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GBAS Planning and Implementation

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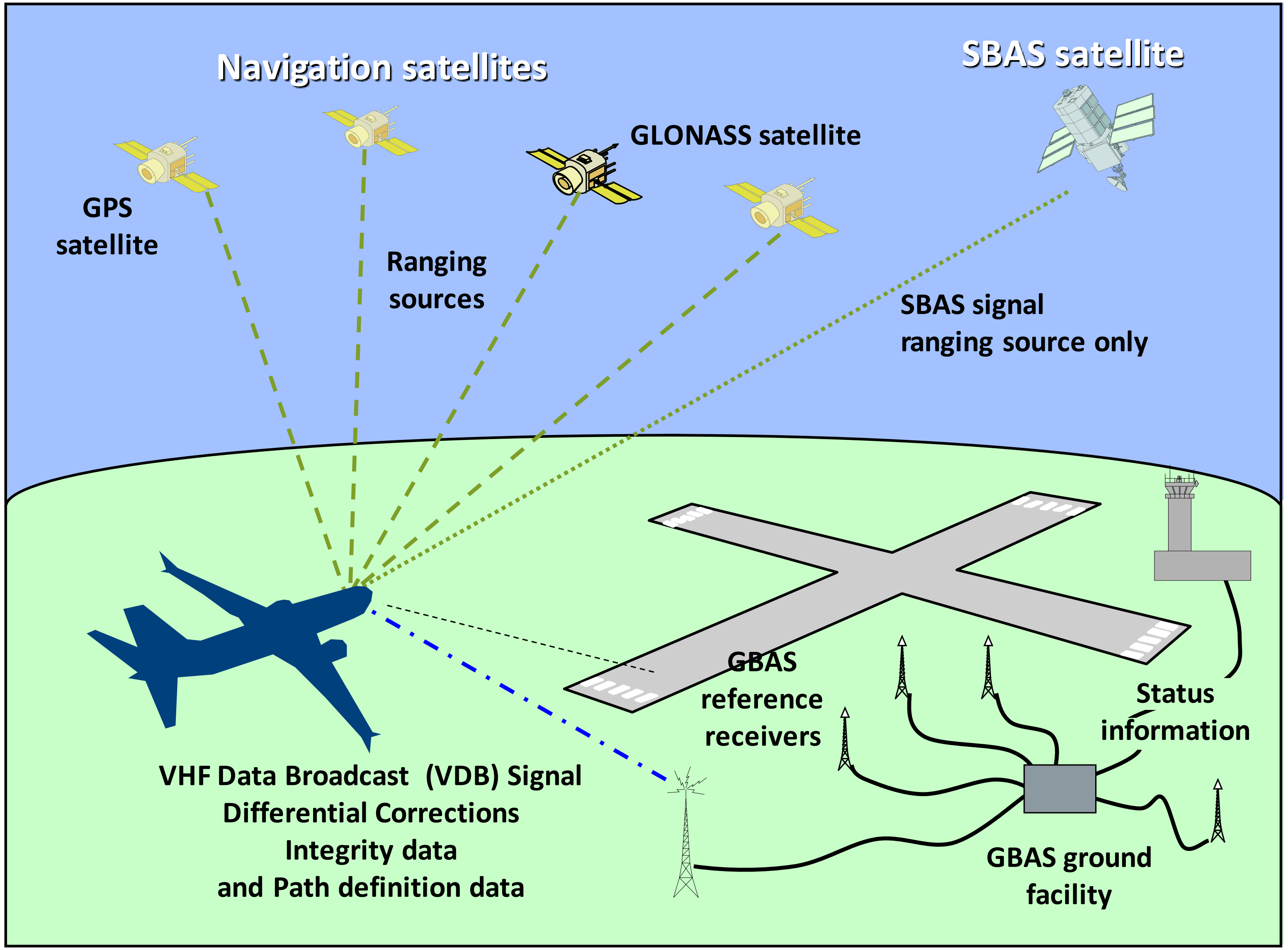
Overview

- GBAS Overview
- Benefits of GBAS
- Implementation considerations (aircraft equipage level, airport suitability,..etc)
- Risks and challenges

Ground Based Augmentation System (GBAS)



Some Potential Benefits of GBAS

Provides high accuracy, high integrity positioning for:

- CAT I, II and III precision approach and landing
- Terminal Area (RNAV/RNP)
- Precision missed approaches
- Take off guidance
- Surface Navigation (future)

Remote Coverage - gives service in areas not covered by SBAS

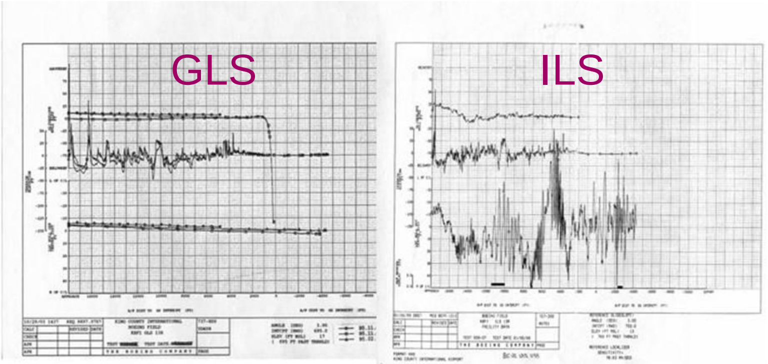
Smaller position integrity bounds can increase availability of precise ‘tailored approaches’ to avoid obstacles, noise sensitive areas or congested airspace (RNAV/RNP)

Multiple runway coverage - one GBAS can serve approaches to all runway ends at an airport, potentially nearby airports

Flexibility – Multiple approaches to the same runway (different glide slopes, offset approaches, etc.)

Why GLS?
Airline Perspective – Site Specific

- Improved Performance
  - Less susceptible to interference from buildings, vehicles, terrain
  - Eliminates need for “critical areas” required for ILS beam protection
- Increased Capability
  - Multiple glide-paths, displaced thresholds, staggered touch-downs &, offset localizer paths
  - Steeper, lower noise profile glide-paths could increase night operations
  - Increased efficiency from reduced separation as a result of wake vortex mitigation
  - Low RNP capability in terminal area and for surface operations
  - Precision guidance for departures
- Cost Avoidance
  - Fewer diversions
  - Reduced fuel reserves from improved access to ETOPS and destination alternates
  - Reduced landing fees. (Some airports are expected to pass savings to airlines.)
  - Reduced flight inspection
  - Improved Safety
  - Provide precise ILS-like guidance in places where ILS is not feasible




Instrument Landing System glideslope and localizer

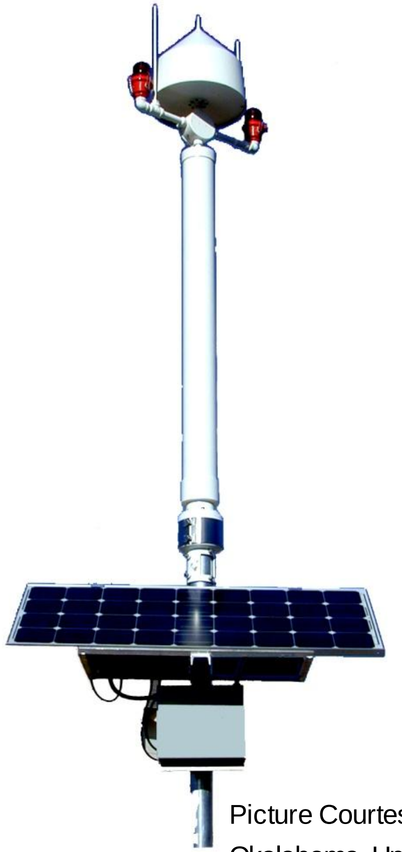
Why GLS?
Air Navigation Service Provider's Perspective

- Lower Infrastructure Costs Compared to ILS
  - Single GBAS serves all runway ends and in some cases multiple airports
  - Improved availability
- Improved Performance
  - Not susceptible to interference from buildings, vehicles, terrain
  - Eliminates need for "critical areas" required for ILS beam protection
- Increased Capability
  - Potential for multiple glide paths
- Environmental Considerations
  - Community noise abatement
  - Reduced emissions

Typical GBAS Ground Segment Equipment

SLS-3000

Pictures Courtesy
Honeywell Inc.



Picture Courtesy
Okalahoma University

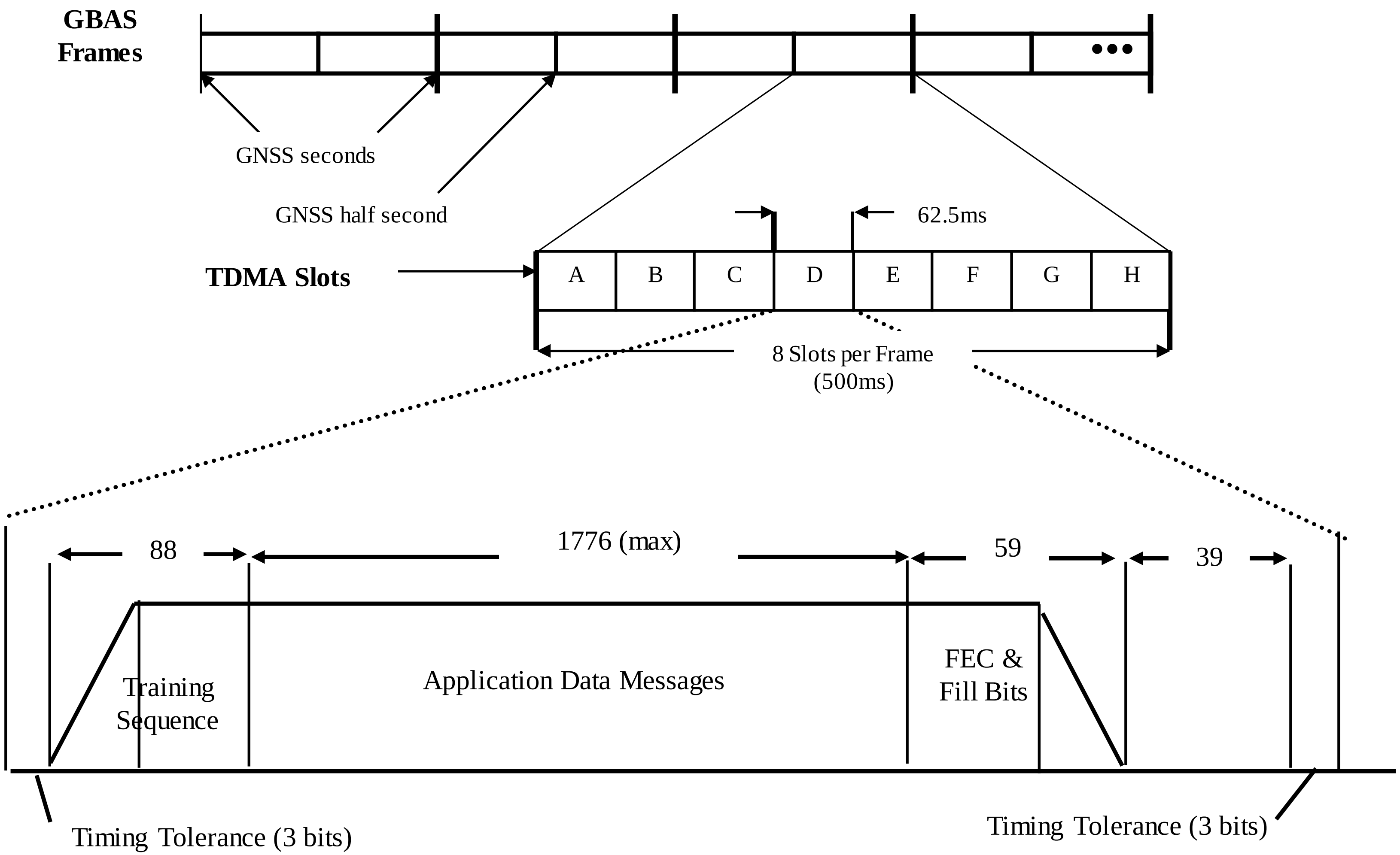
GBAS Ground Station Suppliers

- Honeywell
  - SmartPath™ GBAS (SLS 4000) design approved Sept 2009
    - Operationally approved at Sydney, Newark, Houston, more
    - Prototype in Rio de Janeiro to study equatorial use of GBAS
    - Boeing operated Honeywell GBAS: Moses Lake, Charleston, Portable (PBAS, retired)
- SPECTR – Russian manufacturer – Nearly 100 operational sites in Siberia
- NEC – Japan
  - prototype in 3/2010 and flight trails in late 2010, Tokyo GBAS now operational
- Indra Navia
  - GAST D Prototype at Frankfurt, Operational network of 17 SCAT I stations in Norway
  - Boeing procured several Indra GBAS CAT III capable portable stations for testing
- China Electronics Technology Group Corporation
  - Dongying Shengli Airport (DOY)
  - Design approved ground station – no operational approvals yet

VHF Data Broadcast (VDB)

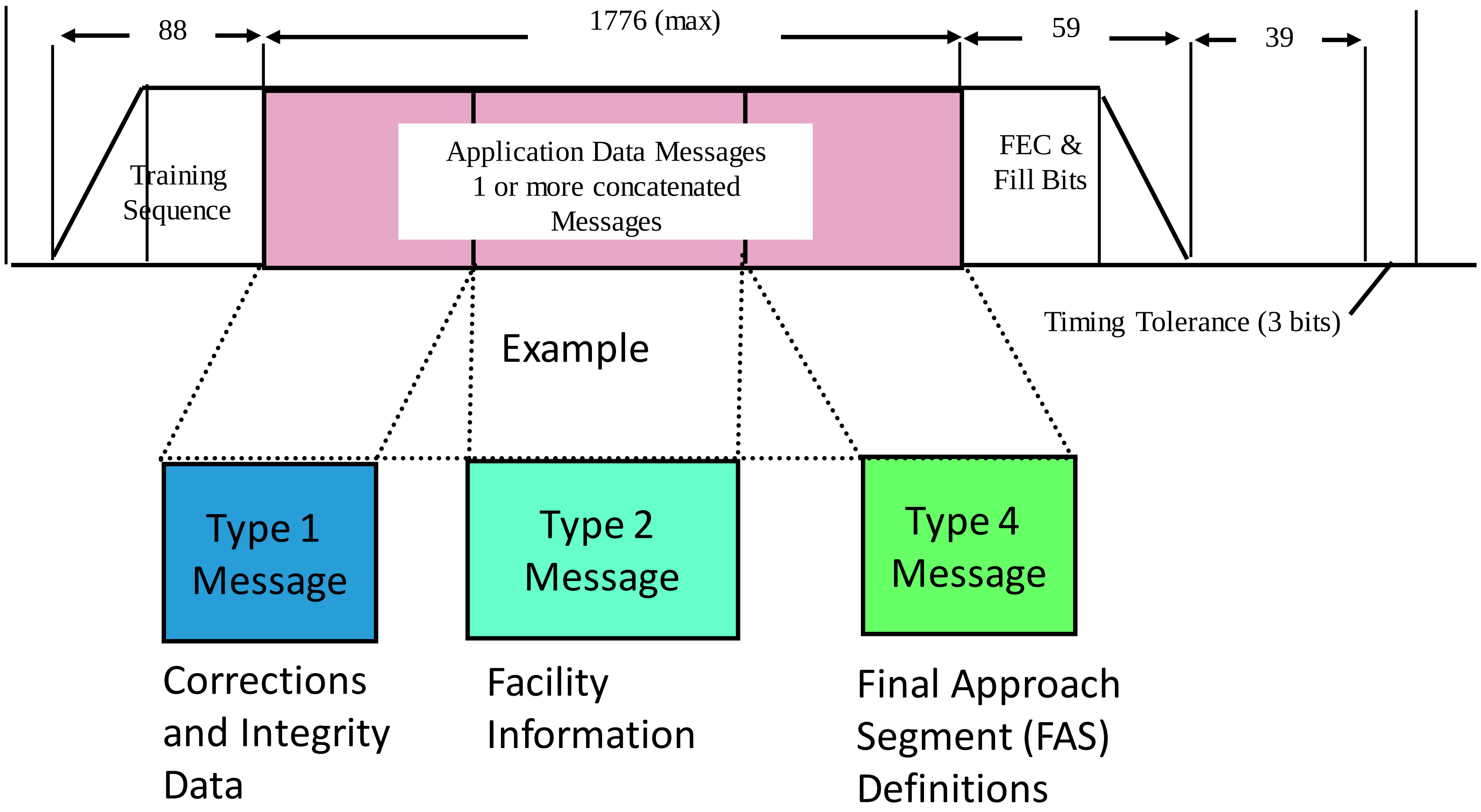
- ICAO has developed Standards and Recommended Practices (SARPS) for VDB
  - VHF Navigation Band (108-118 MHz)
  - Broadcast Only (no airborne transmissions in band)
  - Differential 8 Phase Shift Key (D8PSK)
  - 32.5 kilo bits per second rate
    - 10.5 kilo phase transitions per second with 3bits/transition
  - TDMA slot system
    - 2 frames per second & 8 slots per frame
    - synchronized to GPS time
    - Allows nearby ground stations to share frequencies

VDB Slot Structure



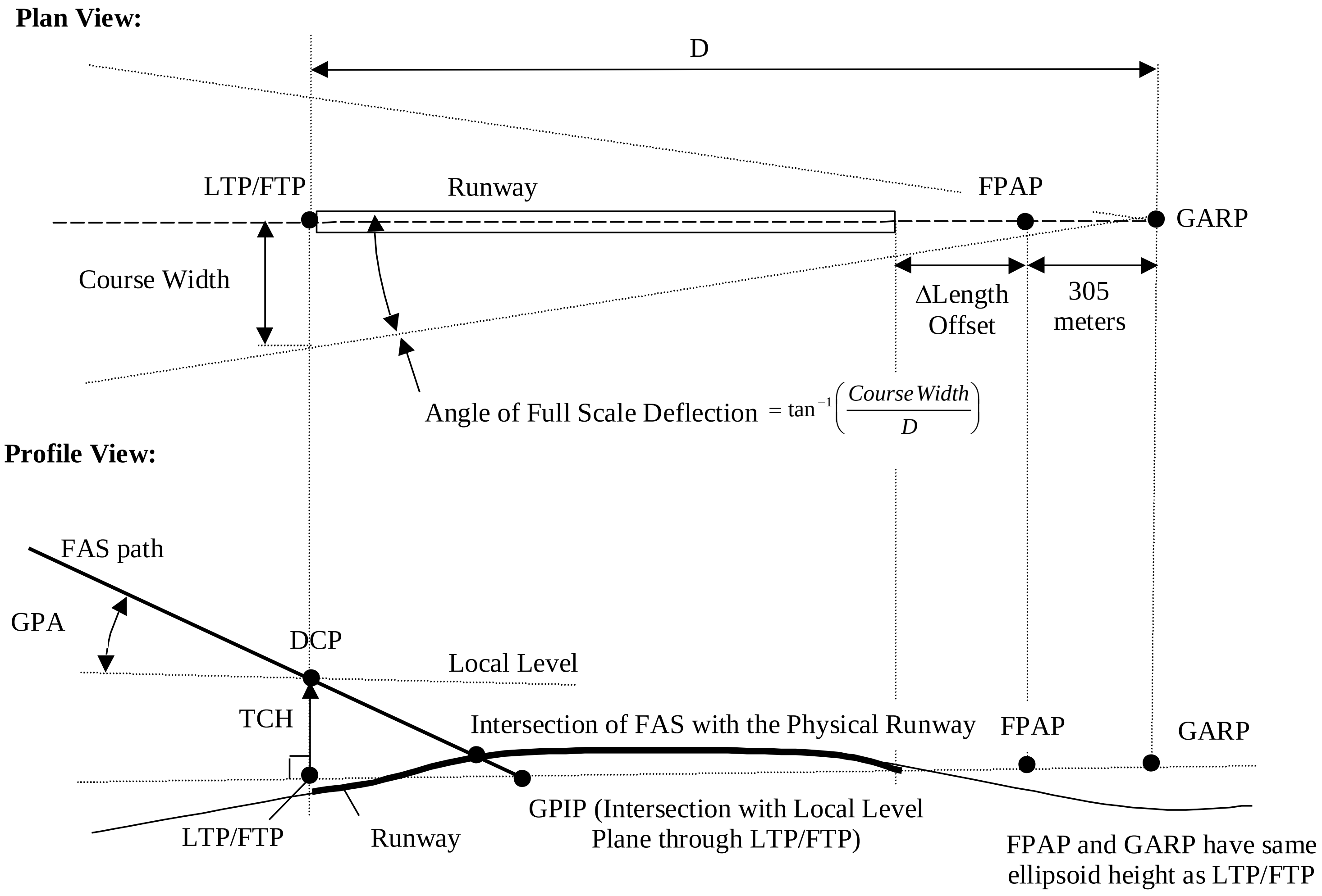
Note: The service provider will assign a subset of the 8 slots to a single GBAS installation. The remaining slots are available for use by other stations. Each slot is available for GBAS signal transmission twice each second during the 62.5ms slot period.

VDB Messages



Note: The service provider may put one or more message types within the slot burst payload. A burst must have at least one message. It can have as many as are allowed by the maximum length and the uplink minimum and maximum rates for each message type

Final Approach Segment Definition



DCP — datum crossing point
FAS — final approach segment
FPAP — flight path alignment point
FTP — fictitious threshold point
GARP — GBAS azimuth reference point
GPA — glide path angle
GPIP — glide path intersection point
LTP — landing threshold point
TCH — threshold crossing height

- LTP/FTP, FPAP, TCH & GPA – Fully Define the Final Approach Segment (FAS)
- Same type of FAS defined for SBAS APV (including LPV)
- Very flexible so that the FAS can be placed wherever desired
- Can match existing ILS guidance and VASI/PAPI
- Can create offset threshold approaches, multiple glideslopes etc.

Reference: ICAO SARPS Annex 10 Guidance Material for GBAS

737NG GLS - Tuning A GLS Approach

737NG Navigation Control Panel

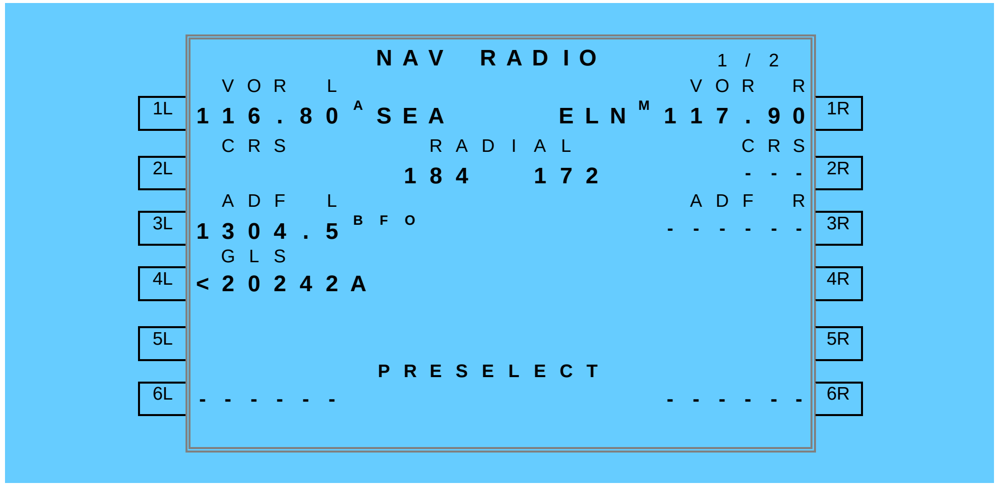
Moves Standby Selection to Active

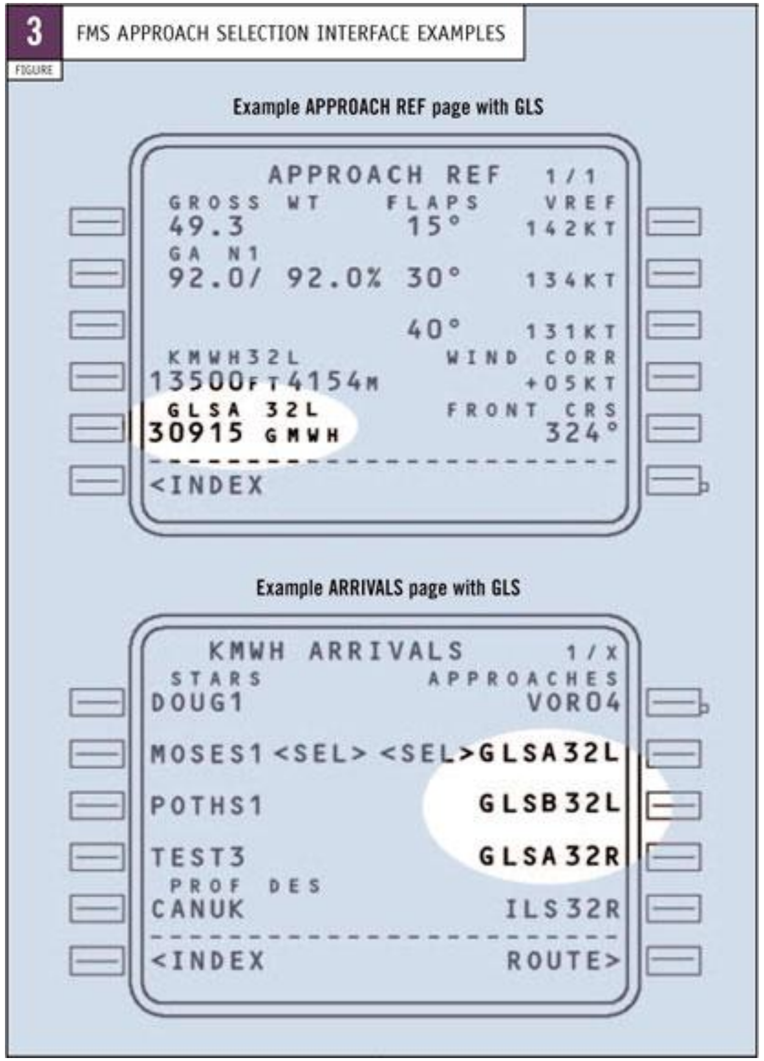
Keypad entry changes
Value in Standby Selection

Cycles through Modes: ILS, VOR, GLS

GLS Flight Management System (FMS) Approach Selection Interface

- The GLS procedures are selected on the CDU in the same way that ILS is.





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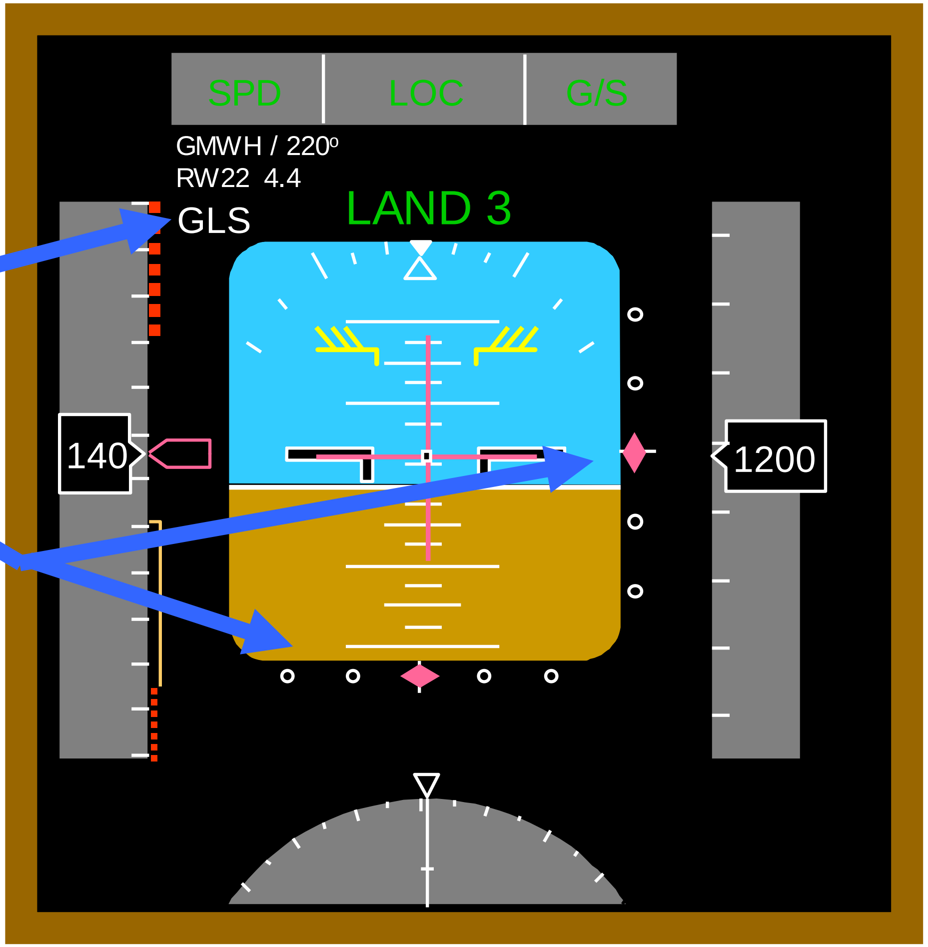
GLS Information on the Primary Flight Display

- Common Flight Mode Annunciator and auto-flight annunciations
- Data block indicates approach data and type
- Common deviation display "ILS – like"
- Common crew procedure



Implementation considerations

Aircraft equipage level

- What percentage of aircraft operating into that airport are GLS equipped
- How will mixed traffic be supported

Airport suitability

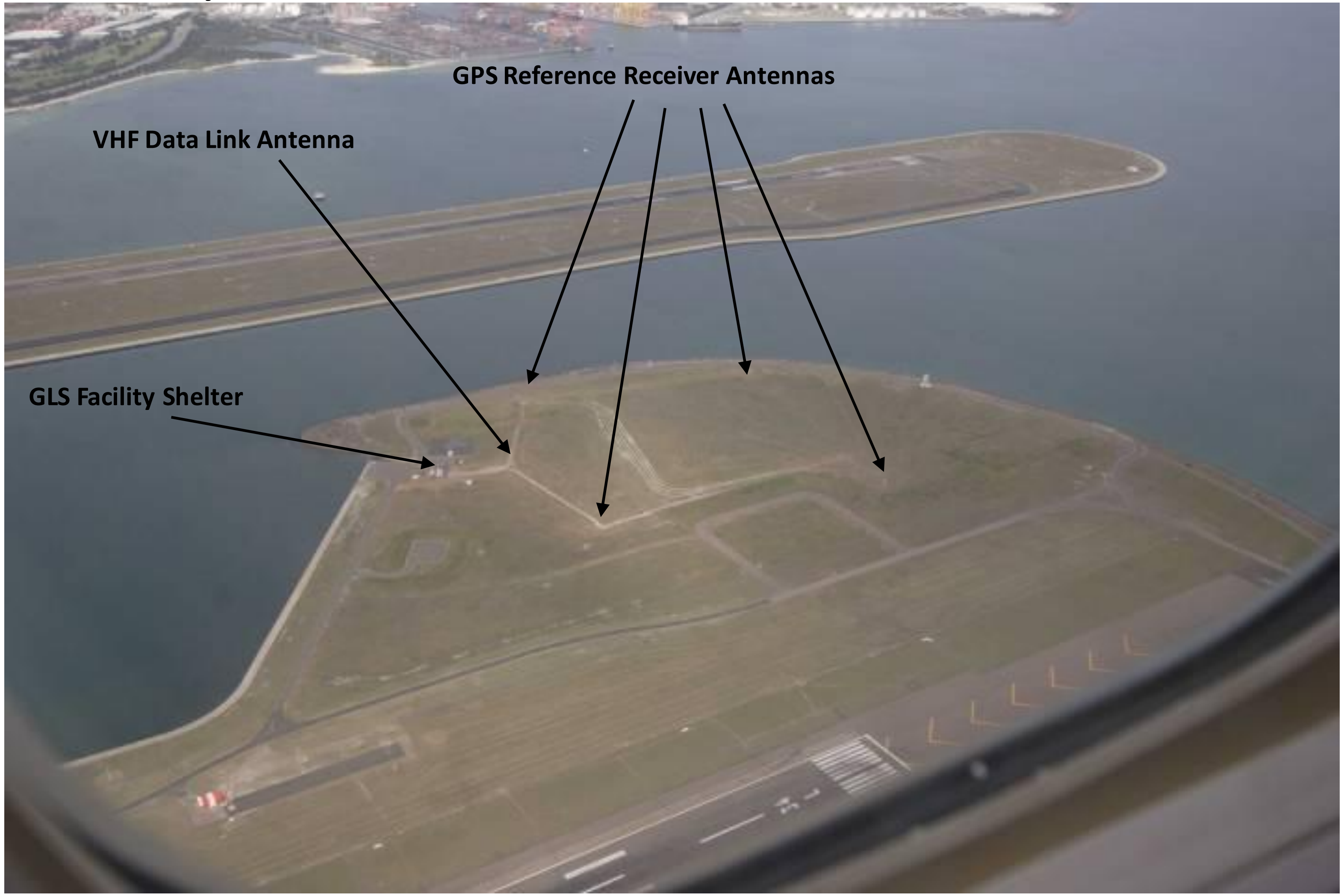
- Is there a suitable location for the GBAS elements?
- What is the ionospheric environment?
- Are there runways that can’t be served with ILS?

Support for Advanced Operations

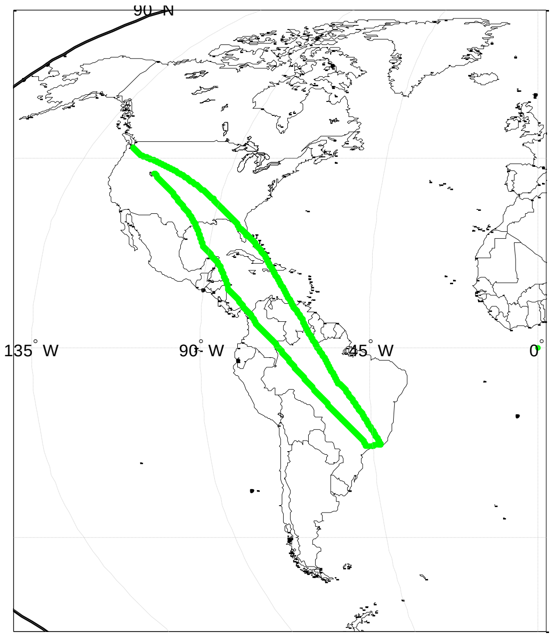
- Can ATC integrate the more advanced operations like RNP to short final
- Can CAT II operations using GAST C be considered?
    - Needs SBAS integration or other iono mitigation

Example: GBAS Installation at Sydney

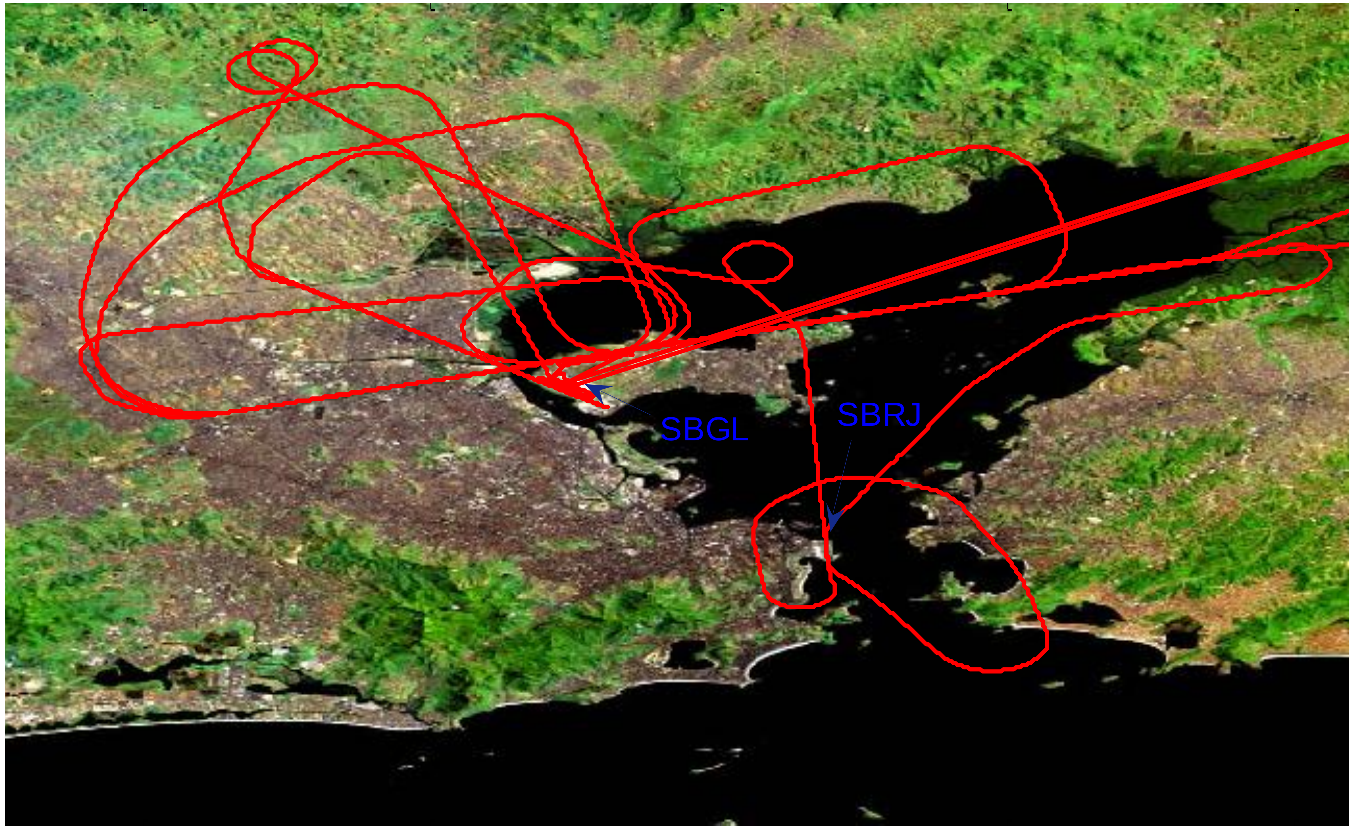
Example: GBAS Installation at Sydney (Continued)



Test Flights in Rio de Janeiro, Brazil - 2007



Dual frequency data collected throughout the ferry flight to support airframe multipath analysis and ionospheric error studies



FAA Test Prototype at Galeao Antonio Carlos Jobim (SBGL)

- 17 total approaches, with 11 autolands
- 4 coverage assessment low altitude approaches over the runways at nearby Santos Dumont (SBRJ)

Iono measurements made with dual frequency receivers

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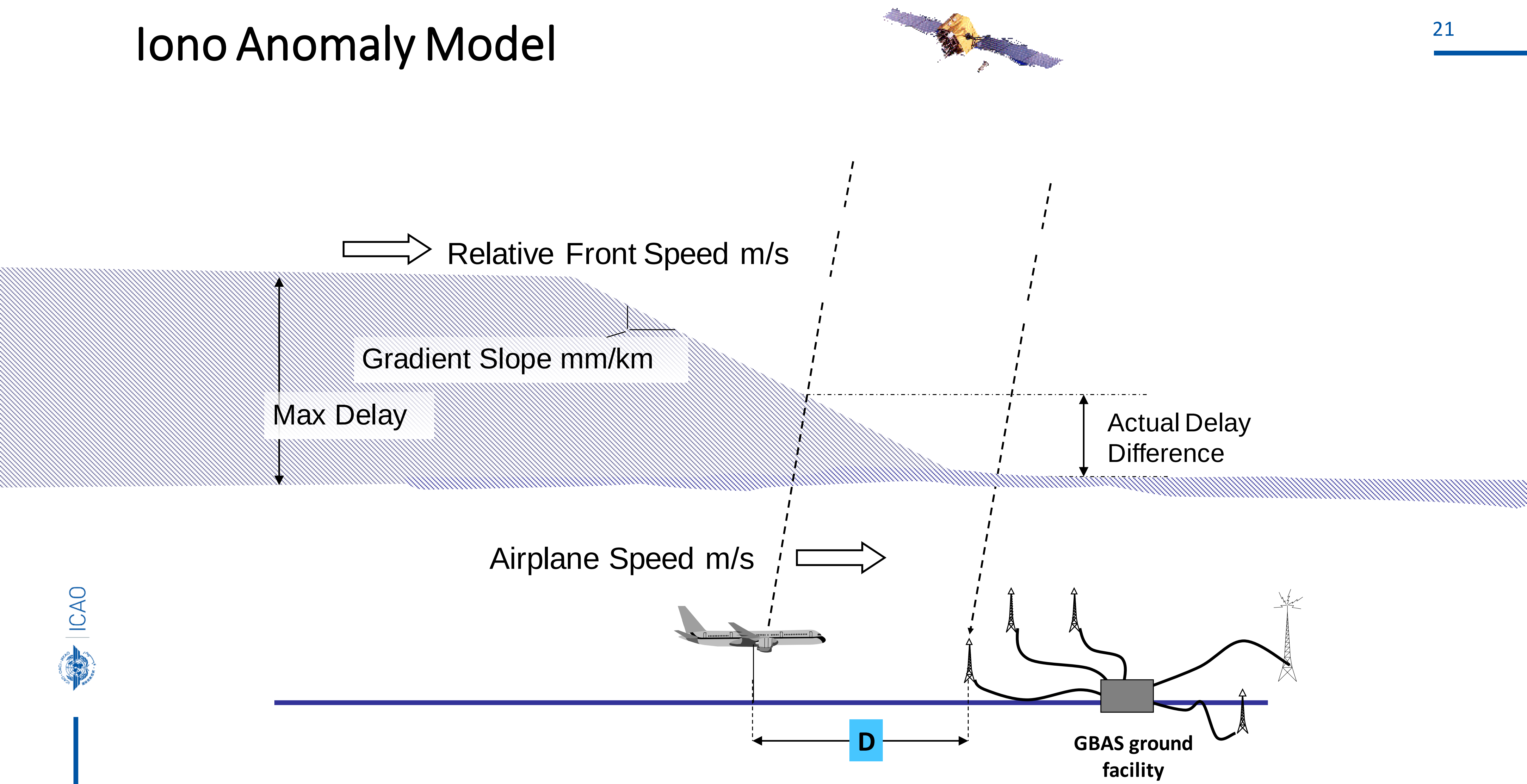
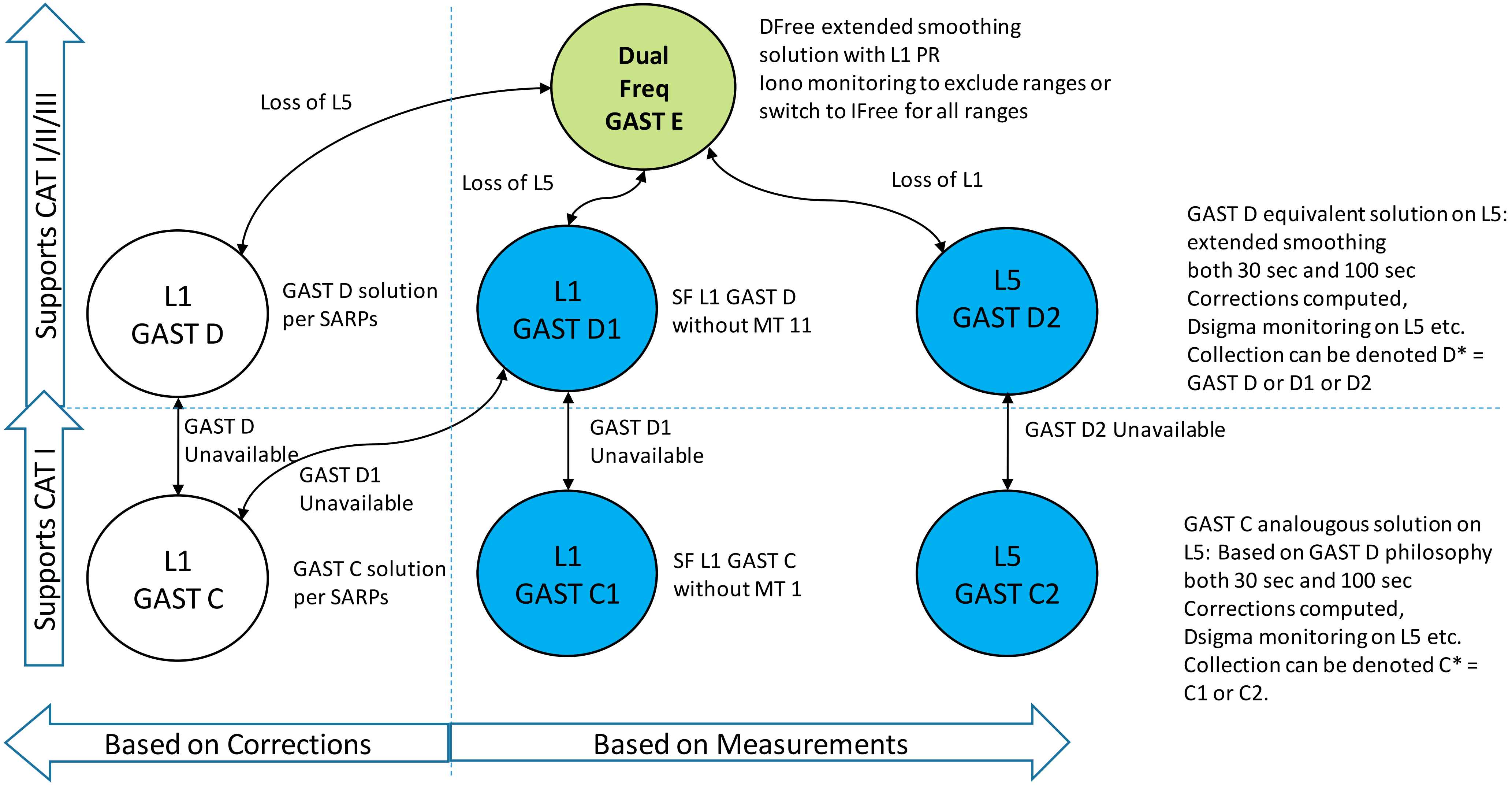
Iono Anomaly Model



GBAS Approach Service Types

- GBAS has evolved in order to support more advanced operations
  - First version was designed for CAT I operations
  - Later an updated version was introduced to support CAT II/III operations
- A GBAS ground station may support multiple types of capabilities with multiple generations of equipment
- To deal with this issue, the concept of GBAS Approach Service Types (GAST) has been developed.
- A GAST is a matched set of ground and airborne requirements that, when used in concert, produce desired performance with quantified accuracy, integrity and continuity
  - Original CAT I development - GAST C
  - Later CAT II/III development – GAST D
  - New services types to support Dual Frequency Multi Constellation (DFMC) are under development

Proposed GBAS Approach Service Types



Risks and Challenges

GBAS CAT I Operational Today

- Works well in mid-latitudes where ionosphere is well behaved

GBAS CAT II Operational at one airport

- Potential for more
- Requires some Iono mitigation strategy & Operational approval

GBAS for CAT II/III Standards are ready

- No Ground station currently being developed

DFMC GBAS for robust CAT I/II/III is under development

- Should allow GBAS to be implemented anywhere with high availability
- Progress is slow
  - Level of effort expended by States on development decreasing over time
  - Recent GNSS RFI experience
- DFMC aircraft equipage will only start in 2030 and build slowly

Questions ?