Cockpit Visualization of Curved Approaches based on GBAS

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Contents

- Motivation

- Testing infrastructure

- Simulation and flight test results

- Discussion

- Conclusion
Current Situation

- Only few avionics systems or landing aids are able to provide guidance for curved approach procedures

- Usually, curved approaches are only laterally guided

- Laterally and vertically guided curved approaches are categorized as RNP AR or Advanced RNP

- RNP AR has many requirements for design, aircraft equipment and flight crews

- Satellite navigation is de-facto main navigation source for curved approaches

- Navigation solution is usually augmented by either INS or SBAS/GBAS
Motivation

- Growing complexity of Air Traffic
- Growing demands for emission reduction – especially noise
- Satellite navigation allows precise navigation
- GBAS provides flexibility to design flexible and curved precision approaches
- Terminal Area Path (TAP) functionality already described in RTCA standard
- How can laterally and vertically guided (precision) curved approaches be enabled for a large range of users?
Terminal Area Path Functionality

- TAP functionality allows design of curved approach paths
- Track-to-fix and radius-to-fix legs can be defined
- Additionally, a displacement sensitivity can be assigned to every individual leg

- At this value Full Scale Deflection (FSD) will be reached
- Every TAP can be linked to a Final Approach Segment (FAS)
- FAS is a straight-in final segment in a ILS-look-alike fashion
- During a TAP the deviations are linear, during a FAS they are angular
Curved Precision Approach with TAP functionality

- Goal is to keep current avionics architecture unchanged
- For autopilot and flight director the (usually fixed) runway direction is an important parameter next to the deviations
- Runway direction is set by pilot or FMS
- GBAS receiver only passes the value on to connected systems
- Idea: GBAS receiver changes runway direction
  - During a straight leg it is the track
  - During a curved leg it is the tangent to the curve
- Interfaces between receiver and aircraft remain unchanged
- Flight director and autopilot receive unchanged parameter set
- Issue: Turn anticipation
Testing Infrastructure

- Generic Experimental Cockpit (GECO)
- Ground Based Augmentation System (GBAS) Ground Station with TAP broadcast
- Advanced Technology Research Aircraft (ATRA, A320)
Display Layouts

- Different display layouts were used
  - ”Raw data” with ILS-look-alike indications
  - Map display
  - Diamond shaped deviation symbols
  - Adaptive runway direction indication
Display Layouts

- Additionally flight director in PFD (green bars)
- Tunnel display as alternative display concept
Testing of Curved Precision Approaches

- Two TAPs were designed and implemented

- Simulator trials were conducted with different pilots (16 pilots, 32 approaches)

- During the trials approaches were conducted manually and automatically

- Main variable was the lateral and vertical displacement sensitivity (full-scale deflection indication)

- Flight trials were conducted with this sensitivity

- Three different display methods were investigated during manually conducted approaches
Simulation Results – TAP A

- Standard deviation of lateral displacements at a given distance to the threshold
- Approaches conducted manually
- Different displacement sensitivities investigated
Simulation Results – TAP B

- Better performance than during TAP A
- Well within RNP 0.1 full scale deflation margins
- All approaches with raw data display layout
Flight Test Results – TAP A

- Manually conducted TAP A approaches with different display layouts

- Displacement sensitivities kept constant with RNP 0.1 values
  - Laterally 0.1NM (185m)
  - Vertically 50ft (15m)
- Laterally good results with tunnel display
- Laterally well below RNP 0.1 FSD with all display layouts

- Vertically good results with all display layouts (constant glide slope)
- Vertically within 50ft FSD
Flight Test Results – TAP B

- Manually conducted TAP B approaches with different display layouts
- Generally better flight path following performance than during TAP A
- Laterally with tunnel display well below FSD for CAT I FSD at threshold
- Vertically good results with all display layouts (constant glide slope)
- Vertically within 50ft FSD
Impact of Curved Approaches on ATM

- Manually conducted precision approach procedures are feasible but may require additional pilot support (flight director or suitable displays)

- Using GBAS TAP functionality as enabler for precision curved approaches allows predictable and up-to-date trajectory based aircraft operations because the approach paths are controlled on ground

- Therefore, even complex procedures with fixed vertical profiles can be tuned by the pilot with only five digits

- 4D performance of individual aircraft types and especially controller workload in mixed traffic scenarios would have to be subject to further investigations
Conclusion

- Curved precision approaches possible with GBAS and TAP functionality

- Flight Path following accuracy is dependent on lateral displacement sensitivity and TAP design

- RNP 0.1 sensitivity was found by pilots as the most suitable one in simulator trials

- Transition between altitude sources (barometric to GBAS) is an issue

- TAP design can compensate this issue with continuous glide slope (a curved precision approach all the way)

- The indication of this design architecture needs to be considered in a tunnel display

- Precision curved approaches could be realized with minor modifications on current avionics
Thank you very much for your attention!

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