RESEARCH ON A-PNT IN EUROPE

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Short/Mid-term A-PNT
Evolution of legacy technologies

- Enhance legacy technologies
- Make use of legacy infrastructure and equipage
- Feasible in short/mid term

Long-term A-PNT
New technologies

- Improve performance to support more demanding procedures
- Increase spectrum efficiency
- Use CNS synergies

Scope limited to enroute and TMA applications
Why A-PNT

- Wide implementation of PBN applications in all phases of flight
  - FRA based on RNAV 5 in en route airspace
  - SIDs/STARs predicated on RNP 1 with RF legs in high density TMAs
  - SIDs/STARs predicated on RNAV 1 in additional TMAs
  - Low altitude helicopter routes predicated on RNP 0.3
  - RNP/APCH (LNAV/VNAV and/or LPV minima) at all instrument RWY ends

- GNSS is the nominal sensor for all PBN operations (required for RNP)

- DF-MC GNSS on the horizon

- Is there still a need for terrestrial backup?
Why A-PNT

- Arguments for terrestrial backup
  - GNSS vulnerabilities
  - Gradual implementation of DF-MC starting not earlier than 2025
  - State liability for navigation service provision
  - Sovereignty

- A-PNT today:
  - DME/DME (+VOR/DME)
  - ILS/DME

- Future A-PNT must be better
  - Performance
  - Spectrum
  - CNS synergies
How good is DME today?

- Measured accuracy twice better than standards
  - Range error: $2\sigma < 0.1$ NM
  - DME/DME NSE: $2\sigma < 0.3$ NM
- Extensive coverage
DME issues

- Low ramp in DME range error (0.01NM/s) not detected in DME/DME/IRS mode

- Range integrity needed to demonstrate suitability for RNP reversion (min $10^{-5}$/h)

- Although executive monitors are required, no minimum integrity level in ICAO Annex 10

- Nevertheless integrity requirements included in FAA and EUROCAE specifications and therefore modern transponders comply
  - FAA E-2996
  - EUROCAE ED-57 (for DME-P supporting final approach operations)
DME improvements – Short Term Standardisation

- Update ED-57
  - Reflect actual performance of modern transponders and harmonize with other specifications
  - Include guidelines for integrity derivation of DME ground equipment

- Propose improvements compatible with current technology which can be smoothly deployed (e.g. faster rise time)

- Document the use of DME/DME for RNP 1 reversion

- EUROCAE WG107
  - Update ED-57 MOPS for DME ground equipment
  - Write MASPS RNP Reversion using DME/DME Positioning
DME improvements – Mid Term

Hybrid ranging

- DME is a two-way ranging system
- Transponders overload in high traffic density areas
- One way ranging
  - Broadcast from ground (pseudorandom pulse pair sequence)
  - No capacity limitation
  - Needs time synchronisation

- Hybrid ranging
  - Two-way ranging – relative synchronisation
  - One-way ranging – relative range measurements
  - Reduced risk of transponder overload
  - Compatibility with legacy interrogators
DME improvements – Mid Term
Multi-DME

- Snapshot method to compute 3D position in ECEF with RAIM algorithm
- Minimum number of ground stations
  - 3 (4 to eliminate ambiguity)
  - Additional range for integrity
  - Baro altitude can be used as additional range
- RAIM targets
  - Full OPMA compliance
  - HIL: $10^{-7}$/h; PFA: $10^{-4}$/h; PMD: $10^{-3}$/h
  - Assumed transponder integrity: $10^{-3}$/h
- Initial analysis in Paris CDG area
  - RNP1 protection level is achievable
  - Potential complexity of selection algorithm (15504 possible combinations) solved

$2\sigma_{\text{DME}} = 0.2\text{NM}$ (standards)

$2\sigma_{\text{DME}} = 0.1\text{NM}$ (actual)
LDACS-NAV

- ICAO standardization process ongoing
- OFDM system with 500 kHz bandwidth
- Shares the DME band (960 and 1164 MHz)
- One-way ranging

- Initial simulations in German airspace
  - 159 ground stations
  - Time synchronisation 20ns
  - No terrain masking
  - No limitation on # of channels

- Excellent performance but some optimistic assumptions
LDACS-NAV

- The network of ground stations required for COM not sufficient to support NAV
- LDACS-NAV rather a complementary ranging source
- Combined DME-LDACS simulations
  - 69 LDACS stations
  - Accuracy improvement mainly in the vicinity of these facilities

- Main research objectives
  - Characterise threats (multipath, tropospheric delays, sync errors)
  - Define mitigation strategies and integrity monitoring functions
eLoran

- Robust alternative to GNSS
  - Complementary physical characteristics (low frequency, high power)
  - Additional data channel (LDC) to convey corrections for major error sources and integrity data
  - Potential multi-modal use: Maritime, Land-mobile, Aviation, Time source

- eLoran for Aviation
  - Can meet RNP 0.3 requirements
  - The use of ADF antenna may facilitate retrofitting
  - Not a wide agreement in aviation community for the use of eLoran
  - Aviation community not the main driver
One of the main source errors: Additional Secondary Factors (ASF)
- Due to propagation over land and elevated terrain
- Correction provided typically by measurements recorded in transmitter specific maps / databases

Novel performance assessment approach:
- Build accurate ASF model, to be integrated into coverage prediction models or Kalman-based filters
- Quantify accuracy, integrity and obtainable RNP levels by combining various models (ASF, SNR, HDOP)
Multitude of legacy and new positioning sources investigated

One of the key aspects: **Transition**
- Service legacy aircraft
- Gradual deployment of new ground and on-board systems

Potential solution: Modular A-PNT
- Fuse various ranging sources in an aggregated positioning solution with integrity
- Need to handle systems with different performances, failure modes and maturity levels

Concept to be further investigated and developed
A-PNT Transition

- Main factors that may influence the long-term solution and transition
  - GNSS interference environment
  - Availability and robustness of DFMC GNSS
  - Operational need (higher performance)
  - Worldwide agreement
  - Spectrum pressure on L band
  - Incentives

- Coordinate CNS approach to group COM/NAV/SUR upgrades into a single upgrade would facilitate Airspace Users buy-in

- The long-term A-PNT solution may depend on the progress driven by COM/SUR or by non-aviation applications