Contextual note – SESAR Solution description form for deployment planning

Purpose:

This contextual note introduces a SESAR Solution (for which maturity has been assessed as sufficient to support a decision for industrialization) with a summary of the results stemming from R&D 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, relevant system impacts as well as additional activities to be conducted during the industrialization phase or as part of deployment. This contextual note complements the technical data pack comprising the SESAR deliverables required for further industrialization/deployment.

Improvements in Air Traffic Management (ATM)

The work performed in this Solution "Enhanced Rotorcraft operations in the TMA" was to assess and validate the benefit of integrating piloting support of both enhanced vision systems that increased the safety and reliability of rotorcraft operations through dedicated symbology for specific rotorcraft operations including visual segments and automated flight path following by autopilot system. The objective was to assess and validate the benefit of having SBAS based navigation for advanced Point-In-Space RNP approaches and departures to/from FATO by defining the corresponding rotorcraft specific contingency procedures in case of loss of communication. As the SBAS navigation, the corresponding contingency procedures was needed to comply as much as possible with profiles adapted to exploit rotorcraft performances, reduce fuel consumption and noise emission. The pilot was supported during these operations by dedicated symbology presented on a Head Mounted Display system.

In fact the OI step AOM-0104 has been split into two: The part that has achieved end of V3 (standards PinS approaches, AOM-0104-A) is in fact a gap in the baseline and should be captured there. The new OI step AOM-0104-B (Advanced Point-in-Space RNP approaches and departures) has been covered here with new technologies and advanced PinS approaches.

The SESAR1 project P04.10 activities have achieved fully V3 maturity level for the "Standard PinS" only. The development of "Advanced PinS" concept (e.g. curved procedures in the initial, intermediate, and missed approach segments) using possible new enablers such as SVS, EVS, etc, have been addressed in these SESAR 2020 activities.

The solution impacts the following KPAs:

- Safety is improved thanks to the use of an HMD during PinS operations (facilitating the VFR-to-IFR transitions during take-off and IFR-to-VFR transitions during approach, which are usually high-workload phases for the rotorcraft pilot), and through the introduction of GNSS contingency loss procedures (in particular in the final curved approach of a PinS procedure where the pilot shall maintaining safe separation during visual segment)
- Human performance for manual piloting is improved thanks to the use of an HMD during PinS (pilot's eyes-out conformal display of the flight trajectory allows improved performance to follow precisely the allocated trajectory). This KPA isn't impacted for automated flight path following by autopilot system (reducing workload down to performance observation)
- Efficiency benefits from advanced PinS procedures, in detail fuel consumption and respectively noise reduction as well as time consumption.

- Access and equity for rotorcraft users are improved through smaller footprints of advanced PinS connecting more FATOs to IFR routes.

Operational Improvement Steps (OIs) & Enablers

- OI step (fully covered):
  - AOM-0104-B: Advanced Point-in-Space RNP approaches and departures
- Required enablers:
  - A/C-01 Enhanced positioning for LPV/RNP based on Single Frequency SBAS
  - A/C-04b Flight management and guidance for RNP 0.3 (Category H(rotorcraft)) in all phases of flight, except final approach
  - A/C-05a APV Barometric VNAV
  - A/C-06 Flight management and guidance for LPV approach based on SBAS
  - A/C-07 Flight management and guidance for RNP transition to ILS/GLS/LPV
  - PRO-250 Rotorcraft procedures for IFR access to VFR FATOs
  - REG-0009 AMC for Curved Approaches
- Optional enablers:
  - A/C-02a Enhanced positioning using GBAS single frequency
  - A/C-23a Synthetic vision in low visibility conditions
  - A/C-83 Head Mounted Display for PinS procedures
  - BTNAV-0502 Update of Minimum Performance Standard for Enhanced Vision (EV)
  - BTNAV-0503 New ARP standard for Transport Category Airplane HUD/SVS systems
  - BTNAV-0504 Update of Minimum Performance Standard for Airborne Synthetic Vision (SV)
  - CTE-N07a GBAS Cat I based on Single-Constellation / Single-Frequency GNSS (GPS L1)
  - STD-067 DO-253D "GBAS MOPS" & DO-246E "GBAS ICD"
  - STD-043 EN 303 084, Ground Based Augmentation System (GBAS) VHF ground-air Data Broadcast (VDB)
  - STD-025 Harmonisation Specifications on Ground Based Augmentation System Ground Equipment to Support Category I Operations
  - REG-HNA-03 AMC for LPV approach based on SBAS
  - REG-HNA-04 AMC for RNP transition to ILS/GLS/LPV
  - PRO-251 ATC Procedure to handle SNI IFR rotorcraft operations using PinS
- Dependency with solution:
  - PJ.02-05: Independent Rotorcraft operations at the Airport

All the required enablers have been validated by PJ01-06 and amongst the optional enablers, A/C-23a, A/C-83, REG-HNA-03 and REG-HNA-04 have been validated by PJ01-06. Regarding the HMD system installation, an issue with the head tracker had a strong impact on the system usability. This head tracker issue has been demonstrated to be an integration issue on the DLR helicopter. The same head tracker has been successfully used in PJ03-04a and achieved there a V3 maturity level (see PJ.03-04a D4.060 §4.1 HMD enabler reaching V3 maturity level). Therefore, the HMD is also proposed for V3 maturity level within PJ.01-06 solution.

Applicable Integrated Roadmap Dataset is DS19. Some change requests have been initiated for DS20. The pre-requisite SESAR1 project P04.10 (GA and Rotorcraft Operations) activities have achieved fully V3 maturity level for the "Standard PinS" only. The development of "Advanced PinS" concept (e.g. curved procedures in the *initial*, *intermediate*, *final* and *missed approach* segments) using possible new enablers such as SVS, EVS, etc, are addressed in this solution.

Background and validation process

The SESAR Solution has been validated on different ATM environments, setting up different scenarios and making use of different platforms. It covers three Validation Exercises, briefly detailed in the following points:

- The Real Time Simulation was set prior to the flight trials in Braunschweig. Therefor this exercise was needed to verify the functional setup and provide further test scenarios that cannot be conducted in the flight trials. Additionally the generic and safe environment of a simulator allowed multivariate testing under controlled conditions what allowed a better statistical analysis. The scenario layout in the means of the approach and departure path has been the same as for the flight trials.
- Within the first Flight Trial campaign, IFR Advanced Point-in-Space (PinS) procedures on Braunschweig airport have been performed. An EC135 research helicopter was equipped with its standard avionics suite, completed with a TopEagle Head Mounted Display and real-time simulated Flight Management System and Navigation Display. The scenarios have been designed to assess the navigation performance, human factors, and workload under day conditions for a single pilot IFR configuration. During these validation activities, the traffic was considered, and in particular its impact on crew workload. The basis of the validation assessment was the crew's feedback in the form of test reports. This validation exercise aimed to cover the use case titled "Advanced PinS procedure using HMD" as defined in SESAR2020 PJ01-06 OSED document, in nominal and abnormal conditions, with the helicopter being flown manually (without autopilot coupling).
- The Flight Trials at Airbus Helicopters included flight testing of IFR Advanced Point-in-Space (PinS) approaches to Donauwörth heliport with BK117 D-2 and EC135 helicopter equipped with a Helionix integrated avionics suite (Head Down Display). The scenarios included assessment of the navigation performance, human factors and crew workload. The basis of the validation assessment was flight test data analysis and crew feedback in the form of post-flight test reports. This validation exercise aimed to cover activities in nominal and abnormal conditions, with and without autopilot coupling.

Results and performance achievements

Accessibility and **Equity**: PinS approaches including RF legs provide greater flexibility for helicopters to fly approaches in dense airspaces and constrained mountainous terrain. As demonstrated in the

AHD flight trials, PinS approaches with RF legs were executed with high accuracy and low crew workload. These factors, coupled with greater design flexibility and smaller footprint of the advanced PinS procedures, contribute to enhancing accessibility and equity of helicopter in dense airspaces by de-conflicting with fixed wing traffic to runways (so called SNI procedures). Furthermore, accessibility to mountainous as well as noise-sensitive locations is greatly improved, thanks to the RF legs that help avoid crossing terrain and/or residential areas.

Capacity: A direct consequence of increased accessibility to dense airspaces is an increase in the capacity and throughout, by allowing rotorcraft to approach/depart in parallel of fixed wing traffic, and without additional infrastructural needs.

Predictability and **Safety**: The results of this exercise have shown that RF legs were accurately flown to the desired path following, and well within the RNP containment limits. The results from this exercise show that the autopilot coupled approaches had very low overshoot at leg transitions. Therefore RF legs in the PinS procedures are predictable and repeatable. Consequently, safety is enhanced by the fact that the chance of proximity to obstacles is low when remaining on the desired path. Executing PinS approaches in uncontrolled airspace, where ATC may have very limited or no coverage, requires the flight crew to be vigilant and responsible for adequate separation to other VFR traffic encountered in VMC.

Recommendations and Additional activities

The following conclusions are drawn regarding concept clarification:

- Rotorcrafts tend to fly with nonzero slip angles. Slip angles are particularly high in side winds, which make it difficult to fly turns in this situation. Exercise #1 and #2 with HMD assistance but no autopilot showed that pilots need to turn their heads like in visual flight to allow a smooth transition from IMC to VMC. Exercise #3 showed that the autopilot is effective in following the desired path despite side winds.
- RF legs ending at the FAF/FAP and RF legs connected the IDF do not impose a safety issue, either with HMD assisted manual flight, or autopilot coupled flight. The technology and guidance in all exercises allowed a precise and reliable intercept of the glide path. Pilots reported time pressure during this transition, and therefore a short straight level-off segment between RF leg and final glidepath is recommended.
- Concerning the HMD only, there was a limitation on the guidance quality of our prototype. The HMD should have guided the pilot to a higher altitude than the minimum at the IDF and beyond. The concept of 3D pathway does not work optimal during the departure if it is designed to go along the lowest allowed altitude. If there is only a lower limit constraint to fulfil, the system should guide the pilot to climb at best rate to meet the level-off constraint as early as possible. This is considered as an industrialization issue to be fixed in the FMS that computes the desired altitude profile.
- Concerning autopilot-coupled head down display, pilots reported carefree handling and large spare capacity for the pilot to take on any other tasks, such as actively see and avoid other aircraft, or focus on communication when required. Descents during the RF legs, either as

continuous descent, or stepwise descent, were also flown to a good level of accuracy. Lateral containment was always within RNP 0.3. Primary flight information, navigation information overlaid on synthetic external view on the head down display (HDD) format was considered to be good feature for situation awareness during IFR to VFR transitions.

- As this exercise is aimed to contribute to V3 maturity that implies availability for operational use, it has been demonstrated that advanced PinS with adequate automation serves the purpose of enhancing helicopter access to dense airspaces and difficult terrain. However, it is found that the use of PinS procedures in helicopters is rather limited to a few operators. To further increase its operational use, it is recommended to actively promote the use of PinS procedures by supporting pilot use cases among rotorcraft and GA operators and by actively promote the creation of an European network of low level IFR procedures.

Further work is also required to investigate the following operational cases:

- Eyes-out pilot assistance functions, together with autopilot coupling, during standard/advanced PinS procedures in uncontrolled airspaces:
    - Many helicopters, and almost all EMS helicopters, operate in uncontrolled airspaces. During PinS procedures in VMC and even VMC-IMC borderline conditions, it is common to encounter other VFR traffic during precision approaches. With no ATC coverage in uncontrolled airspaces, maintaining adequate separations becomes the responsibility of the pilot, which leads to higher workload. The provision of assistive on-board functions, in communication and surveillance, as well optical eyes-out systems, which may allow the pilot to remain coupled on the approach procedure while actively seek and avoid other VFR traffic, needs to be explored in greater depth.
- Eyes-out pilot assistance functions during IFR-VFR transitions at or before the MAPt:
    - By definition, PinS approaches are flown to a point in space which may not be aligned with the FATO threshold. A proceed visually segment provides a level of obstacle clearance, but during proceed VFR visual segment, the pilot is responsible to see and avoid obstacles between PinS and FATO. It is also known that FATO may not lie in direct line-of-sight from the PinS. Thus, a technical and human factors investigation is required to identify technologies to assist this IFR-VFR transition in order to improve safety of helicopters and separation from fixed-wing traffic.
    - Thanks to the use of HMD during Advanced-PinS, the opportunity arises to enhance pilot's situation awareness with respect to surrounding terrain, obstacles, traffic, and landing spot before and after the MAPt.
    - Further investigations are needed to definitely identify appropriate symbology, display means and associated human factors on how to best support crew during IFR-VFR transitions, in particular during degraded visibility conditions.
- RF legs after the FAF and larger turns ending at FAF (falling under RNP-AR):
    - In mountainous terrain or small airspaces in the vicinity of busy airports, it may not always be possible to define PinS satisfying the PANS-OPS criteria. It may be necessary to reduce the lateral and vertical obstacle clearance zones and to allow

greater flexibility in the approach procedures, such as large course changes ending at FAF, turns after the FAF, in order to avoid terrain or the glidepath of fixed wing traffic. It is therefore necessary to investigate the flyability and human factors of approaches beyond PANS-OPS criteria in the direction of RNP-AR.

- Detect and avoid unmanned traffic:
  - Due to the significant increase in drone usage, operators have raised the flag about the continued safety during PinS procedures, without the means to detect unknown/non-cooperative traffic by existing surveillance equipment (since these are currently not reported by transponders and difficult to spot by eyes). Therefore, special detection means by technology, such as the new ACAS standards, low-cost radar technology, and other communication means to detect and eventually avoid non-cooperative traffic, as well as the associated human factors and crew feedback during PinS approaches needs to be investigated.

Actors impacted by the SESAR Solution

Airspace Users (Rotorcraft pilots) and TMA Controllers.

Impact on Aircraft System

Pre-requisite is a helicopter with IFR approach operational certification according to CS-27 (small rotorcraft) or CS-25 (large rotorcraft). Further approvals impacting equipment installations and/or software applications are:

- FAA AC 20-138D for airworthiness approval of positioning and navigation systems, for GNSS and GNSS augmentation, RNAV equipment for RNP operations, RF leg capability, and Baro-VNAV equipment. It also includes performance considerations for rotorcraft enroute, terminal and offshore RNP 0.3, and RNP APCH operations.
- EASA AMC 20-27 for airworthiness approval for RNP APCH including APV Baro-VNAV operations.
- EASA AMC 20-28 for airworthiness approval of RNAV using GNSS augmentation and down to LPV minima.

Additional system installations, such as flight director or autopilot may be necessary to fulfil the display, HMI and automation functions. The aforementioned documents must be carefully studied regarding the actual aircraft configuration that is under consideration.

Impact on Ground Systems

Advanced PinS relies wholly on RNAV and RNP concept using GNSS or GNSS augmentation such as WAAS or EGNOS. As such, advanced PinS concept is intended for helicopter flight operations in locations which do not possess IFR infrastructure, or dense airspaces where resources are shared by many airspace users. In this context, advanced PinS is not expected to have any impact on ground systems.

Regulatory Framework Considerations

Currently helicopter PinS procedures can be designed according to ICAO documentation and encoded using ARINC 424 specification. Some recommendations are given as follows:

- Procedures for Air Navigation Services — Aircraft Operations, Volumes II (PANS-OPS) (Doc 8168, 6th edition 2 - 2014)
    - Part IV of this document is devoted to construction of helicopter point in space procedures based on PBN concept. It includes PinS departures, PinS approach (RNP APCH to LNAV and LPV minima). This section does not explicitly mention RF leg applicability for helicopters. For future evolutions, it is recommended to include RF leg capability for helicopters.
    - As shown in the validation results, IFR-certified rotorcraft with autopilot coupling of the flight route are able to maintain very low cross-track errors despite strong side winds. Therefore, it is recommended to relax some obstacle clearance criteria to further ease rotorcraft access in obstacle-rich and mountainous terrain.

- As demonstrated by validation results, helmet mounted synthetic vision systems improve situational awareness of helicopter pilots. Therefore, another important recommendation is for the regulatory bodies (e.g. EASA) to provide sufficient guidance material for the airworthiness approval of enhanced, combined and synthetic vision technologies for helicopter IFR operations. EASA NPA 2019-09 is a first step this direction.

Standardization Framework Considerations

Adequate level of standardization is already achieved by the ICAO documents referenced earlier. For the purpose of procedure encoding, ARINC 424-21 (2016) defines all necessary encoding rules for helicopter PinS in the navigation database. Thus, no additional standardization considerations are expected nevertheless PJ01-06 suggests that the visual part of the PinS procedures might be standardized and eventually coded in A424 in order to be integrated in the guiding system while remaining advisory

Considerations of Regulatory Oversight and Certification Activities

Helicopters tend to operate in all low-level airspaces, both controlled and uncontrolled. Whereas there is sufficient ATC coverage and oversight in controlled airspaces, this is not necessarily the case of uncontrolled airspaces. The problem worsens when VFR traffic intercepts helicopter PinS procedure, for which the flight crew require additional attentiveness for traffic avoidance.

Commission Implementing Regulation (EU) No 923/2012 adopted on 26.09.2012 lays down the common rules of the air and operational provisions regarding services and procedures in air navigation. This regulation stipulates that both IFR and VFR flights are permitted and receive flight information in Class G airspace. A speed limitation of 250 kts is applicable to all flights in Class G airspace below 10000 ft. However, some States currently do not fully authorize IFR in Class G airspace. For instance, Germany issued directives to establish radio mandatory zones (RMZ) for IFR flight operations at uncontrolled aerodromes, however IFR flight in Class G airspace is not permitted.

Therefore, it is recommended that EASA and/or national authorities to propose definite rules that promote IFR operations for helicopters while ensuring safety and adequate separation between helicopters and other VFR traffic during PinS operations in uncontrolled airspaces. Further, system degradations such as SBAS loss, GPS loss, autopilot failure should be considered in rulemaking. As GPS loss or jamming cannot be ruled out, alternate means of navigation using other satellite constellations or inertial systems must be explored. Finally, safety and avoidance of noncooperative traffic is a nascent area that must be understood and explored in detail.

Solution Data pack

The Data pack for this Solution includes the following documents:

- PJ.01-06 V3 VALR (D5.1.030), Edition v00.04.00 (04.12.2019), the document constitutes the V3 validation report of solution PJ.01-06 covering enhanced rotorcraft operations in the TMA.
- PJ.01-06 V3 SPR-Interop/OSED (D5.1.010)
    - Part I (Edition v00.04.00, 22.11.2019), the document contains Operational Services and Environment Description (SPR-INTEROP/OSED) of enhanced Rotorcraft operations in the TMA
    - Part II SAR (Edition v00.04.00, 22.11.2019), the document contains the Safety Assessment for a typical application of the PJ.01-06 Solution in TMA operations.
    - Part IV HPAR (Edition v00.02.00, 20.09.2019), the document contains the results of the activities conducted according to the Human Performance (HP) assessment process in order to derive the HP assessment report for PJ.01-06 including requirements and recommendations
    - Part V PAR (Edition v00.04.00, 29.11.2019), the document contains the Performance Assessment Report (PAR) for enhanced Rotorcraft operations in the TMA.

- PJ.01-06 V3 CBA (D5.1.040), Edition v00.06.00 (21.10.2019), the document provides the Cost and Benefit analysis for SESAR Solution PJ01-06 at V3 level.
- PJ.01-06 V3 TS/IRS (D5.1.050), Edition v00.04.00 (25.11.2019), The TS/IRS describes the impact on the current EATMA architecture, the functional architecture in the EATMA model, the functional requirements, the non-functional requirements and the different implementations on rotorcraft and simulator.

Intellectual Property Rights (foreground)

Note: The solution and all documents in the Solution Data pack have to be SJU foreground

The foreground is owned by the SJU.