Release 5 SESAR Solution ID #06

Controlled time of arrival (CTA) in medium-density/medium-complexity environments

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 solution "Controlled time of arrival (CTA) in medium-density/medium-complexity environments" has been defined for medium density/complexity environment in one single ACC where E-AMAN is already implemented. CTA is issued to either i4D aircraft or basic RTA-equipped aircraft. When i4D is available, the solution takes advantage of the navigation performance associated with i4D aircraft (meeting time constraint with a precision up to +/-10 seconds).

Respecting the ideal of constraining a flight only when needed, the CTA Solution involves an AMAN-derived time constraint (CTA) being instructed to the flight for achievement by the on-board avionics systems (RTA). Airborne information (e.g. EPP, ETA min/max) when available from suitably equipped aircraft, may be used by the ground systems in determining it.

A CTA constraint is set on a defined fix, normally within the TMA or at TMA entry, on a Standard Instrument Arrival procedure associated with an arrival runway (STAR). The CTA is proposed, via ground/ground system coordination, to the ATCO in the en-route sector for implementation, if/when appropriate (e.g. applicable in their traffic situation at the time).

If accepted for implementation by the en-route ATCO, CPDLC datalink exchanges or voice may be used to instruct the CTA to the flight. In addition, and when airborne equipment enables it, the downlink of on-board 4D trajectory data may be used in monitoring the setting of the CTA and the progress of the flight towards it.

Environmental sustainability is improved for aircraft assigned with CTA by the provision of enhanced time/delay management over an extended range (from an earlier stage of flight until the constraint point), and by allowing the aircraft to self-manage its own speed profile to an already known time constraint (thereby enhancing flight/fuel/energy efficiency). No overall negative impact is identified.

CTA operations also provides a measure of increased time predictability over the constraint point, for both the flight and for ATC, although a significant degree of 'unpredictability' (e.g.

what the aircraft will do, and what speed it will target, when it actually engages RTA) is also inherent in the concept.

Operational Improvement Steps (OIs) & Enablers

OI Step:

TS-0103 Controlled Time of Arrival (CTA) in medium density/complexity environment fully covers SESAR Solution #06

Enablers

- AGDLS-ATC-AC-14d New SPR for data link exchange of instructions or clearances related to CTA allocation (4DTRAD)
- AGDLS-ATC-AC-15d New IOP for data link exchange of instructions or clearances related to CTA allocation (4DTRAD)
- AGDLS-STD-01 ICAO Provisions for ATN Baseline 2
- APP ATC 148 System Support For Controlled Time of Arrival (CTA)
- BTNAV-STD-02 Navigation Performance in ICAO provisions for Enhanced CTA
- ER APP ATC 119 Enhance Air/Ground Data Communication for Step 1
- REG-0100 Regulatory Provisions for Datalink Extension (DLS II)

Applicable Integrated Roadmap Dataset is DS17.

Background and validation process

Pre-SESAR, CTA Operations were the subject of several projects, such as ERAT and CASSIS. Within SESAR, CTA investigation was continued within various federating and third-level projects, which looked at both ground- and airborne- aspects of the concept.

The main method of validation was RTS with CTA/E-AMAN only operations nevertheless other RTS validations were conducted investigating the integration of the CTA concept with advanced concepts (ASAS for instance).
Several FTS were also conducted, investigating potential benefits and the predictability offered by the concept.
Wide-scale flight trials, within SESAR and pre-SESAR CASSIS trials, were also conducted with aircraft equipped with current RTA functionality, and two flight trials, within SESAR were conducted with aircraft equipped with i4D RTA functionality (validating i4D airborne and ground requirements).

In parallel, an Expert Group was maintained within CTA validation activities, comprised of operational (ANSP/ATC and Airspace Users), and technical (airborne and ground industry) representatives. The group provided an additional forum for CTA topics/issues to be identified and discussed.

Results and performance achievements

The main results from the various validation activities conducted in support of Solution #06 indicate that:

- When an arrival time constraint is required for a flight, environmental sustainability can be increased if the aircraft systems are allowed to self-manage the energy of the flight to the AMAN time constraint (rather than when management is done by ATCO implementation of AMAN constraints/advisories).
- When an arrival time constraint is required for a flight, delivery of the aircraft to its time constraint over a fix is normally more accurate/predictable when given to the aircraft systems to achieve (rather than when delivery is done by ATCO implementation of AMAN constraints/advisories)
    - For i4D aircraft delivery accuracy/reliability is guaranteed 95%, ±10 seconds, for cases defined in ED75D/DO236C Change1.
    - Albeit unguaranteed, wide-scale flight trials have demonstrated a potentially significant level of adherence to a time constraint (85%, ±30 seconds) for some suitably equipped aircraft.
- The concept of flying to a single time constraint could be applied with some RTA technology installed on aircraft currently operating, although current RTA technology/functionality:
    - Is not harmonised across aircraft types
    - Is not harmonised in relation to flight phases (some RTAs operate in 'cruise only', others operate in 'descent')
    - Is not subject to standards such as those being developed for i4D aircraft operating to CTA
    - Does not provide the guaranteed airborne delivery accuracy/performance available with i4D aircraft
- Airborne trajectory information (e.g. ETA Min/Max and EPP) is potentially very useful for the CTA concept
    - ETA Min/Max – Useful for AMAN in updating ground predictions and when considering whether a CTA is appropriate in the first place (e.g. likely/possible within the aircraft capability/performance)
    - EPP – Useful for ground systems (and also possibly for ATCOs) in predicting to some degree how an aircraft might fly to a CTA constraint, and potentially in monitoring its progress to it.
- There is a physical limit to the amount of time that an aircraft can gain/lose by speed management alone in order to meet a CTA – at 200 NM the 'ETA Min/Max window' available is in the region of 7 minutes wide.

- The natural or 'unconstrained ETA' for the flight (determined by its desired Cost Index) and the relationship between that and the location of any CTA within the aircraft's ETA Min/Max capability, will be significant.
  - Slow flying aircraft (with low/single-digit CI) will have little capacity to slow down further in order to meet a CTA, and operationally may not wish to fly faster (burn more fuel) to meet it.
- Even in MED density traffic flows, when time constraints exist, it will not always be possible for all aircraft that are capable of flying to a CTA to be offered one, because:
  - Due to traffic demand on the runway the required AMAN time for the flight lies outside the physical capability for the aircraft to achieve a CTA through speed manipulation only.
  - Due to prevailing traffic situations it might not be possible to provide the 'free-speed-management' associated with the concept.
  - Due to prevailing traffic situations it might not be possible to provide a required (unrestricted) altitude profile.
- The uncertainty of each aircraft's behaviour when given a CTA (e.g. what speed each individual aircraft will target and start to fly to, when/if the RTA function is engaged in the FMS needs to be managed by ATC.
- CTA operations brings changes to the ATC workload, and the type of workload, experienced by ATCOs:
  - Whenever extended arrival management systems are used, some of the workload associated moves from TMA to En Route Ops, diminishing workload in TMA but increasing it in En Route
  - In addition, the 'Hands-off' approach to CTA flights (e.g. facilitating speed control and constraint management by aircraft systems rather than by direct ATCO 'control/intervention') decreases physical workload but, on the other hand, increases 'mental/monitoring' workload, which may be a significant Human Factors issue.
- CTA operations are not intended to target a specific Capacity increase, and validations have suggested that in a MED/MED environment CAP can be maintained while conducting CTA operations.

Recommendations and Additional activities

Possible CTA-related development:

The CTA concept in a MED/MED density/complexity situation has been investigated, and while considered operationally and technically feasible, some additional development and investigation is probably still needed.

Some areas for further work might include:

- There is a need to develop mitigations, as far as is possible, to some of the uncertainties inherent in the CTA operation, including the uncertainty over what speed the aircraft might target when RTA is actually engaged in the FMS. This is especially relevant if contemplating CTA operations in traffic situations where aircraft are in close proximity to each other (e.g. an isolated busy flow/situation in MED/MED).
    - In the shorter term, developments in ground tools to better assist the ATCO in this aspect could be considered (i.e. ground trajectory prediction improved to be more 'air-like', so that tools/predictions of likely aircraft behaviour are closer to an airborne 'reality' and are 'usable' by the ATCOs in assessing whether it is OK or not to give a CTA)
    - In the longer term, the possibility for an airborne 'What-if' to be developed, with airborne 'what-if' information being available to the ground prior to RTA engagement, could be investigated.

- The ability to 'Retain CTA' in the aircraft systems (rather than cancelling it altogether if/when a short-term tactical intervention is being carried out) has been shown to increase flexibility for the ATCOs conducting CTA Ops and this is appreciated by them.
    - Investigation could focus on how new support tools could assist the ATCO in best knowing when they can, or cannot, use such a function, thereby increasing the potential use of CTA. This investigation could also assess whether/how different ATC techniques used during tactical interventions might affect AU CTA benefits, and to what extent.

- While accepting that higher predictability and higher accuracy of time keeping is usually an advantage, no direct assessment of the time accuracy actually needed for CTA operations has really been conducted, although validations have indicated that different CTA time-keeping accuracies at different CTA locations, might be viable, depending on the traffic levels.
    - Investigation could look at what accuracy (and granularity) is actually needed when the CTA fix is located at various distances from the runway. This investigation could also focus on the benefit/cost to the AUs if ground is using different accuracies.

- Airborne FMS systems have been designed mainly with the airborne operation in mind, and much of the functionality that is available in the aircraft today is not intended for ATM purposes. One area of concern for ATC in CTA operations is the wide dispersion of airborne speed (and altitude) when aircraft are self-managing and controlling to a CTA time. Some of this dispersion can be narrowed by having the CTA fix located so as to coincide with when/where the aircraft's speed is adjusted to be in compliance with airspace speed constraints. Some of this dispersion could also be narrowed by having the aircraft operating to suitably stringent 'operational windows' that could be designed into a STAR.

- Investigation could focus on how the FMS systems could be developed/enhanced to accommodate various types of 'operational windows' that might be considered by ATC to be desirable on the STARs.

- This solution has been validated in single ACC environments (e.g. Rome, Arlanda). If deployment is foreseen into multi ACC environment and more particularly on cross-border operations, investigation should focus on aspects like transmission of the STAR to aircraft and other ACC.

Possible related development in other areas:

- Even though the Extended AMAN concept is seen as mature and has been chosen for early deployment (PCP #AF1) there are some aspects of E-AMAN operations, especially related to potential CTA operations within E-AMAN, which could still be considered as needing development/investigation.
  - A CTA operation relies heavily on a stable AMAN sequence and operation, even at extended range. Sensitivity for changes to the E-AMAN sequences operating at these long ranges probably still needs to be investigated (with a view towards it being decreased) and the overall robustness of the E-AMAN sequence to disturbance (for whatever reason) probably also needs to be further developed.
  - When considering sequence changes on a highly stable sequence an E-AMAN "what-if" function has been recognised as being potentially useful, and the provision of such a feature in the E-AMAN could also be an area of investigation in the future
  - When operations such as CTA are not possible (e.g. due significant weather) or when high stability in the sequence at extended range is no longer required/needed, the possibility to alter E-AMAN operational and frozen horizons (from a determined time) and altering them online is desirable and could be an area for investigation.
  - Some E-AMAN operations and concepts presently being tested (e.g. XMAN) do not include CTA operations in their current testing/development. If such concepts come to fruition as they are currently tested then how CTA might be incorporated into them in the future would still need to be investigated.

Actors impacted by the SESAR Solution

Airspace Users: Pilots
APP and ACC: TMA ATCOs (including SEQ MAN) and En Route ATCOs

Impact on Aircraft System

Where/if CTA operations on the ground seek to take advantage only of current airborne functionality - i.e. using CTA with aircraft that are already equipped with 'Basic RTA' functionality, and with current CPDLC Baseline 1 CTA messages to HH:MM precision - no impact is foreseen on airborne systems.

Where/if CTA operations on the ground seek to take advantage of – or where they intend to rely on – elements such as:

- Guaranteed precision of airborne delivery/performance to a CTA time (95% +/- 10 seconds)
- CPDLC messaging enabling delivery of CTA instructions with HH:MM:SS precision (Baseline 2).
- ETA Min/Max information exchange capability
- EPP information downlink capability

Then airborne systems for flights in this type of CTA operation will need to provide these elements.

These elements are already covered within current i4D/RTA developments, within anticipated future CPDLC developments and within ongoing ADS-C developments/mandates.

Impact on Ground Systems

Ground providers intending to implement a CTA operation will firstly need to determine what level/type of CTA operation they intended to apply - CTA using current RTA technology, CTA using i4D technology, or both.
The impact on individual ground systems will vary accordingly. The impact will also vary according to what current functionality is already provided in the host system, and what upgrades or new functionality is required.
In any case, to provide a CTA operation an ANSP will need:

- An AMAN, or improvements to an existing AMAN, enabling arrival management and CTA operations at 'extended range' (i.e. an AMAN allowing sufficient stabilisation of the sequence and all CTA message exchanges (plus assessment/instructions) to be completed a minimum of 5 – 10 minutes prior Top of Descent of the arriving aircraft.

- An AMAN, or improvements to an existing AMAN, that supports CTA operations, with appropriate sequencing logic and appropriate ATC strategies incorporated within it.

Appropriate ground-ground system communications, internally and with external partners, enabling delivery of all CTA-related (and appropriate AMAN-related) messaging when/where required with the granularity required for the CTA (hh:mm and/or hh:mm:ss).

- A CPDLC function and message set(s) that is appropriate for the CTA operation and granularity that it intends to deploy. Note: The CTA time may also be delivered by voice.

- An appropriate HMI, that allows all necessary CTA functions to be done in a suitable manner by all concerned actors (AMAN Sequence Manager, Planning and Executive ATCOs), and all necessary CTA-related messages/status to be displayed where/when required.

- A level of automation in these message exchanges will be necessary. To what extent depends on what the local implementation will aim for.

Regulatory Framework Considerations

ICAO material (PANS-ATM, PBN Manual) may be available later (2016).

Standardization Framework Considerations

ED-228A EUROCAE Safety and Performance Requirements Standard for Baseline 2 ATS Data Communications (Baseline 2 SPR Standard).

ED-229A EUROCAE Interoperability Requirements Standard for Baseline 2 ATS Data Communications (Baseline 2 INTEROP Standard).

ED-75D (MASPS for RNP for area navigation)

Considerations of Regulatory Oversight and Certification Activities

Some material (e.g. SPR, INTEROP, VALRs with OPS analyses, OSED, standards, design development history etc.) may be used to support building regulatory process and documentation during Industrialization phase.

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Solution Data pack

The Data pack for this Solution includes the following documents:

- 05.06.01 D84 Deliverable Step 1 - fully validated SPR
- 05.06.01 D85 Deliverable Step 1 - fully validated INTEROP
- 09.01 D57 Aircraft & System Performance and Functional requirements
- 09.01 D58 Interface requirements between the aircraft and the ATC system
- 10.02.01 D88 Updated Step 1ATC TM System Requirements - Cycle 3
- 10.07.01 D76 - AGDL System Requirements - Final TS 2016
- 10.09.02 D64 Step 1 Technical Specification final

Intellectual Property Rights (foreground)

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