GLS Approaches using SBAS: a SBAS to GBAS converter

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Structure of this Presentation

• PBN Approach Navigation
• Who uses What system and Why
• The GLASS approach to 3D approaches
• Integrity in Approach Navigation
• The GLASS processing chain
• Flight Inspection
• Conclusions
Differential GPS (GNSS) Principle

- GPS is a ranging system, position \((x,y,z,t)\) is determined by triangulation.
- Receivers at fixed and known location can determine ranging error.
- True range – measured range = range correction.
- Correction can be sent to user near the fixed receiver.
- User applies correction and gets better position accuracy.
- But what about integrity, continuity, availability?

Diagram: Diagram showing the principle of Differential GPS with a satellite, GPS receiver, and correction transmitter.
Ground Based Augmentation System (GBAS)

- Differential GPS for aviation with multiple antennas and receivers (three to four)
- Cross checking of measurements from different receivers
- Averaging mitigates uncorrelated errors
- Redundancy of hardware
- Multi day calibration of station noise & multipath values
- Integrity data provided to user locally using VHF link
- Final Approach Segment Data Blocks (up to 49)
- Known as GLS
Final Approach Segment Data Block

- Localizer and glidepath computed from augmented GNSS data
- Uses local augmentation system (GBAS, LAAS)
- ILS like guidance
Final Approach Segment Data Block

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<table>
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<th>Operation Type</th>
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<td>Airport Identifier</td>
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<td>Runway</td>
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<td>HAL (metres)</td>
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<td>VAL (metres)</td>
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Satellite Based Augmentation System (SBAS)

- Differential GPS intended to serve a large area.
- Known reference station distributed across a continent
- Corrections are split into individual constituents
- There are fast correction, long term corrections and ionosphere corrections as well as satellite position corrections as part of the long term corrections
- Correction and integrity data provided to the user on GPS frequency via geostationary satellite

\[ \rho_{\text{corrected},i} = \rho_{\text{CSC},i} + \left[ \rho_{\text{PRC},i}(t_{\text{c}}) + \rho_{\text{RRC},i}(t_{\text{c}}) \times (t - t_{\text{ref}}) \right] TC_i + c \Delta t_{\text{av,cop}} + IC_i \]
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RNP Approach to LPV Minima

- Provides ILS like guidance on final of RNP approach
- Localizer and glidepath computed from augmented GNSS data
- Uses Satellite Based Augmentation System (EGNOS, WAAS)
- Can enable decision heights as low as 200ft AGL, normal is 250 ft
- Final approach segment data block is stored in aircraft navigation database
Augmentation Systems and main Users

GBAS

Commercial Air Transport

What is the reason for this allocation?

SBAS

General Aviation & Regional
SBAS not for Commercial Air Transport? – “Historical view”

Manufacturers say: „Large airports and hubs have xLS anyway, for our customers SBAS is not necessarily to be added, those retro fit certification are not worth the cash.”
No Mandate ... “Chicken-and-Egg Problem”

Airframers & Avionics Suppliers

Airlines

ATC

Only build new functionality
IF
the Airlines will buy it!

Only provide benefits
IF
the Airframers have built it!

Only buy new functionality
IF
ATC gives benefits for it!
Augmentation Systems and Users

GBAS

Commercial Air Transport

SBAS

General Aviation & Regionals

Low cost GBAS

receiver for GA

GLASS
Integrity Data (Protection Levels)

- Each GBAS and SBAS receiver computes protection levels
- Protection levels are the position uncertainties at 99.999998%
- Protection levels are compared to a maximum allowed value, the Alert Limit which is dependent on approach operation type
Stanford Integrity Plot

- Graphical representation of integrity

![Stanford Integrity Plot](chart)

- **Unavailable**
- **Misleading Information**
- **Hazardously Misleading Information**

Demo with bin resolution of 0.25 m

**Protection Level [m]**

**Navigation System Error [m]**

Log (number of samples) of total 1 samples
Stanford Integrity Plot

- Graphical representation of integrity

Demo with bin resolution of 0.25 m

Available

Misleading Information

Hazardously Misleading Information

Protection Level [m]

Unavailable

Navigation System Error [m]

log(#samples) of total 1 samples

0

1

0.8

0.6

0.4

0.2

0

-0.2

-0.4

-0.6

-0.8

-1
Technical: SBAS to GBAS Differences

- 4 dimensional covariance position error ellipse (horizontal shown)
Technical: SBAS to GBAS Differences

- 4 dimensional covariance position error ellipse (horizontal shown)
- SBAS bounds horizontal error

Approach direction
Technical: SBAS to GBAS Differences

- 4 dimensional covariance position error ellipse (horizontal shown)
- SBAS bounds horizontal error
- GBAS bounds lateral error
Technical: SBAS to GBAS Differences

- 4 dimensional covariance position error ellipse (horizontal shown)
- SBAS bounds horizontal error
- GBAS bounds lateral error
  → SBAS HPL is larger than GBAS LPL

- Inflate GBAS lateral error by adding factor $F$ to error distribution

$$\sigma_i^2 F \sigma_{pr \_gd \_x}^2 [i] + \sigma_{mapo}^2 [i] + \sigma_{pr \_ar}^2 [i] + \sigma_{iono}^2 [i]$$
$P_{\text{corrected},i} = P_{\text{CSC,j}} + P_{\text{RC},i(t_{\text{gti}})} + R_{\text{RC},i(t_{\text{gti}})} \times (t - t_{\text{gti}}) TC_{i} + c \Delta_{\text{sys,corr}} + IC_{i}$

$\sigma_{i}^{2} = \sigma_{pr,\text{gnd}}^{2}[i] + \sigma_{\text{pr,prop}}^{2}[i] + \sigma_{\text{pr,atm}}^{2}[i] + \sigma_{\text{iono}}^{2}[i]$
GLASS Results: Ground Testing

• VAL limited to 25.4 due to bit allocation in VDB, normal FASVAL is 50m
One Week Testing on Ground

- Data recorded at the SBAS receiver location
- Inflator consistency
- Vertical inflation much higher due to lateral/horizontal mapping
One Week Testing on Ground

SBAS with bin resolution of 0.50

System Unavailable
Alarm epochs: 212

GLASS GBAS with bin resolution of 0.50

System Unavailable
Alarm epochs: 89128

LPV VAL 99.98 %
HMI Epochs: 00

MI Epochs: 00

LPV VAL 92.40 %
HMI Epochs: 00

MI Epochs: 00
Flight Validation

- Flight Calibration Services performed standard GBAS Flight Validation
Selected FCS Results
Selected FCS Results
Comparison of the costs of ILS, GBAS and GLASS for 20 years and a lifespan of the systems of 10 years. GLASS is clearly more inexpensive than the two other systems. A GBAS station is only more inexpensive in scenarios with the lowest initial costs.
Conclusion

- The system works as expected
- Parameters within specifications for GBAS
- Cost can be brought down compared to GBAS
- Time to Alert requirements to be investigated.

“Assessment completed against GBAS GAST-C ("Cat I") flight inspection criteria as there are no flight inspection criteria for a system such as GLASS. The classification of "Limited Use" reflects this discontinuity in standards even though the GLASS fulfils all flight inspection relevant requirements of a GBAS GAST-C installation.”