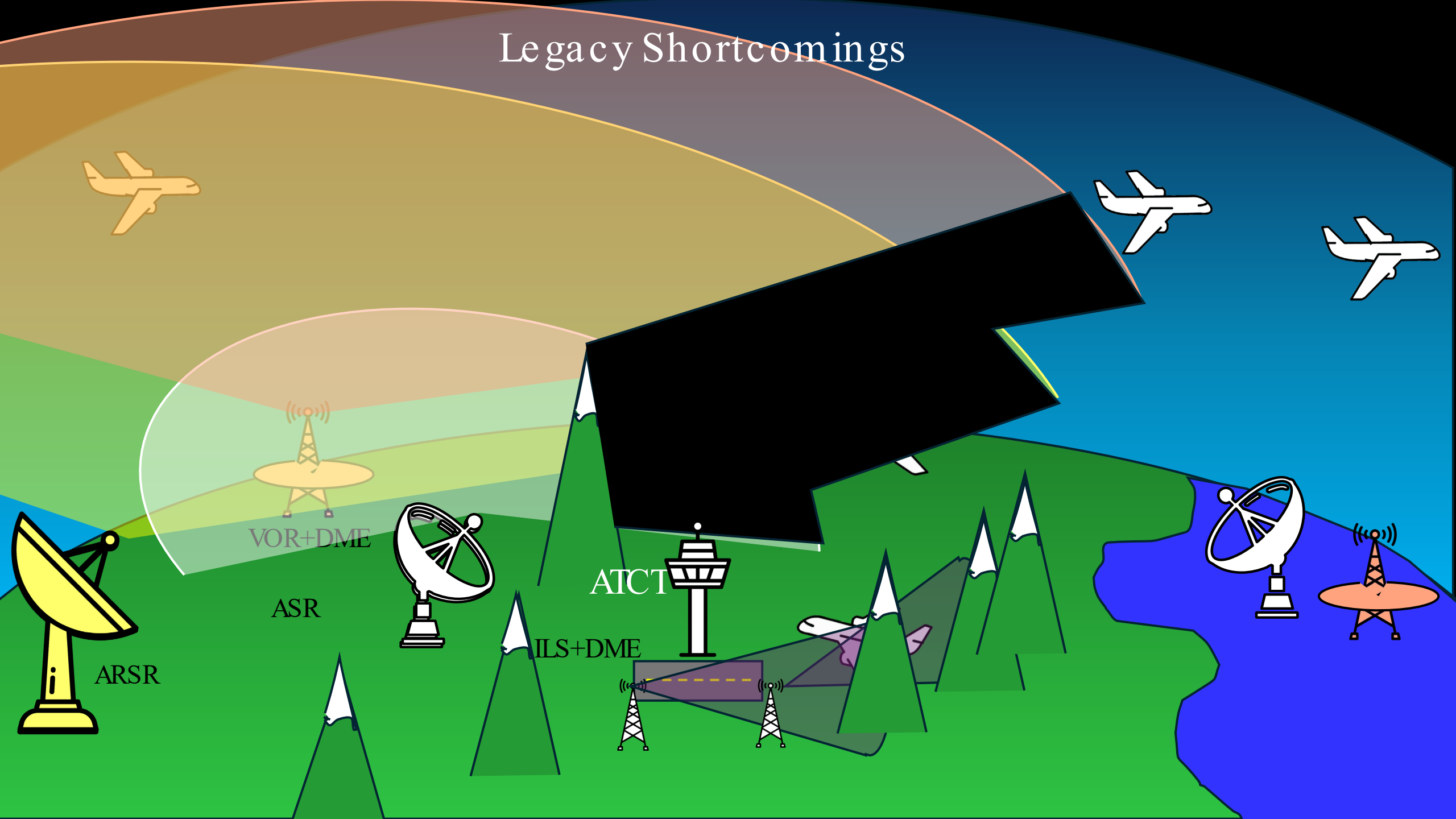
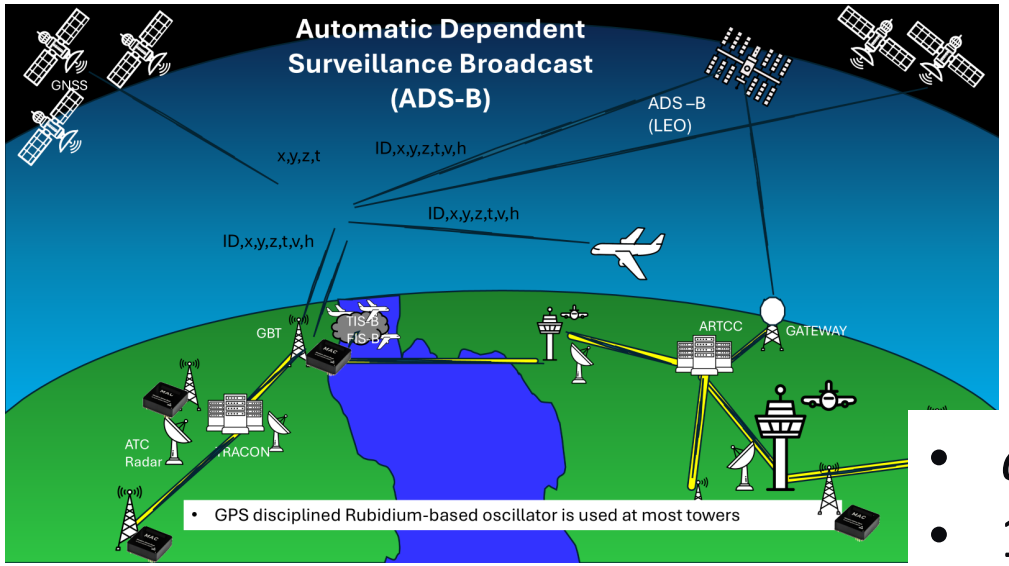
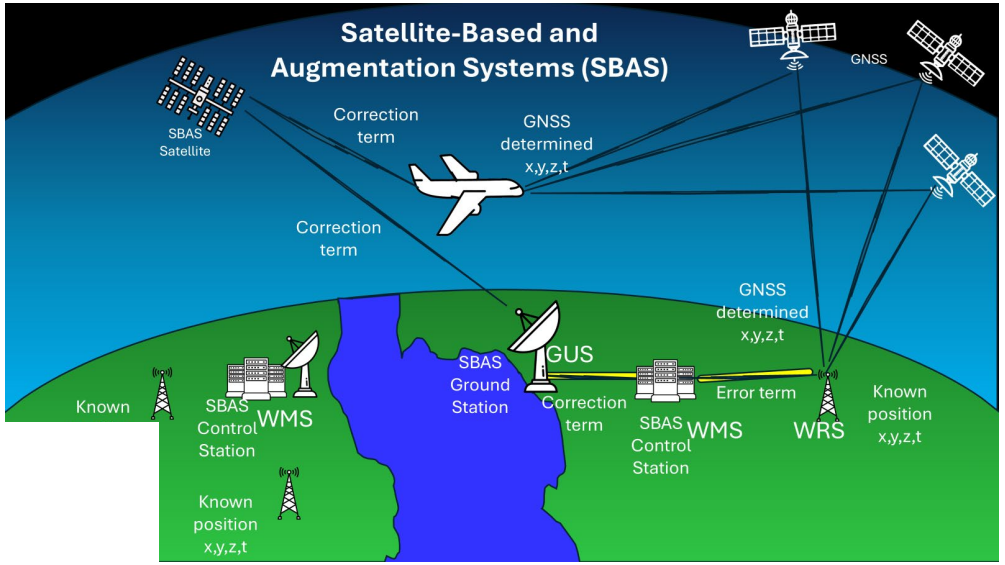
Legacy Shortcomings

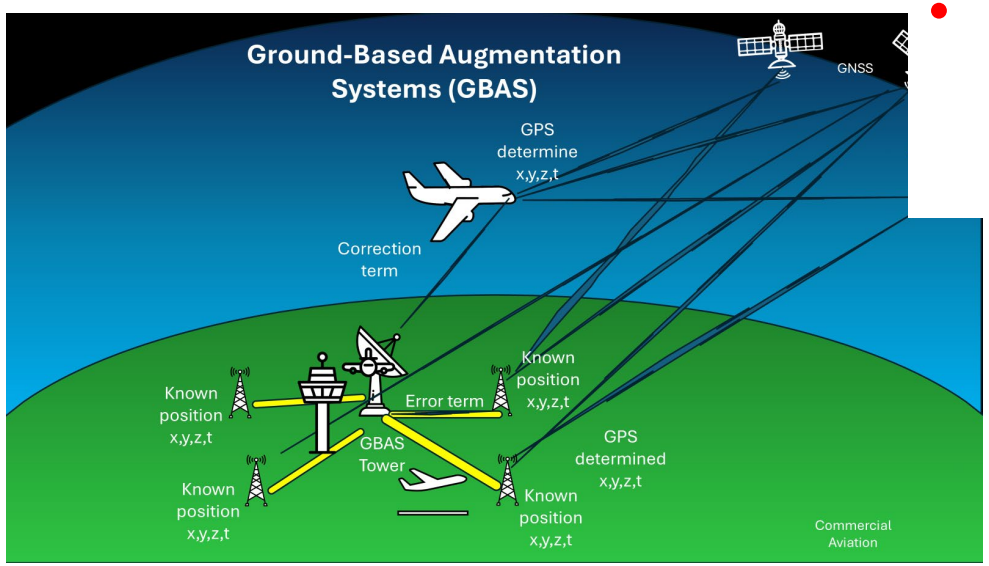


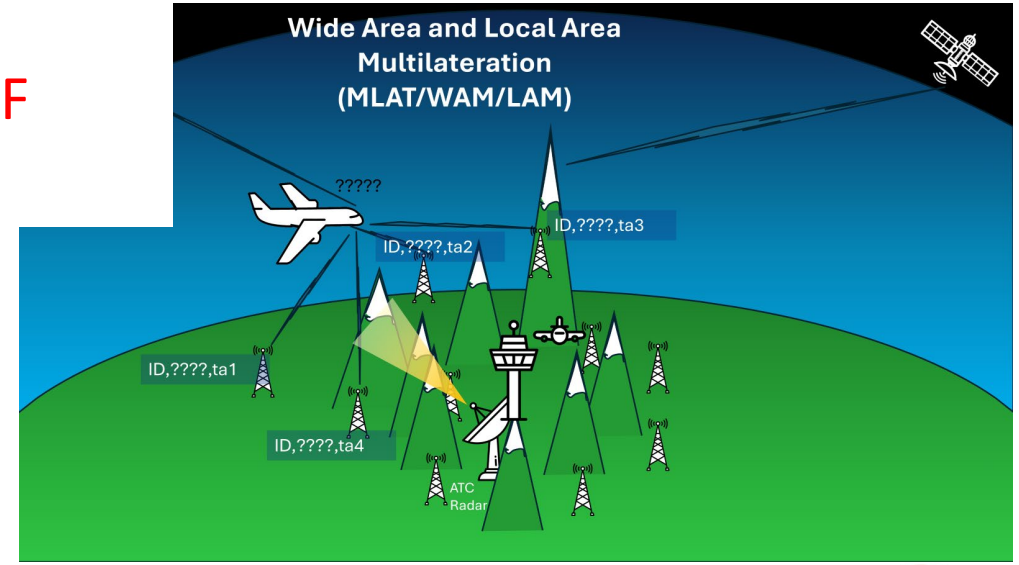
Better Times: NextGen, GNSS and Other Time-Based Improvements



- $d = c\Delta t$
- 1m ≈3ns
- Retire VHF/UHF systems







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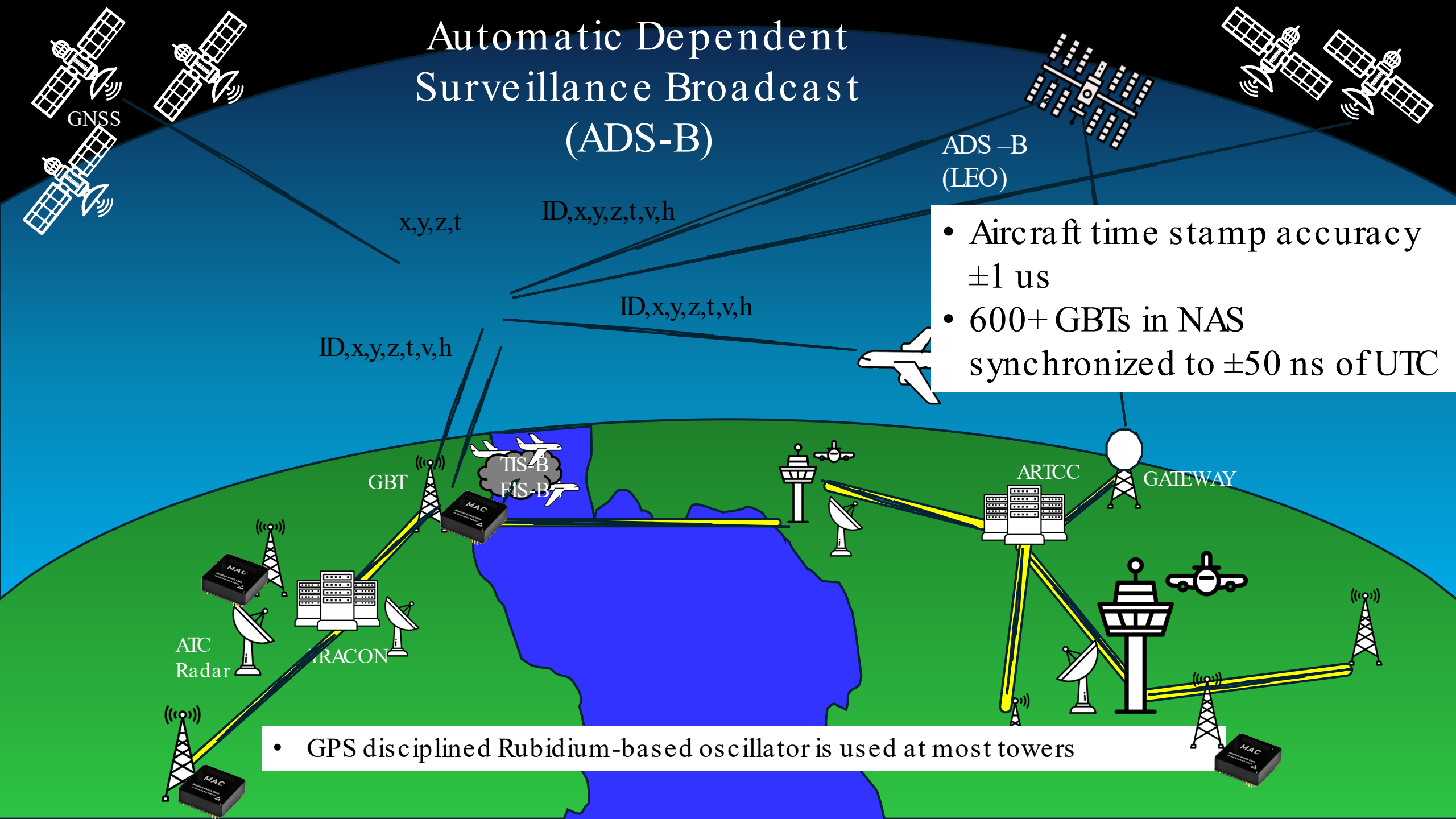
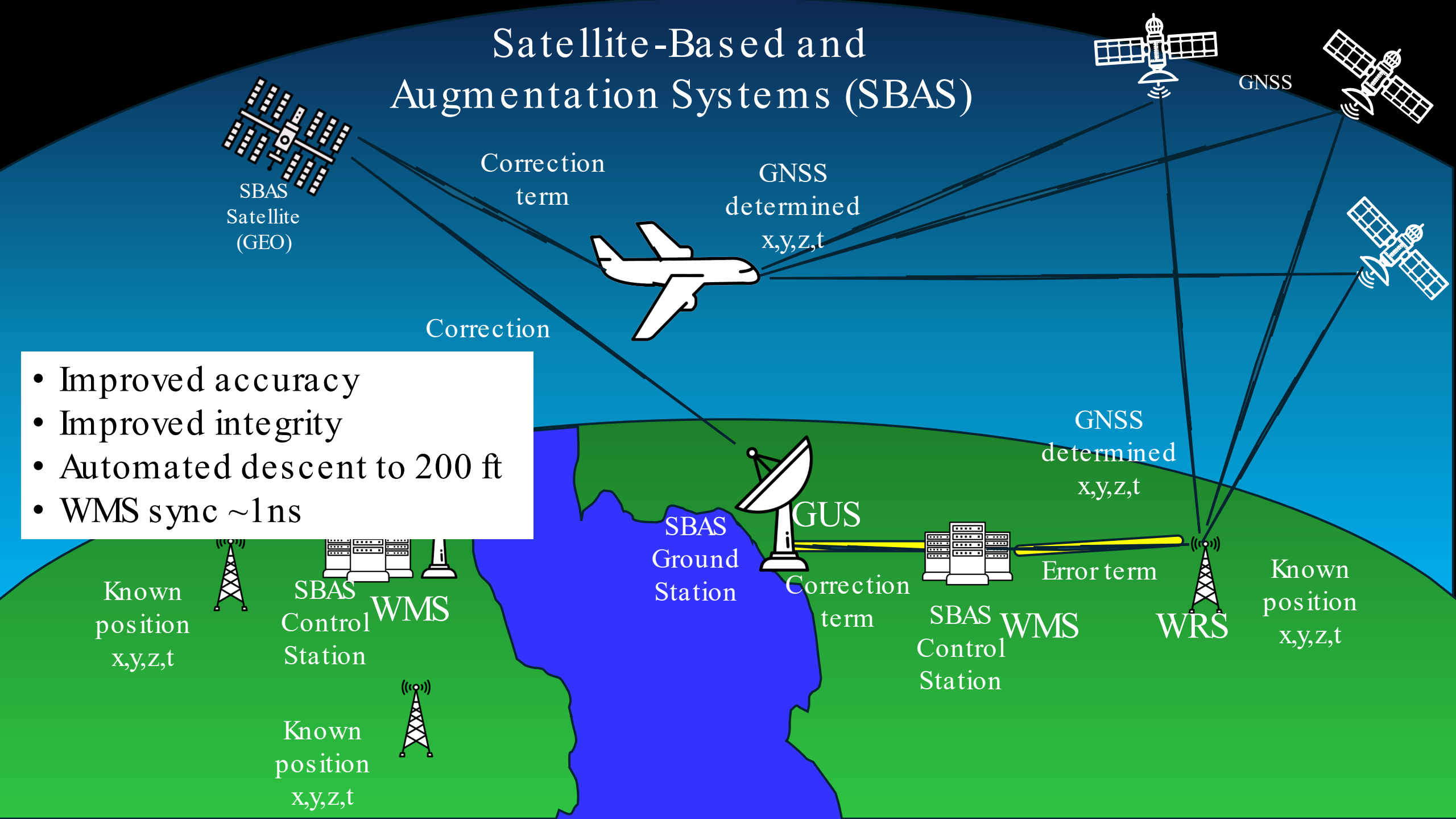
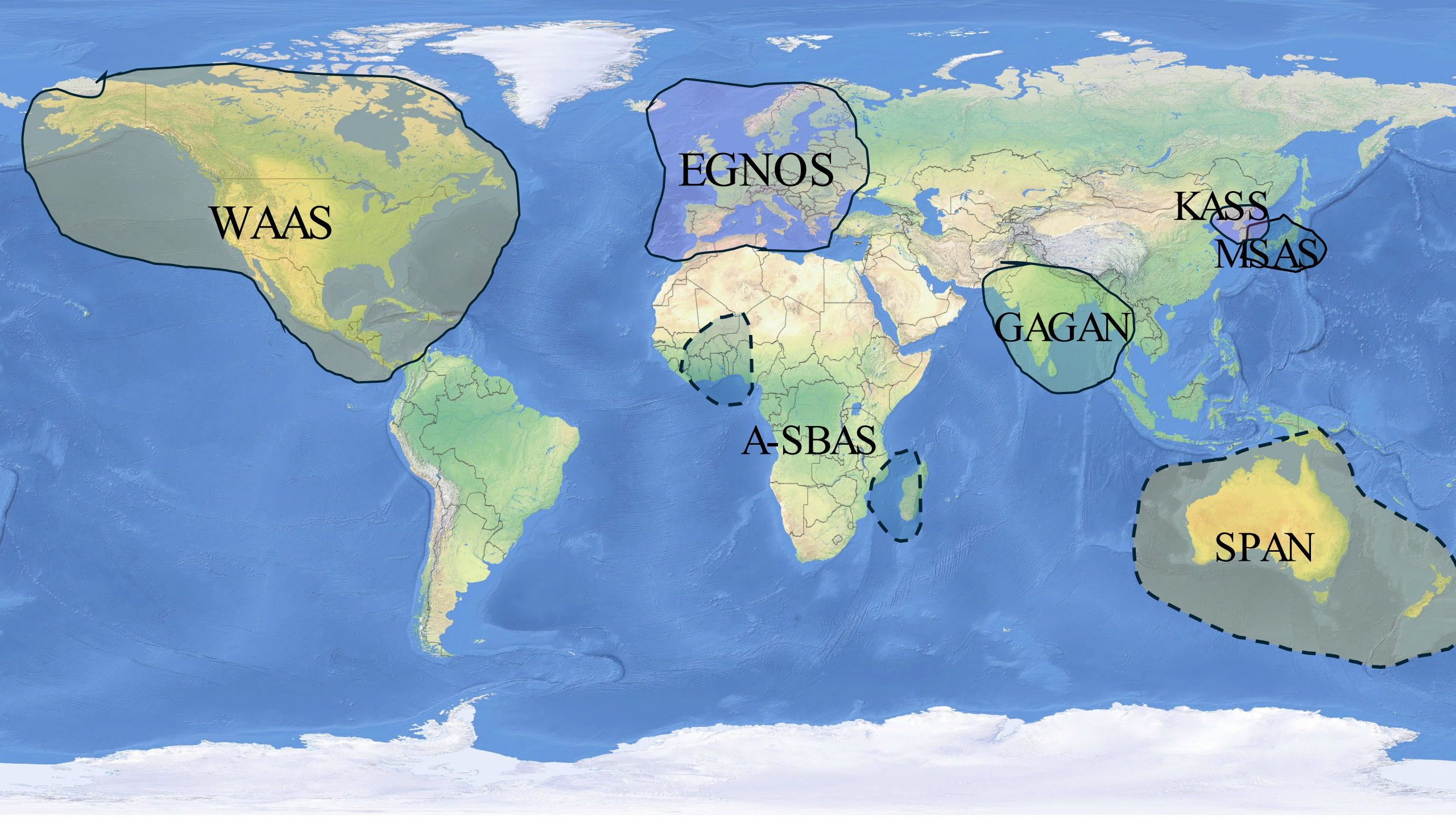

Automatic Dependent Surveillance Broadcast (ADS-B)
GNSS
ADS –B (LEO)
x,y,z,t
ID,x,y,z,t,v,h
ID,x,y,z,t,v,h
ID,x,y,z,t,v,h
• Aircraft time stamp accuracy ±1 us
• 600+ GBTs in NAS synchronized to ±50 ns of UTC
GBT
TIS-B
FIS-B
ARTCC
GATEWAY
ATC Radar
IRACON
MAC
• GPS disciplined Rubidium-based oscillator is used at most towers

Satellite-Based and Augmentation Systems (SBAS)

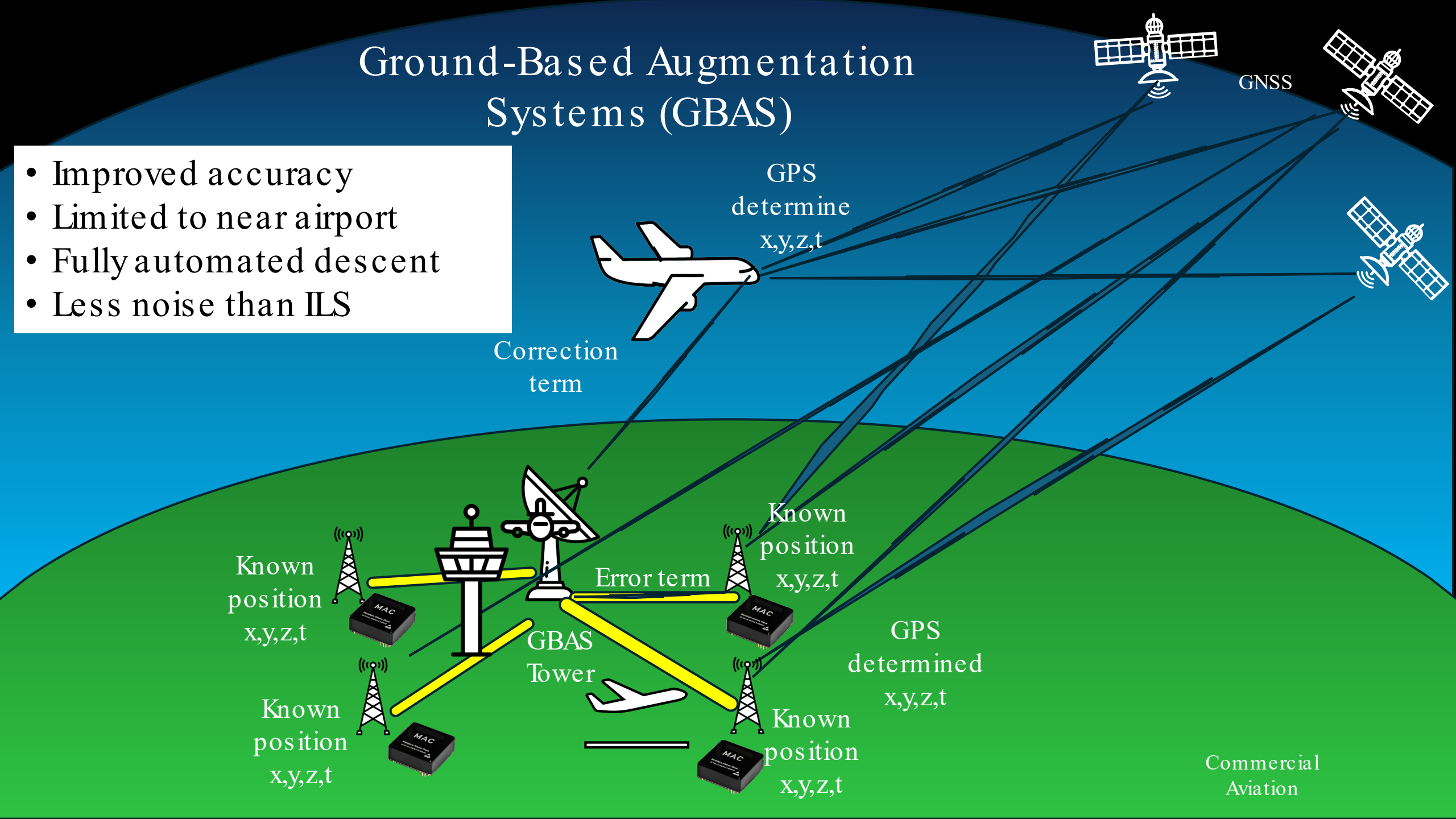


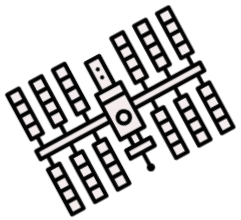
- Improved accuracy
- Improved integrity
- Automated descent to 200 ft
- WMS sync ~1ns


WAAS
EGNOS
KASS
MSAS
GAGAN
A-SBAS
SPAN

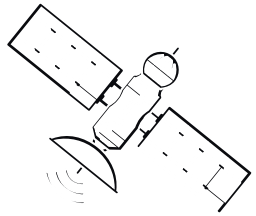
Ground-Based Augmentation Systems (GBAS)

- Improved accuracy
- Limited to near airport
- Fully automated descent
- Less noise than ILS





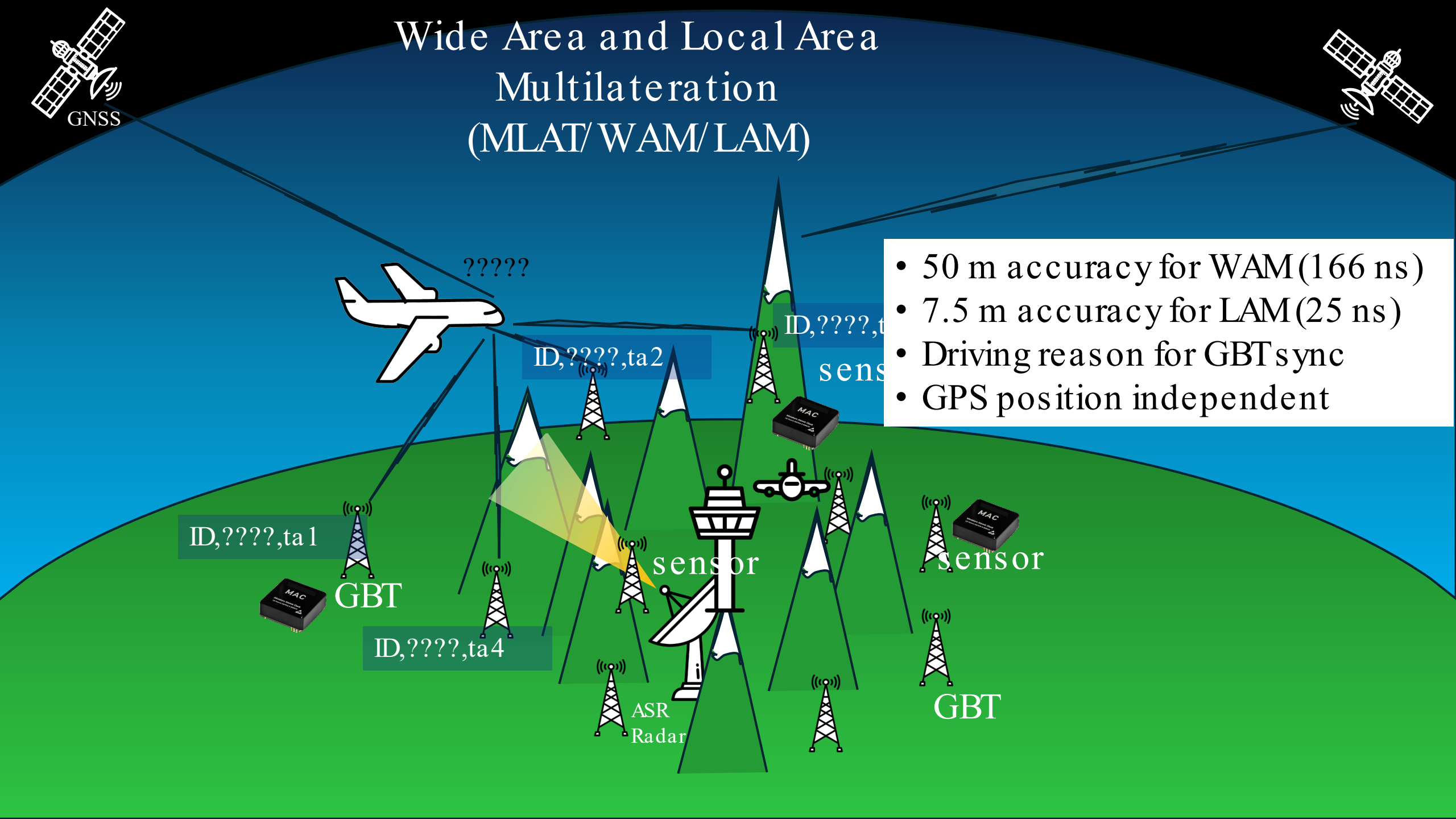
Time Of Arrival Solutions



System	Sites in NAS	Update Rate (s)	Typical Distance Cruise (NM)	Typical Distance Terminal (NM)	Typical Distance Approach (NM)	Horizontal Accuracy 95% confidence (m)	Timing (ns)
ADS-B	>600	1	0.13	0.06	0.04	93	310
SBAS (WAAS)	38	1	0.13	0.06	0.04	7.6	25
GBAS	3	0.5	N/A	0.03	0.02	1	<1

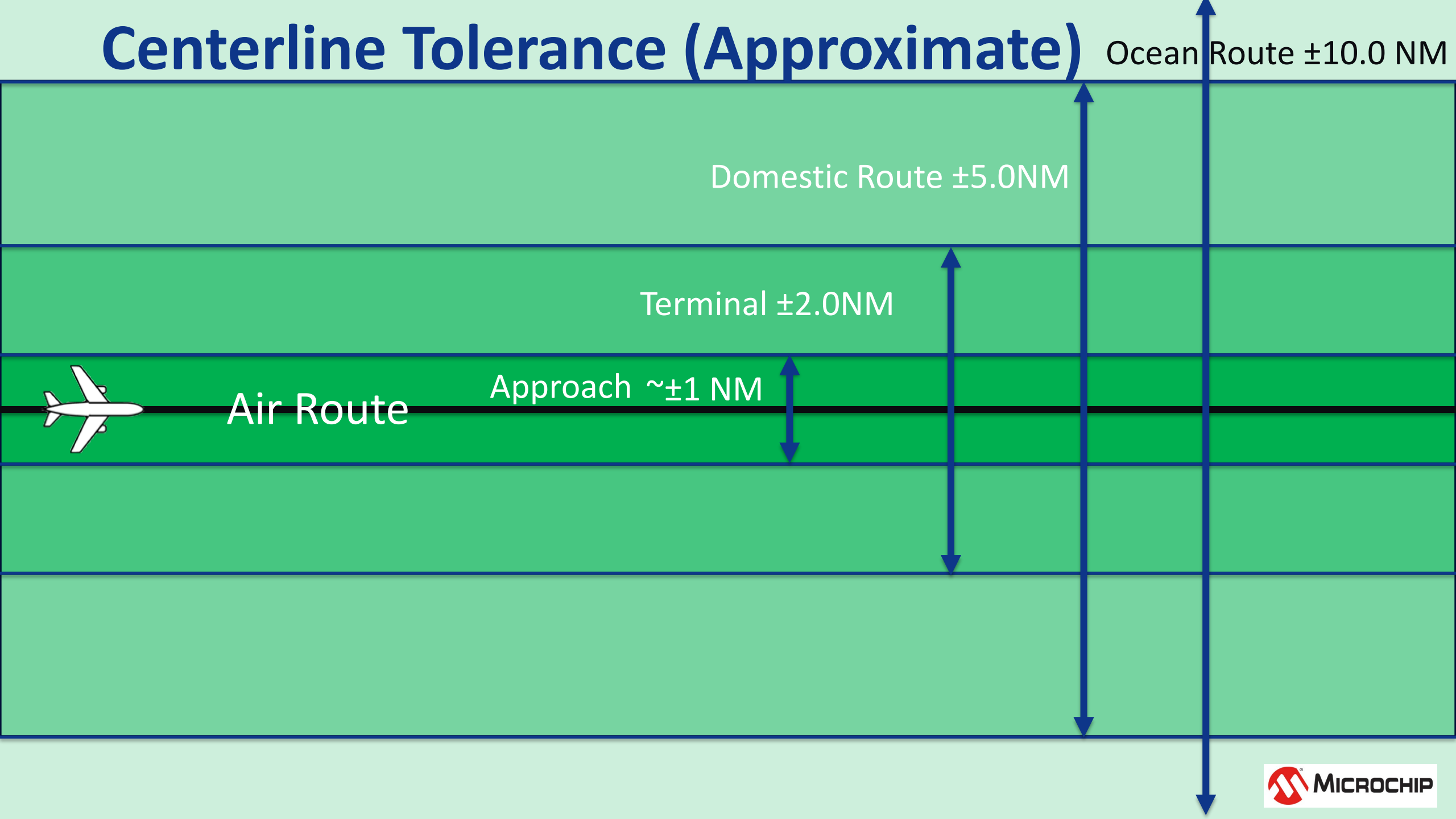
- Much faster updates and improved position allow smaller air corridors
- GNSS allows virtual waypoints
- Line of site issues significantly improved but some areas still vulnerable
- Over ocean coverage with GNSS and LEO ADS-B relay
- High levels of integrity

Wide Area and Local Area Multilateration (MLAT/WAM/LAM)

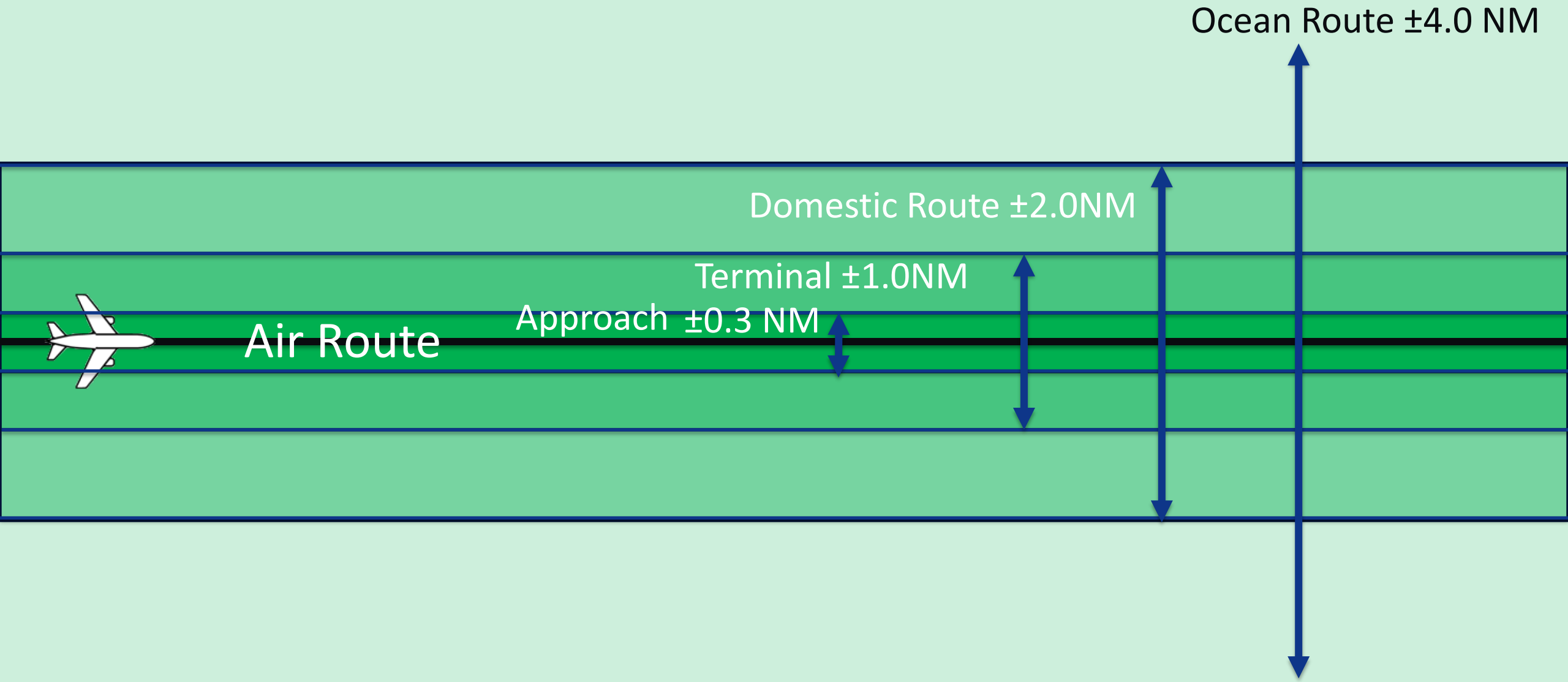


- 50 m accuracy for WAM (166 ns)
- 7.5 m accuracy for LAM (25 ns)
- Driving reason for GBT sync
- GPS position independent

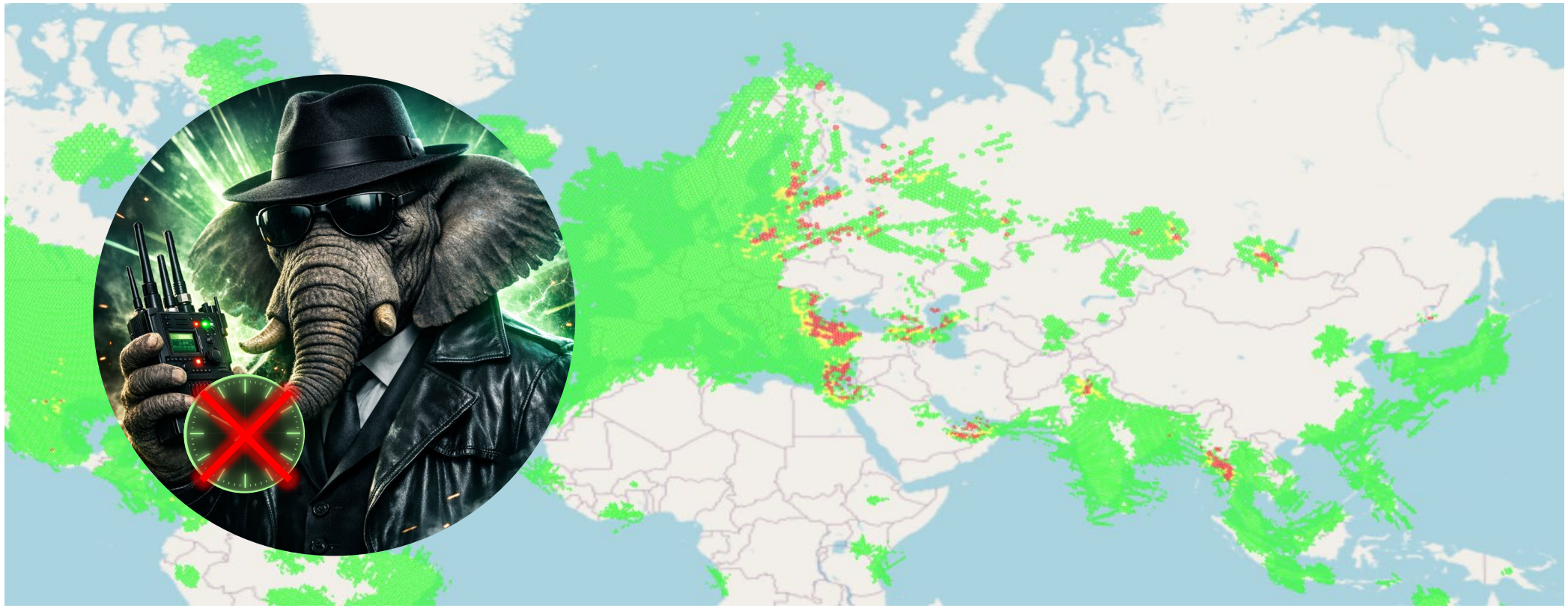
Centerline Tolerance (Approximate)



Centerline Tolerance (RNAV/RNP)



Troubled Times: Operations During GNSS Denial?



- **ADS-B,SBAS and GBAS dependent on GNSS**
- **WAM and LAM were designed to operate during GNSS denial**
- **Many WAM/LAM sensors are synchronized by GNSS, with minimal holdover capabilities**

https://gpsjam.org/?lat=39.98982&lon=1.60650&z=1.5&date=2026-03-02

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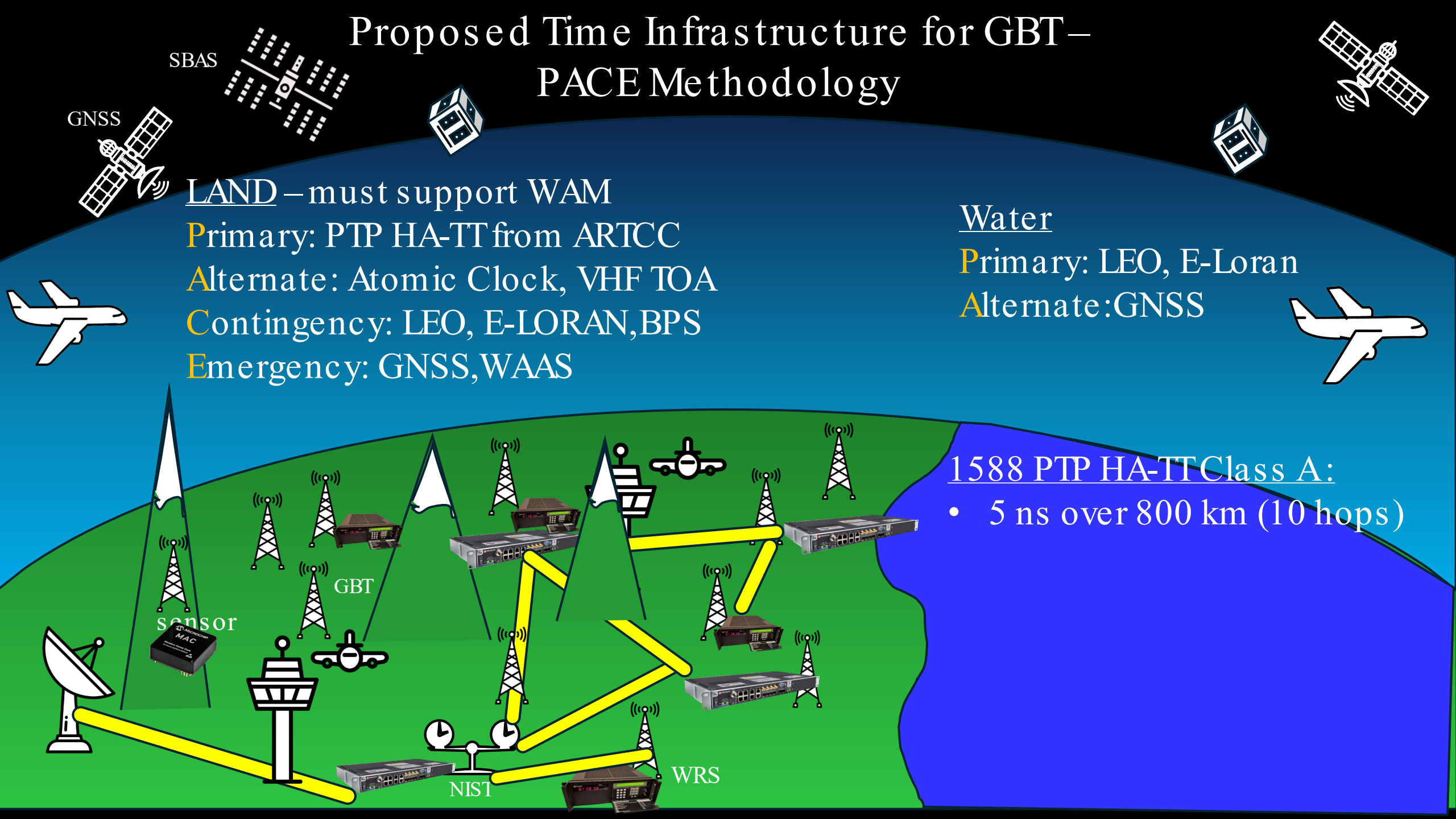
The Best Times are Still to Come: BNATCS and GNSS Time Independence

- **FAA Order 1770.68**
  - Remove dependence on GNSS as primary source of time
  - Mandates creation of “Enterprise Time and Frequency Service”
  - Time via NTP and PTP directly traceable to NIST or USNO to all NAS equipment
  - Timing requirements must meet the existing system requirements
- **Implementation**
  - Core ARTCC already deployed/ in process PTP-HA-TT
  - New ATC radars deployed/ in process NTP
  - ~10 ns required to support high accuracy MLAT

Proposed Time Infrastructure for GBT–PACE Methodology



Thank You!

(Time really did fly in this presentation)