***SESAR Solution PJ.14-03-04***

***APNT short term Solution – RNP 1 reversion based on DME/DME***

This contextual note introduces SESAR Solution 14.03.04 APNT short-term solution with a summary of the activities contributing to deliver it. It provides to any interested reader (external and internal to the SESAR programme) an introduction to the SESAR Solution in terms of scope, main operational and performance benefits. This contextual note complements the technical data pack comprising the SESAR deliverables allowing on going TRL6 assessment.

**Improvements in Air Traffic Management (ATM)**

Alternative-Position, Navigation and Timing (A-PNT) is the technological enabler related with the need to introduce ground and airborne systems that can support currently defined and standardized PBN and other CNS-based operations and provide a backup with the required level of performance in case of degradation and absence/loss of GNSS.

This subject is particularly important in the context of European PCP-IR planning RNP1 SIDS or STARS for major TMA within 2024. Indeed, according to the existing regulations, RNP1 navigation requiring integrity requires the use of GNSS positioning. Therefore, the GNSS loss may become a critical issue for the design of TMA airspace complying with PBN-IR.

Three technical threads have been investigated by the SESAR PJ14-03-04 (PJ14 WP10) solution aiming at the maturation of A-PNT.

* A short-term solution relying on the assumption that most of current aircraft DME/DME navigation can support RNP 1 reversion without any modification in the avionics, if the ground infrastructure provides a required level of integrity, and if appropriate flight crew is appropriately trained.
* The mid-term APNT solution has explored the capability to fit multi-DME positioning in the existing FMS with RAIM algorithm to fully comply with RNP requirements involving OBPMA features, for the continuation of RNP1 operations in case of GNSS loss, without any operational impact from flight crew or ATC perspective, and using existing DME ground infrastructure.
* The long-term APNT solution considers new technology currently not existing on board the avionics.

The short-term solution will provide a reversionary solution in case of GNSS outages based on the current capabilities of the ground and airborne systems, as a first step towards more advanced solutions that can only be implemented in mid/long-term. This reversionary capability will facilitate successful deployment of RNP1 SIDs or STARS planned by the European IR-PBN.

**Operational Improvement Steps (OIs) & Enablers**

Object of the solution is limited to the system enabler:

* CTE-N08c : Enhanced DME (CR 02759)

This system enabler contributes to support:

* AOM 603 : Terminal Airspace enhancement with the use of RNP based instrument procedures (e.g. RNP1 SIDs and STARs)
* AOM-0605: Enhanced Terminal Operations with RNP transition to ILS/GLS/LPV

**Background and scope of SESAR 2020 activities**

In the framework of SESAR 1, the project 15.3.2 carried out a study to investigate the possibility to perform RNP operations in case of GNSS unavailability (caused for example by a system loss or GPS outage). RNP operations targeted were mainly RNP 1 and, depending on demonstrated performances, RNP 0.5 or RNP 0.3, in terminal areas. The first backup solution identified was the use of DME/DME/IRS navigation. Applicability of this solution on aircraft in their current state (i.e. with existing certified avionic systems, without envisaging systems evolutions) was the main objective of this study performed by Airbus and its partners Thales and Honeywell.

The study has first identified the ground and on‐board failure modes and error types that can impact the accuracy and/or integrity of the DME/DME/IRS solution. The impact of all these potential failure modes has been assessed by laboratory tests. Based on AC20‐138C requirements for RNP 1 (which is not dedicated to DME infrastructure) test objective was to assess avionics system behavior in case of detected or undetected erroneous data in the DME positioning chain, and in the presence of existing FMS protection mechanisms. The study concluded that Requirements for RNP reversion in Terminal areas (RNP 1) can be satisfied as long as DME ground stations used in the RNP operation guarantee a minimum integrity rate of 10‐5 per hour.

In the same project, Thales, as a major manufacturer of DME transponders, has assessed their products integrity performance as well as the possibility to improve them. The results showed that all current Thales transponders meet a 10‐6 integrity requirement, although ICAO annex 10 doesn’t include any integrity requirements for DME systems. This is a consequence of two past developments. First, it is related to the Precise DME (DME/P) developments triggered by MLS some decades ago. Second, since DME has been introduced as a replacement for ILS Marker Beacons, ILS‐requirements have been added to terminal (low power) DME/N, and the associated core modules have been generally kept the same by the manufacturers also for the high power en‐route DME/N. This can be seen in the DME transponder specification of the FAA (FAA‐E‐2996), which includes requirements in reliability, integrity and continuity.

Compliance to FAA (FAA‐E‐2996) is currently declared by all major DME transponders OEMs. Therefore, it was concluded that the improvement of the integrity and other parameters of the DME systems is already achieved and further improvements are not required. Rather, it is necessary to formalize the actual DME performance (including integrity level baseline) in an European standard, and define a concept for using the DME/DME/IRS solution to provide GNSS backup for RNP 1 operations based on this performance. This concept will provide an acceptable means of compliance for the RNP 1 reversion based on DME/DME in all TMA environments where modern DMEs are deployed.

The activities related to the Short‐Term A‐PNT solution in WP10 are mainly related to the support of the EUROCAE WG‐107 which has as objectives:

* The update of ED‐57 (MOPS for DME Ground Equipment) to bring the standard in line with current equipment capabilities.
* Develop MASPS for “RNP Reversion using DME/DME Positioning”. The MASPS would describe an acceptable means of compliance to permit prolonged support to PBN operations requiring an RNP navigation specification in case of a GNSS outage, while taking credit for the updated capabilities in ED‐57.

Considering the fact that DME systems complying with the updated ED‐57 are already deployed and have been in operation for many years, the scope of the short-term A-PNT activities does not include validation exercises.

**Results and achievements**

The SESAR partners that contribute to the short-term A-PNT solution are providing a major contribution to EUROCAE WG 107 both for the update of ED-57 and for the definition of the MASPS for RNP reversion based on DME/DME. The work has confirmed the preliminary conclusions of SESAR 1 in what regards the achieved performance of the DME transponders that are currently in production. The update of the ground DME system MOPS is focused on:

* Minimum Integrity level specification
* Range accuracy requirements
* Service continuity requirements

In addition, a methodology for the integrity demonstration is being defined, such that the integrity levels achieved by different OEMs can be compared and validated.

The updated performance requirements for the DME transponder are reflected in the TS-IRS document.

The delivery of the updated MOPS and the new MASPS are currently planned for end 2020.

Moreover, an economic assessment was carried out to estimate the financial benefits brought by the availability of the GNSS reversion capability in different TMAs. Overall the business case shows mostly positive results. The assessment estimates also the ATFCM delay resulting from a capacity breakdown at two different airports caused by a GNSS outage. However, the CBA results largely depend on the assumptions considered (with high sensitivity notably on the frequency and duration of the GNSS outages). These assumptions may not be fully applicable in all operational environments, therefore further research may be required to re-visit the assumption in the CBA and include other case studies.

**Recommendations and Additional activities**

The initial planning of WG107 activities envisaged the delivery of the MOPS and MASPS documents by end 2019, in the same time frame with the end of SESAR 2020 wave 1. Currently the updates in what regards the performance requirements have been identified, however, further work is needed in order to finalize additional MOPS updates regarding:

* Testing procedures
* Spectrum mask improvements (to accommodate spectrum sharing with other aeronautical systems, e.g. LDACS)
* Common design integrity demonstration methodology

In what regards the MASPS, further refinements are needed on:

* The RNP reversion concept
* Potential impact on avionics and on aircrew procedures
* Multipath errors over bound

Therefore the delivery of both documents been delayed for end 2020.

Consequently it is recommended that in wave 2, the Long-Term A-PNT solution (Solution 81) continues to support EUROCAE WG-107 for finalizing MPS and MAPS documents, to ensure full alignment in both operational and technical dimensions. Note that the Multi-DME technology included in Solution 81 and has to consider the transponder performance as well.

Moreover, before the implementation of this reversion solution, it is recommended that the following elements are further considered, taking into account the published version of the EUROCAE MASPS for RNP reversion based on DME/DME

* Potential need to update Flight Manual, regulations and even certifications so RNP1 reversion procedures can be flown using DME/DME
* Address the open points not covered by the CBA and re-visit the considered assumption and their applicability to the concerned TMA. Further research may be needed to include other case studies.

Although currently the implementation of RNP 1 is foreseen only to enable SIDs/STARs, the opportunity and capability to support RNP1 reversion based on DME/DME beyond TMA could be investigated.

**Actors impacted by the SESAR Solution**

The main impact of the short-term A-PNT solution is on ANSP organizations which will decide to provide the RNP 1 reversion based on DME/DME. The assessment of the supporting ground infrastructure will have to be executed in line with the new MASPS, and potentially old DME systems will have to be replaced by new systems that comply with the updated ED-57 MOPS.

**Impact on Aircraft System**

Aircraft systems are not impacted by the short-term A-PNT solution.

**Impact on Ground Systems**

Only ground DME systems that do not comply with the updated standard may be impacted. If these facilities are intended to support RNP 1 reversion operations, the systems may have to be replaced.

**Regulatory Framework Considerations**

The solution will support RNP1 reversion navigation based on ground navigation systems, i.e. DME network. Therefore the solution is in accordance with

* Commission Implementing Regulation (EU) 716/2014, known as the PCP IR,
* Commission Implementing Regulation (EU) 2018/1048, known as the PBN IR and
* EASA ED Decision 2018/013/R which provides Acceptable Means of Compliance and Guidance Material to PBN IR.

**Standardization Framework Considerations**

Currently the performance requirements and the use of ground and airborne DME systems for area navigation are standardised mainly through the following documents:

* ICAO Annex 10 - Volume 1, Aeronautical Telecommunications - Radio Navigation Aids,
* EUROCAE ED57 Minimum Performance Specifications for Distance Measuring Equipment Interrogator (DME/N and DME/P) (Ground Equipment)
* DO-189, Minimum Operational Performance Standards for Airborne Distance Measuring Equipment (DME) Operating within the Radio Frequency Range of 960-1215 MHz
* EUROCAE ED54 “Minimum Performance Specifications for Distance Measuring Equipment Interrogator (DME/N and DME/P) Operating within the Frequency Range 960 to 1215 MHz (Airborne Equipment)
* FAA TSO C166C: Distance Measuring Equipment (DME) Operating Within The Radio Frequency Range Of 960-1215 Megahertz
* ARINC 709: MARK 5 AIRBORNE DISTANCE MEASURING EQUIPMENT
* DO-283B Minimum Operational Performance Standards for RNP for Area Navigation
* DO-236C Minimum Aviation System Performance Standards: Change 1 Required Navigation Performance for Area Navigation
* ICAO PBN MANUAL, DOC 9613, 4th Edition, Performance Based Manual

The short-term A-PNT solution contributes to the update of EUROCAE ED57 in what regards the performance level of DME N. In addition, the MASPS under development by EUROCAE WG107 will describe the operational concept and an acceptable means of compliance for supporting RNP 1 reversion based on DE/DME. This reversion solution will not require the update of any of the other standards and specifications listed above.

**Solution Data pack**

The Data pack for this Solution includes the following documents:

* D10.3.01 - Technical specifications / Interface Requirements Specifications (TS/IRS)-v0.2.0
* D10.3.02 – CBA for RNP reversion based on DME/DME v0.1.0

**Intellectual Property Rights (foreground)**

The IPR for the data pack deliverables is owned by the PJ. 14-03-04 members, and licensed to SJU under conditions.

The IPR for the EUROCAE documents updated/developed with the contribution of the Short-term A-PNT solution belongs to EUROCAE.