Final Project Report

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Abstract

The project aim was to study the possibility to integrate the military A/C in civil airspace following the SESAR rules by using the technologies already available. The project led to the production of several documents reporting the state of the art of military A/C avionics and the new features required for the integration. In order to meet the objectives, it was designed, developed and tested an additional avionic device named TCA, with the capabilities not yet present in the standard military avionic system. It was integrated in the avionics allowing the military A/C to support the SESAR requirements.

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This deliverable consists of SJU foreground.

Acronyms

Acronym	Definition
ADS-B	Automatic Dependent Surveillance Broadcast
ARES	Airspace Reservation
ASAS	Airborne Separation Assistance System
ASPA	ASAS Spacing
ATM	Air Traffic Management
CPDLC	Controlled Pilot Data Link Communication
CTA	Controlled Time of Arrival
CTO	Controlled Time Over
FMS	Flight Management System
IMMS	Mission Management System
OFA	Operational Focus Areas
IOSED	Operational Service and Environment Definition
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)
TCA	Trajectory Computing Algorithms
TMA	Terminal Manoeuvre Area
TRL	Technology Readiness Level
V&V	Verification and Validation
VALR	Validation Report
VP	Verification Plan
VR	Verification Report
VS	Verification Strategy

1 Project Overview

Project 9.03 aimed at assessing what are the Initial and Full 4D capabilities applicable for military aircraft integration in the SESAR target concept 2020 environment;

Aimed to define, develop and validate, through a prototype some “dedicated” 4D functions (or ground-based supplementary support functionalities) in order to guarantee equivalent “Initial and Full 4D capabilities” for military aircraft when comparing with the capabilities applicable to mainline aircraft, taking into consideration the airborne legacy equipage and integration constraints;

Aimed to verify the compatibility between mission trajectory and business trajectory according to the current 4D military aircraft on board capabilities (e.g. MMS, advanced navigation configurations, flight control, height measurement accuracy, etc.);

Aimed to assess new separation modes and 4D contract to be developed and validated with the purpose of guaranteeing 4D capabilities equivalent to the civil ones in mainline aircraft

1.1 Project progress and contribution to the Master Plan

The 9.3 was the last of the three military projects foresaw by SESAR. It made use of the enablers studied in 9.20 (and 15.2.8) and 9.24 for testing the possibility to allow the military actors to operate in civil airspace. The core of the 9.3 is the Trajectory Computer Algorithm system which allows to comply with ASPA and with the CTA part of i4D requirements. The TCA was not integrated with the A/C avionics but only linked to the flight test instrumentation so the reached TRL is low (4). Nevertheless the project offered valuable materials for the future implementation also as A/C retrofit. The project contributed to the ATM Master Plan (ref [2]) giving the military stakeholder several inputs for understanding the importance of the interoperability between mission and trajectory.

The activities addressed by P09.03.00 contributed to the following system Enablers as captured in the ATM MasterPlan (Source: https://www.atmmasterplan.eu/data/enablers)

EN Code	EN Title	P09.03.00 activities /contributions	Maturity before project	Maturity after project
A/C-61	Handling of additional military datalink messages in military aircraft for ATM purpose.	Use of the link 16 data link for sending CPDLC / ADS-C data. Development of SW interface for converting row data coming from MIDS to data readable and usable by standard computer operating system in order to allow military A/C to fly i4D.	V1 TRL 2	V2 TRL 4
A/C-26	Airborne traffic situational awareness to support in flight operations (ATSA-AIRB), including	Use of ADS-B in data for ASPA manoeuvres. The data coming from surrounding A/C was converted by a SW interface and sent to the TCA computer which indicates the	V1 TRL 2	V2 TRL 4

	reception (ADS-B in), processing and display	speed and route for maintaining the separation required. This capability allows the military A/C to become the Interval Manager for separation purpose.		
A/C-48	Air broadcast of aircraft position/vector (ADS-B OUT) compliant with DO260A	Use of ADS-B out data for ASPA manoeuvres. The data send by military A/C is received by ATC and surrounding A/C .This capability allows the military A/C to become a target for separation purpose.	V1 TRL 2	V2 TRL 4
A/C-13	Flight management and guidance to improve longitudinal navigation (4D contract)	Use of TCA allows the 4d contract	V1 TRL 2	V2 TRL 4
A/C-17	Flight management and guidance to support ASAS self-separation (SSEP)	Use of TCA and ADS-B allows ASAS self separation	V1 TRL 2	V2 TRL 4
A/C-29	Onboard conflict detection and resolution to support ASAS self-separation	Use of TCA and ADS-B allows ASAS self separation	V1 TRL 2	V2 TRL 4
A/C-15a	Flight management and guidance for ASAS spacing with target aircraft flying direct to metering point	Use of TCA and ADS-B allows ASAS spacing	V1 TRL 2	V2 TRL 4
A/C-37a	Downlink of trajectory data according to contract terms	Use of the link 16 data link for sending ADS-C data	V1 TRL 2	V2 TRL 4
A/C-11	Flight management and guidance for improved single time constraint achievement (CTA/CTO)	Use of TCA allows the time constraint achievement (CTA/CTO)	V1 TRL 2	V2 TRL 4
A/C-31b	Data link exchange of clearances or instructions for full 4D operations	Use of TCA allows and link 16 allows the i4d and full 4d data exchange	V1 TRL 2	V2 TRL 4
A/C-72	Use of FMS/MMS data base to support mission trajectory	TCA coupled with MMS allows to fly OAT/GAT	V1 TRL 2	V2 TRL 4

The main 9.3 project contribution to SESAR objectives is for solutions "Time Based separation", "Controlled time of arrival (CTA) in medium density/medium complexity environment".

1.2 Project achievements

The project produced a number of technical documents really useful for understanding the military A/C gaps in terms of compliances with the civil world. The same documents have also highlighted the minimum set of requirements necessary for having the adherence with the SESAR rules and a list of improvements in terms of avionics requirements.

In particular, they were studied the military navigation capabilities for transport-type, fighter and trainer aircraft and proposed high level avionic military architectures for transport, fighter, trainer for implementing the i4D and ASPA solutions.

Assessment of level of compliance for adhering to the i4D and separation requirements for different kind of military A/C has been produced.

The core of the project was the development of the additional "flight Management System" able to satisfy the i4D and separation requirements. This additional FMS is called TCA in the frame of the 9.3 project.

The TCA also contains the interface SW able to convert the row data coming from ADS-B and link 16 in a format readable by the standard operating systems. The TCA SW was developed following the requirements gathered from project PB.4.2, P4.5 and P5.5.1 as well as from projects 9.1 and 9.2 covering airborne Initial 4D and Full 4D.

On the basis of CPDLC, ADS-B and ADS-C data and the A/C flight parameters, the TCA computes a speed demand that allows the pilot to input manually the correct A/C speed in order to reach a designated way point at the requested time and in case of separation, to maintain the required distance from a target A/C.

In the frame of the project the Alenia military A/C simulators have been enhanced for supporting the evaluation of the technical solutions i.e TCA, use of ADS-B and Link 16. A portable C27J simulator was set up for performing a validation exercise in the frame of OFA 3.2.1 (EXE 805). The TCA system was also tested at Rig level making use of real radio equipments (MIDS, MIU).

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1.3 Project Deliverables

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

Reference	Title	Description
D03	Assessment on Interoperability of existing military platforms - Final Issue	This deliverable represents the final issue of the assessment on interoperability of existing military platforms. It is intended to present results on mission and trajectory management interoperability based on results and evidences coming from the operational and operative WPs. Then analysis of functional requirements coming from projects 9.1 and 9.2 allows to define I4D and F4D (if available) functionalities for civil aviation. By allocating functional requirements to military equipment, compliance of existing military platforms can be evaluated. Compliance level of military platform versus I4D/F4D functionalities is a basis for future Key-4D functions definition. This issue define the

		basis for future Key-4D functions definitions by presenting interoperability options.
D05	New-Key 4D function definition – Final Issue	The document represents the final Issue of "New Key-4D function definition". It concerns as main scope the update of the Key-4D functions for military aircraft already defined in the first issue of this document and the definition of the HMI functions related to the defined Key-4D functions. Key-4D functions represent the set of SESAR 4D navigation functionalities which are applicable to military aircraft and which will be investigated by 9.3 in order to find a technical solution for civil-military interoperability. Key-4D functions are presented in the document as functional requirements in order to assure a parallel approach with the initial and full 4D projects. Definition of functional schemes of SESAR 4D navigation functionalities and allocation of these functional schemes to a generic military Mission Computer architecture will be important activities in order to understand the impact of SESAR 4D navigation functionalities on a generic Mission Computer architecture. Functional schemes for the HMI of considered Key-4D functions have been developed in the document so that data flows to and from HMI elements (i.e. Control Panels and Displays) can be identified. This document represents the basis for the definition of System Architecture and HMI in the next deliverables.
D07	Aircraft Architecture and HMI Definition - final	Due to the new key-4D functions implementation, the A/C avionic architecture and HMI require to be adapted. Previous deliverable D06, starting from the conclusions of D04 (definition of key-4D functions) and D05 (definition of top level requirements for HMI), performed an analysis, for both transport and fighter aircraft types, of the i4D and ASPA S&M functio and flight crew tasks. The activity resulted in the identification of a set of aspects and requirements that are fundamental for developing solutions for the computing architecture, HMI and flight crew procedures. The present document D07 analyzes D06 results in order to provide a final solution for the computing architecture, HMI and flight crew procedures. This job was conducted with the support by HMI-Operability specialists and pilots.
D08	WA2.1 - Phase #1 - Software Design Description	This deliverable describes the software design of the Key 4D software application to be employed in flight simulator and flight trials, in the context of the project 9.3. The HMI functions will be described in the upcoming deliverable D11.
D09	Key-4D Software Delivery Note (TCA interim 1 release note)	This document contains the availability note for Software Development Iteration 1 assessing its formal availability for integration and validation activities.

D10	Phase #1 – Preliminary Integration Report (TCA interim 1 release note)	The document describes the set of applicable technical requirements the prototype complies with. The software developed is compliant with a subset of the functional requirements defined in **Error! Reference source not found.**, which are related to the Target Aircraft Data Processing function, ETO min/MAX function, Computation Accurate Reliable Time Estimation (CARTE) data exchange function, Status Monitoring (SM) data exchange function, ASPA Preparation Procedure Checks (APPC) function, Computation Accurate Reliable Time Estimation (CARTE) data exchange during Achieving Phase function, Status Monitoring (SM) - All phases Function, Safety Condition Check (SCC) - All phases function, while the full compliance will be accomplished in the following development iterations.
D11	HMI Software Delivery Note	This document contains the availability note for Software Development Iteration 1 assessing its formal availability for integration and validation activities.
D13	WA2.2 – Flight simulator modification completed and TCA computer integrated (with adapters)	This document contains the summary of the activities carried out on the Flight simulator in order to allow its integration with the TCA computer and to perform the testing activity for de-risking the flight trials.
D14	Coupling Simulator and ATC SW Design Description Issue 1	The document aim is to explain the activity performed for linking the C27J A/C simulator with the Air Traffic Control Simulator located in Alenia Aermacchi. Main Objective of the activity is to demonstrate at simulator level the capability of the C27J equipped with the ADS-B in/out functionalities to perform the ASAS procedures depicted in the 9.3 validation scenario document.
D16	WA2.3 Phase 1 - Overall Technical Validation Plan	This document provides the description of the verification and validation plan about interoperability implementation of initial 4D and the Airborne Separation Assurance System (ASAS S&M) in the scope of military aircraft within some specific Operational Scenario where the OAT and GAT should work contemporary. The document is focussed on activities that will take place on 2015. This document is written taking into consideration previous studies run in the scope of ASAS and i4D.
D17	WA2.3 Phase 1 – ASAS Functions Technical Validation Report (at simulation level)	The present document forms the Validation Report for 9.3 ASAS S&M exercise executed by AleniaAermacchi, ENAV, SELEX ES. The verification objective of the exercise has been set to demonstrate compatibility among military and civil A/C Separation ASPA S&M on an Extended Operational horizon. The military A/C is equipped with a TCA (Trajectory Computer Algorithm) that, associated with the original FMS, supports the ASAS requirements It draws from experience gathered during the previous work on elements of the system and development of the Operational concepts.

D18	WA2.4 Phase #2 - Key-4D Functions Integration Report at simulation level	This document contains the summary of the activities carried out on the C27 J Flight simulator in order to allow its integration with the TCA computer and to perform the i4 D testing activity
D19	WA2.4 Phase #2 - Ground Test Report	This document contains the Verification report on test performed on Link 16 and SW interfaces integrated with TCA computer and ATN i4D data over Link16. The tests have been performed in Alenia test bed in Turin premises where has been integrated the Selex-ES equipment's and SW components developed during the projects (HMI and i4D algorithms)
D20	WA2.5 Phase #2 - Flight Test Report (at simulation level)	The present document forms the Validation Report for 9.3 Initial 4 D exercises executed by AleniaAermacchi and SELEX ES (now FINMECCANICA AIRCRAFT DIVISION and FINMECCANICA Security & Information Systems). The verification objective of the exercise has been set to demonstrate the capability of a military A/C equipped with an external Trajectory Computer Algorithm (TCA) system to fly in I4D mode. The exercise has been performed following the scenario depicted in D16 document. The military A/C is equipped with a TCA (Trajectory Computer Algorithm) that, associated with the original FMS, supports the i4D requirements. This document contains a synthesis of all the V&V tests and results, as well as conclusions and recommendations regarding the maturity of Initial 4D aircraft function. The document mainly focuses on the i4D functionality validation In order to validate the Initial 4D concepts at simulator level, the set-up of a system composed of C27J Flight Simulator, TCA system composed by ground and air parts, has been developed. The V2 tests have been successfully executed. This document contains a synthesis of all the V&V tests and results, as well as conclusions and recommendations regarding the maturity of Initial 4D aircraft function.

1.4 Contribution to Standardisation

N/A

1.5 Project Conclusion and Recommendations

The 9.3 activity led to the design and development of a Trajectory Computing Algorithm system (TCA) capable to be interfaced with real communication system (in our case the link 16 system composed by MIDS and MIU) allowing the transmission of CPDLC and ADS-C messages between ground and air needed for the trajectory management and ADS-B for what concerns the A/C parameters exchange among A/C and ground.

The TCA HMI was not integrated with the A/C avionic as originally planned in the PIR documents but it consisted in an engineering interface. For this reason the human performances was not assessed by using the TCA prototype.

The initial 4 D scenario depicted in the D16 document was successfully tested in Alenia by using the C27J flight simulator integrated with the TCA. In these tests the link 16 equipment was simulated. The data exchanged from ground and air were in the format expected by using the real equipment and also the flight data sent by the C27J simulator to the TCA were in the native format.
The conducted tests have to be considered at high added value since demonstrated the capability of the system to manage the data received from ground and from the A/C itself giving as result the proper information to the pilot.

The tests conducted in ENAV allowed to verify that the use of ADS-B IN/OUT as enabler for ASAS S&M in conjunction with the TCA meet the SESAR ASAS S&M requirements.

A more deep integration of the TCA solution could improve the military A/C capacity to interoperate in civil airspace.

In particular it was demonstrated the possibility to improve the military A/C operability without the necessity to modify the A/C MMS.

The Ground tests activities performed in Torino Caselle demonstrated the capability of the TCA system to be interfaced with the real network equipment. This means that a further integration of the TCA on a real A/C will lead to the demonstration that it can allow a military A/C to fulfil the SESAR i4D requirements.

The use of Military Mission Systems (MMS) / Mission Computers to emulate FMS functions is still dependent on the results of ongoing SESAR R&D efforts. Hence, the options for acquiring onboard automated trajectory management functions in military aircraft remain uncertain.

The airborne surveillance requirements regarding the new separation modes, defined in SESAR for military aircraft operating in a mixed mode environment, will be required to sustain both business and mission trajectory for all aircraft types in accordance with agreed concepts. No distinction has been made regarding the applications to be considered for the various military aircraft types. Applications have not yet been standardised for that purpose.

The ATM concepts also addresses advanced capabilities that potentially offer the means of achieving demanding performance requirements, in particular the very high-end capacity target through more precise longitudinal navigation performance, 4D contracts as well as separation and self separation functions supported by ASAS applications. These requirements rely on ADS-B but have a much longer R&D cycle and/or a limited initial deployment. The timeframe for initial availability and progressive State aircraft equipage with such advanced functionalities will not take place before 2020.

Future ATM concepts call for the prevalence of aircraft-centric views, with multiple functionalities intertwined, relating both to the exchange and processing of information. Avionics are taking on a growing importance and have a fundamental role to play in the design of future concepts. Particular attention needs to be paid to substantiating aspects like the use of airborne computers (Flight Management Systems - FMS or Military Mission Systems – MMS), the introduction of initial and full 4D functions in relation to trajectory management with flight control/flight guidance, new separation modes, some human-machine interface issues and the use of navigation data bases.

A key requirement derived from future ATM concepts is the need to ensure the capability to synchronise airborne and ground system trajectories and to make available during the flight, through data link, the trajectory computed onboard.

Advanced ATM concepts rely heavily on the use of advanced navigation capabilities and shared data to enable lateral/vertical/longitudinal trajectory management. The concept itself sets challenges for the direction of future navigation capabilities.

Key military aviation assumptions are that during baseline and step 1 periods only modern military transport-type aircraft will be impacted by limited trajectory requirements, following the same approach as commercial mainline aircraft (with adapted schedules). For steps 2 and 3, other aircraft types may be accommodated in trajectory structures, mainly on the basis of existing capabilities and ground interface support.

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] B.01-D83-Integrated_Roadmap_DS15_Release_Note

[5] D03 - Assessment on Interoperability of existing military platforms - Final Issue

[6] D05 - New-Key 4D function definition – Final Issue

[7] D07 - Aircraft Architecture and HMI Definition - final

[8] D08 - WA2.1 - Phase #1 - Software Design Description

[9] D09 - Key-4D Software Delivery Note (TCA interim 1 release note)

[10] D10 - Phase #1 – Preliminary Integration Report (TCA interim 1 release note)

[11] D11 - HMI Software Delivery Note

[12] D13 - WA2.2 – Flight simulator modification completed and TCA computer integrated (with adapters)

[13] D14 - Coupling Simulator and ATC SW Design Description Issue 1

[14] D16 - WA2.3 Phase 1 - Overall Technical Validation Plan

[15] D17 - WA2.3 Phase 1 – ASAS Functions Technical Validation Report (at simulation level)

[16] D18 - WA2.4 Phase #2 - Key-4D Functions Integration Report at simulation level

[17] D19 - WA2.4 Phase #2 - Ground Test Report

[18] D20 - WA2.5 Phase #2 - Flight Test Report (at simulation level)

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