# RESEARCH ON A-PNT IN EUROPE

2018 iCNS Conference

Presented to the PNT Advisory Board by:
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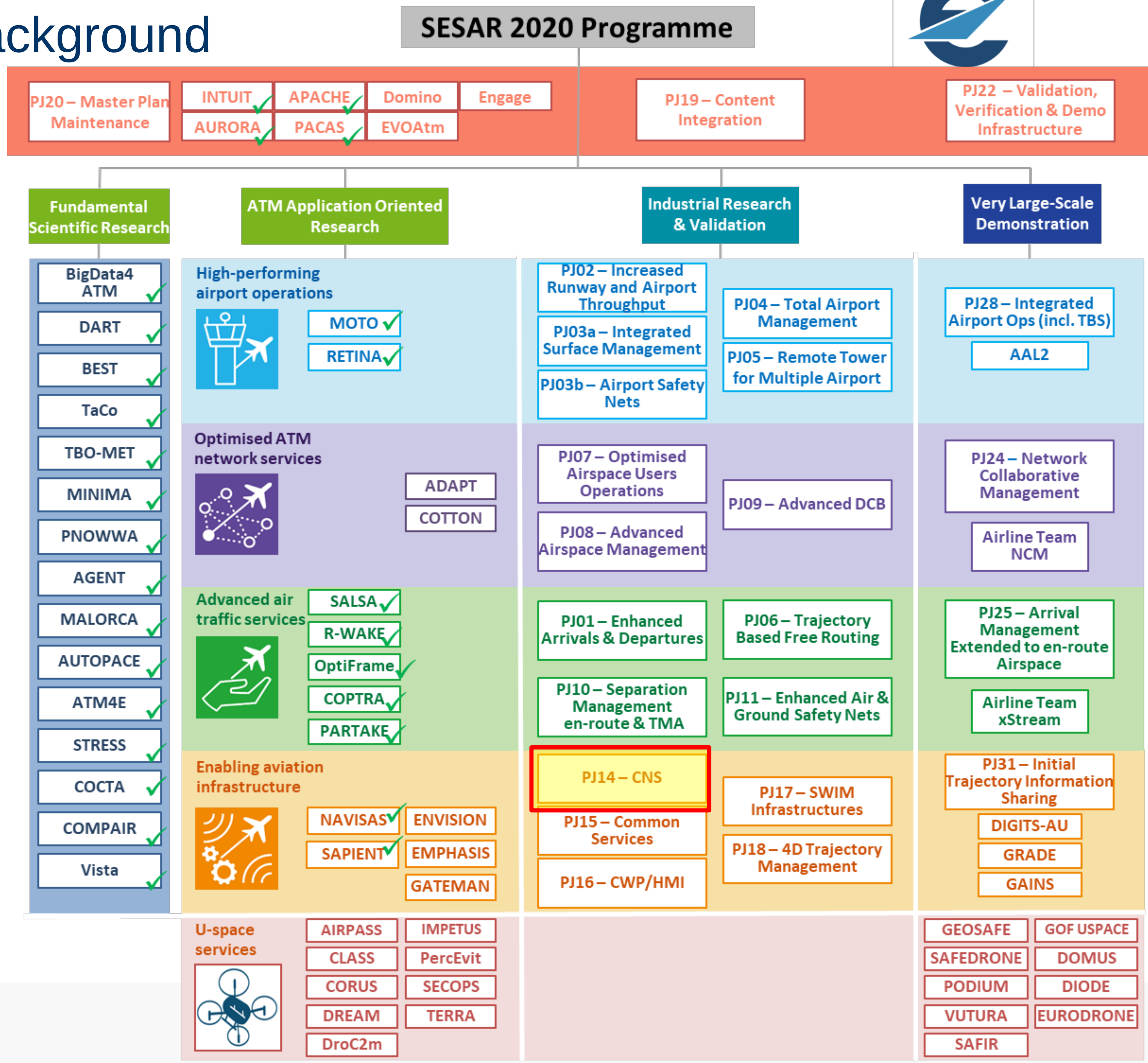
# SESAR: Background



# SESAR: Background

PJ 14-03-04 A-PNT:

- EUROCONTROL (strategy, policy)
- DLR (long-term efforts, strategy, **solution lead**, focal point Navigation)
- Thales
- Honeywell
- Enaire

| Solution Ref. | Solution Title | Maturity Level 2019 |
|---|---|---|
| PJ.14-01-01 | CNS environment evolution | TRL2 |
| PJ.14-02-01 | FCI Terrestrial Data Link | TRL4 |
| PJ.14-02-02 | Future Satellite Communications Data link | TRL4 |
| PJ.14-02-04 | FCI Network Technologies incl. voice solutions & military interfacing | TRL4 |
| PJ.14-02-05 | Development of new services similar to FIS-B to support ADS-B solutions for General Aviation | TRL4 |
| PJ.14-02-06 | Completion of AeroMACS development | TRL6 |
| PJ.14-03-01 | Advanced GBAS cat II-III operations (e.g. offset touchdown) | TRL4 |
| PJ.14-03-02 | Multi Constellation / Multi Frequency (MC/MF) GNSS | TRL4 |
| PJ.14-03-04 | Alternative Position, Navigation & Timing – short term (A-PNT) | TRL6 |
| PJ.14-04-01 | Surveillance Performance Monitoring | TRL4 |
| PJ.14-04-03 | New use & evolution of Cooperative & Non-Cooperative Surveillance | TRL4 |

# 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

# A-PNT at ICAO Navigation Systems Panel

- **12th Air Navigation Conference in 2012 led to Recommendation 6/7 d) based on input from USA**:
  - ICAO to assess “the need for, and feasibility of, an alternative position, navigation and timing system” (DOC 10007)
  - Resulted in job card assigned to NSP (Job Card NSP 009.03)
  - Current conclusion: need = YES, feasibility = current terrestrial navigation aids are sufficient
  - In PBN airspace, DME/DME and Inertial is the primary option (no more conventional route structure)
- **5th Panel Meeting (Nov 2018) agreed to reorient JC9 to deliver**:
  - Report on Alternative Position Navigation and Timing (APNT), including consideration of the feasibility of a long-term replacement or enhancement of DME as the main APNT system
  - Motivated by SESAR project work, including on CNS Spectrum Efficiency
  - Need to recognize that 960 – 1215 MHz L-Band Spectrum is under significant internal and external pressure
  - **Engagement of US in this topic would be very desirable**

# SESAR Project 14-03-04 A-PNT

Requirements

Scope limited to enroute and TMA applications

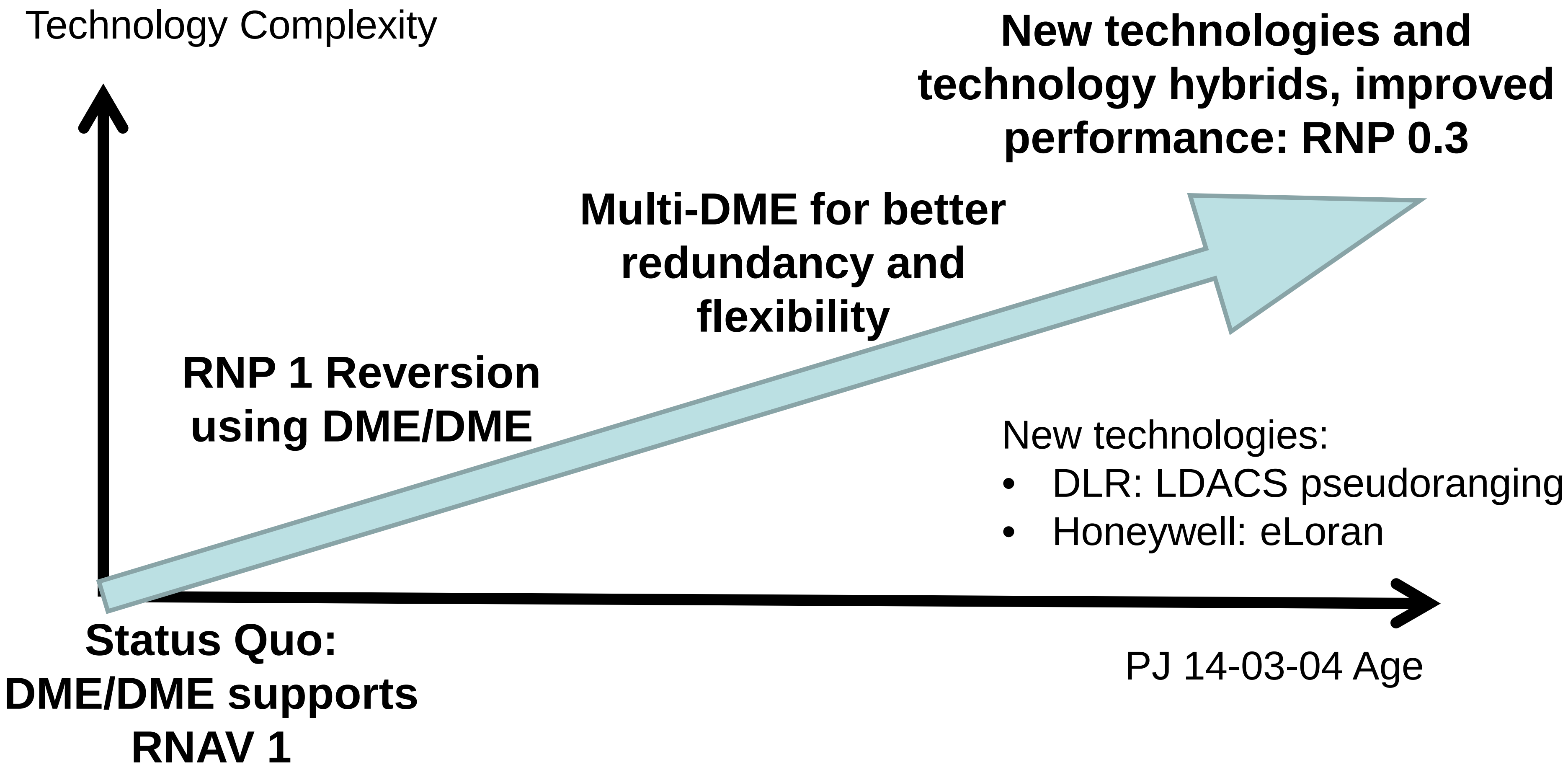
## Short/Mid-term A-PNT Evolution of legacy technologies

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

## Long-term A-PNT New technologies

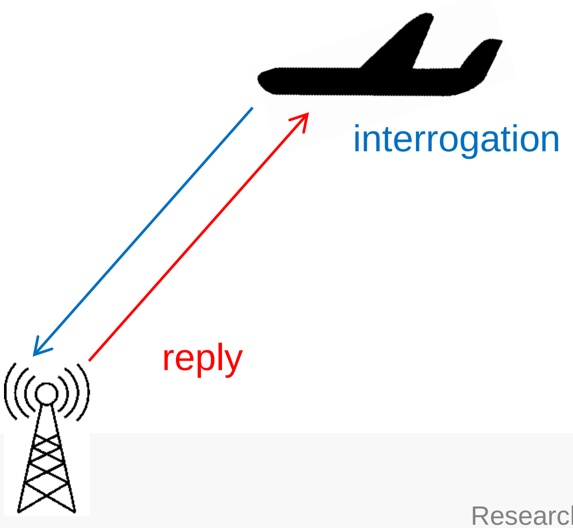
- Improve performance to support more demanding procedures
- Increase spectrum efficiency
- Use CNS synergies

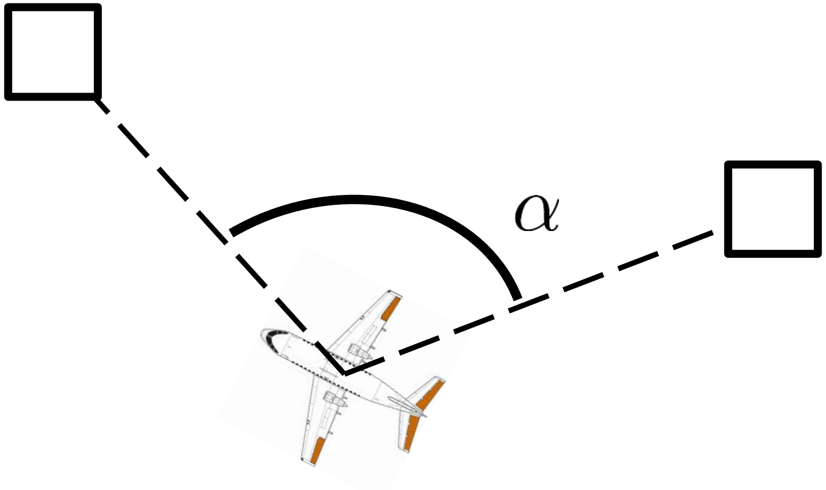
# The Time Perspective



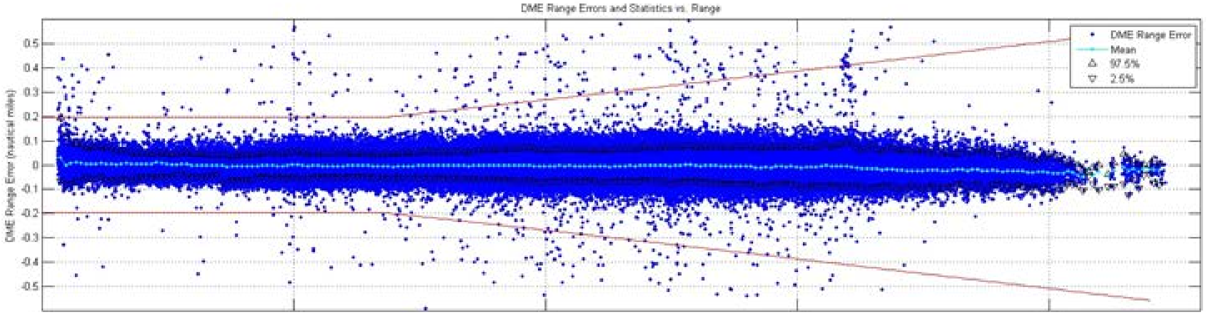
# Background: DME

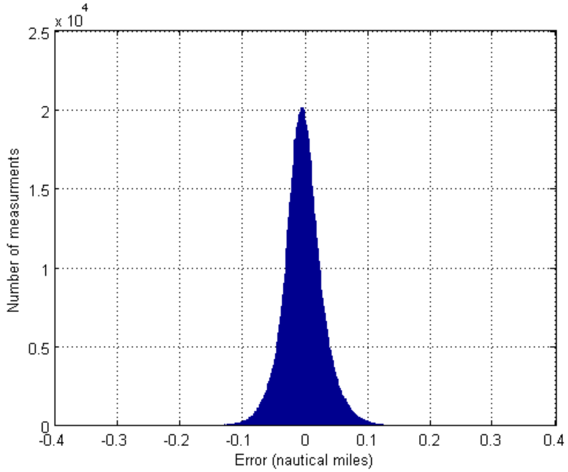
- Distance Measuring Equipment
- De-facto state-of-the-art A-PNT system
  - Two-way ranging
  - Constrained geometry: subtended angle $30^\circ \leq \alpha \leq 150^\circ$



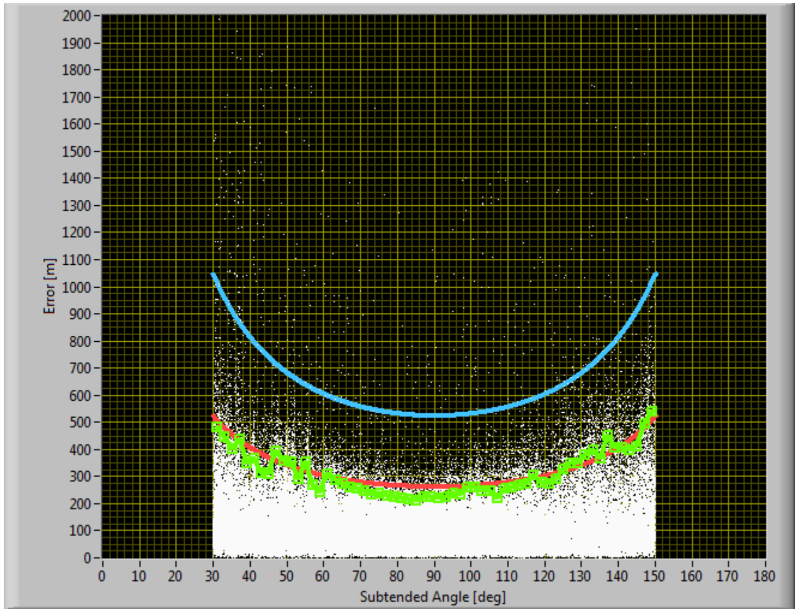



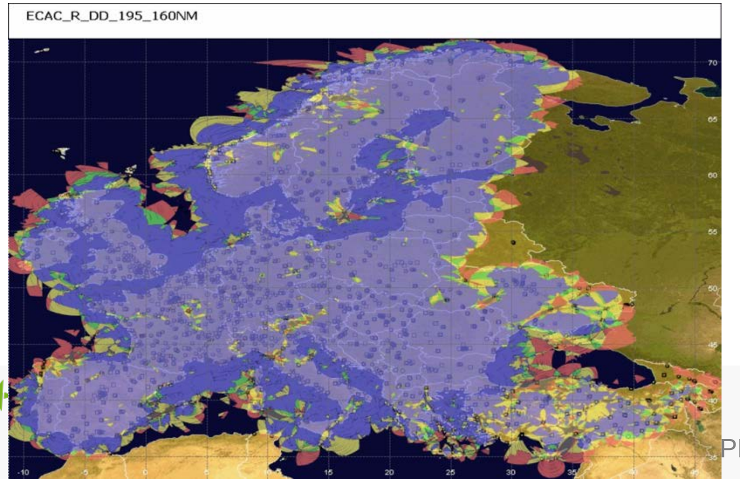
# How good is DME today ?



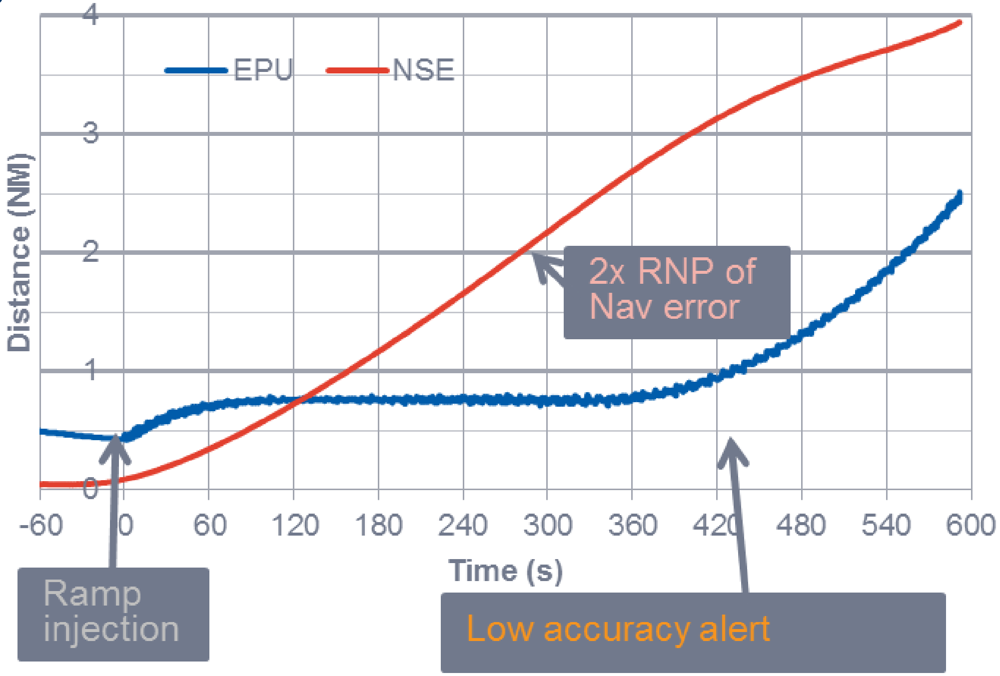

- Measured accuracy twice better than standards
  - Range error : 2σ < 0.1NM
  - DME/DME NSE: 2σ < 0.3 NM
- Extensive coverage



# DME issues:
# A systematic look at existing hazards

- EPU: Estimated Position Uncertainty
- 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)

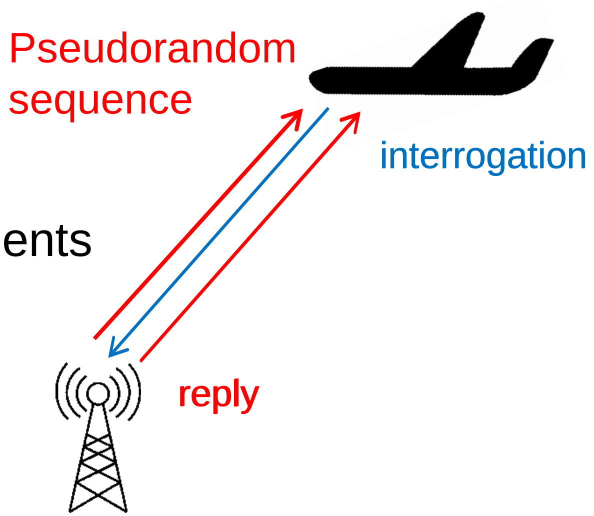
# DME improvements – Short Term Standardisation

- 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

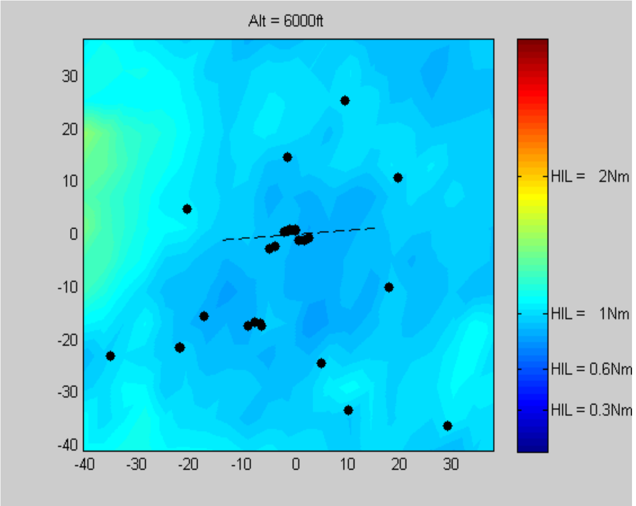
- DME is a two-way ranging system
- Transponders overload in high traffic density areas
- One way ranging
  - Broadcast from ground (pseudorandom pulse pair sequence)
  - No capacity limitation
  - Needs time synchronisation

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

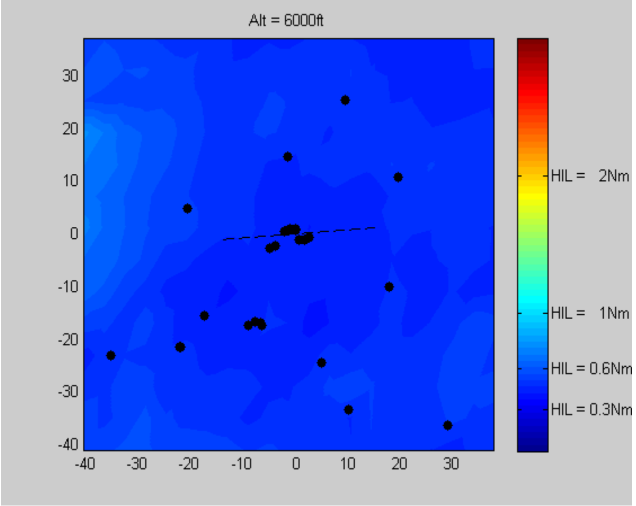


# DME improvements – Mid Term
# Multi-DME

- 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



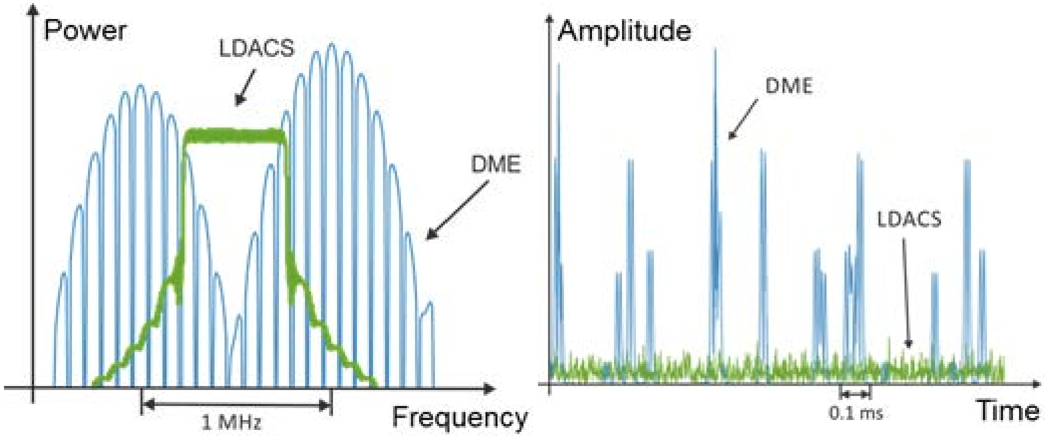

$2\sigma_{DME}$= 0.2NM (standards)




$2\sigma_{DME}$= 0.1NM (actual)

# LDACS: L-Band Digital Aeronautical Communication System

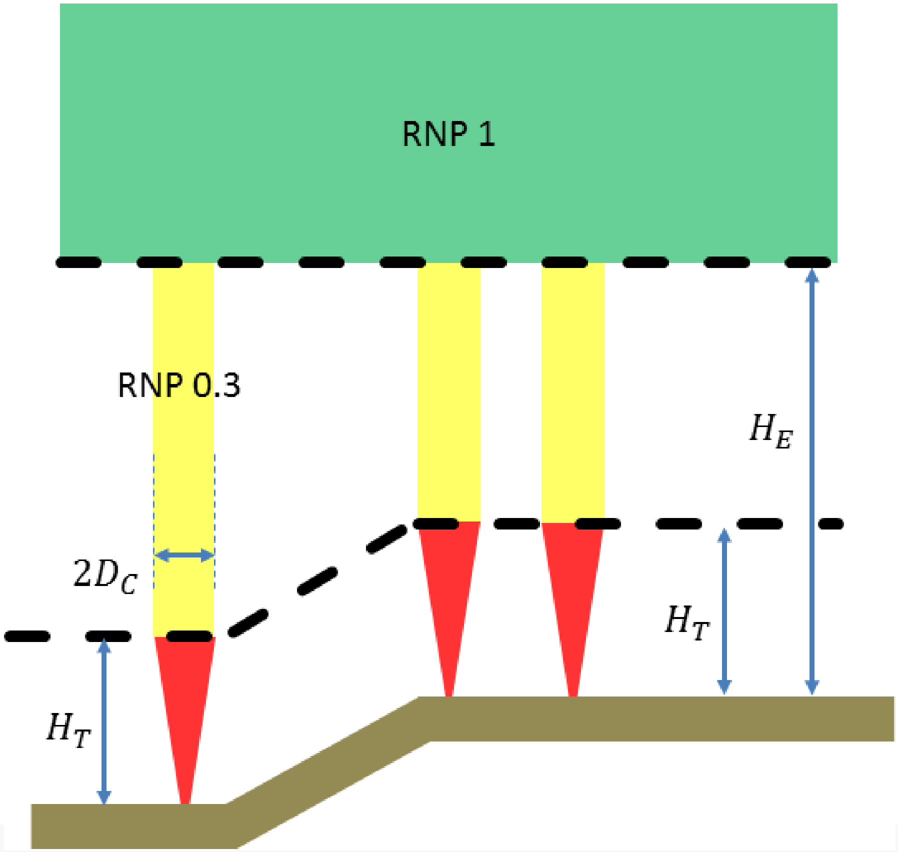
- State-of-the-Art communications system
  - Safety-of-Life rated
  - Full protocol stack
- Demonstrated as a source of pseudoranging
  - $\sigma_\rho \leq 20$ m
- Compatible with DME
  - In-lay channels



# Proposed Requirements for Next Generation APNT

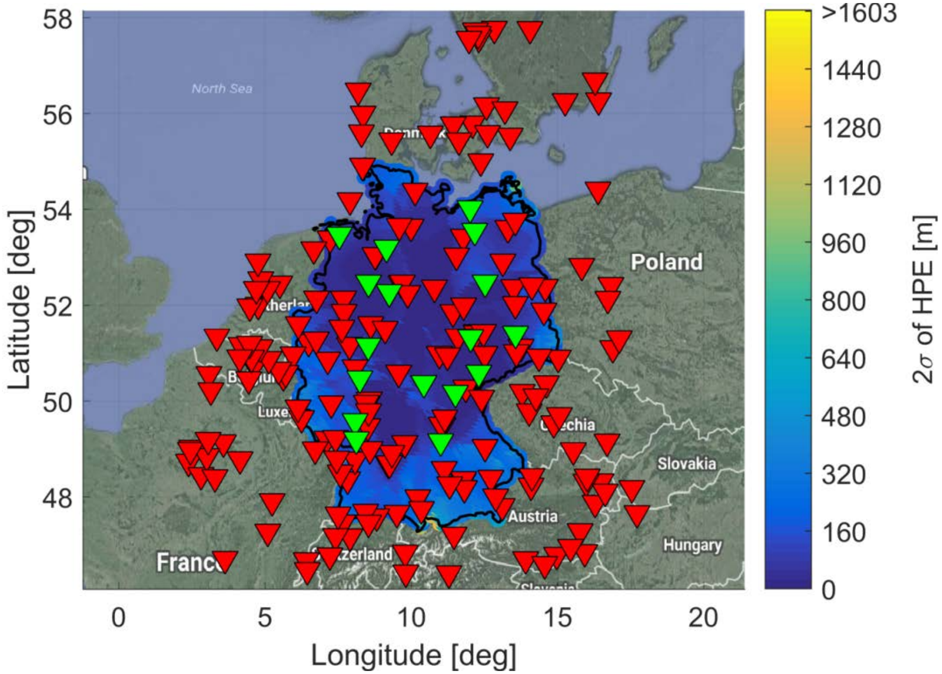
- Robust RNP 1: leave-one-out methodology
  - At FL 100 and above

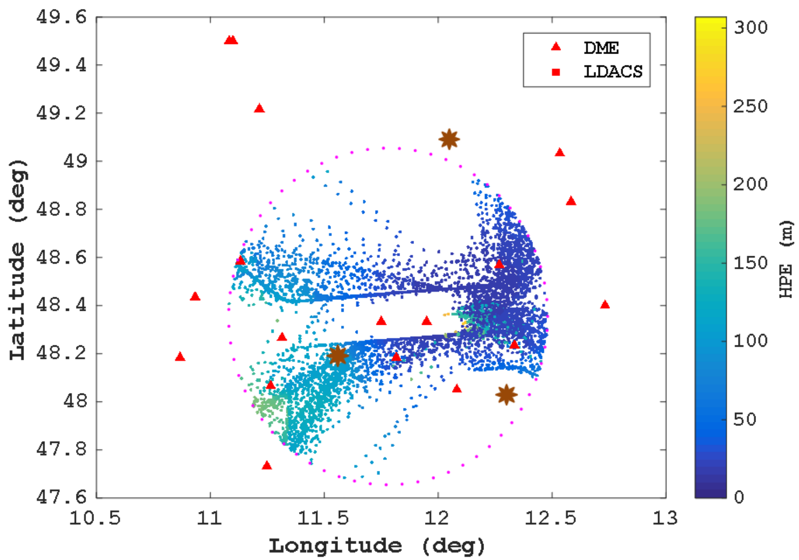
- RNP 0.3:
  - In select terminal areas
  - Service runway ends



# Hybrid LDACS-DME meets new requirements

- Robust RNP 1 at FL 100 with 17 stations for Germany
- RNP 0.3 at FRA, MUC with 3 stations



# eLoran

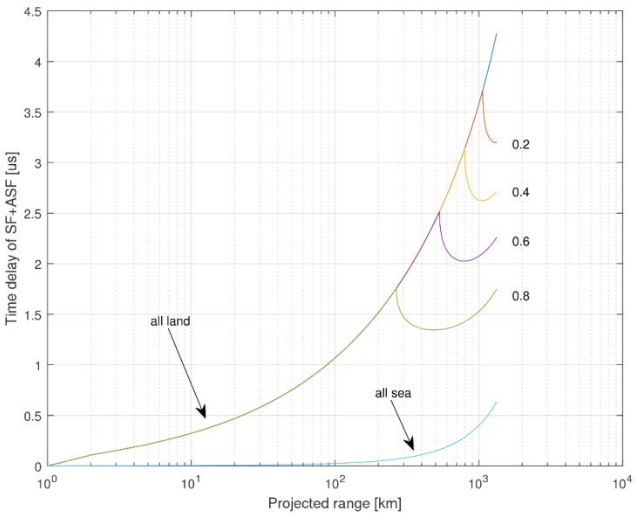
- Robust alternative to GNSS
  - Complementary physical characteristics (low frequency, high power)
  - Additional data channel (LDC) to convey corrections for major error sources and integrity data
  - Potential multi-modal use: Maritime, Land-mobile, Aviation, Time source

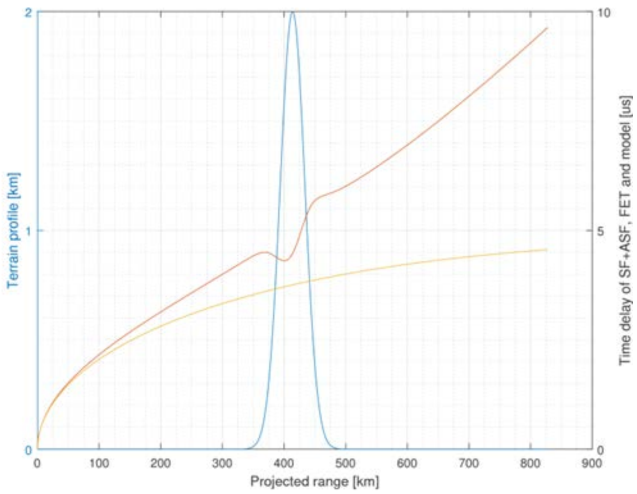
- eLoran for Aviation
  - Can meet RNP 0.3 requirements
  - The use of ADF antenna may facilitate retrofitting
  - Not a wide agreement in aviation community for the use of eLoran
  - Aviation community not the main driver

# eLoran

- 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

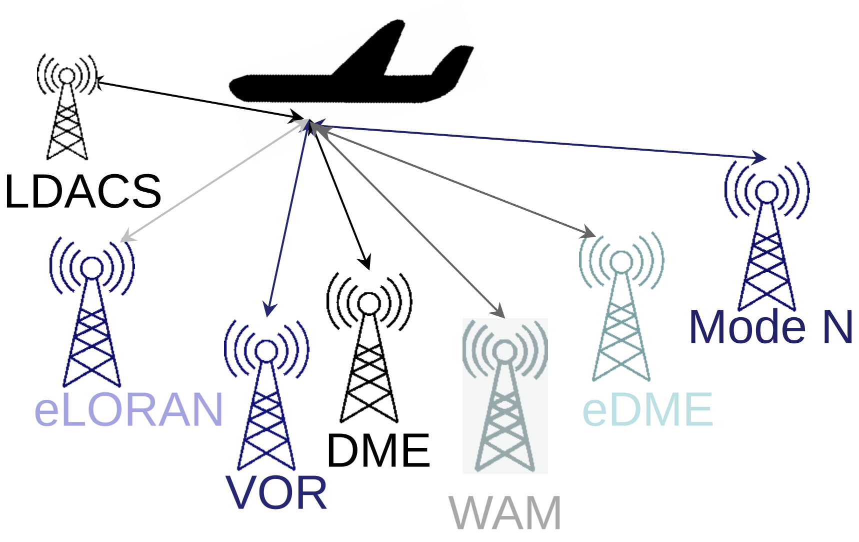
- Novel performance assessment approach:
  - Build accurate ASF model, to be integrated into coverage prediction models or Kalman-based filters
  - Quantify accuracy, integrity and obtainable RNP levels by combining various models (ASF, SNR, HDOP)



# Modular A-PNT

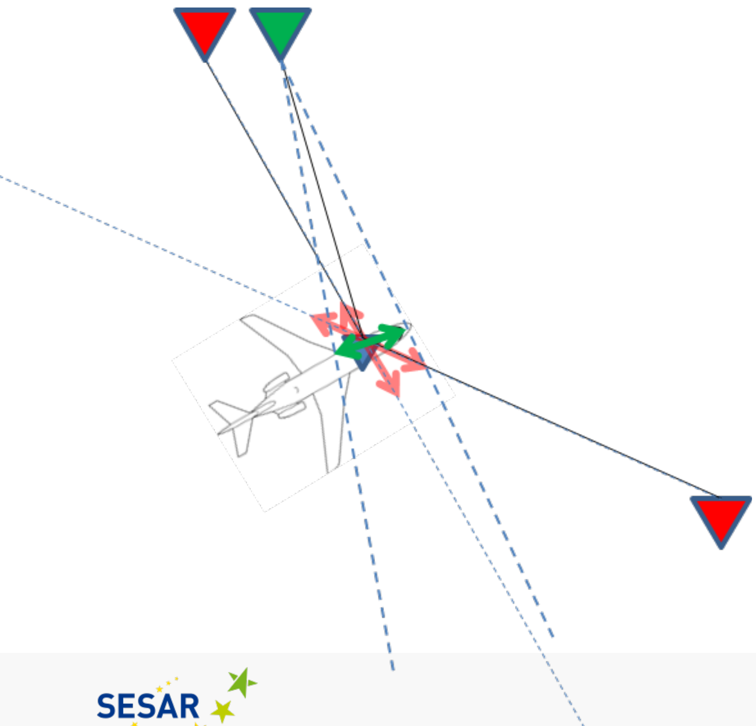
- Multitude of legacy and new positioning sources investigated
- One of the key aspects: **Transition**
  - Service legacy aircraft
  - Gradual deployment of new ground and on-board systems




- 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

# Modular A-PNT

- Methodology to hybridize radionavigation technologies
- Increased redundancy
  - Increased robustness
  - Ability to derive RAIM-like integrity bounds



- Can accommodate different types of measurements:
  - Two-way Ranging (e.g. DME)
  - Pseudoranging (e.g. LDACS)
  - Angular (e.g. VOR)
  - Barometric

# A-PNT Transition

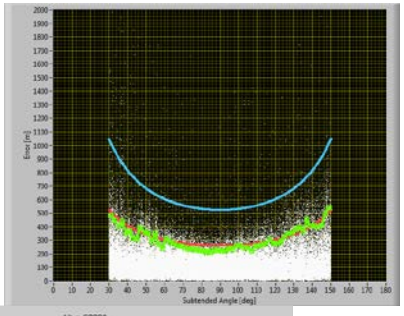
- Main factors that may influence the long-term solution and transition
  - GNSS interference environment
  - Availability and robustness of DFMC GNSS
  - Operational need (higher performance)
  - Worldwide agreement
  - Spectrum pressure on L band
  - Incentives

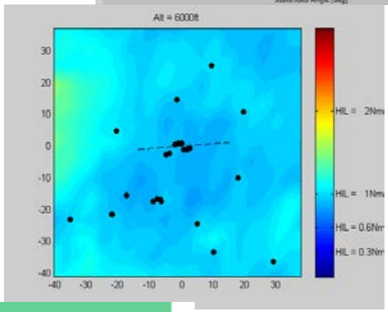
- Coordinate CNS approach to group COM/NAV/SUR upgrades into a single upgrade would facilitate Airspace Users buy-in

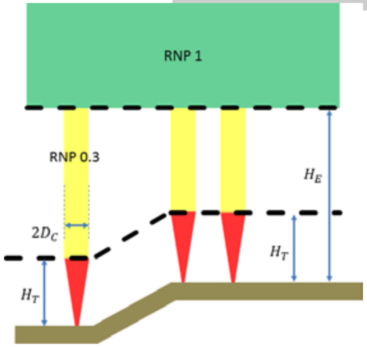
- The long-term A-PNT solution may depend on the progress driven by COM/SUR or by non-aviation applications

# Summary

- SESAR PJ 14-03-04 A-PNT:
  - Short term effort:
    - Update to DME Mops
    - Standardization of DME reversion for RNP 1
  - Medium term effort:
    - Implementation of Multi-DME in FMS
  - Long term effort:
    - LDACS for navigation
    - eLoran for aviation
    - Modular A-PNT for RNP 0.3








- **Engagement of US in this topic would be very desirable**

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