Final Project Report

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Abstract

The Trajectory Management Framework En Route, working jointly with its TMA counterpart project, is a consolidating project that has captured the flight and trajectory exchange needs from across the En Route and TMA projects and consolidated them to provide a coherent set of trajectory management requirements. These requirements describe operational interoperability between stakeholders for revising and updating a common view of the planned trajectory. In turn, this supports a number of SESAR Solutions.

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This deliverable consists of SJU foreground.

Acronyms

Acronym	Definition
ADD	Aircraft Derived Data
ADS-C	Automatic Dependent Surveillance - Contract
AMAN	Arrival Manager
ATFCM	Air Traffic Flow and Capacity Management
ATC	Air Traffic Control
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
ATS	Air Traffic Services
CTA / CTO	Controlled Time of Arrival / Controlled Time Over
EATMA	European ATM Architecture
EPP	Extended Projected Profile
ETA	Estimated Time of Arrival
FAA	Federal Aviation Authority
FIXM	Flight Information Exchange Model
FMS	Flight Management System
IAS	Indicated Airspeed
IOP	(Flight Object) Interoperability
iSWIM	Initial System Wide Information Management
PCP	Pilot Common Project
R&D	Research & Development
RNAV	Area Navigation
SESAR	Single European Sky ATM Research
TMA	Terminal Manoeuvring Area
TMF	Trajectory Management Framework
TP	Trajectory Prediction

V&V	Verification & Validation

1 Project Overview

The Trajectory Management Framework En Route, working jointly with its TMA counterpart project, is a consolidating project that has captured the flight and trajectory exchange needs from across the En Route and TMA projects and consolidated them to provide a coherent set of trajectory management requirements. These requirements describe operational interoperability between stakeholders for revising and updating a common view of the planned trajectory

1.1 Project progress and contribution to the Master Plan

To achieve the consolidation of trajectory management needs from across the En Route and TMA projects, use cases have been collated from initial material provided by the primary projects and then further developed, where necessary, to express the trajectory management aspects. This collation of trajectory management material was captured in an internal project document, the TMF Technical Note. This working document allowed project members to express the trajectory management needs in a consistent manner across all the TMF use cases, aiding in the checks for consistency and coherence between the concepts. The TMF Technical Note was also subject to regular wide review and input from across the programme, being used as a means of coordination to ensure that the TMF use cases remained aligned with the developing concepts in the primary projects.

The trajectory management requirements were derived from operational TMF use cases and captured in the TMF INTEROP document. These requirements are expressed at the level of operational interoperability needs, independent of specific design solutions or technologies. This coherent set of trajectory management requirements forms a framework for stakeholders to revise and update a common view of the planned trajectory. In turn, this supports a number of SESAR Solutions, as described under Dataset 14 of the Integrated Roadmap (see Ref [11]), listed below:

- #28 Automated Assistance to Controller for Seamless Coordination, Transfer and Dialogue through improved trajectory data sharing: TMF contributed through the definition of operational information exchanges between ATS units to maintain a common view of the ground planned trajectory in order to conduct further operations, starting initially with standard coordination and transfer and the associated information exchanges.
- #06 Controlled Time of Arrival (CTA) in medium density/complexity environment: TMF consolidated the requirements on how ATC manage the downlink of trajectory information from the aircraft (through ADS-C) and the management of a time constraint on the trajectory (the CTA) between different ATS units.
- #05 Extended Arrival Management (AMAN) horizon: the interoperability provided by the Trajectory Management Framework can be used by this solution to meet the flight and trajectory data needs of the AMAN. The framework provides an up-to-date common view of the planned at the extended horizon which may be within the operational area of responsibility of a different ATS unit to the AMAN.
- PJ.10-02a Improved Performance in the Provision of Separation: this is a SESAR2020 solution for which the TMF can provide some initial support, primarily in the areas of the management of trajectory information from the aircraft (through ADS-C) and publication of a CTO as required by the TRACT concept; and through the initial work TMF has undertaken in analysing ADS-C EPP behaviour and its use in improving ground trajectory prediction.

The TMF projects also systematically assessed validation and verification (V&V) needs resulting from analysis of the TMF use cases. These validation needs were mapped to the objectives defined by the various validations within the programme. This work also led to the identification of gaps where validation needs were not being addressed.

For some of the gaps identified during the V&V needs analysis, internal validation activities within the TMF projects were initiated. These were typically V1/V2 validations, using fast time simulation techniques or trajectory performance analyses. Priority was attached to those relating to the use of downlinked trajectory data from the aircraft through the ADS-C exchanges. Other gaps were addressed, where possible, through the real time simulations of other primary projects.

This V&V needs analysis was performed on a annual basis, allowing it to be updated as solutions matured and as V&V gaps were addressed. Those remaining V&V needs identified as not addressed in in the final delivery form a set of V&V objectives to be addressed under the SESAR2020 programme.

The final delivery of the V&V needs (Ref [4]) is a deliverable managed by P05.05.01, the TMA Trajectory Management Framework project. Consequently, it is not included in the list of deliverables from this project. It is mentioned, however, as it formed as significant element of the project work, providing the direction for the project's validation achievements.

1.2 Project achievements

Operational Requirement Consolidation and Coordination

The requirements work undertaken by the project has captured, at the operational level, a definition of what trajectory information needs to be exchanged, when and by which stakeholders. These operational requirements have been consolidated into a framework that supports multiple SESAR Solutions and importantly allows stakeholders to maintain a common view of the trajectory which is seen as an essential building block for future Trajectory Based Operations. These requirements form the operational underpinning for the Flight Object Interoperability that needs to be deployed under PCP AF#5 (iSWIM) and for the sharing of the aircraft trajectory via ADS-C ATN Baseline 2 services under PCP AF#6 (Initial Trajectory Sharing).

The extensive coordination of the requirements with other projects has resulted in the trajectory management use cases being consolidated within the European ATM Architecture (EATMA) model and for trajectory management aspects to be embedded within the architecture content integration process. The EATMA tools are now in a position to maintain the TMF use case material and are capable of auto-generating the TMF technical note previously produced by the project. This is expected to help secure a stronger interaction between trajectory management and SESAR Solutions for future work.

Trajectory Management Validation

The value of the validation needs analysis undertaken by the project lay in identifying the set of lower level R&D questions for trajectory management that needed answering and maintaining the picture of where they were being addressed or where gaps existed in the programme. This helped to inform the validation strategies for those projects managing the overall En Route and TMA domains, whilst also identifying topics that could be addressed internally within the TMF projects. From the set of identified V&V needs, the project undertook validation activities to:

- Determine whether the use of Mass and Speed Schedule parameters downlinked via ADS-C from the aircraft reduces variation between ground and air trajectories and improves the accuracy of the ground trajectory prediction;
- Study the stability of the ADS-C EPP data elements to provide insights into the appropriate conditions under which they can be used by the ground systems;
- Demonstrate that the ETA min/max accuracy and integrity characteristics allow AMAN to build a reliable arrival sequence, and assess the impact of ground/ground and air/ground delays on the acceptability of a CTA proposal;
- Assess whether Aircraft Derived Data (ADD) as provided by Mode-S improves the accuracy of ground based trajectory prediction; and

- Assess whether operational staff at an ATSU are made aware of relevant trajectory data, focussing on the presentation of ATC tactical modifications to the Local Traffic Manager role to improve flow and capacity management processes.

The main findings from these studies are summarised in the conclusions and recommendations section of this report.

1.3 Project Deliverables

The following table presents the relevant deliverables that have been produced by the project.

Reference	Title	Description
D822	TMF-IOP Technical Note for 2014 (4.5 Deliverable)	This document describes the TMF concept, collates the trajectory management use cases captured from the primary projects and consolidates them to produce a coherent operational description of the TMF capability. The TMF Technical Note was produced on a yearly basis; this deliverable represents the final deliverable produced directly from the project. Note, however, that a subsequent update has been captured through the content integration processes of the European ATM Enterprise Architecture (EATMA) which now maintains the material and that EATMA tools are now in a position to auto-generate the TMF Technical Note.
D823	TMF INTEROP for Step 1 Initial Release	This document defines the operational interoperability requirements for the exchange of flight and trajectory information between stakeholders in support of a number of different SESAR Solutions. These SESAR Solutions are identified, along with the specific requirements of the framework that are applicable to support that Solution. These operational requirements are allocated to the different Functional Blocks of the ATC system. The initial release has been delivered by this project; the final release (to which this project will contribute) will incorporate feedback from the final exercises in the validation campaign and is managed by the TMA counterpart project.
D811	Step 1 Internal Validation Exercise Report (4.5 Deliverable)	Reports on a fast time simulation that supports the feasibility of the Controlled Time of Arrival (CTA) solution by investigating the impact of ground-ground and air-ground coordination delays on the acceptability of the CTA proposal chosen from within an ETA min/max interval provided by the aircraft.
D820	VP-771 Validation Report (4.5 Deliverable)	Reports on an initial validation using EPP data to enhance a ground trajectory predictor and an investigation into EPP behaviours that may be relevant to the integration of EPP data into ground systems.

D13	S1 RNAV-ADD contribution to V2 Validation Report	Reports on an initial validation to assess the use of Mode-S Aircraft Derived Data to improve ground based trajectory prediction and to assess the ground TP accuracy for route following RNAV equipped aircraft.
D16	S1 ATFCM-FUA contribution to V3 Validation Report	Reports on a validation of trajectory management support to the Enhanced ATFCM Processes Operational Focus Area, whereby the Local Traffic Manager is provided with tactical trajectory modification to assess the impact on flow management and an assessment of the benefits of flow rerouting proposals made by the Local Traffic Manager.

1.4 Contribution to Standardisation

CP3.1 is a coordination plan between SESAR and the FAA, looking at common concepts for the exchange of trajectory information. The aim of the coordination with the FAA is to ensure that the semantic meaning of trajectory information defined for FIXM (the Flight Information eXchange Model) is common to both regions through an agreed and understood concept of use for that information. This will promote wider acceptance of the proposed data information exchange standard among the global community.

During 2013, the P04.05 Project Manager led the SESAR input to CP3.1. TMF use cases developed by the project were input to the group to describe the SESAR concepts that exchange trajectory information. Standardization work for FIXM is currently on-going.

1.5 Project Conclusion and Recommendations

The main findings from the project can be summarised as follows:

- For Air/Ground trajectory data exchange through ADS-C ATN Baseline 2 services:
  - Mass and Speed Schedule data provided by the aircraft can improve ground TP accuracy and improve alignment between ground and airborne views of the trajectory, particularly during climb and descent phases of flight.
  - For the dataset compiled by the project, it was observed that flight crew procedures are required to maintain information in the Flight Management Computer when flying in selected guidance modes (such as when instructed to fly headings by ATC). Differences in when waypoints are considered to be sequenced and update to cruise level information can have significant impact on downstream waypoint time and level information provided by the aircraft.
  - Consequently, data management techniques (checking and cross comparison in the ground system) should be designed to control and inhibit elements of the air trajectory data enriching the ground systems in such circumstances.
- For the negotiation of a CTA as required by several SESAR solutions, fast-time modelling by the project determined that coordination delays of up to 4 minutes still allow significant rates of CTA proposals to be successfully accepted by the flight crew. This negotiation delay can be apportioned across both Air/Ground and Ground/Ground exchange of the CTA proposal between actors.

- For Aircraft Derived Data provided though Mode-S surveillance sources:
    - The use of Indicated Airspeed (IAS) can improve ground trajectory prediction through an improvement in along-track accuracy.
    - The integration of Mode-S IAS is only considered relevant for tactical trajectory prediction as the use of such a parameter is likely to lead to instabilities for ground system use of a planned trajectory.
- For Ground/Ground trajectory exchange:
    - An early validation by the project demonstrated the operational acceptability and system performance gains possible through the sharing of trajectory revisions to maintain a common view of the plan, in this case between the Local Traffic Manager and ATC actors in support of enhanced ATFCM processes.
    - Additionally, evidence from validations conducted elsewhere within the programme indicate that the concept of sharing a common view on the trajectory as defined by the TMF is a capability well received by controllers as it enables seamless operations across service providers.

The project recommends that to further the integration of trajectory data from the aircraft into ground systems the following should be considered:

- To gather a large ADS-C dataset comprising a variety of operators, FMS manufacturers and routeing combinations. With a fully representative EPP dataset that captures the complexity of the flight deck, the ATC operations and actual MET conditions a more rigorous approach to integrating the ADS-C data with the ground system can be pursued.
- To create an ADS-C emulation capability that can be used in arrangement with ATC simulations. This presents a means to measure the benefit of utilising ADS-C data in a structured validation environment across a variety of ATC systems, including flight data processing, ATCO decision support tools and supervisor sector management.

2 References

[1] SESAR Programme Management Plan, Edition 03.00.01

[2] European ATM Master Plan

[3] Multilateral Framework Agreement (“MFA”) signed between the SJU, EUROCONTROL and its 15 selected members on August 11, 2009, amended on 14 June 2010, 19 October 2010 and 2 July 2012

[4] P05.05.01 Trajectory Management Framework in the TMA, TMF-IOP V&V Needs for 2015, D841, Edition 00.01.01

[5] P04.05 Trajectory Management Framework En Route, TMF Technical Note for 2014 (4.5 Deliverable), D822, 00.01.00

[6] P04.05 Trajectory Management Framework En Route, TMF INTEROP for Step 1 Initial Release, D823, 01.01.00

[7] P04.05 Trajectory Management Framework En Route, Step 1 Internal Validation Exercise Report (4.5 Deliverable), D811, 00.01.01

[8] P04.05 Trajectory Management Framework En Route, VP-771 Validation Report (4.5 Deliverable), D820, 01.00.00

[9] P04.05 Trajectory Management Framework En Route, S1 RNAV-ADD contribution to V2 Validation Report, 00.01.00

[10] P04.05 Trajectory Management Framework En Route, S1 ATFCM-FUA contribution to V3 Validation Report, 00.02.00

[11] B.01 Consolidation & Coordination of ATM Target Concept, Integrated Roadmap - DS14 Release Note, D82, 00.01.00

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