Total System Error Performance During Precision Approaches

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GBAS Mode of Operation

1) GNSS (GPS) signal
2) Every Reference Station compares received GNSS Ranges with known Positions (Differential corrections)
3) Info about Pseudo-Range calculations and integrity data for every satellite in view
4) Transmission of GBAS data to MMR equipped A/C via VDB antenna

(Differential corrections)

Source: AENA, OPTIMAL
Motivation

- GLS was introduced as “ILS look-alike” straight-in CAT I landing aid

- Although certified as such, ICAO did not allow GLS as landing aid for parallel approaches

- The goal of this study was to gather data for ILS and GLS approaches and enable parallel approaches with GLS

- Flight trials with a transport category aircraft were conducted

- To show:
  - GLS Total System Error (TSE) is at least as small as ILS TSE
  - GLS TSE is within requirements for precision approaches
Error Sources

Total System Error (TSE) consists of:

- Navigation System Error (NSE); the error between actual position and the estimated position of the navigation system
- Flight Technical Error (FTE); the error between defined flight path and estimated position
- Path definition Error (PDE) is neglectable
Flight Trial Setup

- DLR’s Advanced Technology Research Aircraft (ATRA)
- Airbus A320-232
Flight Trial Setup

- Experimental cockpit display on F/O side
- Manual flight only for all approaches
Flight Trial Setup

- Experimental curved GLS approaches (part of different investigations)
- Error data on final approach segment used for this study
Flight Trial Setup

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<th>Dates of Flights</th>
<th>No. of ILS Appr.</th>
<th>No. of GLS Appr.</th>
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- Different flights used for investigations
- Still a small sample size
Methods

- Manually conducted ILS or GLS approaches used for investigations
- Data used from straight final segment only (approx. 7km from threshold)
- Position data from a Septentrio GNSS receiver used for investigations
- Reference trajectory calculated with commercial software, dual frequency GPS carrier phase solution (assumed true position)
- GBAS position data calculated with PEGASUS toolset provided by EUROCONTROL
- ILS data taken from basic avionics recordings
- FTE = Deviations; TSE = Distance between desired flight path and reference trajectory
Results – Total System Error ILS

- Mean ILS TSE at a given distance to runway threshold
- Standard deviation depicted as vertical bar
- Black vertical line indicates decision height
Results – Total System Error GLS

- Mean lateral GLS TSE at a given distance to runway threshold
- Triangles indicate number of samples for a given distance bin
- Decreasing number of samples as go-arounds were conducted
Results – Total System Error GLS

- Mean vertical GLS TSE at a given distance to runway threshold
- Triangles indicate number of samples for a given distance bin
- Decreasing number of samples as go-arounds were conducted
GLS Lateral Error Decomposition

- Major error component of GLS TSE is the FTE (green)
- Navigation System Error (NSE) is very small
GLS Vertical Error Decomposition

- Major error component of GLS TSE is the FTE (green)
- Small sample size especially after 1km from runway threshold due to go-arounds
GLS Vertical Navigation System Error

- Small sample size especially after 1km from runway threshold due to go-arounds
- Standard deviation slightly larger than in the lateral case
Comparison ILS & GLS lateral TSE

- Direct comparison in the last, straight part of the approach shows that the TSE is similar
Comparison ILS & GLS vertical TSE

- Direct comparison in the last, straight part of the approach shows that the TSE is similar
Conclusion

- The Flight Technical Error is the major error component of the GLS Total System Error

- The observed GLS TSE is at least as small as the observed ILS TSE

- GLS TSE is within the assumptions of the Collision Risk Model (CRM) for ILS category I approaches
  - CRM specifies a standard deviation of 22.4m for the lateral TSE at 1200m away from runway (observed lateral std. dev. < 4m)
  - As well as a standard deviation of 7m for the vertical TSE at 1200m away from the runway threshold and a glide path angle of 3.5 degrees for Braunschweig airport (observed vertical std. dev. < 6m)

- Even though the investigated sample size is small, the TSE of both systems look similar and therefore, the use of GLS for parallel approaches should be allowed
Thank you very much for your attention!

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