VERY LARGE-SCALE DEMONSTRATION

PJ38-ADSCENSIO DEMOR R2

Deliverable ID:	D.1.6
Dissemination Level:	PU
Project Acronym:	ADSCENSIO
Grant:	101017626
Call:	H2020-SESAR-2020-2 submitted for H2020-SESAR-2020-2 / 25 Jun 2020
Topic:	SESAR-WAVE3-07-2020 - Downlinking Flight Trajectory to improve ATM performance
Consortium Coordinator:	DSNA
Edition Date:	27 June 2023
Edition:	02.00.00
Template Edition:	02.00.06

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Authoring & Approval

Authors of the document

Beneficiary	Date
DSNA	14/04/2023
AIRBUS	14/04/2023
AIRTEL	14/04/2023
ANS CR	14/04/2023
DFS	14/04/2023
ENAIRE	14/04/2023
ENAV	14/04/2023
EUROCONTROL	14/04/2023
HONEYWELL	14/04/2023
HUNGAROCONTROL	14/04/2023
INDRA	14/04/2023
LEONARDO	14/04/2023
NATS	14/04/2023
PANSA	14/04/2023
SKYGUIDE	14/04/2023
BULATSA	14/04/2023

Reviewers internal to the project

Beneficiary	Date
DSNA	26/04/2023
AIRBUS	26/04/2023
AIRTEL	26/04/2023
ANS CR	26/04/2023
DFS	26/04/2023
ENAIRE	26/04/2023
ENAV	26/04/2023
EUROCONTROL	26/04/2023
HONEYWELL	26/04/2023
HUNGAROCONTROL	26/04/2023

EUROPEAN PARTNERSHIP

Co-funded by
the European Union

INDRA	26/04/2023
LEONARDO	26/04/2023
NATS	26/04/2023
PANSA	26/04/2023
SKYGUIDE	26/04/2023
ESSP (LTP to DSNA)	26/04/2023

Reviewers external to the project

Beneficiary	Date
N/A	N/A

Approved for submission to the S3JU By - Representatives of all beneficiaries involved in the project

Beneficiary	Date
DSNA	26/06/2023
AIRBUS	26/06/2023
AIRTEL	26/06/2023
ANS CR	26/06/2023
DFS	26/06/2023
ENAIRE	26/06/2023
ENAV	26/06/2023
EUROCONTROL	26/06/2023
HONEYWELL	26/06/2023
HUNGAROCONTROL	26/06/2023
INDRA	26/06/2023
LEONARDO	26/06/2023
NATS	26/06/2023
PANSA	26/06/2023
SKYGUIDE	26/06/2023

Rejected By - Representatives of beneficiaries involved in the project

Beneficiary	Date
N/A	N/A

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Document History

Edition	Date	Status	Beneficiary	Justification
Ed.00.00.01	27/12/2022	Draft	All project beneficiaries	Strawman sent to partners to develop their contributions
Ed.00.01.00	17/04/2023	Draft	All project beneficiaries	Version distributed to partners for review
Ed.00.01.00	08/05/2023	Draft	All project beneficiaries	Version distributed to partners for approval
Ed.01.00.00	12/05/2023	Delivered	All project beneficiaries	Version submitted to SJU
Ed.01.01.00	19/05/2023	Delivered	All project beneficiaries	Revision of section 5. Version submitted to SJU
Ed.02.00.00	27/06/2023	Delivered	All project beneficiaries	Updates provided after SJU review. Version submitted to SJU

Copyright Statement

EUROPEAN PARTNERSHIP

Co-funded by the European Union

ADSCENSIO

ADS-C ENABLES AND SUPPORTS IMPROVED ATM OPERATIONS

This demonstration report is part of a project that has received funding from the SESAR3 Joint Undertaking under grant agreement No 101017626 under European Union's Horizon 2020 research and innovation programme.

Abstract

This second release of the Demonstration Report (DEMOR R2) presents the results of the 12 exercises performed in the framework of the ADSCENSIO project (PJ38) and described in the Demonstration Plan Release 2 (D1.5). It supersedes the DEMOR R1 (D1.2).

The objectives were to demonstrate improvements of ATM operations enabled by the use of ADS-C data, with the support of the suitable technical infrastructure.

From an operational perspective, common situations encompassing a variety of ATM processes have been evaluated:

- Traffic Flow management,
- 2D consistency check and conformance monitoring,
- Conflict Detection and Resolution,
- Traffic sequencing, and
- Facilitation of continuous vertical evolution (for descending or climbing flights).

From a technical perspective, two solutions aiming at sustaining VDL2 have been demonstrated:

- The definition, development and use of the "ADS-C Common Service" (ACS) is a major element of this demonstration by reducing the number of simultaneous ADS-C connections and avoiding the situation where the same information is downlinked several times for multiple ANSPs.
- SATCOM/VDL2 dual link is suitable for managing ADS-C connections.

The document also provides in dedicated annexes:

- The executive summary of D3.1 providing the results of the analyses conducted by WP3;
- The final version of the inputs to standardisation and industrialisation of the ACS from WP5.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Table of Contents

List of Tables

List of Figures

EUROPEAN PARTNERSHIP

Co-funded by the European Union

1 Executive summary

The Very Large Demonstration ADSCENSIO project is aimed at demonstrating improvements of ATM operations enabled by the use of ADS-C data, with the support of the suitable technical infrastructure.

The output of the project will feed the elaboration of a deployment strategy in preparation of Common Project 1 (CP1) regulation[1].

The ADSCENSIO project included:

- 9 operational exercises (real-time operations, shadow mode or post-flight simulations based on recorded data) conducted by eight European ANSPs, which aimed at demonstrating the added value of the use of ADS-C data in various common ATM operational areas (i.e. traffic flow management, 2D consistency check and conformance monitoring, conflict detection and resolution, traffic sequencing, and facilitation of continuous vertical evolution for descending or climbing flights), and
- 3 technical exercises, which aimed at demonstrating the appropriateness of proposed infrastructure to convey and distribute ADS-C data to ground consumers based on VDL2 & SATCOM technologies.

The operational improvements address several key performance areas: Human Performance, Safety, and overall system Performance, improving flight efficiency targeting reduction of fuel consumption and associated CO_2 emissions. Airspace capacity increase and delay reduction are expected to improve too.

Several operational exercises, in particular the real-time operations, relied on the use of the ADS-C Common Service (ACS) developed in ADSCENSIO, which enabled an optimisation of the use of the datalink resource to reduce the number of simultaneous ADS-C connections, communalize ground customers' needs and to avoid same information to be downlinked several times. The specifications of the ACS have been provided to the OEP WST 12.2 for the standardisation of this service in the perspective of the CP1 AF6 mandate.

As a result of these 3 years activities, the project reached some outstanding achievements.

[1] The deployment of the European ATM Master Plan is supported by "Common Projects" European Commission Implementing Regulation no. 2021/116, Common Project 1 (CP1), was published the 2021/02/02 into the EU Official Journal. CP1 aims to steer Air Traffic Management (ATM) modernization in Europe, and contains the required ATM functionalities and sub-functionalities, in particular the ATM Function 6 (AF6): Initial Trajectory Information Sharing.

EUROPEAN PARTNERSHIP
Co-funded by the European Union

- More than 60000 flights collected with ADS-C contracts established. This represents more than 3 400 000 ADS-C EPP reports which have been put at the disposal of the members allowing statiscal analyses about EPP predictability, stability and looking for operational performances /weaknesses. Those data were also derived to enhanced Trajectory Predictor tools used on ground to estimate aircraft trajectories and associated performances.

- Operational evaluations : up to TRL7 for features requested for CP1 (ADS-C EPP display and 2D conformance monitoring tool). MUAC is even beyond TRL7 having deployed while others ANSPs are on this path having demonstrated the technical feasibility along with the implementation. Advanced ATM features (like CD&R tools) were also matured in PJ38 thanks to the combined effort done for some members involved in PJ18 – Sol56 and/or PJ18- Sol53B.

- Multilink with SATCOM & VDL is considered TRL7 on going having obtained airborne certification while the ground segment covered in IRIS project experienced delays for the ground infrastructure approval (expected in June 2023 with start of revenue flights fitted with SATCOM capabilities after the summer 2023).

- ADS-C Common Service reached TRL 7 having been developed similarly to the DSD Fast Track meaning from the conceptual phase up to prototypes, running daily in representative environnement. In total, three instances were implemented and operated. The ACS specification (ADS-C Common Service Requirements including the CONOPS, ADS-C Common Service SWIM ICD) were produced by PJ38 and transfered to the Operational Excellence Programme WST 12.2 who has taken the responsibility to describe the Concept of Operations (CONOPS) upon which the development of standardisation material will be prepared, thereby detailing the requirements applicable to the operational deployment of such common services. The access to ADS-C data via a common server proves efficient for ANSPs, source of additional benefits for airspace users, and contribute to a better management of datalink capacity.

The project elaborated 14 industrial and deployment recommendations along with 2 regulation and standardisation recommendations.

Air Traffic Services Baseline 2 („ATS-B2“), based on the use of ADS-C EPP data developed with the EUROCAE standards ED-228/ED229 rev.A, are confirmed satisfying and valuable for the sake of CP1 mandate.

Beyond the benefits derived from the display of ADS-C information required by CP1; the processing of data content combined with the use of CPDLC B2 is to generate additional improvements and pave the way to Trajectory Based Operations.

Eventually, it is timely and relevant to continue the development, implementation and deployment work under the umbrella of SESAR 3.

2 Introduction

2.1 Purpose of the document

This document is the Demonstration report (DEMOR) for PJ38 project describing the results of the conducted validation activities. The document is used for assessing the technical feasibility, operational performance, safety and interoperability of the 4D trajectory.

The document provides a set of relevant conclusions and recommendations principally for the processing and use of ADS-C EPP data by ground operators.

2.2 Scope

PJ38 ADSCENSIO project builds on the work achieved in Wave 1 DIGITS and DIGITS-AU projects.

The detailed description of this project and these exercises are included in the Demonstration Plan (D1.5, Ed 02.00.00, 11 March 2022).

This document was produced in two steps considering the project was extended by 6 months because of the impact of Covid-19 crisis in 2021 and 2022 (end in June 2023 instead of December 2022).

This first release (D1.2) is delivered in 2022 in accordance with the initial plan defined in the Grant Agreement. It includes the consolidated results of four exercises and some initial results for three other ones.

The second release (D1.6) is delivered in May 2023 and it includes the consolidated results from all exercises.

2.3 Intended readership

The intended readership for this document is the ATM Community at large. The project participants, the SESAR Joint Undertaking and any member, affiliate or associate having access right to this document might be interested to understand, up to a significant level of detail, what, who, why, when, where and how the demonstration took place.

More particularly, the member, affiliate or associate having access right to this document and taking part in SESAR 2020 PJ18-W2 Solutions 53, 56 and 57, or to the projects ALBATROSS and HERON might be interested by this document, as there is a strong synergy among these projects.

2.4 Background

Figure 1: The time line from early SESAR works to ADSCENSIO

The project ADSCENSIO comes in the continuity of various projects in Research and Demonstration focusing on Air Ground datalink synchronization. The majority of these activities have been conducted in previous SESAR initiatives (initial-4D, PEGASE, DIGITS-PJ31/DIGITS-AU, PJ10, PJ18) or related project (Iris).

Compared to the Very Large Demonstration DIGITS-PJ31 – from which ADSCENSIO-PJ38 is the direct continuation- the focus is put on the ground system development while DIGITS-PJ31 was centred on the airborne side.

2.5 Structure of the document

This Demonstration plan is broken down into seven parts and three Annexes:

- Part 1 summarizes the document
- Part 2 introduces the purpose of the document and provides guidance to the reader
- Part 3 provides the context and scope of the demonstrations with reference to the overall SESAR programme, and provides a summary of the Demonstration Plan
- Part 4 provides the detailed results of the validation exercises conducted in ADSCENSIO
- Part 5 lists the conclusions and recommendations
- Part 6 summarizes the communications and dissemination activities
- Part 7 lists the references
- Appendices A to L include the report of each ADSCENSIO exercise
- Appendix M provides the executive summary of D3.1 (i.e. data analysis performed by WP3)
- Appendix N includes the PJ38 WP5 final inputs to standardisation and industrialisation of ACS.

2.6 Glossary of terms

Term	Definition	Source of the definition
4D Skyways	The SESAR PJ18-W2 4D Skyways project (2020-2023) aims to continue research conducted to date on Trajectory Management in order to enable the deployment of trajectory-based operations under a single European sky.	European Commission CORDIS
4DTM	"4D Trajectory Management" is the name of SESAR Project PJ18 during the SESAR2020 wave 1, that hosted in particular the Solution 18-06 focussed to the enhancement of Trajectory Prediction computation based on information extracted from the ADS-C flight data (notably EPP).	Summary based on PJ18 Final Project Report
AAP	A bespoke transport protocol between the AES and GDGW	Honeywell description (section 6.10)
ADS-C	A means by which the terms of an ADS-C agreement will be exchanged between the ground system and the aircraft, via a data link, specifying under what conditions ADS-C reports would be initiated, and what data would be contained in the reports. ADS-C content includes among others: position, altitude, speed, managed modes, estimation to waypoint, elements of navigational intent and meteorological…	SESAR Concept of Operations Step 1, Edition 2015
ADS-C Demand Contract	The demand contract provides the capability for an ATSU to request a single demand report from an aircraft and specify which optional ADS-C data groups are required (if any) in addition to the basic ADS-C information.	ED-228A
ADS-C Event Contract	The event contract provides the capability for an ATSU to request and receive event reports from an aircraft (for configurable event types) containing optional ADS-C data groups in addition to the basic ADS-C information.	ED-228A
ADS-C Periodic Contract	The periodic contract provides the capability for an ATSU to request periodic reports (in configurable time intervals) from an aircraft and specify which optional ADS-C data groups are required (if any) in addition to the basic ADS-C information.	ED-228A

Term	Definition	Source of the definition
Authentication	The process that ensures and confirms a user's identity	
Authorization	the security mechanism to determine access levels or user/client privileges related to system resources including files, services, computer programs, data and application features	
Container.	Nodes exist within a container. Examples of containers are brokers and client applications. Each container MAY hold many nodes.	AMQP Standard
Endpoint	Location at which information is received to invoke and configure interaction.	https://reference.swim.aero/glossary.html
EPP	Specifies the aircraft predicted trajectory up to 128 waypoints including for each waypoint, Latitude, Longitude and when available, Fix, Level, ETA, Airspeed, Vertical type(s), Lateral type(s), Level constraint, Time constraint, Speed constraint. When available, provides the relevant data for the trajectory as Current gross mass and EPP trajectory intent status. It indicates the date and time these values were computed.	Baseline 2 ATS Data Communications Standard: ED-228 march 2014 edition
CWP	Controller Working Position, i.e.: the operator (ATCO/AFISO) work station including necessary ATS systems.	06.09.03 – D09 – Contingency TWR trial 1 validation report
FDP or FDPS	System responsible for collecting and interrogating aircraft position-related data derived from on-board navigation and position fixing systems for presentation to the ATC controllers. FDPS uses this information to then probe for potential conflicts.	EUROCONTROL, NM Glossary (2014)
FMS	An integrated system, consisting of an airborne sensor, receiver and computer with both navigation and aircraft performance databases, which provides performance and RNAV guidance to a display and automatic flight control system.	ICAO, Technical Committee of the Regional Safety Oversight Cooperation System, ADVISORY CIRCULAR, AC : 91-008
Iris	The Satellite Communications System for Safe and Secure Air Traffic Management Data Links and Voice. The project will make use of a SATCOM Class B, based on ATN/OSI.	http://esamultimedia.esa.int/docs/telecom/Iris.pdf

Term	Definition	Source of the definition
Link	A link is a unidirectional route between two nodes. A link attaches to a node at a terminus. There are two kinds of terminus: sources and targets.	AMQP Standard
Node	Nodes are named entities responsible for the safe storage and/or delivery of messages. Messages can originate from, terminate at, or be relayed by nodes. Examples of AMQP nodes are producers, consumers, and queues. Producers and consumers are the elements within an application that generate and process messages. Queues are entities that store and forward messages.	AMQP Standard
Source (Terminus)	Kind of terminus tracking outgoing messages.	AMQP Standard
Subscription	An agreement to receive information.	
Subscription Management	Subscription management provides a client with the means of customising the set of datalink messages that it receives via the publication mechanism.	
Target (Terminus)	Kind of terminus tracking incoming messages.	AMQP Standard
Terminus	A terminus is responsible for tracking the state of a particular stream of incoming or outgoing messages. There are two kinds of terminus: sources and targets.	AMQP Standard
TESLA	Airbus Defence and Space platform for Conflict Detection and Resolution	

Table 1: Glossary of terms

2.7 List of Acronyms

Acronym	Definition
4DTM	4D Trajectory Management
A/C	Aircraft
A/G	Air/Ground
ACARS	Aircraft Communication Addressing and Reporting System
ACC	Area Control Centre

Acronym	Definition
ACS	ADS-C Common Service
ADEP	Aerodrome of Departure
ADES	Aerodrome of Destination
ADS-B	Automatic Dependent Surveillance – Broadcast
ADS-C	Automatic Dependent Surveillance – Contract
ADSCENSIO	ADS-C ENables and Supports Improved ATM Operations - SESAR Project
AES	Airborne Equipment SATCOM
AF6	ATM Function 6
AFISO	Aerodrome Flight Information Service Officer
AFTN	Aeronautical Fixed Telecommunications Network
AGR	Air-Ground Router
AMAN	Arrival Manager
AMQP	Advanced Message Queueing Protocol
ANS	Air Navigation Service
ANSP	Air Navigation Service Provider
API	Application Programming Interface
APP	Approach
APT	Airport
ARINC	Aeronautical Radio, Incorporated
ASN.1	Abstract Syntax Notation One
ASS	Assumption
ASTERIX	All-purpose structured EUROCONTROL surveillance information exchange
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATFCM	Air Traffic Flow and Capacity Management
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATS	Air Traffic Services

Acronym	Definition
ATSU	Air Traffic Services Unit
AU	Airspace User
B2B	Business to Business
BADA	Base Of Aircraft Data
CAS	Calibrated Airspeed
CBT	Computer Based Training
CD&R	Conflict Detection & Resolution
CDA	Current Data Authority
CDG	Paris Charles de Gaulle airport
CLNP	Connectionless Network Protocol
CM	Context Management
CMF	Communication Management Function
CMU	Communications Management Unit
CNP	Communication Network Provider (e.g. SITA, or Collins)
COM	Communication
CONOPS	Concept of Operations
COP	Coordination Point
CP1	Common Project 1
CPDLC	Controller–Pilot Data Link Communication
CRT	Criteria
CS-ACNS	Certification Specifications -Airborne Communications, Navigation and Surveillance
CSP	Communication Service Provider
CSV	Comma Separated Value file format
CTA	Controlled Time of Arrival
CWP	Controller Working Position
DCB	Demand and Capacity Balancing
DCDU	Datalink Control and Display Unit
DEMOP	Demonstration Plan
DEMOR	Demonstration Report

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Acronym	Definition
DIGITS	Demonstration of ATM Improvements Generated by Initial Trajectory Sharing – SESAR Project
DIGITS-AU	DIGITS Airspace User part – SESAR Project
DIST	Distribution
DLFEP	Datalink Front End Processor
DLS	Datalink Services
EASA	European Union Aviation Safety Agency
EATMA	European ATM Architecture
ECAC	European Civil Aviation Conference
EDUU	Karlsruhe Upper Area Control Centre
EFD	ETFMS Flight Data message
eFPL	Extended Flight Plan
EIH	Eurocontrol Innovation Hub
ENR	En-Route
EPKK	Krakow airport
EPP	Extended Projected Profile
EPWA	Warsaw airport
ESA	European Space Agency
ETA	Estimated Time of Arrival
ETFMS	Enhanced Tactical Flow Management System
EUR	Europe
EUROCAE	European Civil Aviation Equipment
EXE	Exercise
FANS	Future Air Navigation System
FDP	Flight Data Processing
FDPS	Flight Data Processing System
FIR	Flight Information Region
FMP	Flow Management Position
FMS	Flight Management System
FPL	Flight Plan

Acronym	Definition
FRAM	Free Route Airspace Maastricht
FTP	Flight Test Procedures
G/G	Ground to Ground
GDGW	Ground Datalink Gateway
GEO	Geostationary Orbit
GES	Ground Earth Station
GFD	Ground Facility Designator
GGR	Ground-Ground Router
GCTS	Tenerife South airport
GMT	Greenwich Mean Time
GPS	Global Positioning System
H2020	Horizon 2020
HERON	Highly Efficient Green Operations – SESAR Project
HMI	Human Machine Interface
HPRF	Human Performance
i4D	Initial 4 Dimension
IAF	Initial Approach Fix
IAS	Indicated Airspeed
IBP	Industry Based Platform
ICAO	International Civil Aviation Organization
ICD	Interface Control Document
INTEROP	Interoperability Requirements
IOC	Initial Operational Capability
IODA	Innovative Operations for Departures and Arrivals
IOP	Interoperability (uses for ground-ground as well as air-ground
IQR	Interquartile Range
ISA	Instantaneous Self-Assessment
ISO	International Organization for Standardization
ITF	Iris Test Facility

Acronym	Definition
KPA	Key Performance Area
KPI	Key Performance Indicator
KUAC	Karlsruhe UAC
LCS	Light Cockpit SATCOM
LSAG	Geneva ACC
LSAZ	Zurich ACC
LFBB	Bordeaux FIR
LFEE	Reims FIR
LFFF	Paris FIR
LHBP	Budapest airport
LHCC	Budapest FIR
LOF	Logon Forward
MEP	Message Exchange Pattern
MET	Meteorological
MONA	Monitoring Aids
MS	Milestone
MTCD	Medium Term Conflict Alert
MUAC	Maastricht Upper Area Control Centre
NAN	Next Authority Notified
NDA	Next Data Authority
NDB	Navigation Database
NGFMS	Next Generation Flight Management Systems
NM	Network Manager
NOK	Not OK
NSA	National Supervisory Authority
NTP	Network Time Protocol
OBJ	Objective
OEP	Operational Excellence Programme
OLDI	On-Line Data Interchange

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Acronym	Definition
OPRF	Operational performance improvement
OPS	Operations
OPSF	Operational feasibility
OS	Operating System
OSED	Operational Service and Environment Definition
OSI	Open Systems Interconnection
OST	One Sky Team
PA	Process Abort
PANS	Procedures for Air Navigation Service
PBCS	Performance Based Communications and Surveillance
PDU	Protocol Data Unit
PEGASE	Providing Effective Ground & Air data Sharing via EPP – SESAR Project
PENS	Pan-European Network Services
PERF	Performance
PJ	Project
PMB	Project Management Board
PMP	Project Management Plan
PS	Publish Subscribe
PTR	Problem Trouble Report
RAD	Radar
RBT	Reference Business Trajectory
RCP	Required Communication Performance
RCTP	Required Communications Technical Performance
REG	Regulatory
REQ	Requirements
RFL	Requested Flight Level
RIO	Risks, Issues and Opportunity
RNAV	Area Navigation
RR	Request and Reply

Acronym	Definition
RSMP	Required Surveillance Monitored Performance
RSP	Required Surveillance Performance
RSTP	Required Surveillance Technical Performance
RSTPSSP	RSTP Satellite Service Provider
RTS	Real Time Simulation
RVSM	Reduced Vertical Separation Minimum
SAF	Safety
SAFE	Safety
SASL	Simple Authentication and Security Layer
SATCAS	Systems for ATC Automated Services
SATCOM	Satellite Communication
SATVOICE	Satellite Voice
SDM	SESAR Deployment Manager
SDU	Satellite Data Unit
SESAR	Single European Sky ATM Research Programme
SID	Standard Instrument Departure
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SNMP	Simple Network Management Protocol
SPR	Safety and Performance Requirements
SQL	Structured Query Language
SSP	Satellite Service Provider
STAM	Short Term ATFCM Measures
STAR	Standard Arrival Route
STCA	Short Term Conflict Alert
STD	Standard
SWIM	System Wide Information Model
SYSCO	System Coordination via OLDI
TBC	To Be Confirmed
TBO	Trajectory Based Operations

Acronym	Definition
TCT	Tactical Controller Tool
TECH	TECHnical
THR	Threshold
TIS	Trajectory intent Status
TLS	Transport Layer Security
TMA	Terminal control Area
TOA	Time Of Arrival
TOC	Top of Climb
TOD	Top of Descent
TWR	Tower
UA	User Abort
UAC	Upper Area Control
UC	Use Case
UNL	UNLimited
UTC	Coordinated Universal Time
UUID	Universally Unique IDentifier
VDL	VHF Data Link
VDL2	VHF Data Link Mode 2
VDR	VHF Data Radio
VGS	VHF Ground Stations
VHF	Very High Frequency
VLD	Very Large Demonstration
WAC	World ATM Congress
WBS	Work Breakdown Structure
WP	Work Package
WST	Workstream
XER	XML Encoding Rules
XML	Extensible Markup Language
XSD	XML Schema Definition

Acronym	Definition
ZRH	Zurich

Table 2: List of acronyms

3 Very Large Demonstration (VLD) Scope

3.1 Very Large Demonstration Purpose

The purpose of the Very Large Demonstration ADSCENSIO project is to perform both:

- Operational evaluations by ATCOs from 9 European areas demonstrating the added value of the use of ADS-C data obtained from the connected DIGITS-AU aircraft, and
- Technical demonstrations evaluating the ADS-C common service (ACS) solution defined, prototyped and used live during this project.
- To convey and distribute ADS-C data received through VDL2 & SATCOM technologies to ground consumers.

ADSCENSIO includes a total of twelve exercises, nine operational evaluations conducted and three technical demonstrations related to VDL2 & SATCOM technologies.

3.2 SESAR Solution(s) addressed by VLD

The table below summarizes the SESAR Solutions addressed in the frame of the VLD ADSCENSIO. It provides the corresponding OI Steps and Enablers.

SESAR Solution ID and Title	SESAR Solution Description	OI Steps ref. (coming from EATMA)	Enablers ref. (coming from EATMA)
Solution 115 Extended Projected Profile (EPP) availability on ground	"EPP availability on ground" technological solution is a first step towards a full ground-air trajectory synchronization required for the implementation of the targeted Trajectory based operations. It allows the provision to the ground systems of the aircraft view on the planned route and applicable restrictions known to the airborne system, together with the corresponding optimal planned trajectory computed on-board and speed preferences. This information is automatically downlinked from the airborne Flight Management System via ADS-C data link to the ground ATC unit which has subscribed to the	IS-0303A - Downlink of on-board 4D trajectory data to enhance ATM ground system performance: initial and time based implementation	ER APP ATC 167 ATC Planned Trajectories improvement with new ADS-C reports, eFPL and surveillance information
			ER APP ATC 119 Enhance Air/Ground Data Communication for Step 1
			ER APP ATC 149a Air-Ground Datalink Exchange to Support i4D - Extended Projected Profile (EPP)
			A/C-33a - Class B SATCOM

SESAR Solution ID and Title	SESAR Solution Description	OI Steps ref. (coming from EATMA)	Enablers ref. (coming from EATMA)
	needed service contract (e.g. Extended Projected Profile & Speed Schedule Profile contracts) and made available to the controllers		A/C-37a — Downlink of trajectory data according to contract terms (ADS-C) compliant to ATN baseline 2 (FANS 3/C)
			AGDLS – ATC-AC-1 - ICAO PANS-ATM for initial ADS-C based services
			AGDLS – ATC-AC-11a – New SPR for PM ADS-C services i4D
			AGDLS – ATC-AC-11c - New IOP for PM ADS-C services i4D
			CTE-C02c - A/G Datalink over ATN/OSI - Multi frequency
			ER APP ATC 100 - 4D Trajectory Management by Synchronization of Air and Ground Trajectories through EPP
			ER APP ATC 119 - Air/Ground Datalink Communication/Protocols for i4D and Controlled Time of Arrival
			ER APP ATC 149a - Air-Ground Datalink Exchange to Support i4D - Extended Projected Profile (EPP)
			REG-0100 - Regulatory Provisions for Datalink Extension (DLS II)
			STD-004 - Review of ATS B2 standards in WG-78/SC-214 for US/EUR convergence

SESAR Solution ID and Title	SESAR Solution Description	OI Steps ref. (coming from EATMA)	Enablers ref. (coming from EATMA)
Solution PJ10-02a Improved performance in the provision of separation with use of ADS-C/EPP data	The Solution aims at improving the separation (tactical layer) in the En-Route operational environment through improved ground trajectory prediction. This is achieved using existing information on lateral and vertical clearances that are known by ADS-C/EPP airborne information.	CM-0209-b - Conflict Detection and Resolution in En-Route using aircraft data in Predefined and User Preferred Routes environments	A/C-37a — Downlink of trajectory data according to contract terms (ADS-C) compliant to ATN baseline 2 (FANS 3/C)
			A/C-48a — Air broadcast of aircraft position/vector (ADS-B OUT) compliant with DO260B
			ER APP ATC 100 — 4D Trajectory Management by Synchronization of Air and Ground Trajectories through EPP
			ER APP ATC 104b — Adapt Controller Conflict Detection and Resolution Tools to Use Enhanced Trajectory Prediction
			ER APP ATC 82 — Enhance EN/APP ACC to use eFPL data
			ER APP ATC 149a — Air-Ground Datalink Exchange to Support i4D - Extended Projected Profile (EPP)
			ER APP ATC 160 — ATC to ATC Flight Data Exchange Using The Flight Object
		CM-0210-b - Ground Based Flight Conformance Monitoring in En-Route using aircraft Data	A/C-37a — Downlink of trajectory data according to contract terms (ADS-C) compliant to ATN baseline 2 (FANS 3/C)
			A/C-48a — Air broadcast of aircraft position/vector (ADS-B

SESAR Solution ID and Title	SESAR Solution Description	OI Steps ref. (coming from EATMA)	Enablers ref. (coming from EATMA)
			OUT) compliant with DO260B
			ER APP ATC 100 — 4D Trajectory Management by Synchronization of Air and Ground Trajectories through EPP
			ER APP ATC 149a — Air-Ground Datalink Exchange to Support i4D - Extended Projected Profile (EPP)
			ER APP ATC 160 — ATC to ATC Flight Data Exchange Using The Flight Object
			CTE-S03b — ADS-B station for RAD and APT surveillance
			ER APP ATC 104d — Adapt Controller Conformance Monitoring Tools to Use Enhanced Trajectory Prediction
Solution #109 Air Traffic Services datalink using SATCOM Class B	SATCOM Class B offers a viable option for air traffic services (ATS) datalink using existing satellite technology systems to support initial four-dimensional (i4D) datalink capability. The technology can be used to support end-to-end air-ground communications for i4D operations, connecting aircraft and air traffic management ground systems.	POI-0018-COM — SATCOM Class B for ATM	A/C-33a — Class B SATCOM
			CTE-C02f — Future SATCOM for ATM: SATCOM Class B in Multilink
Solution PJ18-W2-53B Improved Ground Trajectory Predictions	This key R&D activity focuses on the operational validation of improved CD&R tools to improve separation management (tactical layer) in the En-Route and TMA operational environments. The main goal is to	CM-0209-b - Improved Separation Management with the use of Aircraft Data in Conflict Detection and	A/C-37a Downlink of trajectory data according to contract terms (ADS-C) compliant to ATN Baseline 2 (FANS 3/C)

SESAR Solution ID and Title	SESAR Solution Description	OI Steps ref. (coming from EATMA)	Enablers ref. (coming from EATMA)
enabling future automation tools	increase the quality of separation management services reducing controller workload and separation buffers and facilitating new controller team organisations. The foundation for improved CD&R is the improvement of the ground TP, which will be addressed by the key R&D activity from different perspectives: using(EPP data beyond weight and CAS, using known MET data or introduction of new MET data and capabilities, considering the ATC intent, better integrating known ground trajectory constraints, etc.)	Resolution Tools in En-Route predefined and user preferred routes environments	A/C-48a Air broadcast of position/vector (ADS-B OUT) compliant with DO260B
			ER APP ATC 100 4D trajectory management by synchronization or air and ground trajectories through EPP
			ER APP ATC 104d Adapt controller conformance monitoring tools to use enhanced trajectory prediction
			ER APP ATC 149a Air-ground data exchange to support i4D – Extended Projected Profile (EPP)
		CM-0212 - Improved Separation Management with the use of Aircraft Data in Conflict Detection and Resolution Tools in the TMA	To be defined
Solution PJ18-W2-56 Improved vertical profiles through enhanced	The objective of this key R&D activity is to develop an automation support for ATCOs to issue vertical constraints that support more efficient flight profiles while ensuring separation provision. First step, for flight still in climb, enhanced	SDM-0215 - Enhanced ATC and airborne operation using Data Link for TBO	

SESAR Solution ID and Title	SESAR Solution Description	OI Steps ref. (coming from EATMA)	Enablers ref. (coming from EATMA)
vertical clearances	prediction of vertical profile data are presented to ATCOs to facilitate decision making. In a second more advanced step, the ATC system would generate proposals for conflict-free clearances that take anticipated aircraft performance into account, which can be uplinked to the flight crew by ATCO. In a first step, for a certain flight still in climb, enhanced prediction of vertical profile data are presented to ATCOs to facilitate their decision making on whether using constraints in the vertical dimension is appropriate and sufficient to achieve separation (using eFPL 4D trajectory or performance data, but ideally using downlinked EPP data). In a second more advanced step, in the same situation the ATC system would generate proposals for conflict-free clearances that take anticipated aircraft performance into account, and those proposals are then presented to the ATCO for uplink to the flight crew.	CM-0207-B - Automated Ground Based Flight Conformance and Intent Monitoring in En-Route Improved with Aircraft Downlinked Data	
ADS-C Common Service	The solution "ADS-C common service" consists of a common service that distributes the ADS-C/EPP data downlinked from aircraft to the relevant ground users (e.g. ATS Units and NM Systems but potentially also Airlines, MET providers or other). The ADS-C common service covers: • The collection of ADS-C data from the aircraft via a single ATS B2 ADS-C application dialogue to reduce ATN air-ground network load and use of radio spectrum; • The distribution of data to clients via SWIM ground distribution services (AMQPS and HTTPS technologies).	POI-0081-COM - ADS-C Common service (Business Improvement).	SVC-076 - Distribution of ADS-C reports to ground users using a common service

EUROPEAN PARTNERSHIP

Co-funded by the European Union

SESAR Solution ID and Title	SESAR Solution Description	OI Steps ref. (coming from EATMA)	Enablers ref. (coming from EATMA)
	The overall objective of the ADS-C common service is to establish and maintain an ADS-C connection with an aircraft as early and as long as possible, covering all phases of its flight. The ADS-C common service will collect data whether its departure (ADEP) and/or arrival (ADES) lies outside or inside the area covered by the service		

Table 3: SESAR Solutions under Demonstration

3.2.1 Deviations with respect to the SESAR Solution(s) definition

This section describes the deviations with respect to the SESAR solutions identified in the Grant. It highlights in particular the updates resulting from Wave 2 Industrial Research activities.

Solutions mentioned in the Grant but not considered in the scope of ADSCENSIO:

- Solution PJ10-02b: Has only reached V1 at the end of Wave 1. No new OI Step or Enabler mature resulting from this solution, which is continued in the frame of PJ18-W2-53A - *Improved Ground Trajectory Predictions (TP) enabling future automation tools* (target V2 at the end of Wave2).
- Solution PJ01-W2-08: During the course of the project PJ01W2, the Solution has been divided into 3 independent Solutions:
  - PJ01-W2-08A1: Short term DCB optimisation of TMA and Extended TMA Airspace with TMA Management Tool. This Solution has no commonality with PJ38-ADSCENSIO.
  - PJ.01-W2-08A2: Automatic Controlled Time of Arrival (CTA) for management of arrival in En-Route and on the ground. This Solution targets only V2 at the end of the Wave 2.
  - PJ.01-W2-08B: *Dynamic TMA/E-TMA for Advanced Optimised Descent Operations*. This Solution targets only V2 at the end the Wave 2.
- Solution PJ18-W2-57: *RBT revision supported by datalink and increased automation* – The situation of this Solution is currently under revision, scope and level of ambition not ready for feeding PJ38-ADSCENSIO.

3.3 Summary of Demonstration Plan

3.3.1 Demonstration Plan Purpose

EUROPEAN PARTNERSHIP

Co-funded by the European Union

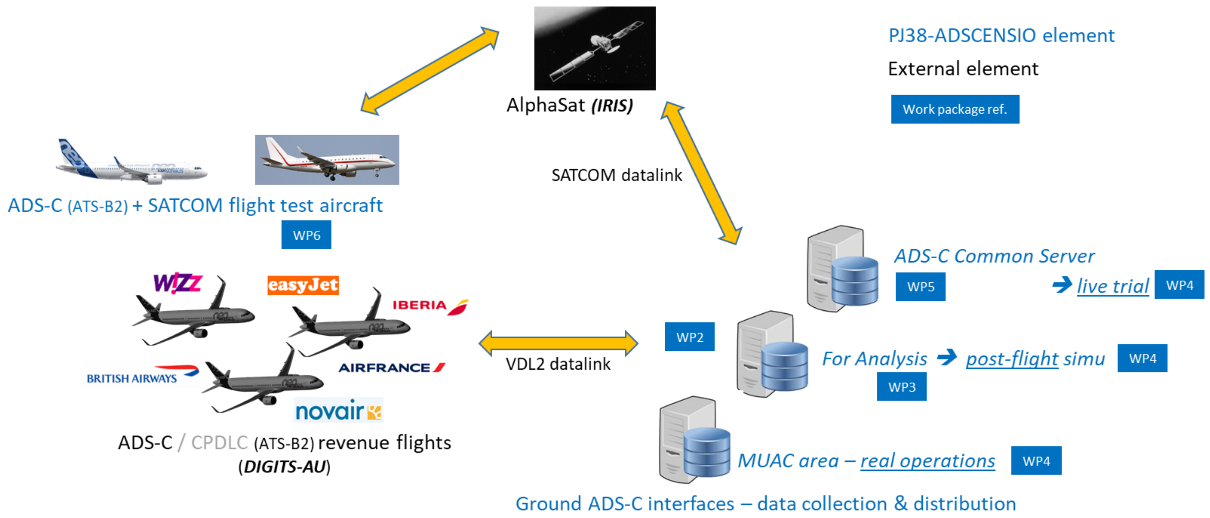


Figure 2: PJ38 ADSCENSIO Demonstration Overview

ADSCENSIO is based on datalink exchanges with aircraft capable of ADS-C ATS-B2 function. In services aircraft have been fitted with the necessary capabilities in the frame of DIGITS-AU (ADS-C ATS-B2 application) and Iris projects (ADS-C ATS-B2 application with specific SATCOM capabilities)

Ground ADS-C interface system is the central element to collect and distribute data either via ADS-C Common Services (ACS) centralising exchanges between ATC centers and aircraft or with local ground ADS-C infrastructure.

PJ38 ADSCENSIO project builds on the work achieved in Wave 1 DIGITS.

Operational evaluation now focuses primarily on the use of EPP by ground operators across their airspace either during:

- Live operations with revenue flights connected to the ATS-B2 test infrastructure,
- or simulations with injection of recorded live flights (connected and non connected)
- or replays of recorded live operations

At airborne level, the ambition is on the demonstration and validation of ATN over SATCOM capabilities with the objective to certify it. Live trials on flight test aircraft are planned in that respect.

Technical demonstrations are also part of the scope to validate the end-to-end performance of ADS-C Common Service and the SATCOM link to convey ADS-C messages.

3.3.2 Operating method description

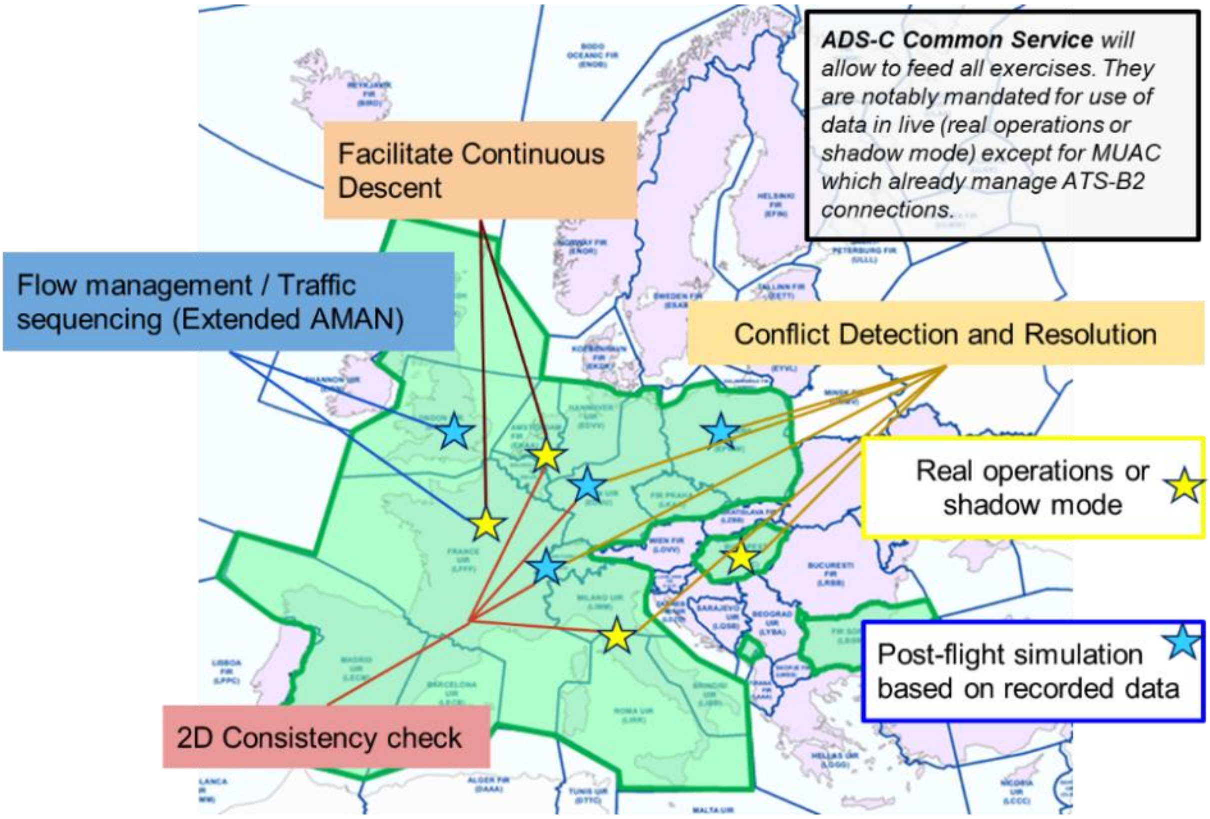


Figure 3: Operating methods and enhanced processes

The participating aircraft do logon with the usual operating procedure by notifying themselves to the ATS B2 test centers.

The ground infrastructure for data distribution and collection, including the use of the ACS prototypes are carried out through the WP2 and WP5.

The ADS-C Common Service allows to collect ADS-C data from aircraft via ATN network and distribute them to interested clients via a ground/ground link (SWIM YP).

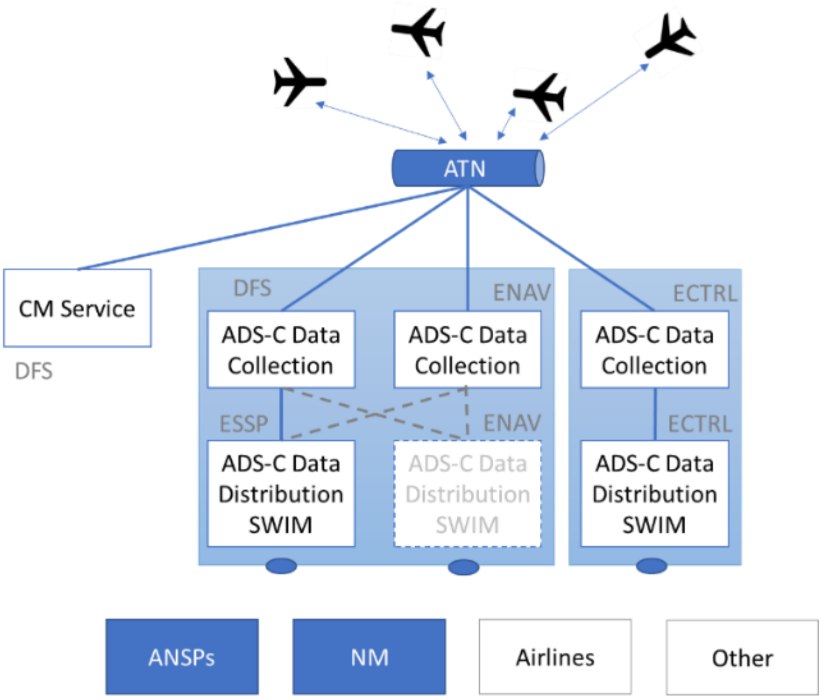


Figure 4 : ACS demo architecture

An agreement was put in place to collect ADS-C data from the same six Airspace Users (Air France, British Airways, EasyJet, IBERIA, Novair and Wizz Air) which participated in PJ31 DIGITS. The Airbus FANS C equipment is fully certified and complies with the current applicable ATS-B2 standard as released in March 2016 (EUROCAE ATS B2 standards Rev A).

The PJ38 project took place while the Covid crisis spread across the entire world, the overall traffic was highly impacted in Europe. The airlines, including the participating ones, faced tremendous challenges to keep their operational capabilities and mitigate their business impacts. While the aviation was recovering with long lasting effects, the connection rate to ATS B2 centers remained unfortunately low, below PJ38 expectations to get sufficient data for the planned validation exercises. A workaround was found to initiate logon from the ground rather than from the aircraft, the Airbus datalink system architecture allowing it. This proved to be an excellent solution to drastically increase the connection rate.

Operational demonstrations (WP4) aim at accessing and considering the use of ADS-C EPP data by ATCOs and FMPs principally through qualitative assessment of the new features targeted by PJ38. Among those ones, there are the display of the EPP data to the operators and being able to detect 2D discrepancies between filed flight plan and current flight plan entered in the flight management system.

Technical analyses supporting the effort of WP4 and more generally the PJ38 objectives were carried out in WP3. Metrics were defined to support the observation of operational and technical features.

3.3.3 Summary of Demonstration Objectives and success criteria

The demonstration objectives and associated success criteria defined in the Demonstration Plan (D1.5) remain valid.

Objectives along with success criteria are presented in 4.2.

3.3.4 Demonstration Assumptions

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
PJ38-ASS-01	ADS-C data provision		The ADS-C Common Service (ACS) is available with appropriate functionalities (including TOA Range demand contracts) and performances	Pre-requisite to be able to carry out ANSP validation exercises	High
PJ38-ASS-02	ADS-C data usability		The received ADS-C data are usable (available on time, not corrupted, etc.)	Pre-requisite to be able to use ADS-C data. The same avionics as in PJ31 will be used. The ACS must ensure that the received data are correctly conveyed to the ANSPs	High
PJ38-ASS-03	VDL2 performances		VDL2 performances support an efficient downlink of ADS-C data	Pre-requisite to be able to downlink the ADS-C data	High
PJ38-ASS-04	Future Covid situation		Future Covid situation will not affect the organisation of the exercises (e.g. travel restrictions)	It is anticipated that the future Covid situation will not be as bad as it was in 2020 and early 2021	High

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
PJ38-ASS-05	No direct support from Datalink Service Providers		The dual link connectivity through SITA's operational network will be in place, but no dedicated support from SITA (or Collins) will be needed to execute the campaign and to analyse the data.	The connectivity through SITA operational ATN is in place, nevertheless neither SITA nor Collins are members of PJ38 and they will not provide dedicated support to the flight campaign.	Data collected in the aircraft, Inmarsat's ground segment and at the ANSP's end systems should provide enough information to analyse the key RSTP/RCTP parameters as well as the EPP functionality. SITA's support will only become critical if detailed network troubleshooting is needed.
PJ38-ASS-06	Inmarsat's support		Inmarsat will support the flight campaign by collecting and analysing the data within their ground segment (AGR, datalink and security gateways).	Inmarsat is not member of PJ38, but the objectives of this campaign are aligned with the ESA Iris program as well as with Inmarsat's own objectives. Inmarsat's support will be needed to analyse the compliance with RSTP/RCTP at the SATCOM boundaries.	Without Inmarsat's inputs (at least raw logs) the RSTP/RCTP analysis will be limited to end-to-end performance (from ANSP logs) with some complementary link-specific performance data obtained from the aircraft logs.

Table 4: Demonstration Assumptions overview

3.3.5 Demonstration Exercises List

The list of the Demonstration Exercises is as follows:

- Operational demonstrations:
    - EXE-PJ38-4-1 (DSNA): ADS-C usage to support FMP decision-making process in Paris ACC
    - EXE-PJ38-4-2 (DSNA): ADS-C usage to issue clearances allowing to optimize flown vertical trajectories
    - EXE-PJ38-4-3 (skyguide): Demonstration of ATM benefits through ADS-C data (EPP – Speed schedule) usage by skyguide
    - EXE-PJ38-4-4 (MUAC): Full ADS-C Operational live trials in Maastricht UAC
    - EXE-PJ38-4-5 (DFS): Demonstration of TP and MTCD benefits through EPP usage
    - EXE-PJ38-4-6 (ENAV): EPP usage
    - EXE-PJ38-4-7 (NATS): ADS-C usage for AMAN in NATS operations
    - EXE-PJ38-4-8 (HUNGAROCONTROL): Demonstration of TESLA system usage and ADS-C EPP data in live trial
    - EXE-PJ38-4-9 (PANSA): Demonstration of iTEC CD-R benefits with EPP usage

- Technical demonstrations:
    - EXE-PJ38-6-1 (Honeywell): EPP over OSI dual link – Honeywell's Embraer EU flight campaign
    - EXE-PJ38-6-2 (Airbus): 4D Flight test with SATCOM system by Airbus
    - EXE-PJ38-6-3 (NATS): Revenue flights with Iris equipped aircraft

Traceability between the demonstration exercises and the objectives/success criteria is provided in 4.2.

3.4 Deviations

3.4.1 Deviations with respect to the S3JU Project Handbook

No deviation with respect to the S3JU Project Handbook.

3.4.2 Deviations with respect to the Demonstration Plan

3.4.2.1 At criteria level

3.4.2.1.1 CRT-38-W3-DEMOP-011

This criterion was eventually not addressed. No partner engaged on it considering the reported deviations. As most of the validation exercises were shifted to the end of 2022, this deviation was discovered too late so that workaround with possible reassessment could not be found.

Rationale is provided in section 3.4.2.2 by ENAV, HUNGAROCONTROL and PANSA.

However there is a close relation with the CRT-38-W3-DEMOP-043 (Reduction of potential infringements or resolved earlier thanks to the availability of EPP information) which is covered.

3.4.2.1.2 CRT-38-W3-DEMOP-041

This criterion was eventually considered as a duplication of CRT-38-W3-DEMOP-002 (The CD&R tools enhanced by the use of additional data with more reliability is adequate for safe service provision according to the ATCOs).

3.4.2.2 At validation exercise level

3.4.2.2.1 EXE-PJ38-4-1 (DSNA): ADS-C usage to support FMP decision-making process in Paris ACC

All the planned activities were conducted, except the use of the on-demand contracts (related to criterion EX1-CRT-38-W3-DEMOP-031) because the ACS did not support on-demand contracts when the exercise platform was developed.

The only variation compared to the Demonstration Plan is related to the planning. The live trials had to be delayed by 6 months because the number of ATS B2 capable flights logged on was ranging from 0 to 2 per day at the time of the initial planned dates. This was identified as risk PJ38-RISK-01 in the Demonstration Plan.

A minimal number of logged on aircraft allowing to conduct the exercise could only be achieved after the implementation of the Autologon procedure by PJ38 WP5 in coordination with the Airspace Users.

Concerning the possibility of using some recorded data for quantitative post-exercise analysis, no need was expressed by the FMP controllers to support the subjective analysis.

3.4.2.2.2 EXE-PJ38-4-2 (DSNA): ADS-C usage to issue clearances allowing to optimize flown vertical trajectories

All the planned activities were conducted, except the use of the on-demand contracts (related to criterion EX1-CRT-38-W3-DEMOP-031) because the ACS did not support on-demand contracts when the exercise platform was developed.

The only variation compared to the Demonstration Plan is related to the planning. The live trials had to be delayed by 6 months because the number of ATS B2 capable flights logged on was ranging from 0 to 2 per day in a given ACC at the time of the initial planned dates. This was identified as risk PJ38-RISK-01 in the Demonstration Plan.

A minimal number of logged on aircraft allowing to conduct the exercise could only be achieved after the implementation of the Auto logon procedure by PJ38 WP2 and WP5 in coordination with the Airspace Users.

Initially, the evaluations were planned for the Paris (LFFF), Reims (LFEE) and Bordeaux (LFBB) but Brest (LFRR) also expressed its desire to participate to the exercise. However, due to the **low number of ADS-C equipped aircraft connected**, the analyses only considered the feedbacks received from Paris (LFFF), Bordeaux (LFBB) and Brest (LFRR).

Concerning the possibility of using some recorded data for quantitative post-exercise analysis, no need was expressed by the ATCOs to support the subjective analysis.

3.4.2.2.3 EXE-PJ38-4-3 (SKYGUIDE): Demonstration of ATM benefits through ADS-C data (EPP – Speed schedule) usage by Skyguide

Due to the amount of data to be treated for the Conflict Detection & Resolution tools analysis, it has been necessary to develop a specific Fast time simulation & replay platform.

As this platform differs from the operational system platform, it would have been necessary to develop additional tools able to interface between CD&R tools and the new Trajectory Predictor. In particular, the new Trajectory Predictor is modular and is developed using recent languages, while the CD&R tools are developed with older languages which makes their integration much more difficult and complex, and hardly feasible in the time available.

Even if technically feasible, the heavy workload needed and the availability of experts developers for this specific development could not be ensured within the timeframe of the project.

Also some data from the Legacy Trajectory Predictor, in particular for the vertical mode computation could not be extracted from the recording, therefore the vertical accuracy (Level error) could not be analysed for comparison with new Trajectory Predictor.

Therefore, as in parallel, the validation platform (skytics) used for validations has been enriched with the new Trajectory Predictor and new CD&R tools detection envelope, the results from validations on CD&R tools using ADS-C EPP and speed schedule data have been used to assess the Conflict Detection & Resolution tools for ADS-C equipped flights.

3.4.2.2.4 EXE-PJ38-4-4 (MUAC): Full ADS-C Operational live trials in Maastricht UAC

MUAC currently has its own connection with the aircraft to establish ADS-C contracts and to receive the ADS-C reports. However, intention is to move to the ADS-C Common Service once it is deployed.

In that context, and even if the core part of EXE-PJ38-4-4 exercise was to focus on the evolution and enhancements of PJ31 ADS-C implementation before full operational deployment, the initial intention was to use PJ38 as an opportunity to build a basic ADS-C Common Service (ACS) Client to early test the future setup. However, this was not finally possible because of the challenging schedule of the project and the workload that the MUAC team in charge of the development had during the project timeframe.

It was already identified as a risk within the demonstration plan the possibility of not being able to accommodate the development of the ACS Client in the timeframe of the PJ38. This risk became a reality despite the mitigation actions in place as it was not possible to deconflict the priorities of the development team before the end of the year. As a result, the EX4-OBJ-38-W3-DEMOP-TECH-0006 could not be demonstrated.

3.4.2.2.5 EXE-PJ38-4-5 (DFS): Demonstration of TP and MTCD benefits through EPP usage

Deviating from the original assumption on exercise execution, the parts of the exercise where live ADS-C data was directly consumed from the ADS-C Common Service was executed at Indra Premises, not at DFS premises. The decision was made for cybersecurity reasons and constraints, which prevented connection of the DFS platform to the ACS interface exposed via public internet in an adequate way. The decision did not affect the exercise execution in content, notably identical software and system architecture was used at DFS and Indra premises and the functionality demonstrated was not affected.

Also deviating from the plan, it was considered that the offline recorded data replay modus was fully substituted with the live data and live traffic activities during the two Exercise days at Indra premises and so it was omitted.

3.4.2.2.6 EXE-PJ38-4-6 (ENAV): EPP usage

The exercise scenario area chosen was the PADUA ACC, as opposed to MILAN ACC which was indicated in the original Demonstration Plan. This was due to the availability of operational tactical resolution tool over the PADUA ACC, such tool not being available over MILAN ACC yet.

Regarding the exercise data collection platform, acquired tracks were not provided with complete flight plans information.

The recording window was initially foreseen to last one week during October 2022. Due to the issues described in F.3.3, it was decided to prolong the duration of data recording period first to two weeks, and finally to a total of 3 weeks (from 24th October to 18th November 2022).

During that period, the exercise figures could be summarised as follows:

- three weeks of shadow mode acquisition,
- 18 days recording data,
- 226 ADS-C equipped flights considered,
- of which, 54 A/Cs performed the log-on.

EX6- OBJ-38-W3-DEMOP-HPRF-0002 deviations

Demonstration Objective ID	Success Criterion ID	Success Criterion	Deviation from the DEMOP
OBJ-38-W3-DEMOP-HPRF-0002	EX6- CRT-38-W3-DEMOP-006	The use of ADS-C data leads to a reduced ATCO R/T usage (e.g.: asking for the aircraft intention) and reduced workload. (Subjective data only)	
	EX6- CRT-38-W3-DEMOP-009	The ADS-C/EPP display supports ATCOs in performing their tasks efficiently and effectively. (Subjective data only).	

Demonstration Objective ID	Success Criterion ID	Success Criterion	Deviation from the DEMOP
	EX6-CRT-38-W3-DEMOP-010	The use of ADS-C data provides assistance to support ATCO decision-making. (Subjective data only)	
	EX6-CRT-38-W3-DEMOP-011	Actual conflicts are detected earlier thanks to enhanced CD tool.	
	EX6-CRT-38-W3-DEMOP-013	2D Consistency check and Conformance monitoring is considered improved by ATCOs. (Subjective data only)	

EX6- OBJ-38-W3-DEMOP-OPRF-0003 deviation

Demonstration Objective ID	Success Criterion ID	Success Criterion	Deviation from the DEMOP
OBJ-38-W3-DEMOP-OPRF-0003	EX6-CRT-38-W3-DEMOP-015	Adherence to on board expected vertical trajectories is enhanced thanks to the use (e.g. display) of TOD information.	Vertical A/C information not available on the HMI
OBJ-38-W3-DEMOP-OPRF-0003	EX6-CRT-38-W3-DEMOP-020	Enhancement of EPP data display for 2D Consistency check.	EPP data not available on the reference CWP for a real time consistency check
OBJ-38-W3-DEMOP-OPRF-0003	EX6-CRT-38-W3-DEMOP-021	Evidence of operational benefits brought by using ADS-C data elements to enhance ground air traffic flow management operations	

EX6- OBJ-38-W3-DEMOP-OPSF-0004 deviation

Demonstration Objective ID	Success Criterion ID	Success Criterion	Deviation from the DEMOP
OBJ-38-W3-DEMOP-OPSF-0004	EX6-CRT-38-W3-DEMOP-023 Same as CRT-38-W3-DEMOP-023	Assess that the display of ADS-C data is considered useful by users (e.g. ATCO).	ATCOs were generally favourable about the usefulness of the EPP data displayed, though no

			specific measurement or assessment were performed

EX6- OBJ-38-W3-DEMOP-TECH-0006 deviation

In the timeframe of the PJ38, with the EXE006 platform performances, was not possible to measure the ACS A/G bandwidth saving and was not possible to demonstrate EX6-CRT-38-W3-DEMOP-037 of the EX4-OBJ-38-W3-DEMOP-TECH-0006.

Demonstration Objective ID	Success Criterion ID	Success Criterion	Deviation from the DEMOP
OBJ-38-W3-DEMOP-TECH-0006	EX6-CRT-38-W3-DEMOP-037 Same as CRT-38-W3-DEMOP-037	The ACS saves A/G bandwidth with regards to an architecture of local ADS-C data acquisition	Not applicable to the demonstration exercise platform

3.4.2.2.7 EXE-PJ38-4-7 (NATS): ADS-C usage for AMAN in NATS operations

The original intention of the exercise was to establish ADS-C Periodic and Demand contracts to the DIGITS' equipped fleet directly from the existing NATS PJ31 test platform while the ACS platform was being developed. This initial phase of the data collection could not be accommodated as the test and development connection point to the SITA ATN backbone was re-prioritised to support operational sustainment activities and the PJ31 platform was unable to support the establishment of demand contracts.

With regards to the second data collection phase, the original intention of the exercise was to establish ADS-C Demand contracts via a NATS developed Client connected to the ACS. However, it should also be noted that ACS support for the TOA Range data group was initially facilitated by Periodic Contract rather than Demand contract. This minor deviation still enabled the data collection for the characterisation of the ETA Min/Max data, although it removed the capability to analyse multiple arrival waypoints on a route.

As the ADS-C data NATS would collect via the ACS would be common with EIH (with the exception of Demand Contracts), it was recognised there would be little benefit in duplicating general ADS-C analysis undertaken by EUROCONTROL in support of EX7-CRT-38-W3-DEMOP-030. As such this criterion was not directly covered by NATS.

As described above, the second phase of the data collection was planned to make use of the ACS platform for the provision of ETA Min/Max data for operational assessment, with the data received through a subscription from a NATS developed ACS client. Due to unexpected resource constraints, NATS encountered a severe delay in establishing a network connection to the ESSP managed ACS distribution server, which was eventually established in January 2023. The provision of TOA Range ETA

Min/Max data for the operational assessment was instead provided by ESSP as recorded on their ACS client connected to their ACS distribution server. Furthermore, this delay impacted NATS ability to use its client to collect statistics on datalink exchanges, however due to the nature of the ACS these statistics would be identical to other clients regardless.

The other main aspect of the original exercise plan that could not be realised due to various constraints, was to make use of a prototype AMAN to provide a quantitative assessment of operational benefits of ETA Min/Max within a queue management support tool. Instead, the characterisation and stability analysis of the ETA Min/Max data provided, was used to facilitate an expert judgement group to determine the benefits of the data in arrival streaming.

3.4.2.2.8 EXE-PJ38-4-8 (HUNGAROCONTROL): Demonstration of TESLA system usage and ADS-C EPP data in live trial

Due to the very low number of ADS-C equipped aircraft in the Hungarian airspace, it was decided to switch the validation exercise into a simulated one. The following points led to this conclusion:

- In July 2022 1,32% of all IFR flights in the Hungarian airspace were equipped with ADS-C, resulting in 101 LHBP arrivals and 101 departures, meaning 3-3 flights per day on average. HungaroControl had no influence on and information about when those aircraft will arrive/depart, and this uncertainty would have made the ATCO rostering difficult (see point 4).

- The TESLA has its own HMI, which is considerably different from the main ATM system (i.e. MATIAS). A direct data connection could not be established between the Tesla and the MATIAS, thus the ATCO should have fed the TESLA system with the same inputs that he already made in the MATIAS to see the added value of TESLA. Consequently, ATCOs in the OPS room should have received training on the Tesla functionalities to be able to work with it in live environment (see point 4).

- The Tesla was supposed to be on a separate screen in the APP and ACC Controller Working position. As described in the previous point, the ATCO should have fed the system on top of managing the live traffic with MATIAS. This extra task hence workload could not be assigned to the Executive Controller, and for the APP the need for an additional APP position was on the table. Adding an extra position just to monitor the ~6 ADS-C capable flights somewhere during the day would not have been feasible. Especially since there was a huge uncertainty as to when those aircraft will be scheduled (see point 1), thus planning ahead the traffic and synchronizing the shifts accordingly was impossible.The idea was that only a handful of ATCOs will receive a training on the TESLA functionalities, so that they can safely operate the system in the OPS room.

- However, with this low number of ADS-C capable flights it would have been extremely difficult/impossible to ensure that the trained ATCO was rostered to the Tesla equipped position at the time those ADS-C aircraft appeared. Based on these points above the team agreed that this low sample size would give insufficient data for meaningful results, especially when considering all the rostering challenges.

This decision led to a redefinition of the platform architecture, and within this context the systems developed by ADS are structured as follows:

- TESLA: Main component implementing all the advanced ground services,
- GENETICS: Flexible and modular system able to reproduce and create air traffic situation,
- SIMUATC: CWP-prototype to demonstrate the TESLA services.

This deviation from the plan affected criterion 041, 011, 012, 030, 031, 032, 033 which could not be addressed, and are mentioned in Table 53 of H3.1.

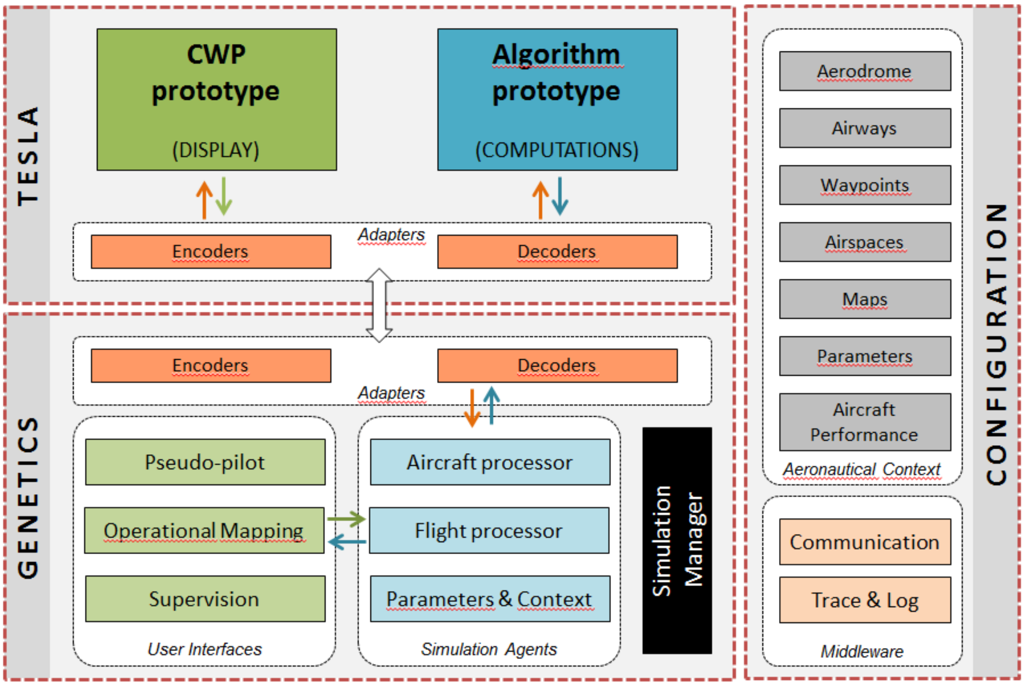


Figure 5: Architecture of the Software components

Some of the success criteria could not be addressed due to switching to simulation. From HP point of view, EX8-CRT-38-W3-DEMOP-011 and EX8-CRT-38-W3-DEMOP-012 would have only made sense in VLD. From the Tech point of view OBJ-38-W3-DEMOP-TECH-0006 could not be assessed either because of switching to a simulation, thus the ADS-C datalink wasn't analysed whatsoever.

However, from the Safety point of view there was only minor difference between CRT-38-W3-DEMOP-002 and CRT-38-W3-DEMOP-041, thus they were merged in the results.

3.4.2.2.9 EXE-PJ38-4-9 (PANSA): Demonstration of iTEC CD-R benefits with EPP usage

The demonstration took place at Indra premises in Madrid. This decision was made due to high risk of significant delay in implementing a stable ADS-C Common Service connection, due to technical issues known to INDRA, which occurred during deployment in DFS, decision was made to utilize existing stable connection. Additionally, instead of using FIR Warszawa airspace, due to not sufficient number of a/c equipped with EPP, it was more beneficial for the exercise to take place in airspace where the EPP data was more available. Therefore, the decision to use the airspace of NATS and DFS.

Due to these changes, we were not able to use ATCOs as initially planned. Instead of managing traffic, ATCOs were only observing traffic and comparing EPP data with real performance. As a result of that the following criteria couldn't be assessed:

- CRT-38-W3-DEMOP-011
- CRT-38-W3-DEMOP-012
- CRT-38-W3-DEMOP-018

3.4.2.2.10 EXE-PJ38-6-1 (Honeywell): EPP over OSI dual link – Honeywell's Embraer EU flight campaign

The plan for this campaign was to fly Honeywell's test aircraft from US to Europe and spend roughly 55 flight hours in European airspace, covering primarily busy core Europe (Germany, UK, Netherlands, France…) and northern Europe (Iceland, Scandinavia).

Unfortunately, due to major aircraft failures unrelated to this project (broken windshield and malfunctioned landing gear) the aircraft had to stay grounded most of the time after arrival to Oslo (Norway). As a result, the aircraft spent slightly over 16 flight hours between Iceland and Scandinavia with no flight time in core Europe. Even with this limited scope, the campaign still provided lots of useful data.

3.4.2.2.11 EXE-PJ38-6-2 (Airbus): 4D Flight test with SATCOM system by Airbus

None

3.4.2.2.12 EXE-PJ38-6-3 (NATS): Revenue flights with Iris equipped aircraft

PJ38 had a dependency on the European Space Agency funded Iris IOC project to provide Space-Ground infrastructure and equip several aircraft with a certified 'Iris' avionics capability. Although the Space-Ground infrastructure was deployed in-time to facilitate the Airbus and Honeywell dedicated flight tests in EXE-PJ38-6-2 and EXE-PJ38-6-1 respectively (see Appendix J and Appendix K), the certification of the revenue flight aircraft and Iris Service Provider was significantly delayed.

The original intention of EXE-PJ38-6-3 was to collect link performance metrics from the Iris equipped aircraft conducting revenue services (referred to as Iris pre-commercial flights). Due to the significant delay of the pre-commercial flights ultimately occurring outside of the PJ38 timeframe, as noted in the DEMOP Release 2, WP6 triggered the initiation of the mitigation action associated with risk PJ38-RISK-02. This mitigation initiated a deviation to the exercise to utilise the Iris Test Facility (ITF) to complement the flight test exercises with ground-based avionics tests that make use of a live SATCOM link.

The tests to be undertaken with the Iris Test Facility were agreed amongst the WP6 partners in a series of small workshops to provide additional complementary evidence of Iris SATCOM performance beyond that collected for system verification. The focus of the tests would be on demonstrating seamless ATN connection throughout transition / switch-over between VDL and SATCOM utilising both ADS-C (NATS) and CPDLC (ENAIRE).

During the detailed planning of the testing which occurred during the later months of the project, INMARSAT recommended that the testing should specifically exercise the routing behaviour during Iris VDL-SATCOM switch-over with NATS' unusual dual connection to both ATN Communication Service Provider (CSP) networks of Collins (ARINC) and SITA. Furthermore, it was realised that to facilitate this specific testing the Airbus Test laboratory would be better suited for representing the aircraft end system rather than the ITF.

Unfortunately, Collins prohibit non-operational end-systems on their production network and establishing the required connectivity to the development (test) networks between the Airbus Test laboratory and NATS end-system was not possible within the remaining timeframe of PJ38. As such exercise EXE-PJ38-6-3 was not conducted.

Co-funded by the European Union

4 Demonstration Results

4.1 Summary of Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-38-W3-DEMOP-SAFE-0001	Safety improvement	CRT-38-W3-DEMOP-001	No safety event is added by the ADS-C Display	No additional safety events are reported nor concerns raised when displaying the ADS-C EPP.	OK
OBJ-38-W3-DEMOP-SAFE-0001	Safety improvement	CRT-38-W3-DEMOP-002	The CD&R tools enhanced by the use of additional data with more reliability is adequate for safe service provision according to the ATCOs.	When the detection envelope of CD&R tools is computed with the use of ADS-C EPP mass and speed schedule data and when aircraft performance models are refined in Trajectory Prediction tools, this improves the Conflict detection and resolution.	OK
OBJ-38-W3-DEMOP-SAFE-0001	Safety improvement	CRT-38-W3-DEMOP-003	There is no increase in the number of tactical conflicts taking into consideration increase in traffic.	It is observed that CD&R prototypes augmented with EPP data have tangible assets. However some infringements happened when running the solution scenario but were explained by the lack of training, practice and	Partially OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
				parametrisation to the targeted sector.	
OBJ-38-W3-DEMOP-SAFE-0001	Safety improvement	CRT-38-W3-DEMOP-004	There is no increase in the number of imminent infringements taking into consideration increase in traffic.	See CRT-38-W3-DEMOP-003	Partially OK
OBJ-38-W3-DEMOP-SAFE-0001	Safety improvement	CRT-38-W3-DEMOP-041	The working of enhanced CD&R tools was appropriate and supported safe service provision		Not Covered
OBJ-38-W3-DEMOP-SAFE-0001	Safety improvement	CRT-38-W3-DEMOP-043	Reduction of potential infringements or resolved earlier thanks to the availability of EPP information.	The controllers can be aware of discrepancies earlier and solve them as soon as the aircraft is transferred to their airspace. For instance, ADS-C can help the controller to be sure an aircraft crossing a military area can exit it before it gets active. The discrepancy indication is considered to be a safety improvement	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-38-W3-DEMOP-HPRF-0002	Human Performance improvement	CRT-38-W3-DEMOP-005	The situation awareness is considered improved by the users (e.g. ATCO).	Globally, it is reported that the use of ADS-C/EPP data would have a positive impact on situational awareness and decision making by allowing to better anticipate the behaviour of the aircraft. Qualitative analysis show that ADS-C/EPP data could enhance the controller’s mental model of the air traffic situation by knowing the intentions of the aircraft	OK
OBJ-38-W3-DEMOP-HPRF-0002	Human Performance improvement	CRT-38-W3-DEMOP-006	The use of ADS-C data leads to a reduced ATCO workload due to reduced radio conversation asking for the aircraft intention.	ATCOs commonly confirmed that having EPP information and aircraft trajectories should decrease the amount of communication with pilots. ATCOs indicated that it would be quicker to check TOD or intended speed by looking in the EPP table rather than asking the pilot	OK
OBJ-38-W3-DEMOP-HPRF-0002	Human Performance improvement	CRT-38-W3-	The user's level of workload is within	ATCOs assessed that having access to the ADS-C/EPP	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
		DEMOP-007	acceptable limits (e.g. ATCO).	data at their discretion has not negatively affected the workload. According to the traffic situation, in particular when complex and/or dense, priority was given to manage the traffic first. Therefore the display of ADS-C/EPP data could be voluntarily interrupted.	
OBJ-38-W3-DEMOP-HPRF-0002	Human Performance improvement	CRT-38-W3-DEMOP-009	The HMI design supports users (e.g. ATCO) in performing their tasks efficiently and effectively.	Majority of ATCOs or FMP considered the developed HMI designs are generally fit for purpose and easy to cope with. ADS-C equipped aircraft are easily identifiable and the corresponding information is understandable. The possibility to display the information on demand is appreciated. Being prototypes, several shortcomings have been identified that would need	Partially OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
				further improvement for future deployments.	
OBJ-38-W3-DEMOP-HPRF-0002	Human Performance improvement	CRT-38-W3-DEMOP-010	The use of ADS-C data provides assistance for user decision in a timely and optimal manner.	According to the situation evaluated, the use of ADS-C data was generally considered positive for user decision to manage the traffic. Nevertheless further enhancements of operational practices, features/tools in using the ADS-C data are expected. The enrichment of ADS-C data may be of interest.	Ok
OBJ-38-W3-DEMOP-HPRF-0002	Human Performance improvement	CRT-38-W3-DEMOP-011	Actual conflicts are detected earlier thanks to enhanced CD&R tool		Not covered
OBJ-38-W3-DEMOP-HPRF-0002	Human Performance improvement	CRT-38-W3-DEMOP-012	The number of spurious detection of conflicts is reduced thanks to enhanced CD&R tool.	The detection envelope can be drastically reduced thanks to data extracted from the ADS-C EPP and speed schedule reports. Therefore, the intersection envelopes of two	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
				flights having trajectories possibly interfering is also largely reduced. ATCOs reported trajectory predictor and conflict detection tools are more precise, showing less spurious conflicts.	
OBJ-38-W3-DEMOP-HPRF-0002	Human Performance improvement	CRT-38-W3-DEMOP-013	2D-CC: 2D Consistency check and Conformance monitoring is considered improved by ATCOs.	ATCOs highlight the usefulness of the visualisation of discrepancy between the ground trajectory and the ADS-C EPP. The filtering of the nuisance 2D discrepancy warnings is successful and is considered to have been reduced to the minimum.	OK
OBJ-38-W3-DEMOP-HPRF-0002	Human Performance improvement	CRT-38-W3-DEMOP-014	The ranked "what-next" recommendations provided by enhanced Conflict-Resolution assistance tool match ATCO's expectations.	The current tested prototypes may not match the mental model of the ATCOs. Unrealistic recommendations of resolutions were offered during exercises (e.g. FL and speed	Partially OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
				values) but the prioritisation of types of resolutions (i.e. directs are preferred before anything else when possible) is in accordance with ATCOs working method	
OBJ-38-W3-DEMOP-OPRF-0003	Operational performance improvement	CRT-38-W3-DEMOP-015	The adherence to on board expected vertical trajectories is enhanced thanks to the use (e.g. display) of TOD information.	A general improvement is observed for the TP adherence to real aircraft vertical trajectories when ADS-C EPP data are taken into account compared to legacy Trajectory Predictor tools. Nevertheless the use of ADS-C EPP data helped to pinpoint discrepancies between filled flight plan and aircraft FMS flight plan happening at waypoints bearing published RAD/ LOAs constraints.	Partially OK
OBJ-38-W3-DEMOP-OPRF-0003	Operational performance improvement	CRT-38-W3-DEMOP-016	CD&R: the number of instructions to modify flights trajectories is reduced thanks	The number of spurious conflicts is reduced with the use of ADS-C EPP and speed schedule,	Partially OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
			to the reduction of spurious detection of conflicts	therefore, there are less trajectory revisions linked to these spurious conflicts	
OBJ-38-W3-DEMOP-OPRF-0003	Operational performance improvement	CRT-38-W3-DEMOP-017	CD&R: The overall distance flown by the whole traffic is reduced thanks to earlier and more accurate conflict detection (and advised resolution).	Only initial (being specific and simulated) quantitative analysis are available but they reveal promising benefits. In the TMA the average track length was reduced by 4%, fuel consumption and CO_2 emission reduced by 6,8 % in the analysed scenarios. In the en-route area while the average track length was reduced by 3%, fuel consumption and CO_2 emission stayed the same while comparing the solution to the reference scenarios.	OK
OBJ-38-W3-DEMOP-OPRF-0003	Operational performance improvement	CRT-38-W3-DEMOP-018	CD&R: The reduced detection uncertainty buffers of the improved CD&R tool MTCD lead to a higher operational performance	New detection envelope calculation using ADS-C EPP and speed schedule data demonstrate the intersection of the detection envelops is reduced.	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
			due to a higher reliability of the planned trajectories.	Consequently the number of conflicts for a same traffic is reduced. The adjustment of the tolerances might be necessary to bring the full benefit	
OBJ-38-W3-DEMOP-OPRF-0003	Operational performance improvement	CRT-38-W3-DEMOP-020	Enhancement of EPP data display for 2D Consistency check.	Prototypes are developed to systematically check the consistency between the ground 2D trajectory and the ADS-C EPP based trajectory. This is considered very positive by the ATCOs. Additional improvement as new filtering rules of the 2D discrepancies can reduce the nuisance warnings to the minimum. The ATCOs provided positive feedback and considered it improves the operational performance compared with PJ31 implementation	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-38-W3-DEMOP-OPRF-0003	Operational performance improvement	CRT-38-W3-DEMOP-021	Evidence is produced of practical cases of operational benefits brought by using ADS-C data elements (both EPP and ETA min/max predictions) to enhance ground air traffic flow management operations	Only initial (being specific to inbound flights to London only) quantitative analyses reveal promising benefits to potentially enhance ground air traffic flow management operations. The consideration is to slow down aircraft in the previous sectors, in particular when the aircraft is in cruise or in descent, in order to reduce the amount of holding delay.	OK
OBJ-38-W3-DEMOP-OPSF-0004	Operational feasibility	CRT-38-W3-DEMOP-023	Display: the display of ADS-C data is considered useful by users (e.g. ATCO).	Operators can manipulate more information thanks to the ADS-C EPP data for which all recognise the usefulness. EPP data are populated with many parameters whose interest can vary from one controller to another.	OK
OBJ-38-W3-DEMOP-OPSF-0004	Operational feasibility	CRT-38-W3-	The CD&R tools enhanced by ADS-C data are	CD&R tools enhanced by ADS-C data are	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
		DEMOP-024	acceptable for the ATCOs.	acceptable for the ATCOs.	
OBJ-38-W3-DEMOP-OPSF-0004	Operational feasibility	CRT-38-W3-DEMOP-025	The system enhancement allows to establish trust in the system	Only assessed under the CD&R perspective, ATCOs agreed that EPP data has to be 100% accurate all the time to be trusted. At this stage, depending on the used prototypes, more stability and reliability are still expected but it is recognised that they have improved since PJ31 and along the PJ38 itself	Partially OK
OBJ-38-W3-DEMOP-OPSF-0004	Operational feasibility	CRT-38-W3-DEMOP-026	The consistency check with ADS-C data in 2 dimensions is acceptable for the ATCOs.	The 2D consistency check and solving with ADS-C data gets positive feedbacks and deemed acceptable	OK
OBJ-38-W3-DEMOP-TECH-0005	Data collection improvement	CRT-38-W3-DEMOP-028	When an ADS-C ETA min/max contract is established, 80% of the ADS-C reports emitted by the A/C provide useful information (not frozen) as agreed through the contract.	On average 90% of the total periodic reports for each flight are providing the TOA Range data. 104 flights (i.e. 14.1%) of all flights provided TOA data in less than 80% of their periodic reports, with almost 40% of these flights having a rate of	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
				TOA data provision more than 70%. Regarding demand contracts, the average is around 91% of the demand reports per flight providing the requested data Only 28 flights (i.e. 15% of all flights) provided TOA data in less than 80% of their demand reports with 42% of these flights having a rate of TOA data provision higher than 70%. Given the high rate of TOA Range provision, a combination of periodic and demand contracts can be used to support the ATC operational needs.	
OBJ-38-W3-DEMOP-TECH-0005	Data collection improvement	CRT-38-W3-DEMOP-029	Provision of regular statistics about the traffic of ADS-C datalink exchanges.	A reliable and robust infrastructure for ADS-C data collection has been demonstrated by means of the ADS-C Common Service	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
				instance run by DFS/ESSP. The ACS prototype has been demonstrated for more than a year in 24/7 operations with live revenue flights.	
OBJ-38-W3-DEMOP-TECH-0006	Access to ADS-C data	CRT-38-W3-DEMOP-030	ADS-C periodic, on event contracts are successfully established and maintained by the ADS-C Common Service, and resulting data shared with the clients in due time.	Assessed through qualitative analysis. No issues were observed during validation exercise using live ADS-C data. No specific measurements were done to evaluate round trip time (RSTP performance) within the infrastructure between the client request and the aircraft. However outcomes observed for CRT-38-W3-DEMOP-0031 by NATS should be applicable.	OK
OBJ-38-W3-DEMOP-TECH-0006	Access to ADS-C data	CRT-38-W3-DEMOP-031	ADS-C on demand contracts are correctly passed through the ADS-C	The analysis indicates that the performance of the ACS-Client architecture should be suitable	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
			Common Service established on client request, and resulting data shared in due time.	for future provision of ADS-C Demand Contract data	
OBJ-38-W3-DEMOP-TECH-0006	Access to ADS-C data	CRT-38-W3-DEMOP-032	Data received via the ADS-C Common Service are reliable (i.e. they faithfully reflect the latest situation provided by the aircraft).	As a general outcomes, as far as observable, the provision and reception of ADS-C data was complete and indeed reflected the real flight progress with all its changes due to directs or cleared climb/descend profiles.	OK
OBJ-38-W3-DEMOP-TECH-0006	Access to ADS-C data	CRT-38-W3-DEMOP-033	The ACS successfully receives, processes and distributes ADS-C data to multiple clients via SWIM in real time.	Connection to the ADS-C Common Server has been established and technically tested.	OK
OBJ-38-W3-DEMOP-TECH-0006	Access to ADS-C data	CRT-38-W3-DEMOP-034	The ACS successfully collects ADS-C data in live flight trials	The ACS successfully collects ADS-C data in live flight trials.	OK
OBJ-38-W3-DEMOP-TECH-0006	Access to ADS-C data	CRT-38-W3-DEMOP-036	The ACS data provision satisfies the operational needs of the clients	By observation during two live demonstration days that ADS-C data from real flights was successfully received in real-	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
				time simultaneously by four ACS clients without an observed interruption or hiccup. It can therefore be indirectly deduced that also the ACS system was successfully receiving data from the "Collector" complete and in real-time.	
OBJ-38-W3-DEMOP-TECH-0006	Access to ADS-C data	CRT-38-W3-DEMOP-037	The ACS saves A/G bandwidth with regards to an architecture of local ADS-C data acquisition	Only qualitatively considered. The saving of bandwidth is evident with the chosen ACS architecture based on the following argument: the ACS maintains only one A/G connection and has been shown in this Demo to successfully share the data with multiple clients. The degree to which the ACS concept/architecture saves A/G bandwidth depends on the number of parallel clients using the data.	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-38-W3-DEMOP-TECH-0007	Availability of multilink via SATCOM	CRT-38-W3-DEMOP-038	End-to-End performance measures match with published SPR.	Honeywell and Airbus flight tests have gathered measurements to support demonstration of ED228A RCP/RSP allocations	OK
OBJ-38-W3-DEMOP-TECH-0007	Availability of multilink via SATCOM	CRT-38-W3-DEMOP-039	Demonstrate ATN/OSI dual link (Iris SATCOM and VDL2) performance with test aircraft avionics	Honeywell has successfully tested failover from SATCOM (preferred) to VDL2 (backup) and recovery back to SATCOM in flight and on the ground. Airbus has successfully performed a flight with a software configuration enabling SATCOM as first subnetwork for ATN exchanges and VDL2 as second subnetwork.	OK
OBJ-38-W3-DEMOP-TECH-0007	Availability of multilink via SATCOM	CRT-38-W3-DEMOP-040	Demonstrate B2 ADS-C v1 interoperability with test aircraft avionics.	Honeywell and Airbus successfully passed the tests during some flights and with the Airbus simulated platforms for different types of contracts and types of report (incl. EPP)	OK

Table 5: Summary of Demonstration Exercises Results

4.2 Detailed analysis of Demonstration Results per Demonstration objective

4.2.1 OBJ-38-W3-DEMOP-SAFE-0001 Results

4.2.1.1 CRT-38-W3-DEMOP-001: No safety event is added by the ADS-C Display

Identifier	OBJ-38-W3-DEMOP-SAFE-0001
Objective	Demonstrate that the use of ADS-C data contributes to improve Safety. It might either be: • a direct improvement of safety level, or • a demonstration that the level of safety is maintained while another aspect of improvement is addressed (Operational efficiency or Human performance).
Success criterion	CRT-38-W3-DEMOP-001 : No safety event is added by the ADS-C Display
Coverage / Comment	Criterion covered by EXE 4-1 (DSNA), EXE 4-2 (DSNA) and EXE 4-9 (PANSA).
Results	No additional safety events are reported nor concerns raised when displaying the ADS-C EPP. A slightly positive impact is even found to be possible because situational awareness and decision making would be improved by the availability of more accurate flight information.
Criterion Status	OK

According to the prototypes developed and their level of integration in the targeted working positions, users reported the need for additional assessments to confirm the same results are applicable with consolidated/agreed design and when fully integrated on operating (production) platforms.

On DSNA EXE-2 exercise, the ADS-C data was displayed on a separated screen and being not a control tool. It was judged acceptable in the context of evaluations but associated with the conditions that it could be used only when the air traffic situation and the workload level allowed it. If ADS-C information is eventually integrated into the radar display of the CWP, the impact on safety should be reassessed.

On PANSA exercise, the ATCOs considered that the data provided by the system was reliable and allowed them to perform their tasks without any issue. Little differences between the tool's data and real performance make the system even more reliable for future operational use.

4.2.1.2 CRT-38-W3-DEMOP-002: The CD&R tools enhanced by the use of additional data with more reliability is adequate for safe service provision according to the ATCOs.

Identifier	OBJ-38-W3-DEMOP-SAFE-0001
Objective	Demonstrate that the use of ADS-C data contributes to improve Safety. It might either be: • a direct improvement of safety level, or • a demonstration that the level of safety is maintained while another aspect of improvement is addressed (Operational efficiency or Human performance).
Success criterion	CRT-38-W3-DEMOP-002 : The CD&R tools enhanced by the use of additional data with more reliability is adequate for safe service provision according to the ATCOs.
Coverage / Comment	Criterion covered by EXE 4-3 (Skyguide), EXE 4-5 (DFS) and EXE 4-8 (HUNGAROCONTROL with BULATSA). This criterion is covered with a combined effort with PJ18.Sol53 / 56 which hosted the injection of EPP data within air traffic management tools such as CD&R. No live experiments with real traffic were conducted with the use of CD&R tools.
Results	The ATCOs are positive about the foreseen awareness situation thanks to: • reliable trajectory computation using aircraft performance (ADS-C EPP data), • the display of the trajectory (flight information (TOC, TOD, type of turns etc…), • more precise detection envelopes When the detection envelope of CD&R tools is computed with the use of ADS-C EPP and speed schedule data and when aircraft performance models are refined in Trajectory Prediction tools, this improves the Conflict detection and resolution.

	This permits to: • Improve the reliability of detected conflicts • Reduce the number of "false" conflicts Overall, it is considered that the implementation of CD&R support tools does not deteriorate human performance impacting safety. The CD&R tools enhanced by the use of additional data with more reliability is adequate for safe service provision according to the ATCOs.
Criterion Status	OK

For conflict detection, HUNGAROCONTROL notes that ATCOs would have ideally relied on MTCD and even on LTCD rather than TCT (the capabilities proposed by their prototype) to start conflict detection earlier in ACC. Solving conflicts in a 12-minute timeframe resulted most of the time to just postponing the conflict. Sometimes the ATCOs saw the conflict far more ahead of time than the CD&R tool.

On the other hand, in APP environment the mid-term conflicts were efficiently solved by the tool however ATCOs would have appreciated more if the tool detects short-term conflicts in a shorter timeframe. With mid-term conflict detection big changes can be foreseen in clearances. If there is a smaller time window, and the ATCO only solves the short-term conflicts it will be a smaller change in clearances (in heading) though it might result in a bit higher ATCO workload.

For conflict resolution, HUNGAROCONTROL clarifies that their ATCOs found that the tool suggestions were often unrealistic and the calculation in the background was hard to understand and would need further development.

Overall for CD&R, the system should be fully accurate to be trusted by controllers and would need to be finely tuned. To build trust, an adequate amount of training and practice are also necessary before implementation.

DFS underlines the combined work done under PJ18-53B with the EX009-OBJ-18-W2-53B-V3-VALP-005 (CRT 1, 2 & 5) criteria. As an outcome, there is no increase in the number of pre-tactical planned conflicts taking into consideration increase in traffic. The improved TP as such reduces false alarms and reveals undetected conflicts. Reduction of false alerts and identification of undetected conflicts could potentially increase situational awareness while reducing the workload for unnecessary checking for false alerts

4.2.1.3 CRT-38-W3-DEMOP-003: There is no increase in the number of tactical conflicts taking into consideration increase in traffic.

Identifier	OBJ-38-W3-DEMOP-SAFE-0001

Objective	Demonstrate that the use of ADS-C data contributes to improve Safety. It might either be: • a direct improvement of safety level, or • a demonstration that the level of safety is maintained while another aspect of improvement is addressed (Operational efficiency or Human performance).
Success criterion	CRT-38-W3-DEMOP-003 : There is no increase in the number of tactical conflicts taking into consideration increase in traffic. Note: Traffic increase cannot be evaluated in VLD by the nature of the project; therefore simulation is considered with recorded data, being artificially increased to generate future (forecasted) traffic.
Coverage / Comment	Criterion covered by EXE 4-8 (HUNGAROCONTROL with BULATSA). This criterion is covered with a combined effort with PJ18.Sol53 which hosted the injection of EPP data within air traffic management tools such as CD&R. No live experiments with real traffic were conducted with the use of CD&R tools.
Results	Conflicts in 12-minute timeframe can be automatically detected by CD&R tool. However it is observed that appropriate CD&R time horizon is crucial otherwise ATCOs either in APP or ACC sectors can detect emerging conflicts sometimes before CD&R which may generate lack of confidence in the tool. Some infringements happened when running the solution scenario (i.e. when an enhanced CD&R tool was used). Several causes are identified as the lack of training and practice with the system that make it difficult for ATCOs to work efficiently. In addition, the CD&R prototype tool has lacks of design and of its parametrisation for Hungarian characteristics, typically restrictions in ACC or speed control in APP. It is recognised that CD&R prototypes augmented with EPP data have tangible assets, nevertheless the current CD&R tool remains prototypes that need design improvement, tuning and operational testing. This need to be considered in the overall criterion assessment.
Criterion Status	Partially OK

4.2.1.4 CRT-38-W3-DEMOP-004: There is no increase in the number of imminent infringements taking into consideration increase in traffic.

Identifier	OBJ-38-W3-DEMOP-SAFE-0001

Objective	Demonstrate that the use of ADS-C data contributes to improve Safety. It might either be: • a direct improvement of safety level, or • a demonstration that the level of safety is maintained while another aspect of improvement is addressed (Operational efficiency or Human performance).
Success criterion	CRT-38-W3-DEMOP-004 : There is no increase in the number of imminent infringements taking into consideration increase in traffic. Note: Traffic increase cannot be evaluated in VLD by the nature of the project; therefore simulation is considered with recorded data, being artificially increased to generate future (forecasted) traffic.
Comment	Criterion covered by EXE 4-8 (HUNGAROCONTROL with BULATSA). This criterion is covered with a combined effort with PJ18.Sol53 which hosted the injection of EPP data within air traffic management tools such as CD&R. No live experiments with real traffic were conducted with the use of CD&R tools.
Results	In low and medium workload the CD&R tool is a good support in the calculation process during conflict resolution. Some infringements happened when running the solution scenario (i.e. when an enhanced CD&R tool was used). See CRT-38-W3-DEMOP-003. It is recognised that CD&R prototypes augmented with EPP data have tangible assets, nevertheless the current CD&R tool remains prototypes that need design improvement, tuning and operational testing.
Criterion Status	Partially Ok

4.2.1.5 CRT-38-W3-DEMOP-041: The working of enhanced CD&R tools was appropriate and supported safe service provision

Identifier	OBJ-38-W3-DEMOP-SAFE-0001
Objective	Demonstrate that the use of ADS-C data contributes to improve Safety. It might either be: • a direct improvement of safety level, or

	• a demonstration that the level of safety is maintained while another aspect of improvement is addressed (Operational efficiency or Human performance).
Success criterion	CRT-38-W3-DEMOP-041 : The working of enhanced CD&R tools was appropriate and supported safe service provision.
Coverage / Comment	Not covered
Results	N/A
Criterion Status	Not covered

4.2.1.6 CRT-38-W3-DEMOP-043: Reduction of potential infringements or resolved earlier thanks to the availability of EPP information.

Identifier	OBJ-38-W3-DEMOP-SAFE-0001
Objective	Demonstrate that the use of ADS-C data contributes to improve Safety. It might either be: • a direct improvement of safety level, or • a demonstration that the level of safety is maintained while another aspect of improvement is addressed (Operational efficiency or Human performance).
Success criterion	CRT-38-W3-DEMOP-043 : Reduction of potential infringements or resolved earlier thanks to the availability of EPP information.
Coverage / Comment	Criterion covered by EXE 4-4 (MUAC) and EXE 4-9 (PANSA). This criterion is covered with a combined effort with PJ18.Sol53 which hosted the injection of EPP data within air traffic tools such as CD&R. No live experiments with real traffic were conducted with the use of CD&R tools.
Results	The controllers can be aware of discrepancies earlier and solve them as soon as the aircraft is transferred to their airspace. For instance, ADS-C can help the controller to be sure an aircraft crossing a military area can exit it before it gets active. The discrepancy indication is considered to be a safety improvement. When using conflict detection tools, the EPP information should help reduce the potential infringements.

Criterion status	Ok

MUAC controllers consider it is good to know that an additional check is done between the ground calculated trajectories and aircraft flight plan data. The 2D conformance/discrepancies checks can be performed before the aircraft is within MUAC airspace. Being aware earlier in the flight, the controllers can solve discrepancies as soon as the aircraft is transferred to MUAC.

The conclusion is that the display of ADS-C data and the 2D discrepancy check performed by the systems contribute to an improvement of Safety.

4.2.1.7 Conclusion

The use of ADS-C data in the operational exercises provided promising results showing improvement in safety can be achieved.

The sole display of ADS-C data provides already some benefits that can be further expanded by the use in air traffic management tools in particular 2D discrepancies feature and CD&R tools. It is expected the number of tactical conflicts and infringements should be reduced. However it is noticed that a certain learning curve is necessary and the current prototypes would need further design improvements and tuning to deliver their full potential for daily use including complex traffic management and future traffic growth.

4.2.2 OBJ-38-W3-DEMOP-HPRF-0002 Results

4.2.2.1 CRT-38-W3-DEMOP-005: The situation awareness is considered improved by the users (e.g. ATCO).

Identifier	OBJ-38-W3-DEMOP-HPRF-0002
Objective	Demonstrate that the use of ADS-C data improves the Human Performance
Success criterion	CRT-38-W3-DEMOP-005 : The situation awareness is considered improved by the users (e.g. ATCO).
Coverage / Comment	Criterion covered by EXE 4-1 (DSNA), 4-2 (DSNA), EXE 4-3 (Skyguide), EXE 4-5 (DFS), EXE 4-8 (HUNGAROCONTROL with BULATSA) and EXE 4-9 (PANSA). This criterion is covered with a combined effort with PJ18.Sol53 / 56 which hosted the injection of EPP data within air traffic management tools such as CD&R. No live experiments with real traffic were conducted with the use of CD&R tools.

Results	Globally, it is reported that the use of ADS-C/EPP data would have a positive impact on situational awareness with better understanding of the current situation and be able to better anticipate the future behavior of the aircraft. Qualitative analyses show that ADS-C/EPP data could enhance the controller's mental model of the air traffic situation by knowing the intentions of the aircraft.
Criterion status	Ok

DSNA reported that the ADS-C data enable the FMP controllers to better understand the current flight situation and to anticipate the aircraft future behaviour, and the controllers to enhance their mental model allowing them to know the aircraft's intentions and monitor the compliance with clearances.

Skyguide point out that the knowledge of turns types (FlyBy / FlyOver) is really useful for conflict detection as types of turns can generate significant deviations.

DFS validates the situation awareness is considered improved by the ATCO. However there are doubts about the systems behaviour under specific conditions, like e.g. heavy weather where many aircraft will divert from their originally planned routes. It would need to be further investigated.

HUNGAROCONTROL, through simulations, get around 50% of positive answers to consider the functions (CD&R) have positive impacts on situational awareness. It is reported that when traffic becomes potentially overwhelming particularly under high traffic workload and high complexity, the use of the assistance tools (CD&R) may be difficult and therefore not improving the situation awareness. APP ATCOs mention also that whilst it is nice to see what changes EPP would bring to the flight leg, TOD, TOC, it does not give more situational awareness, strictly speaking.

PANSA confirms also EPP information has a positive impact on situation awareness. ATCOs indicate that any data reflected real trajectories of aircraft will increase their situational awareness. It is noted that the situation awareness could be further improved by knowing the TP time update (i.e. few seconds ago or in range of minutes).

4.2.2.2 CRT-38-W3-DEMOP-006: The use of ADS-C data leads to a reduced ATCO workload due to reduced radio conversation asking for the aircraft intention.

Identifier	OBJ-38-W3-DEMOP-HPRF-0002
Objective	Demonstrate that the use of ADS-C data improves the Human Performance
Success criterion	CRT-38-W3-DEMOP-006 : The use of ADS-C data leads to a reduced ATCO workload due to reduced radio conversation asking for the aircraft intention.

Coverage / Comment	Criterion covered by EXE 4-9 (PANSA).
Results	ATCOs commonly confirmed that having EPP information and aircraft trajectories should decrease the amount of communication with pilots. ATCOs indicated that it would be quicker to check TOD or intended speed by looking in the EPP table rather than asking the pilot. More generally, knowing the aircraft speed during specific phases (cruise, climb or descent phases) could lead to a decrease in communication with pilots and thus a decrease of workload.
Criterion status	Ok

4.2.2.3 CRT-38-W3-DEMOP-007: The user's level of workload is within acceptable limits (e.g. ATCO).

Identifier	OBJ-38-W3-DEMOP-HPRF-0002
Objective	Demonstrate that the use of ADS-C data improves the Human Performance
Success criterion	CRT-38-W3-DEMOP-007 : The user's level of workload is within acceptable limits (e.g. ATCO).
Coverage / Comment	Criterion covered by EXE 4-1 (DSNA), 4-2 (DSNA), EXE 4-8 (HUNGAROCONTROL with BULATSA).
Results	ATCOs assessed that having access to the ADS-C/EPP data at their discretion has not negatively affected the workload. According to the traffic situation, in particular when complex and/or dense, priority was given to manage the traffic first. Therefore the use of ADS-C/EPP data could be paused. It is also emphasised that having no routine using these data and that HMIs may be new and still not fully finalised, this has generated some biases on the workload assessment. On the other side, some guidances were given to use ADS-C / EPP only when traffic and time permit. Though this resulted in no additional workload, it could be also considered as a limitation to properly assess its level.
Criterion status	Ok

On DSNA, side, both exercices concluded that the workload is not negatively impacted by the use of ADS-C. It should be noted that for EXE-2, the controllers prioritised control tasks over viewing and using ADS-C/EPP data provided on a secondary display used for non-priority tasks. The consequence was that they consulted the 4Me tool to access ADS-C/EPP data when their workload was low.

For HUNGAROCONTROL, a bit slightly lower workload is observed though it is statistically not significant. For one scenario, a huge impact on workload was reported considering the traffic was overwhelming, this largely affected by no routine in handling the HMI. Therefore, lower consideration is given about the outcomes of this scenario.

4.2.2.4 CRT-38-W3-DEMOP-009: The HMI design supports users (e.g. ATCO) in performing their tasks efficiently and effectively.

Identifier	OBJ-38-W3-DEMOP-HPRF-0002
Objective	Demonstrate that the use of ADS-C data improves the Human Performance
Success criterion	CRT-38-W3-DEMOP-009 : The HMI design supports users (e.g. ATCO) in performing their tasks efficiently and effectively.
Coverage / Comment	Criterion covered by EXE 4-1 (DSNA), 4-2 (DSNA), EXE 4-4 (MUAC), EXE 4-8 (HUNGAROCONTROL with BULATSA).
Results	As far as HMI design is concerned, it encompasses both ADS-C EPP display and air traffic management tools containing the EPP information. Majority of ATCOs or FMP considered the developed HMI designs are generally fit for purpose and easy to cope with. ADS-C equipped aircraft are easily identifiable and the corresponding information is understandable. The possibility to display the information on demand is appreciated. Being prototypes, several shortcomings have been identified that would need further improvement for future deployments.
Criterion status	Partially Ok

On DSNA side, the qualitative analysis in EXE-1 confirms that the FMP controllers appreciated the clear design chosen to represent the data related to the ADS-C equipped aircraft: aircraft are easily identifiable and the information understandable.

In DSNA EXE-2, it was decided to display the ADS-C/EPP data on a different screen, i.e. not on the radar screen. The qualitative analysis shows that while a majority of ATCOs would have preferred to have the information directly accessible on the radar screen, others found advantages to presenting the data on a distinct display. This difference depends on several factors such as the appreciation of the usefulness of the data, the way the data were integrated into the control activity, as well as the limitations of the exercise. While displaying the ADS-C/EPP data directly on the radar image might make it easier to use for the main tasks, having it on a side screen would allow freedom of consultation in terms of timing and manner of displaying the data.

Some rooms for improvement are raised like the colour coding, temporisation that lead to revert automatically to another page of the tool, the number of necessary interaction with the HMI (measured with mouse clicks).

MUAC highlights that the list of enhancements performed in the CWP HMI during PJ38 regarding the display of the ADS-C information and the filtering of the nuisance 2D discrepancy warnings are successful. The ATCOs see an improvement compared with PJ31 implementation.

On HUNGAROCONTROL side, the only issue worth to report is the CD&R's heading assistance map element that APP controllers struggled to understand during exercises.

4.2.2.5 CRT-38-W3-DEMOP-010: The use of ADS-C data provides assistance for user decision in a timely and optimal manner.

Identifier	OBJ-38-W3-DEMOP-HPRF-0002
Objective	Demonstrate that the use of ADS-C data improves the Human Performance
Success criterion	CRT-38-W3-DEMOP-010 : The use of ADS-C data provides assistance for user decision in a timely and optimal manner.
Coverage / Comment	Criterion covered by EXE 4-1 (DSNA), 4-2 (DSNA), EXE 4-8 (HUNGAROCONTROL with BULATSA) and EXE 4-9 (PANSA)
Results	According to the situation evaluated, the use of ADS-C data was generally considered positive for user decision to manage the traffic. Nevertheless further enhancements of operational practices, features/tools in using the ADS-C data are expected. The enrichment of ADS-C data may be of interest. It is also pointed out that relying too much on such enhanced tools could reduce the role of ATCOs and their operational practice experience.
Criterion status	Ok

On DSNA side, at FMP controller level, ADS-C/EPP data could support the choice of the best candidate for a speed modification and would be used to define the appropriate sequencing.

At the ATCO level, having more accurate data available with ADS-C would improve decision making at the tactical level. This would be characterized by taking into account, the real aircraft's intentions (provided by FMS) when choosing a clearance/instruction.

On HUNGAROCONTROL side, user decision is principally evaluated through the use of ADS-C EPP within CD&R tools. Such tools are still lacking of stability in the conflict detection. The ATCOs voiced the need to better understand the calculations behind the scene to establish trust. Additionally, ATCOs note that although it is nice to see changes of the flight trajectories thanks to the EPP, the management of separation becomes not necessarily easier.

On PANSA side, during the climb phase of flight, ATCO reported that having information only about crossover altitude and top of climb were not sufficient enough. They identify the need to check estimated flight level at any moment as potentially very useful.

They underline as well their role in conflict detection and resolution could lead them to a feeling of being more passive.

4.2.2.6 CRT-38-W3-DEMOP-011: Actual conflicts are detected earlier thanks to enhanced CD&R tool.

Identifier	OBJ-38-W3-DEMOP-HPRF-0002
Objective	Demonstrate that the use of ADS-C data improves the Human Performance
Success criterion	CRT-38-W3-DEMOP-011 : Actual conflicts are detected earlier thanks to enhanced CD&R tools.
Comment	Not covered
Results	N/A but it is noticed there is a close relation with the CRT-38-W3-DEMOP-043.
Criterion status	Not covered

4.2.2.7 CRT-38-W3-DEMOP-012: The number of spurious detection of conflicts is reduced thanks to enhanced CD&R tool.

Identifier	OBJ-38-W3-DEMOP-HPRF-0002
Objective	Demonstrate that the use of ADS-C data improves the Human Performance
Success criterion	CRT-38-W3-DEMOP-012 : The number of spurious detection of conflicts is reduced thanks to enhanced CD&R tool.
Comment	Criterion covered by EXE 4-3 (SKYGUIDE), EXE 4-5 (DFS)

	This criterion is covered with a combined effort with PJ18.Sol53 / 56 which hosted the use of EPP data within air traffic tools such as CD&R. No live experiments with real traffic were conducted with the use of CD&R tools.
Results	The detection envelope can be drastically reduced thanks to data extracted from the ADS-C EPP and speed schedule reports. Therefore, the intersection envelopes of two flights having trajectories possibly interfering is also largely reduced. ATCOs reported trajectory predictor and conflict detection tools are more precise, showing less spurious conflicts. The decrease of ratio "number of conflict per flight" is a clear trend.
Criterion status	Ok

From DFS and skyguide, with combined effort on PJ18-Sol53B, the assessment of OBJ-18-W2-53B-V3-VALP-004 (CRT 1) reveals that the number of false conflict notification is reduced with the use of enhanced CD&R tools using aircraft data.

4.2.2.8 CRT-38-W3-DEMOP-013: 2D-CC: 2D Consistency check and Conformance monitoring is considered improved by ATCOs.

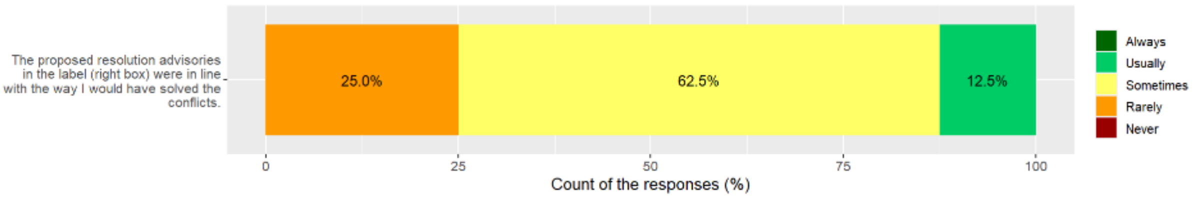
Identifier	OBJ-38-W3-DEMOP-HPRF-0002
Objective	Demonstrate that the use of ADS-C data improves the Human Performance
Success criterion	CRT-38-W3-DEMOP-013 : 2D-CC: 2D Consistency check and Conformance monitoring is considered improved by ATCOs.
Comment	Criterion covered by EXE 4-3 (SKYGUIDE), EXE 4-4 (MUAC) This criterion is covered with a combined effort with PJ18.Sol53 / 56 which hosted the injection of EPP data within air traffic tools such as CD&R. No live experiments with real traffic were conducted with the use of CD&R tools.
Results	ATCOs highlight the usefulness of the visualisation of discrepancy between the ground trajectory and the ADS-C EPP. The filtering of the nuisance 2D discrepancy warnings is successful and is considered to have been reduced to the minimum. The ATCOs see an improvement compared with PJ31 implementation.
Criterion status	Ok

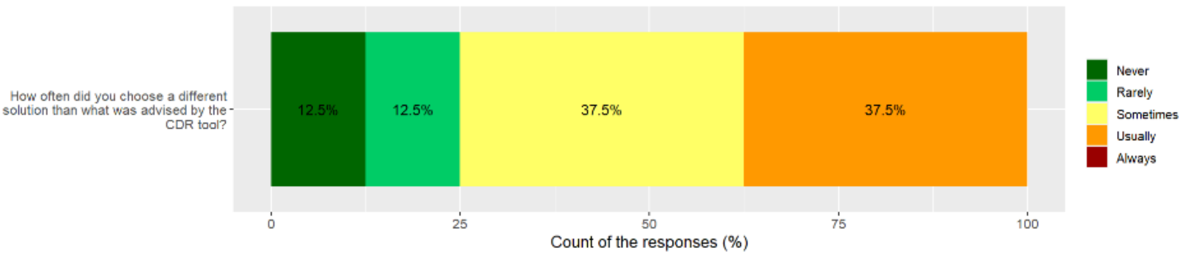
On Skyguide side, for 2D Route Discrepancy detection (consistency check) and solving (incl. alerting), ATCOs highlighted the usefulness of the visualisation of discrepancy between the ground trajectory and the FMS (EPP) trajectory downlinked.

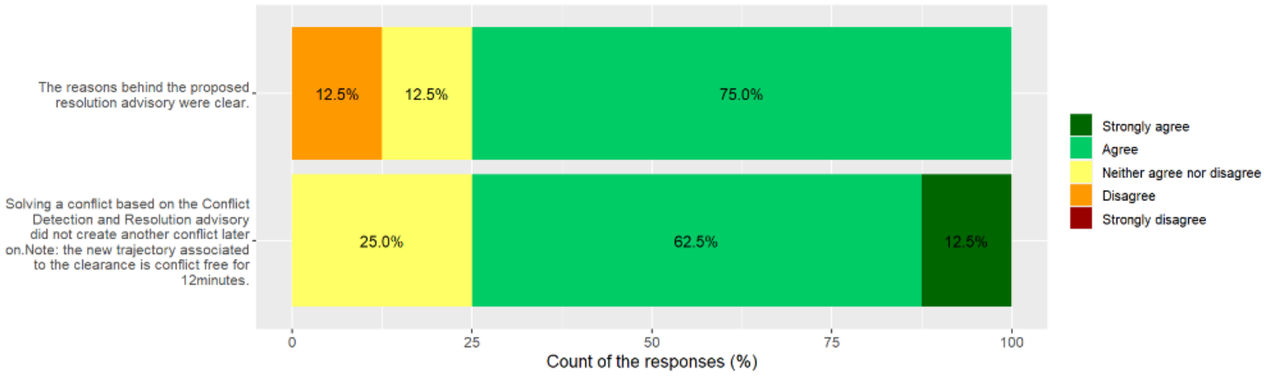
MUAC reports that ATCOs consider that the changes performed during PJ38 in relation with the display and filtering of some of the discrepancy alerts did help to reduce the number of nuisance 2D discrepancy warnings compared with PJ31.

4.2.2.9 CRT-38-W3-DEMOP-014: CR: The ranked "what-next" recommendations provided by enhanced Conflict-Resolution assistance tool match ATCO's expectations.

Identifier	OBJ-38-W3-DEMOP-HPRF-0002
Objective	Demonstrate that the use of ADS-C data improves the Human Performance
Success criterion	CRT-38-W3-DEMOP-014 : The ranked "what-next" recommendations provided by enhanced Conflict-Resolution assistance tool match ATCO's expectations.
Comment	Criterion covered by EXE 4-8 (HUNGAROCONTROL with BULATSA)
Results	The current tested prototypes may not match the mental model of the ATCOs. Unrealistic recommendations of resolutions were offered during exercises (e.g. FL and speed values) but the prioritisation of types of resolutions (i.e. directs are preferred before anything else when possible) is in accordance with ATCOs working method.
Criterion status	Partially Ok







4.2.2.10 Conclusion

Overall it is recognised that the use of ADS-C/EPP data has a positive impact on situation awareness and decision. As a direct effect, it is expected that workload can be reduced in particular thanks to the reduction of voice communication to instruct aircraft or clarify flight crew intentions. If relying on the use of air traffic management tools enhanced by ADS-C EPP data, as CD&R tools, spurious detection should drastically reduced and therefore this would avoid unnecessary use of mental resources. It is also underlined by several ANSPs that these tools still need further design improvement to make them more trusted by the end users while minor changes are only expected for the most advanced ones. Supporting ATCOs with assistance tools and the degree of those assistances is balanced with the human need to stay in the loop to keep considering their own assessment of the situation.

Unfortunately the assessment of criterion CRT-38-W3-DEMOP-0011 has not been performed but looking at the other criteria allocated to OBJ-38-W3-DEMOP-HPRF-0002 and to OBJ-38-W3-DEMOP-SAFE-0001 provide reasonable assumptions to succeed on developing future capacities to detect conflicts earlier.

4.2.3 OBJ-38-W3-DEMOP-OPRF-0003 Results

4.2.3.1 CRT-38-W3-DEMOP-015: The adherence to on board expected vertical trajectories is enhanced thanks to the use (e.g. display) of TOD information.

Identifier	OBJ-38-W3-DEMOP-OPRF-0003
Objective	Demonstrate that the use of ADS-C data improves the Operational performance
Success criterion	CRT-38-W3-DEMOP-015 : The adherence to on board expected vertical trajectories is enhanced thanks to the use (e.g. display) of TOD information.
Comment	Criterion covered by EXE 4-2 (DSNA), EXE 4-3 (SKYGUIDE), EXE 4-5 (DFS)
Results	The consideration of TOD information with EPP data is currently twofold.

	A general improvement is observed for the TP adherence to real aircraft vertical trajectories when ADS-C EPP data are taken into account compared to legacy Trajectory Predictor tools. Therefore the display of vertical information (FLs, TOD) is considered valuable by the ATCOs. Nevertheless the use of ADS-C EPP data helped to pinpoint discrepancies between filled flight plan and aircraft FMS flight plan happening at waypoints bearing published RAD/ LOAs constraints. This was confirmed by absence of corresponding RAD / LOA flight levels in the EPP data.v
Criterion status	Partially Ok

Both DSNA, skyguide underlines an issue with the relevance of TOD information as controllers pointed out cases of vertical discrepancies between the FPL (ground system flight plan), and the FMS FPLN in the ADS-C/EPP where the RAD/ LOAs constraints were not reflected.

Discrepancies were also observed between EPP ToC and current cruise FL instructed by the ATC in case the FMS CRZ FL still reflect the expected cruise FL from the filled flight plan.

DFS mentions that the complexity of the DFS airspace and the traffic flows often prevent the ATCOs from clearing the optimum vertical profile as downlinked.

4.2.3.2 CRT-38-W3-DEMOP-016: CD&R: the number of instructions to modify flights trajectories is reduced thanks to the reduction of spurious detection of conflicts

Identifier	OBJ-38-W3-DEMOP-OPRF-0003
Objective	Demonstrate that the use of ADS-C data improves the Operational performance
Success criterion	CRT-38-W3-DEMOP-016 : CD&R: the number of instructions to modify flights trajectories is reduced thanks to the reduction of spurious detection of conflicts.
Comment	Criterion covered by EXE 4-3 (SKYGUIDE) and 4-8 (HUNGAROCONTROL) This criterion is covered with a combined effort with PJ18.Sol53 / 56 which hosted the injection of EPP data within air traffic tools such as CD&R. No live experiments with real traffic were conducted with the use of CD&R tools.
Results	The number of spurious conflicts is reduced with the use of ADS-C EPP and speed schedule, therefore, there are less trajectory revisions linked to these spurious conflicts.
Criterion status	Partially Ok

Skyguide underlines that this reduction can be significant, i.e. between 10 to 30 % depending on the scenarios. However the number of trajectory revisions is not necessarily drastically reduced when confirmed conflicts must be resolved.

HUNGAROCONTROL considers it is worth mentioning that side effects are reported about testing prototypes embedding new features that may lead to significant changes of CWP putting ATCOs less comfortable with the system. ATCO may be tempted to compensate this by providing more instructions than they are used to doing in their daily job. Training and learning curve should play a role to mitigate this operational effect.

4.2.3.3 CRT-38-W3-DEMOP-017: CD&R: The overall distance flown by the whole traffic is reduced thanks to earlier and more accurate conflict detection (and advised resolution).

Identifier	OBJ-38-W3-DEMOP-OPRF-0003
Objective	Demonstrate that the use of ADS-C data improves the Operational performance
Success criterion	CRT-38-W3-DEMOP-017 : CD&R: The overall distance flown by the whole traffic is reduced thanks to earlier and more accurate conflict detection (and advised resolution).
Comment	Criterion covered by 4-8 (HUNGAROCONTROL)
Results	Only initial (being specific and simulated) quantitative analyses are available but they reveal promising benefits. In the TMA the average track length was reduced by 4%, fuel consumption and CO_2 emission reduced by 6,8 % in the analysed scenarios. In the en-route area while the average track length was reduced by 3%, fuel consumption and CO_2 emission stayed the same while comparing the solution to the reference scenarios. It is observed that shorter route does not generate necessarily less emissions. For instance ATCOs might have instructed some flights to descend to lower flight levels, while still keeping the shorter flight route, but increasing fuel consumption and CO_2 emission in the process.
Criterion status	Ok

4.2.3.4 CRT-38-W3-DEMOP-018: CD&R: The reduced detection uncertainty buffers of the improved CD&R tool MTCD lead to a higher operational performance due to a higher reliability of the planned trajectories.

Identifier	OBJ-38-W3-DEMOP-OPRF-0003
Objective	Demonstrate that the use of ADS-C data improves the Operational performance
Success criterion	CRT-38-W3-DEMOP-018 : CD&R: The reduced detection uncertainty buffers of the improved CD&R tool MTCD lead to a higher operational performance due to a higher reliability of the planned trajectories.
Comment	Criterion covered by EXE 4-3 (SKYGUIDE), EXE 4-5 (DFS) and 4-8 (HUNGAROCONTROL) This criterion is covered with a combined effort with PJ18.Sol53 / 56 which hosted the injection of EPP data within air traffic tools such as CD&R. No live experiments with real traffic were conducted with the use of CD&R tools.
Results	New detection envelope calculation using ADS-C EPP and speed schedule data demonstrate the intersection of the detection envelops is reduced. Consequently the number of conflicts for a same traffic is reduced. The adjustment of the tolerances might be necessary to bring the full benefit.
Criterion status	Ok

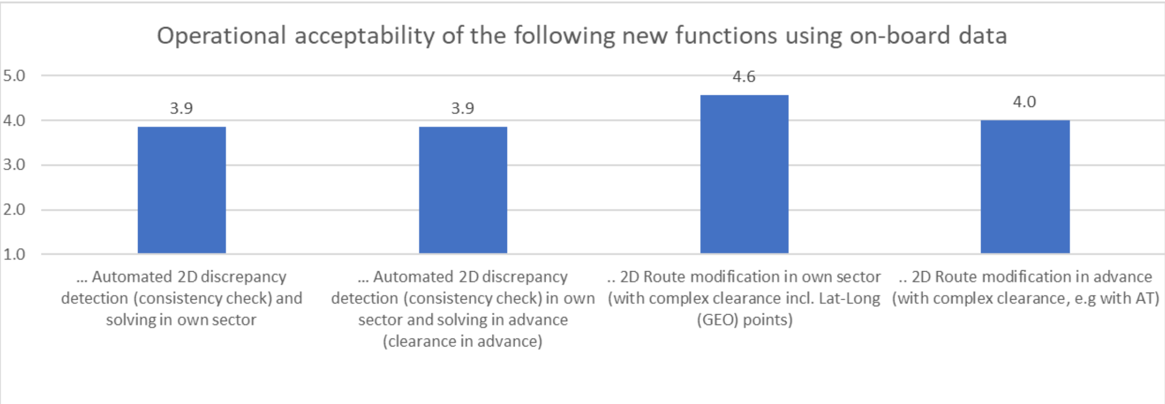
On DFS, it is pointed out that undisturbed climb procedure can be more accurately predicted when using ADS-C EPP information and correct weather information. By enriching TP with EPP data, the number of false conflict notification could be reduced. Potentially, the adjustment of the tolerances might be necessary to bring the full benefit.

4.2.3.5 CRT-38-W3-DEMOP-020: Enhancement of EPP data display for 2D Consistency check.

Identifier	OBJ-38-W3-DEMOP-OPRF-0003
Objective	Demonstrate that the use of ADS-C data improves the Operational performance
Success criterion	CRT-38-W3-DEMOP-020 : Enhancement of EPP data display for 2D Consistency check.
Comment	Criterion covered by EXE 4-3 (SKYGUIDE), EXE 4-4 (MUAC)

	This criterion is covered with a combined effort with PJ18.Sol53 / 56 which hosted the injection of EPP data within air traffic tools such as CD&R. No live experiments with real traffic were conducted with the use of CD&R tools.
Results	Prototypes are developed to systematically check the consistency between the ground 2D trajectory and the ADS-C EPP based trajectory. This is considered very positive by the ATCOs. Additional improvement as new filtering rules of the 2D discrepancies can reduce the nuisance warnings to the minimum. The ATCOs provided positive feedback and considered it improves the operational performance compared with PJ31 implementation. 2D automated detection of discrepancies is considered really useful. Today, Route Adherence Monitoring function exists but it takes more time to see the problem (only when a deviation is in progress), compared to the discrepancy warning (immediately detected). The discrepancy automated detection also allows to quickly see if a clearance has not been properly understood/implemented by the Flight Crew.
Criterion status	Ok

For Skyguide, the impact of better knowledge of aircraft performance and intentions (enabled by better trajectory visualization and EPP reports) is considered by ATCOs *positive* for 2D flight efficiency and *positive* to *very positive* by ATCOs.



The visualization and knowledge of aircraft intent and performance clearly brings strong benefits in terms of situation awareness. Being able to see the aircraft's performance in advance with the EPP makes it much easier to give climb or descent clearances, especially when other aircraft have to be crossed during the evolution

4.2.3.6 CRT-38-W3-DEMOP-021: Evidence is produced of practical cases of operational benefits brought by using ADS-C data elements (both EPP and

ETA min/max predictions) to enhance ground air traffic flow management operations.

Identifier	OBJ-38-W3-DEMOP-OPRF-0003
Objective	Demonstrate that the use of ADS-C data improves the Operational performance
Success criterion	CRT-38-W3-DEMOP-021 : Evidence is produced of practical cases of operational benefits brought by using ADS-C data elements (both EPP and ETA min/max predictions) to enhance ground air traffic flow management operations.
Comment	Criterion covered by EXE 4-7(NATS)
Results	Initial (being specific to inbound flights to London) quantitative analyses reveal promising benefits to potentially enhance ground air traffic flow management operations. The consideration is to slow down aircraft in the previous sectors, in particular when the aircraft is in cruise or in descent, in order to reduce the amount of holding delay. It can be observed that the majority of flights, based on the TOA Range data, can lose between 30s and 90s if the aircraft fly its lowest speed. While this conclusion does not necessarily provide the basis for an enhancement of the queue management concept, it does provide additional confirmation that a 60 seconds delay during cruise phase can be achieved by most DIGITS aircraft types (A320 Family) with some of them able to lose up to 250 seconds.
Criterion status	Ok

4.2.3.7 Conclusion

ADS-C data is proved to be useful to improve the operational performance.

On the vertical aspects, ATCOs underline the great potential of the TOD information to let aircraft fly their optimum profile. However it is pointed out cases of vertical discrepancies between the FPL (ground system flight plan), and the FMS FPLN in the ADS-C/EPP where the RAD/ LOAs constraints were not reflected. Therefore the downlinked TOD is questionned and controllers cannot use the TOD provided by ADS-C to optimise the descent for these aircraft.

On the lateral aspects, gains are foreseen to reduce the overall distance flown thanks to earlier and more accurate conflict detection.

Operational performance gains are also foreseen with the reduction of spurious detection of conflicts by CD&R tool, the enhancement of EPP data display for 2D Consistency check and the enhancement of ground air traffic flow management operations when considering TOA range capabilities.

4.2.4 OBJ-38-W3-DEMOP-OPSF-0004 Results

4.2.4.1 CRT-38-W3-DEMOP-023: Display: the display of ADS-C data is considered useful by users (e.g. ATCO).

Identifier	OBJ-38-W3-DEMOP-OPSF-0004
Objective	Demonstrate that the use of ADS-C data is Operationally feasible beyond what has been demonstrated in PJ31 (i.e. highlight 2D consistency check discrepancies)
Success criterion	CRT-38-W3-DEMOP-023 : Display: the display of ADS-C data is considered useful by users (e.g. ATCO).
Comment	Criterion covered by EXE 4-1 (DSNA), EXE 4-2 (DSNA), EXE 4-3 (SKYGUIDE), EXE 4-4 (MUAC), EXE 4-5 (DFS), EXE 4-8 (HUNGAROCONTROL) and EXE 4-9 (PANSA)
Results	Operators can manipulate more information thanks to the ADS-C EPP data for which all recognise the usefulness. EPP data are populated with many parameters whose interest can vary from one controller to another.
Criterion status	Ok

On DSNA side, not being part of PJ31, there is a positive perceived relevance to use ADS-C EPP data. Among them, FMP preferred the “expected Mach on cruise” and the “Expected descent speed”. ATCOs were interested by WIND, along with TOD and the Altitude associated to the waypoints. Variability on preferred parameters exist. This is explained by the fact that operational situations differ from one ACC to another, working methods may have differences and types of traffic can vary. More studies are expected.

On SKYGUIDE side, the participating ATCOs were very positive about the foreseen awareness situation thanks to the display of the EPP trajectory (flight information (TOC, TOD, type of turns etc.…).

On MUAC side, ATCOs gave positive feedback on the usability of the EPP TOD information being downlinked by the aircraft. It has been proven to be reliable as long as both the air and ground share the same view related to constraints e.g. applicable LOAs included in the FMS, or when there is no restriction on the ground.

In the cases above, if traffic allows, the ATCOs will try to adhere to the aircraft preferred TOD. This is usually translated in a delay of the start of the descent.

As an example, in some specific flows studied it has been observed that during the day, if the traffic situation permits, the TOD can be delayed 20-30 NM on average and during night or during low traffic periods, it can be delayed to 30-40 NM on average.

On HUNGAROCONTROl side, ATCOs expressed that the most useful EPP information were the ToD, ToC points, speed and the more precise vertical profile calculation.

On PANSA side, ATCOs strongly agreed that ADS-C data allowed them to perform all of their tasks successfully. They confirmed that the data was easy to access when performing their tasks.

4.2.4.2 CRT-38-W3-DEMOP-024: The CD&R tools enhanced by ADS-C data are acceptable for the ATCOs.

Identifier	OBJ-38-W3-DEMOP-OPSF-0004
Objective	Demonstrate that the use of ADS-C data is Operationally feasible beyond what has been demonstrated in PJ31 (i.e. highlight 2D consistency check discrepancies)
Success criterion	CRT-38-W3-DEMOP-024 : The CD&R tools enhanced by ADS-C data are acceptable for the ATCOs.
Comment	Criterion covered by EXE 4-5 (DFS), EXE 4-8 (HUNGAROCONTROL)
Results	No details collected from validation exercises. However it was considered that CD&R tools enhanced by ADS-C data are acceptable for the ATCOs.
Criterion status	Ok

4.2.4.3 CRT-38-W3-DEMOP-025: The system enhancement allows to establish trust in the system

Identifier	OBJ-38-W3-DEMOP-OPSF-0004
Objective	Demonstrate that the use of ADS-C data is Operationally feasible beyond what has been demonstrated in PJ31 (i.e. highlight 2D consistency check discrepancies)
Success criterion	CRT-38-W3-DEMOP-025 : The system enhancement allows to establish trust in the system

Comment	Criterion covered by EXE 4-5 (DFS), EXE 4-8 (HUNGAROCONTROL) and EXE 4-9 (PANSA) This criterion is covered with a combined effort with PJ18.Sol53 / 56 which hosted the injection of EPP data within air traffic tools such as CD&R. No live experiments with real traffic were conducted with the use of CD&R tools.
Results	Only assessed under the CD&R perspective, ATCOs agreed that EPP data has to be 100% accurate all the time to be trusted. At this stage, depending on the used prototypes, more stability and reliability are still expected but it is recognised that they have improved since PJ31 and along the PJ38 itself.
Criterion status	Partially ok

4.2.4.4 CRT-38-W3-DEMOP-026: The consistency check with ADS-C data in 2 dimensions is acceptable for the ATCOs

Identifier	OBJ-38-W3-DEMOP-OPSF-0004
Objective	Demonstrate that the use of ADS-C data is Operationally feasible beyond what has been demonstrated in PJ31 (i.e. highlight 2D consistency check discrepancies)
Success criterion	CRT-38-W3-DEMOP-026 : The consistency check with ADS-C data in 2 dimensions is acceptable for the ATCOs.
Comment	Criterion covered by EXE 4-3 (SKYGUIDE) and EXE 4-5 (DFS) This criterion is covered with a combined effort with PJ18.Sol53 / 56 which hosted the injection of EPP data within air traffic tools such as CD&R. No live experiments with real traffic were conducted with the use of CD&R tools.
Results	The 2D consistency check and solving with ADS-C data gets positive feedbacks and deemed acceptable.
Criterion status	Ok

On Skyguide side, the ground trajectory and the ADS-C EPP trajectory can be displayed and the ground system is systematically checking on reception of an ADS-C EPP the consistency between the ground 2D trajectory and the ADS-C EPP trajectory.

4.2.4.5 Conclusion

ATCOs considered that the trajectories and the data displayed would allow them to perform their tasks with some benefits. The 2D consistency check and solving with ADS-C data gets positive feedbacks and deemed acceptable. ATCOs agreed that EPP data has to be really accurate to be trusted.

4.2.5 OBJ-38-W3-DEMOP-TECH-0005 Results

4.2.5.1 CRT-38-W3-DEMOP-028: When an ADS-C ETA min/max contract is established, 80% of the ADS-C reports emitted by the A/C provide useful information (not frozen) as agreed through the contract.

Identifier	OBJ-38-W3-DEMOP-TECH-0005
Objective	Demonstrate a reliable and robust collection infrastructure to set up ADS-C contract and process data
Success criterion	CRT-38-W3-DEMOP-028 : When an ADS-C ETA min/max contract is established, 80% of the ADS-C reports emitted by the A/C provide useful information (not frozen) as agreed through the contract.
Comment	Criterion covered by EXE 4-7 (NATS)
Results	On average 90% of the total periodic reports for each flight are providing the TOA Range data. Regarding demand contracts, the average is around 91% of the demand reports per flight providing the requested TOA data. Inherent logics to ADS-C lead to no longer provide the ETA min/max information, e.g. when the targeted waypoint is no longer included in the flight plan, the ETA min/max information is no longer provided. However deeper analysis may be further envisaged to understand flight conditions for which ETA min / max might not be calculated, therefore downlinked to the ground.
Criterion status	Ok

On average 90% of the total periodic reports for each flight are providing the TOA Range data. 104 flights (i.e. 14.1%) of all flights provided TOA data in less than 80% of their periodic reports, with almost 40% of these flights having a rate of TOA data provision more than 70%.

Regarding demand contracts, the average is around 91% of the demand reports per flight providing the requested data Only 28 flights (i.e. 15% of all flights) provided TOA data in less than 80% of their demand reports with 42% of these flights having a rate of TOA data provision higher than 70%.

Given the high rate of TOA Range provision, a combination of periodic and demand contracts can be used to support the ATC operational needs.

4.2.5.2 CRT-38-W3-DEMOP-029: Provision of regular statistics about the traffic of ADS-C datalink exchanges.

Identifier	OBJ-38-W3-DEMOP-TECH-0005
Objective	Demonstrate a reliable and robust collection infrastructure to set up ADS-C contract and process data
Success criterion	CRT-38-W3-DEMOP-029 : Provision of regular statistics about the traffic of ADS-C datalink exchanges.
Comment	Criterion covered by EXE 4-5 (DFS) and EXE 4-6 (ENAV)
Results	A reliable and robust infrastructure for ADS-C data collection has been demonstrated by means of the ADS-C Common Service instance run by DFS/ESSP. The ACS prototype has been demonstrated for more than a year in 24/7 operations with live revenue flights. Reliability could be demonstrated • by dedicated system verification tests before deployment of the ACS, • by analysis of the data recordings/collections from the ACS, and • by practical use of the ACS in operational demonstration exercises DFS/ESSP run their system for ADS-C data collection system over three weeks of shadow mode acquisition.
Criterion Status	Ok

4.2.5.3 Conclusion

Robust collection infrastructure has been continued in the PJ38 with the introduction of the ADS-C Common Service instances to further optimise the infrastructure. The infrastructure has been proven with the application of the log on initiated by the ground (auto logon) which has considerably increased ADS-C traffic processed by the infrastructure.

Request for TOA range (ETA min / max) group either with on demand or through periodic contracts can be achieved successfully.

It is to be noted that around 100 aircraft are part of the experimentation.

4.2.6 OBJ-38-W3-DEMOP-TECH-0006 Results

4.2.6.1 CRT-38-W3-DEMOP-030: ADS-C periodic, on event contracts are successfully established and maintained by the ADS-C Common Service, and resulting data shared with the clients in due time.

Identifier	OBJ-38-W3-DEMOP-TECH-0006
Objective	Demonstrate that the use of an ADS-C Common Service improves the access to data
Success criterion	CRT-38-W3-DEMOP-030 : ADS-C periodic, on event contracts are successfully established and maintained by the ADS-C Common Service, and resulting data shared with the clients in due time.
Comment	Criterion covered by EXE 4-1 (DSNA), EXE 4-2 (DSNA), EXE 4-5 (DFS), EXE 4-9 (PANSA)
Results	Assessed through qualitative analyses. No issues were observed during validation exercise using live ADS-C data. No specific measurements were done to evaluate round trip time (RSTP performance) within the infrastructure between the client request and the aircraft. However outcomes observed for CRT-38-W3-DEMOP-0031 by NATS should be applicable.
Criterion status	Ok

4.2.6.2 CRT-38-W3-DEMOP-031: ADS-C on demand contracts are correctly passed through the ADS-C Common Service established on client request, and resulting data shared in due time.

Identifier	OBJ-38-W3-DEMOP-TECH-0006
Objective	Demonstrate that the use of an ADS-C Common Service improves the access to data
Success criterion	CRT-38-W3-DEMOP-031 : ADS-C on demand contracts are correctly passed through the ADS-C Common Service established on client request, and resulting data shared in due time.
Comment	Criterion covered by EXE 4-5 (DFS), EXE 4-7 (NATS)
Results	Qualitative assessments were done on this criterion where no issues were observed during validation exercise using live ADS-C data. This is complemented by the work done by NATS having quantitatively assessed round trip time. Among important time observation, although measured at the Client, the deltas between the Demand Request sent from the ACS and the Demand Report received by the ACS can be indicative of the airborne ADS-C performance. The 7080 eligible messages resulted in a long-tail distribution with large outliers, however the average delta was measured at 4.658 seconds, with 95% of deltas measuring under 12 seconds, as expected by the ATS B2 performance specification (see G.3.2.3). The assessment is only considered to be indicative as the times are measured by the client prototype and did not use a high availability ATM network for the ground-ground component. However the analysis indicates that the performance of the ACS-Client architecture should be suitable for future provision of ADS-C Demand Contract data. Further investigation of the Client-ACS architecture could be undertaken to determine if more targeted Demand Contract requests (as opposed to the large data collection method used within this analysis) results in a reduction of large deltas along with removing the EPP data group from the Demand requests could also be considered to see if this has a beneficial impact on the maximum measured deltas.
Criterion status	Ok

4.2.6.3 CRT-38-W3-DEMOP-032: Data received via the ADS-C Common Service are reliable (i.e. they faithfully reflect the latest situation provided by the aircraft).

Identifier	OBJ-38-W3-DEMOP-TECH-0006

Objective	Demonstrate that the use of an ADS-C Common Service improves the access to data
Success criterion	CRT-38-W3-DEMOP-032 : Data received via the ADS-C Common Service are reliable (i.e. they faithfully reflect the latest situation provided by the aircraft).
Comment	Criterion covered by EXE 4-1 (DSNA), EXE 4-2 (DSNA), EXE 4-3 (SKYGUIDE), EXE 4-5 (DFS), EXE 4-7 (NATS)
Results	As a general outcomes, as far as observable, the provision and reception of ADS-C data was complete and indeed reflected the real flight progress with all its changes due to directs or cleared climb/descend profiles.
Criterion status	Ok

On Skyguide side, further analyses were performed in particular with regards to the stability of :

- Comparison of EPP waypoint names to FDP route points
- EPP stability and precision
- TOC and TOD variability
- FMS Modes

showing generally a good stability of the EPP information except when some selected modes are used in certain conditions.

The comparison/consistency of EPP prediction and real flown trajectory was also assessed looking at time, level error on named waypoints. Overall, it is observed that the stability is very high.

It needs to be considered that those outcomes are specific to the skyguide airspace used for these validation activities.

On DFS side, it was observed that when crossing the KUAC airspace, EPP data reflected the given re-routings (Directs) or Flight Level changes, or Times At along with waypoint sequencing being no longer reported in the EPP data as expected.

More analyses and content are provided in Appendix M (refering to the D3.1 – ADS-C data analysis deliverable).

4.2.6.4 CRT-38-W3-DEMOP-033: The ACS successfully receives, processes and distributes ADS-C data to multiple clients via SWIM in real time.

Identifier	OBJ-38-W3-DEMOP-TECH-0006

Objective	Demonstrate that the use of an ADS-C Common Service improves the access to data
Success criterion	CRT-38-W3-DEMOP-033 : The ACS successfully receives, processes and distributes ADS-C data to multiple clients via SWIM in real time.
Comment	Criterion covered by EXE 4-3 (SKYGUIDE), EXE 4-5 (DFS), EXE 4-6 (ENAV) and EXE 4-7 (NATS)
Results	Connection to the ADS-C Common Server has been established and technically tested for months. Information can be found in D3.1 in section 2.3.
Criterion status	Ok

4.2.6.5 CRT-38-W3-DEMOP-034: The ACS successfully collects ADS-C data in live flight trials

Identifier	OBJ-38-W3-DEMOP-TECH-0006
Objective	Demonstrate that the use of an ADS-C Common Service improves the access to data
Success criterion	CRT-38-W3-DEMOP-034 : The ACS successfully collects ADS-C data in live flight trials
Comment	Criterion covered by EXE 4-5 (DFS)
Results	The ACS successfully collects ADS-C data in live flight trials. Information can be found in D3.1 in section 2.3.
Criterion status	Ok

4.2.6.6 CRT-38-W3-DEMOP-036: The ACS data provision satisfies the operational needs of the clients

Identifier	OBJ-38-W3-DEMOP-TECH-0006

Objective	Demonstrate that the use of an ADS-C Common Service improves the access to data
Success criterion	CRT-38-W3-DEMOP-036 : The ACS data provision satisfies the operational needs of the clients
Comment	Criterion covered by EXE 4-5 (DFS), EXE 4-6 (ENAV)
Results	By observation during two live demonstration days that ADS-C data from real flights was successfully received in real-time simultaneously by four ACS clients without an observed interruption or hick-up. It can therefore be indirectly deduced that also the ACS system was successfully receiving data from the "Collector" complete and in real-time.
Criterion status	Ok

4.2.6.7 CRT-38-W3-DEMOP-037: The ACS saves A/G bandwidth with regards to an architecture of local ADS-C data acquisition

Identifier	OBJ-38-W3-DEMOP-TECH-0006
Objective	Demonstrate that the use of an ADS-C Common Service improves the access to data
Success criterion	CRT-38-W3-DEMOP-037 : The ACS saves A/G bandwidth with regards to an architecture of local ADS-C data acquisition
Comment	Criterion covered by EXE 4-5 (DFS)
Results	Only qualitatively considered. The saving of bandwidth is evident with the chosen ACS architecture based on the following argument: the ACS maintains only one A/G connection and has been shown in this Demo to successfully share the data with multiple clients. The degree to which the ACS concept/architecture saves A/G bandwidth depends on the number of parallel clients using the data. The average number of parallel clients to be expected in deployment cannot be fully predicted (not in the scope of the demo) but it is certain that in core European airspace this will be several ANSPs, Arrival Manager, NM and other users at once. So the ACS Distribution architecture will indeed save bandwidth with regards to local ADS-C connections, it is fully scalable and capable of distributing ADS-C data to a theoretically unlimited number of ground clients, without duplicating A/G connections.
Criterion status	Ok

4.2.6.8 Conclusion

In the frame of PJ38, ADS-C periodic, on event and demand contracts are successfully established and maintained by the ADS-C Common Service, and resulting data shared with the clients in due time.

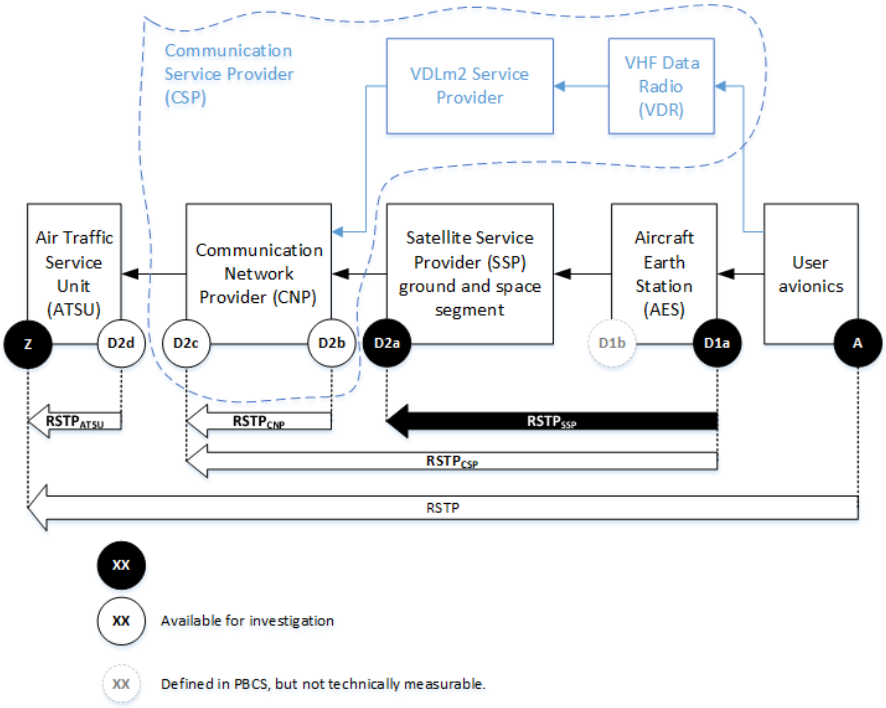
It is expected that the ACS will save A/G bandwidth compared to an architecture of local ADS-C data acquisition. This was qualitatively estimated in PJ38 through WP5 activities.

4.2.7 OBJ-38-W3-DEMOP-TECH-0007 Results

4.2.7.1 CRT-38-W3-DEMOP-038: End-to-End performance measures match with published SPR

Identifier	OBJ-38-W3-DEMOP-TECH-0007
Objective	Demonstrate that a SATCOM/VDL2 dual link is suitable for managing an ADS-C connection
Success criterion	CRT-38-W3-DEMOP-038 : End-to-End performance measures match with published SPR.
Comment	Criterion covered by EXE 6-1 (HONEYWELL), EXE 6-2 (AIRBUS)
Criterion status	Ok

The main objective of the Honeywell exercise was to demonstrate through several flights that the Inmarsat SB-S ATN/OSI service can meet the apportioned 1-way RSTP (Required Surveillance Technical Performance) latency targets, i.e. $RSTP_{SSP}$ from the figure below. Because apportionment between CSP (Communications Service Provider) and SSP (Satellite System Provider) has not been formally agreed, only the CSP limit is shown.



The following table presents the comparison between measured 95% and 99.9% AAP (i.e. the bespoke SB-S transport protocol used for tunnelling of ATN/OSI CLNP packets across the Inmarsat IPv4 BGAN network) downlink latencies and the applicable $RSTP_{CSP}$ limits.

$RSTP_{CSP}$ limits	95% <5sec	99.9% <12sec	Notes
Including all messages	PASS 95% < 2.3 sec	FAIL 99.2% at 12 sec	Out of the 4,886 logged messages 38 (i.e. 0.8%) exceeded the 12 sec latency limit. Nevertheless, all these messages were associated to one of the following non-nominal conditions: • Satellite switch-over above Greenland • Taxiing in Keflavik (Iceland) • Departure from Keflavik (Iceland) Because these are all expectable events at very low satellite elevations it is considered legitimate to exclude them from the statistics.
Excluding messages delayed due to known non-nominal conditions	PASS 95% < 2 sec	PASS 99.9% < 9.4 sec	

All the excessively delayed AAP downlink messages can be attributed to well understood non-nominal conditions and therefore SATCOM performance is considered as compliant with the RSP-160 latency requirements.

To complement the $RSTP_{SSP}$ analysis, the observed ground-ground latency from the Inmarsat's ground gateway to the ANSP end system was consistently below 0.2 seconds and thereby practically negligible compared to the end-to-end latency.

Then, the following tables present a summary of the results per centre type and services using SATCOM media achieved by Airbus:

		ED228A - RCP 130 / A1	
		RCTP Required Communication Technical Performance	
ATC center type	Count of CPDLC	95% (<20sec)	99,9% (<32sec)
ATS ATN B1	299	**99,33%**	**100%**
ATS B2	467	**100%**	**100%**

		ED228A - RSP 160 / A1	
		RSMP Required Surveillance Monitored Performance	
ATC center type	Count of ADS-C with EPP	95% (<90 sec)	99,9% (<160 sec)
ATS B2	674	**98,96%**	**99,11%**

Note: The ADS-C reports that did not meet the performance requirement were observed due to the T5 timer issue.

4.2.7.2 CRT-38-W3-DEMOP-039: Demonstrate ATN/OSI dual link (Iris SATCOM and VDL2) performance with test aircraft avionics

Identifier	OBJ-38-W3-DEMOP-TECH-0007
Objective	Demonstrate that a SATCOM/VDL2 dual link is suitable for managing an ADS-C connection
Success criterion	CRT-38-W3-DEMOP-039 : Demonstrate ATN/OSI dual link (Iris SATCOM and VDL2) performance with test aircraft avionics
Comment	Criterion covered by EXE 6-1 (HONEYWELL), EXE 6-2 (AIRBUS)
Criterion status	Ok

Honeywell had to terminate the campaign earlier due to aircraft problems unrelated to this project (see 3.4.2.2). Therefore, only one informal but successful ATN/OSI dual link testing was thus performed while the aircraft was on the ground in Oslo. This test is backed up by another successful flight test campaign conducted in Seattle/US on 4th of August 2021.

During the development and the certification flight tests by Airbus, the behaviour of the FANS C function "with ATN over SATCOM" and of its contributing systems has been positively assessed by the flight crew.

4.2.7.3 CRT-38-W3-DEMOP-040: Demonstrate B2 ADS-C v1 interoperability with test aircraft avionics.

Identifier	OBJ-38-W3-DEMOP-TECH-0007
Objective	Demonstrate that a SATCOM/VDL2 dual link is suitable for managing an ADS-C connection
Success criterion	CRT-38-W3-DEMOP-040 : Demonstrate B2 ADS-C v1 interoperability with test aircraft avionics.
Comment	Criterion covered by EXE 6-1 (HONEYWELL), EXE 6-2 (AIRBUS)
Criterion status	Ok

The B2 ADS-C application implemented in the Honeywell's NGFMS avionics and used during the flight campaign is an initial prototype with known limitations. This prototype was rather an enabler for SATCOM performance testing than a subject of the test, nevertheless, extensive functional tests were performed during and before the flight campaign to demonstrate the interoperability. This included:

- Successful establishment and termination of all types of contracts (demand, event, periodic).
- Successful establishment of different types of reports (EPP, ground speed, air speed etc.).
- Successful testing of different types of events for the event contracts.
- Successful testing with different ATC test systems (MUAC, Eurocontrol, DFS, SITA)

4.2.7.4 Conclusion

The three criteria defined for OBJ-38-W3-DEMOP-TECH-0007 are all OK . Therefore, this objective is considered as satisfied.

It is to be mentionned that Honeywell and Airbus detected needs for improvement related to the SATCOM link or the ATN/OSI dual link during the flight tests (e.g. loss of ATN link over SATCOM with no recovery). All the issues have been investigated and understood. Some fixes are already available and other ones will be available in the future prototype and product developments. More information is provided in the related Appendixes J (EXE 6-1) and K (EXE 6-2).

4.3 Confidence in Results of Demonstration Exercises

4.3.1 Limitations and impact on the level of Significance

4.3.1.1 Quality of Demonstration Exercises Results

For **DSNA**, the quality of the results for EXE-PJ38-4-1 exercise is considered acceptable and allowed for an acceptable assessment of the HP-related objectives given the maturity of the solution and the limitations of the activity. Among limitations, very small number of flights were logged on, as a consequence, the FMP controllers did not feel (or only slightly) the need to get the ADS-C data to support their activities for the traffic flow management and arrival sequencing. The interpretation of results for the descriptive analysis was hindered by the limited number of questionnaires collected. Finally, part of the FMP controllers' team was trained for ADS-C/EPP use during the month of May and part during the month of November just before the start of the exercise. This may have led to a lack of recall of the use of ADS-C/EPP data for the first group.

For **DSNA**, the quality of the results for EXE-PJ38-4-2 exercise is considered acceptable given the maturity of the solution and the limitations of the activity. The principal limitation was that a very small number of aircraft was equipped and logged on, especially at the beginning of the exercise. This limitation had an impact on the use of the ADS-C/EPP data.

For **Skyguide**, for EXE-PJ38-4-3, the confidence in the validation results is satisfying. Qualitative data and quantitative data are estimated to be sufficient to draw realistic conclusions even if the number of ADSCENSIO ADS-C connected (logon) flights and downlinking ADS-C EPP reports were limited due to the COVID period and the limited number of participating aircraft. This impacted more the statistic side of the Demonstration rather than the operational use of ADS-C EPP data in the ground system. Participating ATCOs to PJ38 local demonstration showed great interest in the ADS-C EPP content and the possibilities of its operational use (new Trajectory Prediction, trajectory visualisation (type of turns, TOC, TOD, aircraft performance…), improved CD&R tools (enhanced detection envelopes), Route Conformance monitoring…). In order to complete the data from the ADSCENSIO flights, as ATCOs were not benefiting from EPP reports during the live trials (no possible impact on their decisions), results from solutions PJ18-W2.53B and PJ18-W2.56 have been also taken into account. Participating ATCOs considered that the validation platform level of performance was really good during the measured runs (from solutions PJ18-W2.53B and PJ18-W2.56 validations) which complement EXE-PJ38-4-3 results.

For **MUAC**, for EXE-PJ38-4-4, the ATS B2 flights were processed by the operational system, but we can differentiate two different setups. From mid-December 2020 until end May 2022 only a sub-set of the controllers had the specific "ADS-C functionality" available on the CWP HMI, while as from the 31st of May 2022, this functionality was made available to all MUAC controllers. It is important to mention, that before making the new functionality available to all MUAC controllers there were changes implemented in both FDPS and CWP HMI systems and that all controller followed a training on ATS B2 functionality. The changes made were in accordance with the results and recommendations obtained during PJ31 DIGITS demonstration.

For **DFS**, the obtained results during real live traffic demonstrations the observations and activities (actions on HMI) lead to a positive reception of quality of the ACS service due to:

- Timely reception of ADS-C data on test site to build up a shadow track simulation and AFTN and OLDI messages to “arm” the system under test
- Regular updates of EPP related indications on the radar track information (label and symbol) representing the real traffic changes (monitored by “live” ADS-B)
- Correct indication of changes, vertical data (TOD, TOC), warning of 2-D deviations from filed flight plan, etc.
- Good “raw EPP” data monitored in the related on-demand display on the CWP/HMI.

For **ENAV**, the results are only indicative because of a very limited number of EPP flights which were not sufficient for the objectives assessment.

For **NATS**, the results are indicative only due to limitations with the setup of the assessment.

For **HUNGAROCONTROL**, the exercise can report on high quality results with regards to the HMI design of the ADS-C enhanced CD&R tools, obtained via questionnaires and debriefing sessions from 8 operational air traffic controllers. The exercise is less certain in answering the questions of how ADS-C data affects traffic management, as the passive shadow validation could not be conducted.

For **PANSA**, The quality of the validation results is considered as medium. Experienced controllers with appropriate ratings participated in the validation exercise but it wasn’t possible to actively control the traffic and observe changes (ATCOs during validation were not aware of any clearance changes given by ATCOs from NATS or DFS).

For **HONEYWELL**, the SATCOM performance results were obtained using production SATCOM avionics (Honeywell’s Aspire 400 AES) and operational Inmarsat’s BGAN network. As a limitation, flight test aircraft spent only slightly over 16 flight hours between Iceland and Scandinavia with no flights in core Europe leads to be not able to draw unambiguous conclusion on SATCOM compliance with the applicable RSTP 99.9% latency targets. Nevertheless, the positive outcomes are consistent with the similarly positive outcomes of the additional flight and lab test campaigns performed by Honeywell under ESA Iris and SESAR PJ.14-W2-107 projects.

For **AIRBUS**, the demonstration here described is the one that has been used for Airbus certification purposes demonstrating compliance to JAR25 1301 (a)(b)(d) and 1309(a) as amended by CRI SE-65.

4.3.1.2 Significance of Demonstration Exercises Results

For **DSNA**, the significance of the results for EXE-PJ38-4-1 and EXE-PJ38-4-2 exercises is considered low because due to live trials as type of validation, it was not possible to have hands on the operational situations (number of flights and complexity of traffic, workload level, etc.) and make them repeatable for all testers. Therefore, the appreciation of the usefulness of the EPP data could vary a lot from one participant to another according to the operational case encountered. Moreover, it was decided to not assess the use of the ADS-C/EPP data during a high traffic period and non-nominal operational situations. In addition, a lack of FMP controllers debriefing ("face to face") did not allow further investigation of the questionnaires' answer.

For EXE-PJ38-4-2, a non-uniform number of questionnaires per ACC was collected which generated difficult interpretation of the results. In addition, the CWP layouts were adapted to accommodate the 4Me tool in two configuration (either one per ATCO or one for two ATCOs) according to the ACCs. This has affected the results.

For **Skyguide**, for EXE-PJ38-4-3, the amount of ADS-C EPP received from ADSCENSIO flights entering the skyguide controlled airspace is sufficient to obtain statistically significant results. Trajectory Prediction tool, Trajectory Management tools and Conflict Detection & Resolution tools have been largely evaluated in PJ18-W2.53B and PJ18-W2.56 by the participants and also via operational demonstrations allowing valuable insight into the concept of using ADS-C EPP data in the ground tools (Trajectory Predictor, CD&R tools, Trajectory management tools e.g. Trajectory editor, trajectory information display, 2D route discrepancy check, Route adherence Monitoring, 3D conformance monitoring).

For **MUAC**, for EXE-PJ38-4-4, during the 20 months this demonstration has lasted, 28,800 ATS B2 flights have been controlled by MUAC ATCOS sending a total of 419,163 ADS-C reports. Those flights were operating under a variety of weather, traffic conditions and under different AU-operating policies from which we can conclude the statistical relevance of the exercise.

For **DFS**, for EXE-PJ38-4-5, since the demonstration could not be run in real shadow mode (which would imply an direct observation channel to real OPS rooms), this limitation does not reduce the significance of the intended results (mainly the usability of "live" ADS_C Common Services based on live ADS-C contracting and data).

In live operations only up to a maximum of three airframes were in flight at a time in the controlled airspace volume. This still helped to establish confidence to the ACS on a functional level and also on a Continuity of service level. From a Capacity level perspective, no statement was therefore possible. It should be complemented by architectural analysis (for scalability etc.) under the assumption of a fully mandated ADS-C environment (all flights, all ATSUs at ECAC region).

For **ENAV**, for EXE-PJ38-4-6, during the 3 weeks of the demonstration campaign, 226 flights were controlled by ENAV ATCOs, identifying a total of seven occurences of tactical conflict advisory alert. From such a result, it can be concluded that the exercise did not provide data with applicable statistical relevance.

For **NATS**, for EXE-PJ38-4-7, the level of significance of the Client-ACS Demand contract assessment should be treated as low as the assessment is only considered to be indicative as, due to setup limitations, the times are measured at the Client prototype and did not use a high availability ATM network between the Client and the ACS prototype. The significance of the analysis on TOA range should be treated as low due the deviation from the planned activities which involved feeding the ADS-C TOA Range data into an AMAN prototype.

For **HUNGAROCONTROL**, for EXE-PJ38-4-8, according to the statistical analysis, no significant differences were observed in the workload and situational awareness values between reference and solution scenarios. The data analysis result suggests that ATCOs had acceptable workload and situational awareness levels in both cases, but the scenario with high traffic count and complexity had a major influence on these values.

In terms of operational significance, the simulated environment can be considered representative as the airspace and traffic samples adhere to the real Hungarian en-route and TMA environment (albeit with missing sector handover constraints). All ATCOs were active controllers at HungaroControl. However, the HMI was not fully tailored to the Hungarian main ATM system, which made the interaction with the system more difficult, regardless of the numerous training sessions.

For **PANSA**, for EXE-PJ38-4-9, some limitations that reduced the level of significance of validation exercise results were observed. The limited number of aircraft sending the necessary information as well as the fact that ATCOs couldn't actively manage the traffic limited the operational significance of the analyzed results.

Nevertheless, for aircraft that can be counted as valid for the exercise, ATCOs identified several positive aspects of the tool that when mature could bring significant benefits.

Additionally, no emergency or abnormal situations were addressed in the validation.

For **HONEYWELL**, for EXE-PJ38-4-10, the results of this exercise significantly increase the confidence that the Inmarsat SB-S service can be used as enabler for the B2 ADS-C. Nevertheless, the results are not meant to be used as the sole proof of compliance with the success criteria linked to this exercise. Results of the ESA Iris program and SESAR 2020 PJ.14-W2-107 should be considered too.

For **AIRBUS**, for EXE-PJ38-4-11, ATS B2 (and even ATN B1) exchanges have been performed in an operational context using the onboard FANS C over SATCOM function with real ATC centres.

Overall, it can be assumed that the PJ38 demonstration with the combined work of PJ18-W2.53B and PJ18-W2.56 validation exercises provided significant results from an operational perspective.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

5 Conclusions and recommendations

5.1 Conclusions

For DSNA, for EXE-PJ38-4-1, the technical feasibility of displaying ADS-C/EPP data for the traffic flow management and arrival sequencing improvements in En-route has been successfully assessed. This was appreciated during the exercise. Based on the exercise results, the ADS-C/EPP data has the potential to improve the traffic flow management and arrival sequencing. The validation exercise at FMP level helped to identify the added-value of ADS-C/EPP data for XMAN operations.

For DSNA, for EXE-PJ38-4-2, the technical feasibility of using and integrating the ADS-C/EPP Data of revenue flights to improve vertical profile on arrival and departure from main surrounding airports has been assessed in the exercise. Based on the exercise results, the ADS-C/EPP data has the potential to improve the ATC service provision on selected CWP. Nonetheless, in order for the ATC to take a better advantage of the ToD information, improvements are still needed to reduce current limitations resulting in vertical discrepancies between the FMS FPLN and the ground FPL, when known LOA apply (although published in RAD and thus known by the Airspace Users). Discrepancies were also observed between EPP ToC and actually flown cruise FL, in cases when the FMS CRZ FL was not updated in climb following last minute changes. Overall, the display of ADS-C/EPP data on the 4Me tool was appreciated. Even though the utilization rate of 4Me was lower than expected, this exercise helped to identify the added-value of ADS-C/EPP data for reducing communication time (ATCO/pilot), enhance mental model of the air traffic situation and provide a better service provision to airspace users.

For Skyguide, for EXE-PJ38-4-3, the amount of ADS-C EPP received from ADSCENSIO flights entering the Skyguide airspace permitted to draw sufficient statistical analysis on the ADS-C EPP reliability and on the use of it in the operational system (trajectory Prediction, CD&R tools, 2D route discrepancy check, Route Conformance monitoring…). The content of the EPP and the triggers need some modifications and this will raise standards evolution in some cases. ATCOs showed great interest in the ADS-C EPP content and the possibilities of its operational use with new Trajectory Prediction, trajectory visualisation (type of turns, TOC, TOD, aircraft performance…), improved CD&R tools (enhanced detection envelopes), 2D route discrepancy check, route conformance monitoring, 3D conformance monitoring and foreseen capabilities with combination of ADS-C EPP and ATS-B2 CPDLC. The benefits of using ADS-C EPP data has been demonstrated from an operational point of view, however the proportion of ADS-C equipped flights has a substantial impact of the potential benefits (performance).

For MUAC, for EXE-PJ38-4-4, the current implementation of the ATS B2 standards both in air and ground systems are operational and proven to be ready for deployment. MUAC ground system is fully operational as from the end of May 2022 and since then the ADS-C information and 2D discrepancy indication are available to all ATCOs. Therefore, it can be claimed that MUAC ground system is ready to comply with the CP1/AF6 mandate.

Note that at the moment MUAC is establishing the ADS-C contracts directly and receiving the reports from the a/c via the DLFEP and not via the ADS-C Common Service (ACS). MUAC will make the transition to the ACS once it is deployed.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

The enhancements performed in the CWP HMI during PJ38 regarding the display of the ADS-C information and the filtering of the nuisance 2D discrepancy warnings were successful. The ATCOs saw an improvement compared with PJ31 implementation.

Other enhancements ATCOs expect to have in the future are:

- Use/Display of the intent status information and/or displaying the EPP information in a different way depending on the mode the aircraft is flying.
- Display of a warning when the Requested Flight Level of the FPL and the EPP one differ.
- Display of the speed schedule
- Vertical discrepancies alerts

From the four topics above, the speed schedule is planned for an implementation early 2024. The remaining other three topics remain under further discussion and local validations, no decision or plan to deploy exists today.

These and other future changes requested by the OPS room will be implemented and incorporated in MUAC's CWP HMI and/or FDPS as part of the normal evolutions of the operational system.

The ATCOs gave positive feedback on the usability of the EPP Top Of Descent (TOD) information being downlinked by the aircraft. It has been proven to be reliable as long as both the air and ground share the same view related to vertical constraints e.g. applicable LOAs included in the FMS, or when there is no vertical restriction planned in the ground system.

If that is the case and when traffic (volume and complexity) allows, the controller can see the optimum TOD computed by the aircraft and will try to adhere to it. This will be translated into more optimal descend profiles, the start of the descent will be initiated a number of nautical miles later comparted to today, which result into fuel saving and reduction of CO_2 emissions.

The ADS-C capabilities can bring immediate benefits to the airlines, not only by providing more optimised descends, but also by getting early direct routings by reducing possible re-routings due to for instance military area activations/de-activations. This can be achieved thanks to better controller awareness on the flight's trajectory. These path reductions will contribute to reduce flown distance and fuel consumption.

Additionally, the better controller awareness on the flight's intent can result in earlier climbs to optimal levels during cruise as controllers are more aware of the climb intent without the pilot intervention.

ADS-C equipage is a major step towards trajectory-based operations, offering controllers a more accurate picture of aircraft intentions, that could help to better predict sector loads and that is being seen as one of the first steps towards future automation.

For DFS, the exercise demonstrated the successful use of live ADS-C data from the ADS-C Common Service in the ATS System. This included functionality for EPP display, 2D and 3D discrepancy monitoring and TP improvements.

Both periodic and event contract data were successfully and reliably processed by the ACS. (Execution of Demand Contracts was verified by a separate test tool)

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Data received was reliable, shared in due time and satisfied the operational needs of the client. Multiple clients (four) were served at the same time.

The ACS architecture served the need to save A/G bandwidth with regards to an architecture of local ADS-C data acquisition.

For **ENAV**, the identification of tactical conflicts, usable and relevant to the demonstration activity ends, took place in only seven different instances and, unfortunately, the sizes of recorded samples were not sufficient to carry out a statistical analysis.

Tactical conflicts triggered by EPP tracks were observed but the separation resolution coupled with what if scenarios did not yield conclusive evidence.

The lack of useful instances as input to the statistical analysis can be considered one of the triggering points that lead only to indicative outcomes. Further developments and refinements planned in the HERON project, with future traffic scenarios and a higher proportion of ADS-C equipped A/Cs, should likely provide more usable data based on ADS-C EPP trajectories., possibly running new exercises on longer time scales.

For **NATS**, regarding the ADS-C TOA Range data, the estimations provided by this data group have shown good accuracy and stability values across the various target metering points. However, depending on the ground tool targeted (i.e. whether it is a tool used in the tactical phase or one that is used in the strategic phase), a more in-depth and targeted analysis should be conducted to understand some of the sudden changes while also making sure that ATC instructions from outside the target sector can be factored in.

Regarding the provision of the ADS-C TOA Range data as requested through the ADS-C Periodic and Demand Contracts, it has been observed that this data group is provided on average in more than 90% of both periodic and demand reports of each flight. Furthermore, looking through the flights where this percentage is below the 80% target objective, it has been observed in the analysis of both types of contracts that the percentage of reports providing TOA Range data is still high sitting around 55% for the periodic reports and around 62% for the demand reports.

Looking purely at the ADS-C data provided, no insights could be generated to explain the reason behind some of the reports not providing the TOA Range data as expected. Therefore, a more in-depth analysis of each flight would be required to understand the exact reasons by looking into the airframe's logs combined with the ATC instructions issued if deemed necessary. The remaining reports where this data group is not provided could be explained by changes in the initial planned route which would see either the target COP or IAF being removed and therefore the periodic and/or demand contracts being refused by the airframe. However, with the current rate of provision for the TOA Range data, a combination of periodic contracts with demand contracts can be used to fulfil the operational needs of the ATC ground systems.

Regarding the Demand contract requests facilitated by the Client-ACS architecture in support of assessing success criteria EX7-CRT-38-W3-DEMOP-031 and EX7-CRT-38-W3-DEMOP-033, the analysis indicates that the performance of the ACS-Client architecture should be suitable for future provision of ADS-C Demand Contract data. Further investigation of the Client-ACS architecture could be undertaken to determine if more targeted Demand Contract requests (as opposed to the large data collection method used within this analysis) results in a reduction of large deltas along with removing the EPP data group from the Demand requests could also be considered to see if this has a beneficial impact on the maximum measured deltas.

For **HUNGAROCONTROL**, the exercise was supposed to be at VLD level, the systems were developed with an emphasis on the interfaces and the ACS. At the very last moment because of the lack of equipped ADS-C flights it had to be switched to a simulation exercise.

A positive impact of EPP usage on conflict detection was identified by the majority of the ATCOs. Furthermore, they have a positive opinion on the concept itself, but have identified room for improvements in usability of those new features.

The use of the CD&R tool supports the ATCOs in identifying long-term conflicts and also suggesting solutions, however, there have been discrepancies between the established procedures and the solution advisory provided by the system. The TESLA HMI was still very different from HungaroControl's main ATM system HMI (i.e. MATIAS).

ATCOs had to get used to the new HMI, which resulted in additional workload, therefore solution advisories provided by the system did not reach its full potential efficiency.

The ATCOs welcomed having information on ToC and ToD on the HMI and could see the positive impact of EPP information taken into account in conflict detection. They emphasized that the EPP information need to be accurate to establish trust. However, the results (metrics analysis) show no improvement in the situational awareness and workload of the ATCOs and this was further confirmed by them during the debriefings. ATCOs appreciated the CD&R tool's HMI design.

Results including logs from GENETICS and TESLA show that the overall track length, fuel consumption and CO2 emission was reduced. In the TMA results are more significant, reaching 4-7% reduction, in En-route track length reduction was noticeable, while fuel consumption and CO2 emission reduction was negligible.

Thanks to the pioneering Free Route Airspace in the Hungarian airspace, the aircraft were already flying their optimal trajectories, which did not require a great number of modifications, resulting in a low number of route instructions for aircraft flying in the En-route sectors. This produced a rather constant value for fuel consumption in these sectors.

Improvement in situational awareness provided by the CD&R tool was considered negligible, while more timely conflict resolutions for ATCOs did take place, resulting in increased capacity of both TMA and En-route airspaces.

Based on the ATCO feedbacks gathered on the debriefings and questionnaires the level of safety can be maintained with the use of the CD&R tool. ATCOs emphasized that however the effects of the use of EPP data are difficult to describe but the additional data is definitely a safety improvement. The quantitative results -logging 3 STCAs during the solution scenarios- indicates that the lack of training and the differences with the current operational system has a huge impact on safe service provision.

For **PANSA**, following the assessment of success criteria linked to each exercise-level objective they were either satisfied or not verified during the validation.

First of all – data provided by the system was considered reliable and possibly bringing benefits in the near future. As observed during the validation, especially values like ToC will bring beneficial information to ATCOs without the need to use voice communication. Tools like medium and long-term conflict detection might greatly benefit from incorporating data from EPP.

The second aspect is that the impact on the human performance is either neutral or positive showing a slightly positive impact overall. The ATCOs were using the tool for the first time however they found it intuitive and expressed a desire to use it in the future.

Concerning operational feasibility, it was determined that the information provided can be helpful in building the situation awareness of ATCOs and reducing radio communication.

For **HONEYWELL**, even though the scope of this exercise was significantly reduced due to the test aircraft's technical problems unrelated to this project, the results significantly strengthen the confidence, that SATCOM can be used as a complementary enabler for B2 ADS-C in the European airspace.

The EPP and other B2 ADS-C contracts were successfully established and operated inflight using the Inmarsat's SB-S service.

The applicable RSTP latency targets were met with good margins, even though for proper assessment of the 99.9th percentile more data would be needed.

No performance degradation was observed even during the flights in the north of Norway (up to 69.8 deg north).

Failover from SATCOM to VDL and back to SATCOM was successfully demonstrated with no impact on the ongoing periodic ADS-C reports delivery.

The exercise also demonstrated that independently implemented B2 ADS-C airborne application can interoperate with the existing B2 ADS-C ground end systems.

For **AIRBUS**, the behaviour of the FANS C function "with ATN over SATCOM" and of its contributing systems has been positively assessed by the flight crew during the development and the certification flight tests.

In particular, the flight tests demonstrated the good behaviour of the airborne systems operating the capacity to perform air/ground ATN exchanges using the SATCOM media/sub network for ATN B1/FANS B and B2/FANS C datalink operations.

Flight tests have also demonstrated the good behaviour of the airborne systems operating in a high-density VDL2 environment, with exposition to Multi-Frequency implementations. Non-regression testing on ACARS network via both SATCOM and VDL were satisfactorily demonstrated. Simultaneous ACARS/ATN transfers using SATCOM were also satisfactorily demonstrated.

No significant issue have been encountered apart from the external interferences, localised which are being investigated with state authorities.

5.2 Recommendations

5.2.1 Recommendations for industrialization and deployment

To further consolidate the promising operational benefits of using ADS-C/EPP data for the benefits of air traffic management performance, the following recommendations are proposed to support the development and implementation of the ATS B2 ADS-C:

Operational Performance & operational feasibility improvement

- **PJ38-REC-INDUS-DEP-01**: Pursue exploring scenarios with live and simulated traffic covering the characterisation of operational situations for ATCOs and FMPs controllers (number of flights, airspace complexity, traffic volume including seasonal effect, workload level, adverse weather conditions forcing flights diversion, etc.) to complement the assessment of the use of ADS-C EPP.
- **PJ38-REC-INDUS-DEP-02:** Pursue analysis and solution and/or best practices identification to allow flight crew to engage managed modes (speed, lateral, vertical) as much as possible. (it is observed that when managed modes are activated, FMS FPLN predictions better reflect what the aircraft will actually fly).
- **PJ38-REC-INDUS-DEP-03**: Pursue analysis and solution and/or best practices identification with LOA/RAD altitude constraints in cruise, which may be not reflected in FMS FPLN resulting in vertical discrepancies between FMS FPLN and filled FPL.
- **PJ38-REC-INDUS-DEP-04**: Pursue analysis and solution and/or best practices identification to allow better alignment between the tactically allocated CRZ FL by ATC and the FMS CRZ FL entered by the flight crew who may retain the one provided in the filled FPL (expecting to be cleared to it later on).
- **PJ38-REC-INDUS-DEP-05:** Pursue calibration activities for trajectory prediction ground tools based on vertical and horizontal aircraft performance (retrieved through ADS-C EPP). This will directly benefit the What-if function providing higher accuracy. ADS-C Common Service, enabling any ANSPs to get all ADS-C EPP reports (even outside their control area), is the preferred option to maximize data availability and minimize the lead time.
- **PJ38-REC-INDUS-DEP-06**: SATCOM should keep being considered and promoted as an adequate complementary enabler for B2 ADS-C.
- **PJ38-REC-INDUS-DEP-07:** Currently, the CP1/AF6 mandates the ADS-C equipage only for new airframes. To be beneficial, the capability to retrofit the current airframes with ATS B2 should be envisaged and promoted to reach quicker a minimum critical mass for quick return on investments and maximised operational benefits.

Human Performance improvement

- **PJ38-REC-INDUS-DEP-08**: Mature the integration of ADS-C EPP data on the CWP (e.g. to identify when and how to display the ADS-C/EPP data) assessing safety impact, ATCO situational awareness and capacity to deliver operational benefits.

Access to ADS-C data

- **PJ38-REC-INDUS-DEP-09**: Generalize the use of the Auto logon functionality for all the ATS B2 equipped aircraft to optimise the benefits of the use of ADS-C/EPP data until deployment phase with active operational ATS B2 centres. Investigation could be carried out to further extend it to normal operations.

- **PJ38-REC-INDUS-DEP-10:** Assess the status of items of ADS-C contract (mandatory/non mandatory) (e.g. Estimated Time Over waypoints) to ensure an optimal use of ADS-C EPP reports in the ground system.

- **PJ38-REC-INDUS-DEP-11:** Define priority rules for ADS-C contracts (periodic, demand, on event) establishment among the different subscribers coping with the capacity limit at aircraft level (4 as per standards).

- **PJ38-REC-INDUS-DEP-12**: In case two ETA Min/Max is required for two waypoints on an aircraft's flight plan, a Periodic contract in addition to a Demand contract can be used to downlink the TOA Range data group from the aircraft. Further investigation should be undertaken to determine if there are better solutions.

- **PJ38-REC-INDUS-DEP-13**: ANSPs should be given priority to join the ACS. Its implementation (instead of having an own link established) would make the deployment quicker, easier and simplify the ground systems infrastructure architecture.

- **PJ38-REC-INDUS-DEP-14**: Considering the different stakeholders involved (SSP, DSP, ANSP) and associated owned infrastructure, the deployment of multi-link would require additional attention on the routers settings to ensure uplink and downlink routes are well defined.

5.2.2 Recommendations on regulation and standardisation initiatives

- **PJ38-REC-REG-STD-01**: The availability and the use of an ADS-C Common Service should be promoted and recognized as a means of compliance to the AF6 CP1 as the PJ38 has demonstrated the benefits of the use ADS-C Common service by ANSPs.

- **PJ38-REC-REG-STD-02:** Even if more exposition is needed and already planned (through IRIS project), it is anticipated that SATCOM capabilities and benefits are promising enough to be considered in applicable regulations (EASA CS-ACNS or equivalent) as an acceptable enabler for B2 ADS-C.

5.2.3 Recommendations for updating ATM Master Plan Level 2

Not applicable.

5.3 Summary of elements supporting the regulation CP1

5.3.1 Purpose and intended readership

The purpose of this section is to make a summary of the outputs of PJ38-ADSCENSIO with regards to evidences expected by institutions in charge of supporting European ATC improvements (e.g. SJU, SESAR deployment manager role, ANSPs not in the partnership and preparing industrialisation).

As input, this section considers:

- SJU expectations expressed during the kick-off meeting of the project then updated on the 13th March 2023 during a review meeting,
- Terms of reference of initial Call and Grant Agreement,
- Objectives as described in the Demonstration Plan (D1.5)

The context is supplemented by information from the contribution of various PJ38-ADSCENSIO members to working groups associated to standardization, VDL2 bandwidth support or activities related to prepare CP1 implementation.

5.3.1.1 Review of SJU expectations

SJU expectations (meeting on 13th March 2023)	Status as per PJ38-ADSCENSIO
Assess environmental benefits	• More direct routes can be instructed. A reduction of 30 NM compared to flight plan has been observed by MUAC in real operations (cf. Annex D and feedback presented during the Airspace World 2023 in Geneva, and in the Dissemination Day on 13th March 2023), thanks to an accurate knowledge of preferred aircraft trajectory. • Still in MUAC airspace, the “Top Of Descent” parameter of EPP has been proven to be reliable as long as both the air and ground share the same view related to constraints. The use of the preferred TOD can avoid earlier descent generally requested by ATC. In some specific flows studied it has been observed that during the day, if the traffic situation permits, the TOD can be optimised to 20-30 NM in average and during night or during low traffic periods, it can be optimised to 30-40 NM on average (cf. Annex D). • The number of spurious alerts of conflict detection is confirmed to be reduced, thus allowing less track stretching (cf. Annex C of Skyguide exercise).

	Note: this should also contribute to ATCO workload reduction and airspace capacity • An early and accurate prediction of the time window a flight can respect to arrive in approach confirms that it will allow reducing the number of holding manoeuvres in London TMA (cf. Annex E of NATS exercise). • Additional estimation based on the ADS-C Data Analysis Report (D3.1), will be pursued in other context (e.g. HERON project) in the continuity of PJ38-ADSCENSIO *Note: not in the Terms of References neither in the Project objectives*
Mitigate increased data traffic due to EPP	• Satcom link validated and airborne system certified to convey ATC messages, thus complementing VDL2 bandwidth • ACS reduces the number of ADS-C reports in a window of ratio of 50% to 80% • Information provided in ADS-C reports (e.g. Top of Descent) is estimated to reduce the number of Controllers-Pilot exchanges that can be done via CPDLC or voice.
Contribute to the CBA of new A/G datalink	*Note: not in the Terms of References neither in the Project objectives. Documented by partners participating in various activities.* Below a list (not complete) of the main projects and initiatives which have provided a report/data/validated assumptions on the VDLM2 capacity crunch: • MultiLink Roadmap Working Group (SDM/EUROCONTROL) 2022/23 - ongoing • FCI Business Case (2022) - AP08 - Future Communication Infrastructure Business Case V1.0 • SDM DLS report (2019 Report on DLS Architecture and Deployment Strategy) • DLS IP1 project (University of Salzburg Report Capacity Assessment study) • ELSA study

	• VDL Mode 2 Capacity and Performance Analysis (SJU 2015 report) The following Task forces/Groups (among others) are also heavily involved in the different aspects both from the infrastructure as well as from the operational side of the Datalink Communication system and service: • COMSG • FCI-TF (Task Force) • DPMG/DSG working groups • The Joint CNS Stakeholder Platform (JCSP) an EASA/EUROCONTROL CNS TEAM initiative participated by many aviation stakeholders. • SESAR Wave 2 FCI projects The initial benefits demonstrated by the PJ38 should contribute to the investment decision in a new A/G datalink
Contribution to community specifications with regard to display on CWP/ATCO screen	• No added-value of a dedicated standardization expressed from the participating ANSPs f • About ATC radar screen: Working Position is currently tailored for each specific environment, ATC function and local controllers' practices. , the PJ 38 has not shown added-value nor need in trying to have a standardized way across ACCs to display EPP on ATCO WP. • ATCOs report the interest of identifying when the trajectory prediction is fed with ADS-C data
Managed/selected mode	• Closed loop clearance rather than –for instance- Radar Vectoring facilitates the flight crew to operate in managed mode. • “2D conformance monitoring” function precisely facilitates this capacity for ATCO. • The use of CPDLC, and notably CPDLC B2, is an almost definite means to get flights operated in managed mode.
Status of standardisation	• The project has validated the only existing source: EUROCAE ED228A/ED229A.
ACS Contextual note	• The Contextual Note for an ADS-C common Service (D1.6.100) is associated to this Demonstration Report.

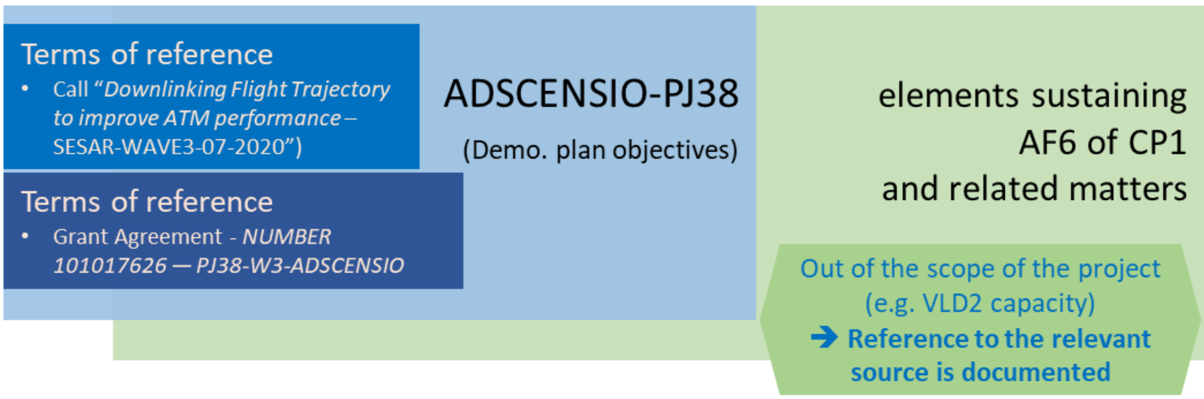
5.3.2 Summary of other elements in relation with deployment out of project objectives

- Air Traffic Services Baseline 2 („ATS-B2“), based on the use of ADS-C EPP data developed with the EUROCAE standards ED-228/ED229 rev.A, are confirmed satisfying and valuable for the sake of CP1 mandate. When improvements are identified, they are communicated to EUROCAE WG78 for inclusion in a further revision of the standard, and possible implementation by suppliers.

- The access to ADS-C data via a common server proves:
  - efficient for ANSPs,
  - source of additional benefits for airspace users, and
  - contribute to a better management of datalink capacity.
  - Ripple benefits on the ATN B1 mandate owing to a single Logon address. An ADS-C common server is satisfying to allow ATM improvement and might be considered as an acceptable means to comply with CP1 mandate.

- Beyond the benefits derived from the display of ADS-C information required by CP1; the processing of data content combined with the use of CPDLC B2 (allowing „complex clearances“ and visibility about their effect on flight) is to generate additional improvements for various specific airspace use cases. The ratio of capable aircraft is an important criteria; it makes sense to consider this aspect to accelerate ATM improvement.

5.3.3 Other lessons learnt and remarks from partnership



The strong relationship with Industrial research SESAR W2-PJ18-4D Skyways, even increased during both projects lifecycles, provides a strong signal that the European ATM community is now determined to deploy and that the Wave 3 Call has been a clever initiative.

EUROPEAN PARTNERSHIP
Co-funded by the European Union

It is timely and relevant to continue and complete under the umbrella of SESAR 3 (Research and Digital Sky Initiative).

EUROPEAN PARTNERSHIP

Co-funded by the European Union

6 Summary of Communications and Dissemination activities

6.1 Summary of communications and dissemination activities

The communication and dissemination actions of the Project will aim at:

- providing concrete examples of technologies which are ready to improve ATM processes,
- illustrating what digitalization can mean for aviation and
- highlighting the major role of coordination enabled by SESAR framework.

The strategy is to act at two levels:

- general scientific popularization, to unveil rapid interest, and
- contribution to operational and technical bodies where the features of practical solutions implementation are addressed.

The project has the following communication and dissemination goals:

- Showcase results to the ATM industry stakeholders through open day type activities, and through professional fora like the World ATM Congress or SESAR Innovation Days.
- Inform publicly about ADSCENSIO developments, their applicability and potential benefits for operations and the environment, targeting both experts in the field and the general public, at European and international level.
- Contribute to the transfer of the results into implementation actions. ADSCENSIO will particularly strongly contribute to the Joint CNS Stakeholders Platform to support the deployment of Common Project 1 (CP1) EC regulation.

6.1.1 Communication at project level

- **April 2021 : EUROCAE Symposium Panel 3: Innovations, Environment and Sustainability**

During this virtual symposium (Covid time), a presentation “Air Traffic Management (ATM), Reducing environmental impact of aviation” describing the high-level mechanisms to reduce aircraft emissions by a reduction in aircraft position uncertainty was provided by HONEYWELL. It introduced TBO concept with the presentation of the EPP transmission and of PJ38 ADSCENSIO. Several hundred people remotely connected to the event.

- **June 2022 : Word ATM Congress Madrid**

During WAC 2022 in Madrid, PJ38-W3-ADSCENSIO participated to the walking tour proposed by the SESAR JU to VIP partners. SDM, Airbus and DSNA presented:

- an overall view of ADSCENSIO high level objectives and operational evaluations;

- the link with CP1 AF6 requirements;
- the work led by the Operational Excellence Programme Workstream 12.2 (ATS B2) towards industrialisation of an ADS-C Common Service in Europe.

Attendees from DG MOVE, FAA, SDM and SJU were welcomed on DSNA's booth

In the FABEC Theatre, MUAC proposed an overall presentation on:

- ATS B2 Set-Up
- MUAC's view on ADS-C immediate and future gains for airlines
- MUAC's overview on ATS-B2 benefits

- **September 2022: LinkedIn Page for PJ18W3 ADSCENSIO**

The page has been created to present the objectives and then work achieved and results obtained by all partners and at Project Level; Contribution (Post) from DSNA, Airbus Defence and Space, PANSA, DFS, INDRA, EUROCONTROL, AIRTEL are provided on this Page

On 1st of November 2022, the page has 153 followers

- **September 2022: Participation to ICAO Innovation Fair**

During ICAO Innovation Fair, DSNA participated to 2 events:

- Sky talk (Sat 24/09): DSNA provided an overall presentation of the ADSCENSIO SESAR Project and a short description of DSNA's objectives in its 2 evaluations (EXE4-1 and EXE4-2)
- Innovation Fair (24-26/09): Reference to ADSCENSIO was mentioned during the presentation of the 2 tools (IODA and 4Me) on DSNA's booth

- **March 2023 : Airspace World Geneva**

ADSCENSIO contributed to the TBO SESSION organised by the SJU in the SESAR theatre. A 10-minute presentation was made by the project coordinator to present achievements and results obtained by the project so far.

ADSCENSIO was nominated for the **SESAR Demonstration Award** (but was not awarded)

Partners contributed to present ADSCENSIO achievements on their respective booth: ENAV, INDRA, ESSP, DFS, PANSA, AIRTEL and DSNA providing demonstrations and presentations (real live EPP data and show the tracks (with the way points) on a map, demonstration of the ADS-C common server…)

During Airspace World, MUAC proposed:

- 2 demonstrations:

Demo 1. ADS-C Data usage by operational and technical expert on safety improvement, increase of ATCOs situational awareness, time saved on the frequency and reduction of the risk for mistakes

Demo 2. ADS-C and advanced CPDLC clearances usage

- A 25-minute presentation on
  - MUAC ATS B2 Implementation roadmap
  - MUAC's ATS B2 Set-Up
  - Statistics – current equipage and known capabilities
  - EPP use cases for increased safety
  - EPP use cases for increased benefits
  - MUAC's overview on ATS-B2 benefits
- **March 2023: Dissemination event 4DSkyways and ADSCENSIO in Eurocontrol Brussels**

On the 21/03/2023, in coordination with 4DSkyways Project Coordinator and partners, a dissemination event was organised in Eurocontrol premises. The following presentations were performed to an audience composed of target stakeholders: ANSPs, ATCOs, Airspace users, Flight crew, Industry, EU institutions, etc.

1. PJ38 ADSCENSIO introduction (DSNA)
   General presentation the Project: Context, partners, plan of presentation, short sum up of project's benefits and achievements
2. Operational evaluations (DSNA+MUAC)
   - Operational evaluations performed by 8 ANSPs addressing 4 main topics:
     - Trajectory Consistency check
     - Conflict Detection and Resolution
     - Optimized Descent
     - Flow management / Traffic sequencing
   - Achievements and benefits for ANSP and Airspace Users by Eurocontrol-MUAC
3. Data collection and auto-logon (Eurocontrol)
   Figures on Data collected and stored, AutoLogon functionality and benefits for operational evaluations. Results on data analysis-technical part
4. Data analysis (ENAV)
   Data Analysis performed for the operational part: ADS-C EPP variability and accuracy, Benefits from ADS-C EPP data for TP enhancement, estimated overfly points and speed predictions. Common Analysis Platform
5. ADS-C Common Server (DFS)
   Architecture of the ADS-C Common Service (ACS) and contribution to standardisation process for a European ACS
6. VDL-SATCOM complementarity (Airbus)
   Results achieved on this second means to exchange Air Traffic Services datalink messages

EUROPEAN PARTNERSHIP

Co-funded by the European Union

A large majority of ADSCENSIO partners participated and contributed to the presentations and exchanges with external participants present that day (PJ18W2 partners and Stakeholders from Airspace users in particular)

As a complement to the presentations, DSNA presented on a dedicated booth Live traffic Demonstrations of the Tool used in EXE 4-1 (benefit of EPP Data for Arrival Management in PARIS ACC) and EXE 4-2 (benefit of EPP Data in ATC service provision in French ACCs)

6.1.2 Communication at Partner level

Honeywell:

On November 14, 2022, in the Czech Air traffic control centre in Prague, Honeywell PJ38 team presented batch tools used for PJ38 data processing. The ATC partners explained their expectations on the FMS shared trajectory, including EPP sharing when autopilot manual modes are in use.

DSNA

In 2022, several presentations to DSNA technical managers was performed: PJ18 and PJ38 expected results in preparation to ATM system evolution to cope with CP1-AF6 requirements

In DSNA official publications (2022 DSNA- Activity report, 2022-DSNA "Lettre des grands programmes"), articles presenting ADSCENSIO's overall objectives and first achievements were published

Skyguide

Specific demonstrations to skyguide operational staff (ATCOs)were performed in 2022 and Q1 2023, on the main following topics:

- Use of ADS-C EPP,
- ADS-C EPP display
- New functionalities using ADS-C EPP (Use cases)
- Trajectory Prediction and Conflict Detection & Resolution tools improvement

On skyguide website, a Project highlight was provided in 2022

PANSA, DFS and Indra

On the 1st of March 2023, in coordination with DFS and PANSA, Indra provided support and guidance for the execution of the PJ18-W2 PJ38 PJ10 PJ32 Demo Day at Indra premises

The Demo Day concerning the PJ38 ADSENCIO project focused in particular on the ADS-C Common Service, providing full explanations about the setup and execution of the exercises executed.

Hungarocontrol

On the company LinkedIn page, two communications were provided

- Post 1: SESAR's PJ38 is making use of ADS-C to enable and support improved ATM operations. HungaroControl teamed up with Airbus Defence and Space to experiment with EPP data and together we delivered an exceptionally successful validation session at our simulator facility in Budapest this week. Thanks to our partners, pseudo pilots and ATCOs, we are leading the way towards enhanced safety and efficiency!
- Post 2: SESAR's PJ38 is making use of ADS-C to enable and support improved ATM operations. HungaroControl teamed up with Airbus Defence and Space to experiment with EPP data and together we delivered an exceptionally successful validation session at our simulator facility in Budapest this week. Thanks to our partners, pseudo pilots and ATCOs, we are leading the way towards enhanced safety and efficiency!

Airbus and Airbus defence and Space

On behalf of the project, Airbus staff makes use of outputs via various specific channels:

- Airbus chairs the EUROCAE WG78 (ADS-C application) and then directly considers feedback for possible further revision.
- Airbus has participated to Joint CNS Stakeholders Platform in 2022, and has joined the Operational Excellence Programme 12.2 (ATS B2) Workshop
- Airbus is to host the project Social event 13th June
- Coordination and exchanges with ANSPs out of European area regularly take place, where the SESAR project PJ38-ADSCENSIO is systematically at the core of the agenda.
- A video is to be produced, potentially released after the end of the project, and for a continuous presentation of its outputs all around the world.

It will target in priority European institutions, Controllers (mainly European), Airlines, and worldwide ANSPs. General public can also be interested. Focus will be put on the capacity to cope with needs for Environment friendly operations thanks to better actions resulting from facilitated anticipation. The key objective is to emphasize information for ground staff to appeal for adapted means and also for Airspace users to be made more familiar with concrete examples. Highlight will be put on the capacity it offers to assist decisions and the increased importance to fly according to the recommended procedure. The video is to be published via public channels, in the continuity of a video produced in 2020. Interviewed with air and ground users are considered.

ENAV: online workshop to be held in April 2023.

NATS :

NATS' approach to communication and dissemination of PJ38 reflects the projects role to demonstrate ATS B2 ADS-C as an enabling technology for ATM operations. As such, the communication and dissemination activities have combined both the NATS led results from the project alongside their application in other SESAR industrial projects; namely PJ02.14.6b 'eORD' and PJ18 '4D Skyways'. The activities include both externally facing online blog articles and a planned attendance at a joint communication and dissemination event with PJ18.

The first online blog article, hosted on the NATS externally facing website was published in July 2022: https://nats.aero/blog/2022/07/digital-skies-leveraging-the-infrastructure-of-the-future/

To promote the blog article, two social posts were also published:
• LinkedIn - https://www.linkedin.com/posts/nats_digital-skies-leveraging-the-infrastructure-activity-6958101571427561472-Q5zN?utm_source=linkedin_share&utm_medium=member_desktop_web
• Twitter - https://twitter.com/NATS/status/1552336699593826304
The NATS LinkedIn post was also shared on the PJ38 LinkedIn sub-site.

6.2 Target Audience Identification

The project targeted three types of audience:

- Professionals in aviation, in particular active staff (pilots, controllers), associations (EBAA, ACI Europe, A4E, IATA), airlines, industry (aircraft and aircraft equipment manufacturers, Avionics and ATC Systems)
- General public, for global awareness on contribution for community
- Institutions and Politics, to support deployment, in particular standardization bodies (e.g. EUROCAE), European decision makers and regulators (ICAO, EASA, EUROCONTROL, EC) and
- Other organisations out of European area (e.g. FAA, RTCA, CAAC and ATMB)

6.3 Project High Level Messages

The project communicated around the foundations it uses:

- technological means,
- digitalization,
- Air-Ground coordination

and the key performance areas addressed by demonstration activities:

- flight efficiency,
- safety,
- datalink technical improvements.

The key summary was to demonstrate that:

Digitalization (use of data) + Air-Ground coordination
=
assist Air Traffic Controllers to take decision improving safety and flight efficiency
+
allow an optimal use of available datalink communication technologies.

The aim of the communication actions was to highlight the results demonstrated by PJ38-ADSCENSIO and explain how these results can prepare ATS B2/ADS-C implementation to pave the way for a sustainable aviation.

7 References

For what concerns the general collaboration between all the members of the programme:

[1] SESAR3 Membership Agreement

[2] SESAR3 Programme Management Plan

For what concerns the definition of the solutions being addressed by the project, their initial maturity levels and the target maturity dates aimed for:

[3] ATM Master Plan

[4] SESAR Maturity Report

[5] SESAR Release Strategy

For what concerns the specific scope of work covered by this project and the general way of working expected from all projects in the SESAR3 programme:

[6] 101017626 ADSCENSIO Grant Agreement

[7] SESAR3 Project Handbook

7.1 Reference Documents

[8] D1.5 Edition 02.00.00- PJ38 ADSCENSIO DEMOP Release 2

[9] D5.2 – PJ18-06a-TRL6 Data Pack

[10] D4.2 – PJ10-02a-V3 Data Pack

[11] D 1.2 – PJ31 DIGITS/DIGITS-AU Demonstration report

[12] STD-004 — SESAR Solution #115 – Review of ATS B2 standards in WG-78/SC-214 for US/EUR convergence

[13] POI-0018-COM — SESAR Solution #109 – SATCOM Class B for ATM

[14] D2.1.001 Edition 01.00.00 - SESAR Solution 53 A/B Initial SPR-INTEROP/OSED for V2/V3 – Part I

[15] D2.2.002 Edition 03.00.00 – SESAR Solution 53B Initial TS/IRS for V3

[16] D3.1.001 Edition 02.00.00 - SESAR Solution 56 Initial SPR-INTEROP/OSED for V2- Part I

[17] D3.1.002 Edition 03.00.00 - SESAR Solution 56 Initial TS/IRS for V2

[18] ED-228A: Safety And Performance Requirements Standard For Baseline 2 ATS Data Communications (Baseline 2 SPR Standard)

[19]ED-229A: Interoperability Requirements Standard For Baseline 2 ATS Data Communications (Baseline 2 Interop Standard)

[20]ED-230A: Interoperability Requirements Standard For Baseline 2 ATS Data Communications, FANS 1/A Accommodation (FANS 1/A Baseline 2 Interop Standard)

[21]ED-231A: Interoperability Requirements Standard For Baseline 2 ATS Data Communications , ATN Baseline 1 Accommodation (ATN Baseline 1 Baseline 2 Interop Standard)

[22]ICAO, "Doc 9880: Manual on Detailed Technical Specification for the Aeronautical Telecommunication Network (ATN) using ISO/OSI standards and protocols - part 1

[23]Bass et al., "Software Architecture in Practice”, 3rd Ed., Addison-Wesley, 2013

[24]ISO 25010:2010, "Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) - System and software quality models"

[25]OASIS, "Advanced Message Queuing Protocol (AMQP) Version 1.0," October 2012.

[26]ITU International Telecommunication Union, "Information technology – ASN.1 encoding rules: XML Encoding Rules (XER)," 02/2021 Edition 4.0.

[27]EUROCONTROL, "Specification for SWIM Technical Infrastructure (TI) Yellow Profile, Edition 1.1," EUROCONTROL, July 2020.

[28] D3.1 Ed 01.00.00 - PJ38 ADS-C Data Analysis

[29] D3.1.105 - SESAR Solution 56 VALR for V2

[30] D2.2.105 - SESAR Solution 53B VALR for V3

[31] D2.1.105 - SESAR Solution 53A VALR for V2

Appendix A Demonstration Exercise #01 (EXE-PJ38-4-1 by DSNA) Report

A.1 Summary of the Demonstration Exercise #01 Plan

A.1.1 Exercise description and scope

DSNA first exercise focused on traffic flow management and arrival sequencing improvements in En-route thanks to the use of ADS-C data. DSNA aimed at demonstrating operational benefits of ADS-C/EPP data in both Traffic flow management and Arrival Management Extended to En Route Airspace.

Live trials were conducted from 24 October 2022 to 20th January 2023. They focused on ATFM service provision in Paris ACC (LFFF) in coordination with adjacent ACCs and CDG and Orly approaches.

To be able to conduct these live trials, DSNA has upgraded the current operational tool used by the FMP controllers (IODA) with the integration of ADS-C data made available via the ADS-C Common Service.

In aim to assess the overall objectives described in the DEMOPLAN, a questionnaire was built. This questionnaire (two pages) presented a list of questions with open and/or closed answer modalities (Likert[2]) and it aimed at collecting the FMP controllers' perception of the interest of using ADS-C EPP data (utility) and their impact on the control activity (workload, situational awareness, decision making, future activities, safety, etc.) as well as the usability of the tested solution design. The questionnaire was developed in collaboration with the Paris ACC operational expert and made available to all FMP controllers who, after having used the IODA EPP display, were interested in providing their feedback (on voluntary basis). This method allowed the qualitative analysis of the first use of the ADS-C EPP data on the FMP controllers' position.

A.1.2 Summary of Demonstration Exercise #01 Demonstration Objectives and success criteria

The demonstration objectives for EXE-PJ38-4-1 were to demonstrate that from an operational perspective, the use of ADS-C data:

- **does not induce any safety events,**

[2] Likert scales aimed at measuring on a linear continuum, going from negative (1) to positive (5) or from strongly disagree to strongly agree as applicable

- **improves the Human Performance of FMP Controllers** (improved situational awareness, workload within acceptable limits, tasks performed efficiently and effectively, and decisions taken in a timely and optimal manner),
- **improves the Operational performance** (enhanced ground air traffic flow management operations),
- **is Operationally feasible** beyond what has been demonstrated in PJ31 (display of ADS-C data considered as useful by FMP Controllers)

From a technical perspective, the objective was to demonstrate that the use of an **ADS-C Common Service** enables the access to data (reliable ADS-C data are received through ADS-C periodic, on event and on-demand contracts).

A.1.3 Summary of Validation Exercise #01 Demonstration scenarios

Revenue Flights non-equipped with ADS-C downlink capabilities are considered as the reference. Before ADSCENSIO, the FMP controller took decisions based on information provided by NM.

During the ADSCENSIO live trials, ADS-C data provided by revenue flights equipped with ATS B2 were also displayed on the IODA HMI in addition to the other available data (mainly provided by NM). The FMP controller used the ADS-C data in addition to the other data to optimise the traffic flow.

A.1.4 Summary of Demonstration Exercise #01 Demonstration Assumptions

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
PJ38-ASS-01	ADS-C data provision		The ADS-C Common Service (ACS) is available with appropriate functionalities (including TOA Range demand contracts) and performances	Pre-requisite to be able to carry out ANSP validation exercises	High
PJ38-ASS-02	ADS-C data usability		The received ADS-C data are usable (available on time, not corrupted, etc.)	Pre-requisite to be able to use ADS-C data.	High
PJ38-ASS-03	VDL2 performances		VDL2 performances support an efficient downlink of ADS-C data	The same avionics as in PJ31 will be used.	High
PJ38-ASS-04	Future Covid situation		Future Covid situation will not affect the organisation of the exercises (e.g. travel restrictions)	The ACS must ensure that the received data are correctly conveyed to the ANSPs	High

Table 6: Exercise #01 Demonstration Assumptions overview

A.2 Deviation from the planned activities

All the planned activities were conducted, except the use of the on-demand contracts (related to criterion EX1-CRT-38-W3-DEMOP-031) because the ACS did not support on-demand contracts when the exercise platform was developed.

The only variation compared to the Demonstration Plan is related to the planning. The live trials had to be delayed by 6 months because the number of ATS B2 capable flights logged on was ranging from 0 to 2 per day at the time of the initial planned dates. This was identified as risk PJ38-RISK-01 in the Demonstration Plan.

A minimal number of logged on aircraft allowing to conduct the exercise could only be achieved after the implementation of the Autologon procedure by PJ38 WP5 in coordination with the Airspace Users.

Concerning the possibility of using some recorded data for quantitative post-exercise analysis, no need was expressed by the FMP controllers to support the subjective analysis.

A.3 Demonstration Exercise #01 Results

A.3.1 Summary of Demonstration Exercise #01 Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
EX1-OBJ-38-W3-DEMOP-SAFE-0001	Demonstrate that the use of ADS-C data does not degrade safety	EX1-CRT-38-W3-DEMOP-001	No safety event is added by the ADS-C Display	En-Route	**No safety events were added** by the ADS-C EPP display. **ADS-C/EPP data have no impact on safety**	OK
EX1-OBJ-38-W3-DEMOP-HPRF-0002	Demonstrate that the use of ADS-C data improves the Human Performance	EX1-CRT-38-W3-DEMOP-007	The FMP Controller level of workload is within acceptable limits	En-Route	The **workload** was assessed as **not impacted** by the use of the ADS-C/EPP data in the FMP controller's activity	OK
EX1-OBJ-38-W3-DEMOP-HPRF-0002	Demonstrate that the use of ADS-C data improves the Human Performance	EX1-CRT-38-W3-DEMOP-005	The situation awareness is considered improved by the FMP Controller	En-Route	The **situational awareness** was assessed as **positively impacted** by the use of the ADS-C/EPP data in the FMP controller's activity. ADS-C/EPP data could support the FMP controllers to better **understand the current flight situation** and to **anticipate the aircraft future behaviour**.	OK
EX1-OBJ-38-W3-DEMOP-HPRF-0002	Demonstrate that the use of ADS-C data improves the	EX1-CRT-38-W3-DEMOP-009	The HMI design supports the FMP	En-Route	The tested HMI was appreciated by the FMP controllers. ADS-C/EPP equipped	OK

	Human Performance		Controllers in performing their tasks efficiently and effectively		aircraft were **easily identifiable** and data **understandable.** The possibility to display ADS-C/EPP data **at FMP controllers' discretion was appreciated.**	
EX1-OBJ-38-W3-DEMOP-HPRF-0002	Demonstrate that the use of ADS-C data improves the Human Performance	EX1-CRT-38-W3-DEMOP-010	The use of ADS-C data provides assistance for the FMP Controller decision in a timely and optimal manner	En-Route	The **decision making** was assessed as **positively impacted** by the use of the ADS-C/EPP data in the FMP controller's activity. ADS-C/EPP data could support the FMP controller's **choice of the best candidate** for a speed modification and could be used to choose the **appropriate sequencing**	OK
EX1-OBJ-38-W3-DEMOP-OPRF-0003	Demonstrate that the use of ADS-C data improves the Operational performance	EX1-CRT-38-W3-DEMOP-021	Evidence is produced of practical cases of operational benefits brought by using ADS-C data elements (both EPP and ETA min/max predictions) to enhance ground air traffic flow managemen t operations	En-Route	No input/feedback was received. therefore, this objective should be considered as **not assessed**.	Not covered
EX1-OBJ-38-W3-DEMOP-OPSF-0004	Demonstrate that the use of ADS-C data is Operationally	EX1-CRT-38-W3-DEMOP-023	The display of ADS-C data is considered	En-Route	FMP controllers assessed as **useful** the ADS-C/EPP data to analyse the flying	OK

	feasible beyond what has been demonstrated in PJ31 (i.e. highlight 2D consistency check discrepancies)		as useful by FMP Controllers		situation, choice of the candidate of the regulation and monitor the regulation	
EX1-OBJ-38-W3-DEMOP-TECH-0006	Demonstrate that the use of an ADS-C Common Service enables the access to data	EX1-CRT-38-W3-DEMOP-030	ADS-C periodic, on event contracts are successfully established and maintained by the ADS-C Common Service, and resulting data **are received**	En-Route	No feedback concerning problems with the connection to the ACS was recorded.	OK
EX1-OBJ-38-W3-DEMOP-TECH-0006	Demonstrate that the use of an ADS-C Common Service enables the access to data	EX1-CRT-38-W3-DEMOP-031	ADS-C on demand contracts are correctly passed through the ADS-C Common Service established on client request, and resulting data **are received**	En-Route	**No on-demand contracts have been issued** because the ACS did not support on-demand contracts when the exercise platform was developed	Not covered
EX1-OBJ-38-W3-DEMOP-TECH-0006	Demonstrate that the use of an ADS-C Common Service enables the access to data	EX1-CRT-38-W3-DEMOP-032	Same as CRT-38-W3-DEMOP-032 Data received via the ADS-C Common Service are reliable	En-Route	No feedback concerning problems with the connection to the ACS was recorded.	OK

Table 7: Exercise #01 Demonstration Results

A.3.2 Analysis of Exercises Results per Demonstration objective

A.3.2.1 EX1-OBJ-38-W3-DEMOP-SAFE-0001 Results

This objective aimed to demonstrate that the use of ADS-C data **does not degrade safety** (CRT-38-W3-DEMOP-001).

No safety events were added by the ADS-C EPP display.

Globally, as shown in Figure 1, FMP controllers considered the information to have **no impact on safety** or a **slightly positive impact.**

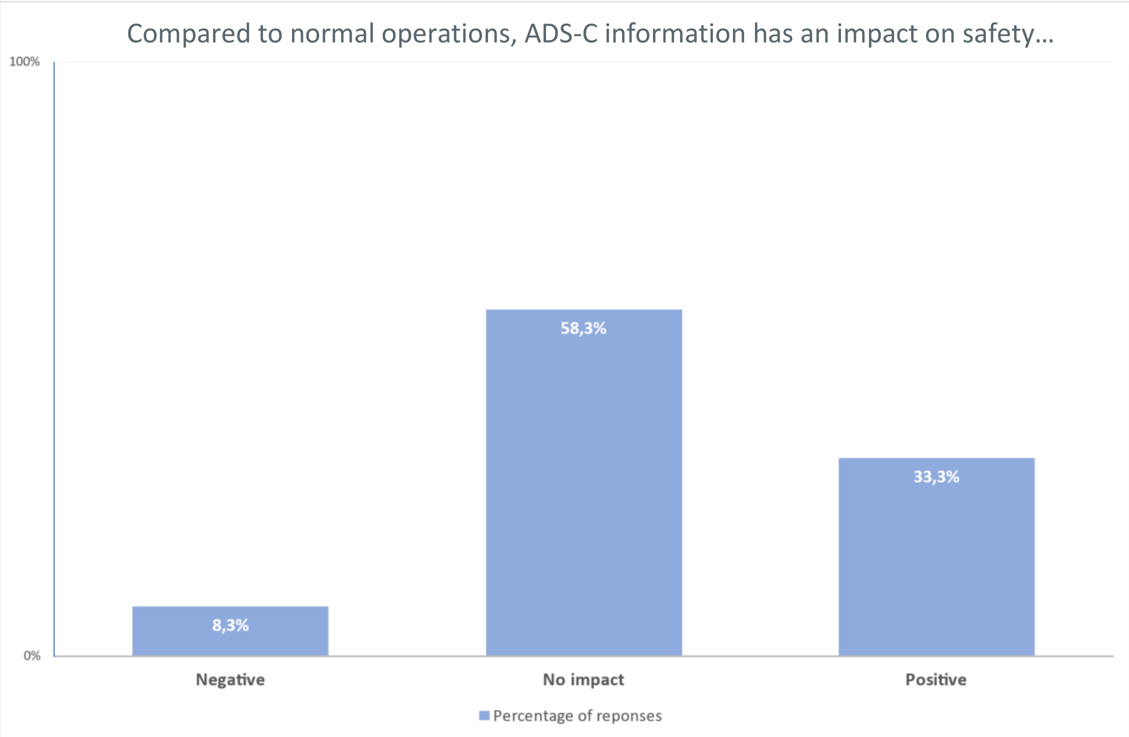


Figure 6 EXE-PJ38-4-1: Impact on safety

In addition, the FMP controllers rated the confidence in the ADS-C data **slightly more positively** compared to the ETFMS data that they currently use (Figure 2).

Figure 7 EXE-PJ38-4-1: Impact on confidence

A.3.2.2 EX1-OBJ-38-W3-DEMOP-HPRF-0002 Results

This objective aimed to demonstrate that the use of ADS-C **data improves the Human Performance.**

FMP controllers were asked about the type of impact the integration of ADS-C/EPP data has on:

- **situational awareness** (EX1-CRT-38-W3-DEMOP-005)
- effectiveness of **decision making** (EX1-CRT-38-W3-DEMOP-010)
- **workload** (EX1-CRT-38-W3-DEMOP-007).

Figure 3 shows that FMP controllers consider that the use of ADS-C/EPP data would **have a positive impact on situational awareness and decision making** dimensions.

The **workload** was assessed **as not impacted** by the use of the ADS-C/EPP data in the FMP controller's activity.

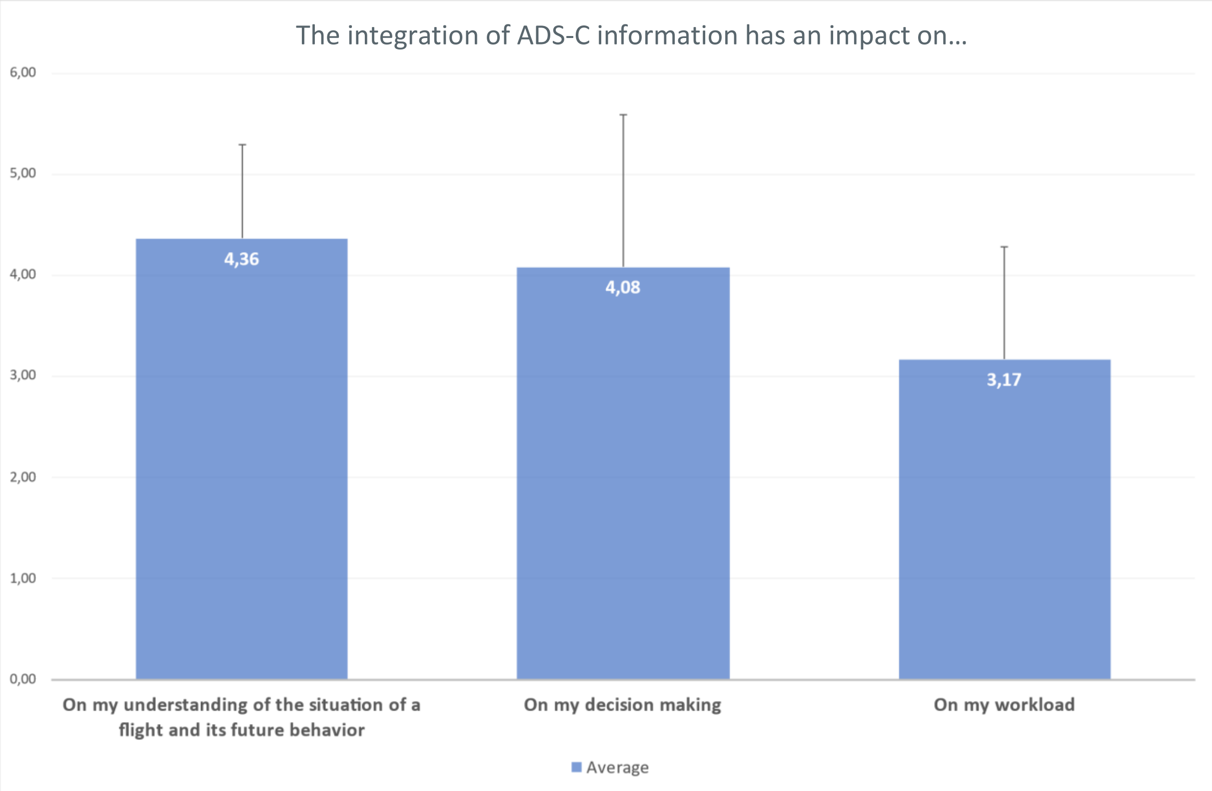


Figure 8 EXE-PJ38-4-1: Impact on human performance

Regarding the **situational awareness**, the qualitative analyses showed that ADS-C/EPP data could support the FMP controllers to better **understand the current flight situation** and to **anticipate the aircraft future behaviour**.

Regarding **decision making**, the qualitative analyses showed that ADS-C/EPP data could support the FMP controller's **choice of the best candidate** for a speed modification (expected Mach in cruise, expected descent speed, wind) and could be used to choose the appropriate sequencing (see EX1-OBJ-38-W3-DEMOP-OPSF-0004 Results).

The usefulness of ADS-C/EPP data **is to be associated with XMAN (Extended Arrival Management) procedures to improve flight efficiency** that are within the range of responsibility of the FMP controller in Paris ACC. Using the **ADS-C /EPP data could support XMAN operations** to improve environmental performance and optimise traffic flow.

The difference in the assessment of the impact on human performance could depend on the **profile of the participant** who filled in the questionnaire. In fact, among the participants there was a great variability in terms of level of expertise and experience as FMP controller. This aspect could facilitate the understanding and management of traffic flow and, as a result, provide a broader view of the operational impact of ADS-C/EPP data on FMP controller activity.

Regarding the impact of the use of ADC-S data on **workload**, the inputs provided via the open-ended questionnaire answers did not allow for a more detailed analysis of the score to the closed-ended question. However, this impact was considered **no significant**.

A specific part of the questionnaire was dedicated to the **design** of the IODA EPP. FMP controllers were asked to comment on the data display (EX1-CRT-38-W3-DEMOP-009) in order to assess its usability. Figure 4 shows a very **positive rating in all dimensions assessed**.

The qualitative analysis confirmed that the FMP controllers appreciated the clear design chosen to represent the data related to equipped aircraft on the IODA EPP interface: the ADS-C equipped aircraft were **easily identifiable** and the **information understandable**, the possibility to display ADS-C/EPP data **at FMP controllers' discretion was appreciated** as it left the possibility to choose when to display it.

Although there were no major issues raised, some points for improvement were raised concerning the (already known) **overlapping** of some information displayed (ADS-C data hidden by the labels of other aircraft).

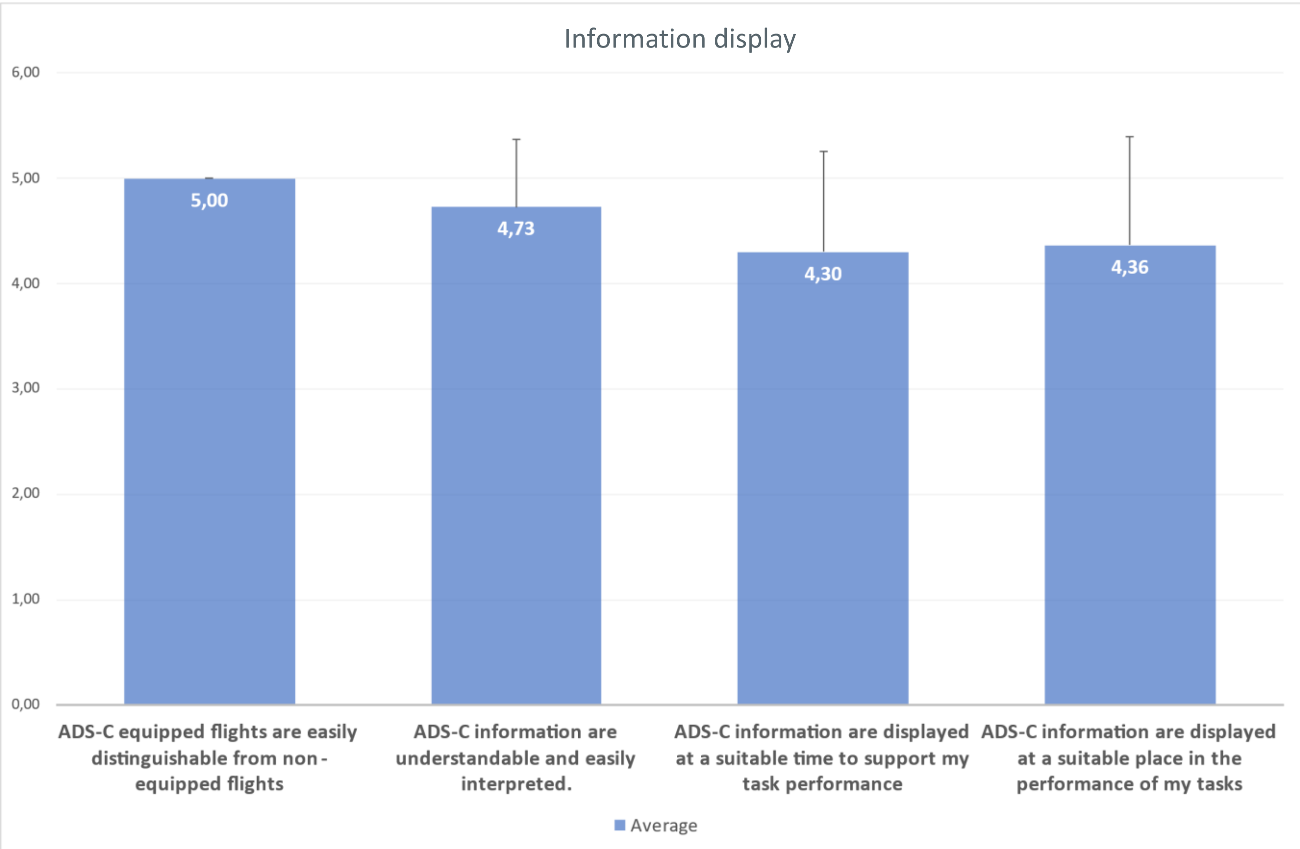


Figure 9 EXE-PJ38-4-1: Information display

A.3.2.3 EX1-OBJ-38-W3-DEMOP-OPRF-0003 Results

This objective aimed to demonstrate that the use of ADS-C data improves the **Operational performance** (EX1-CRT-38-W3-DEMOP-021 Evidence is produced of practical cases of operational benefits brought by using ADS-C data elements (both EPP and ETA min/max predictions) to enhance ground air traffic flow management operations).

No input/feedback was received. therefore, this objective should be considered as **not assessed**.

A.3.2.4 EX1-OBJ-38-W3-DEMOP-OPSF-0004 Results

This objective aimed to demonstrate that the use of ADS-C data is **Operationally feasible** beyond what has been demonstrated in PJ31 (i.e., highlight 2D consistency check discrepancies) (EX1-CRT-38-W3-DEMOP-023 The display of ADS-C data is considered as useful by FMP Controllers).

Figure 5 shows a **positive score for the utility** of ADS-C data, for the following tasks:

- Analysis of the flying situation
- Choice of the candidate & of the regulation
- Monitoring of the regulation.

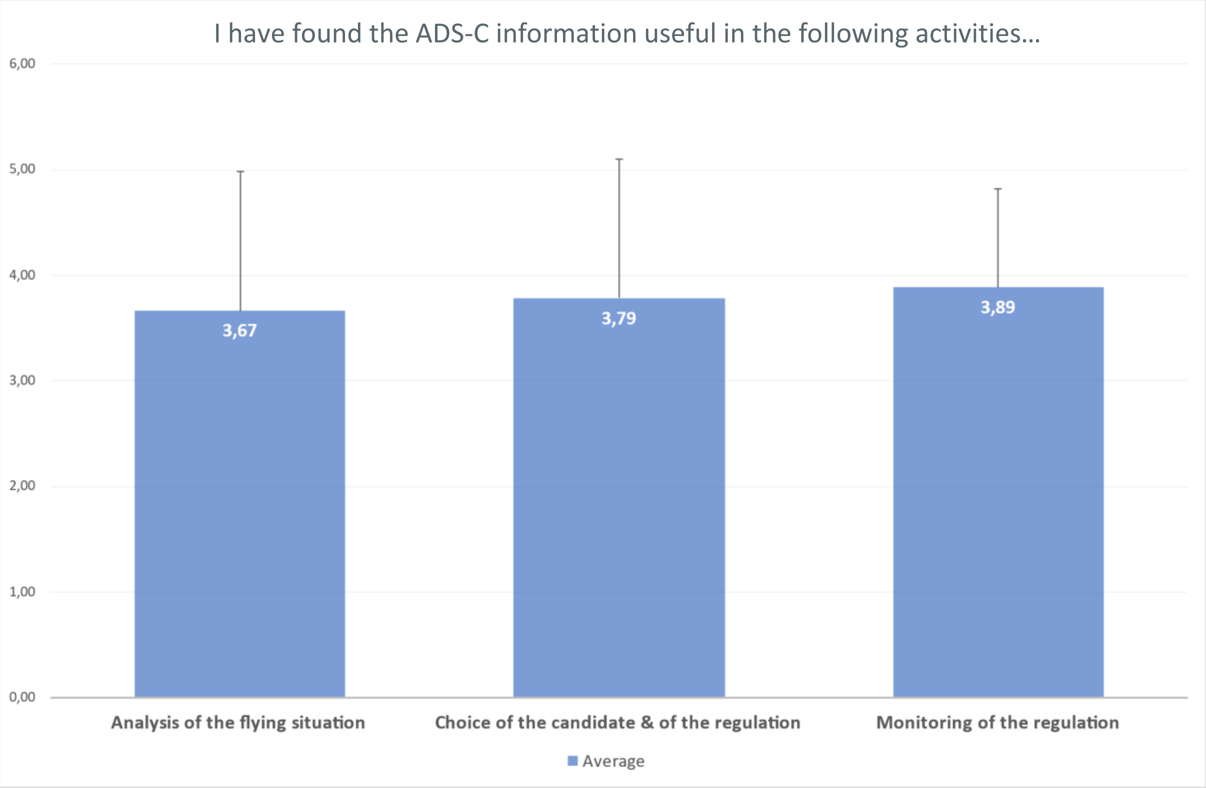


Figure 10 EXE-PJ38-4-1: Utility

Figure 6 shows the rankings of the **most and least used data**. Considering the wording of the question, no conclusions can be drawn as to whether this ranking also reflects the level of usefulness.

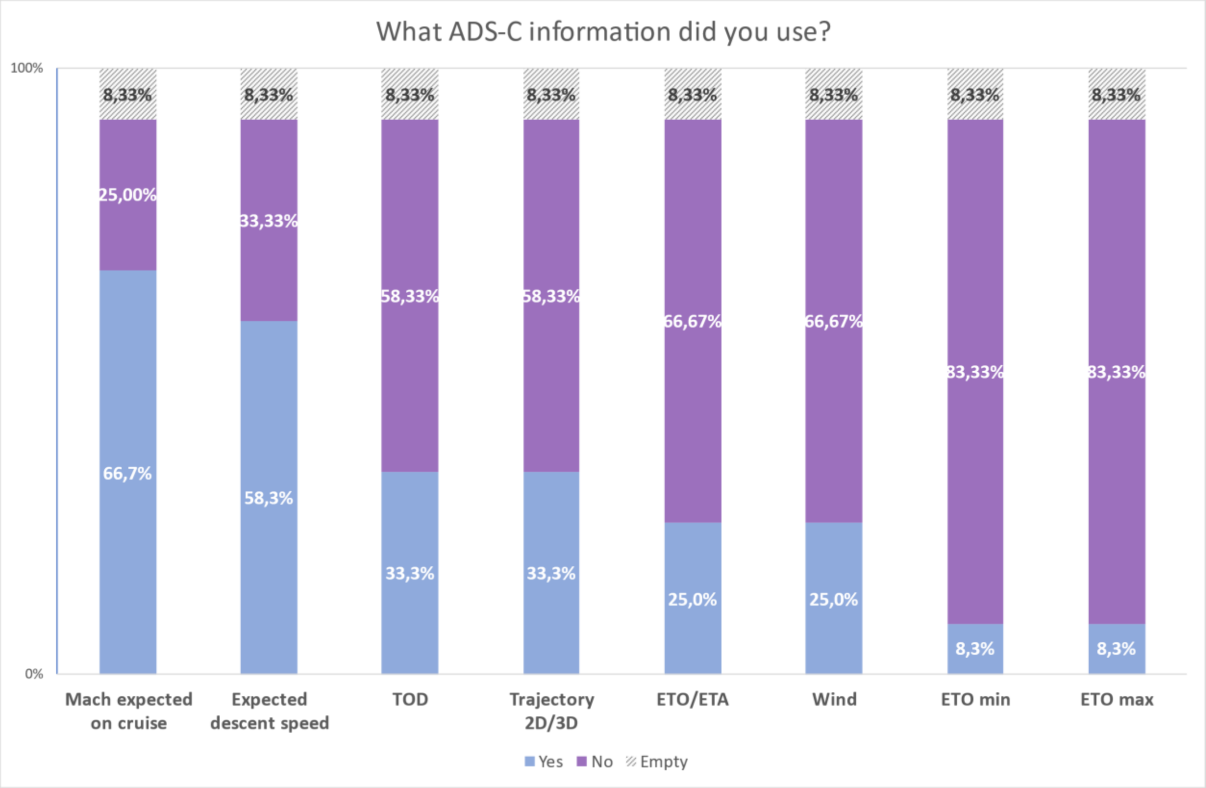


Figure 11 EXE-PJ38-4-1: Most used ADS-C data

However, according to the answers, the **Mach expected on cruise** and the E**xpected descent speed** were the most used data.

The analysis of these answers was not easy, on the one hand because of the **low number of questionnaires** received with few additional free comments, and on the other hand because of the difficulty of the participants to project themselves into a future operational situation (with more aircraft equipped). Because the exercise took place during the operational activity with live traffic of FMP controllers, it was not possible to focus on specific situations. This and the fact that there **were few aircraft logged on**, may have **negatively impacted** the need for the FMP controllers to use certain ADS-C/EPP data (see Confidence in the Demonstration Results).

A.3.2.5 EX1-OBJ-38-W3-DEMOP-TECH-0006 Results

This objective aimed to demonstrate that the use of an ADS-C Common Service enables the **access to data**.

All FMP controllers were able to visualize and use the information displayed on the IODA tool when needed.

The associated criteria (EX1-CRT-38-W3-DEMOP-030 ADS-C periodic, on event contracts are successfully established and maintained by the ADS-C Common Service, and resulting data are received) (EX1-CRT-38-W3-DEMOP-032 Data received via the ADS-C Common Service are reliable) were evaluated in a purely **qualitative way**, as no quantitative or technical input could be used. Indeed, during the exercise, no connection problems were reported by neither technical team nor operational FMP Controllers.

A deviation from the planned activities must be reported for the criterion EX1-CRT-38-W3-DEMOP-031 (ADS-C on demand contracts are correctly passed through the ADS-C Common Service established on client request, and resulting data are received). **No on-demand contracts have been issued** because the ACS did not support on-demand contracts when the exercise platform was developed.

A.3.3 Unexpected Behaviours/Results

No unexpected behaviour of IODA Server and interface for traffic sequencing in Paris ACC displaying the ADS-C data was observed during the exercise.

A.3.4 Confidence in the Demonstration Results

A.3.4.1 Level of significance/limitations of Demonstration Exercise Results

As anticipated in the DEMOPLAN (PJ38 – RISK–01), the significance level of the exercise was negatively impacted by the low rate of logged on aircraft. The limitations and their consequences for the **quality** and **significance** of the exercise are presented in the following sections.

A.3.4.2 Quality of Demonstration Exercise Results

The quality of the results of the DSNA first exercise is considered **acceptable** and allowed for an acceptable assessment of the HP-related objectives given the maturity of the solution and the limitations of the activity.

However, the following **limitations** impacted the quality of the results:

- EXE-PJ38-4-1-Limitation001: A very **small number of aircraft were equipped and logged on**, especially at the beginning of the exercise. This limitation had an impact on the use of the ADS-C/EPP data on the IODA tool. Indeed, ADS-C data were available for a very small number of flights, as a consequence, the FMP controllers did not feel (or only slightly) the need to get the ADS-C/EPP data to support their activities for the traffic flow management and arrival sequencing.

- EXE-PJ38-4-1-Limitation002: A relatively **limited number of questionnaires** were collected and used for analysis. In addition, the number and type of **questions answered varied** widely by participant. This complicated the interpretation of the results for the descriptive analysis and impacted the quality of the results obtained.

- EXE-PJ38-4-1-Limitation003: Part of the FMP controllers' team was trained in using the IODA interface with and without the ADS-C/EPP data during the month of May and part during the month of November just before the start of the exercise. This may have led to **a lack of recall of the use of ADS-C/EPP data** for the first group.

A.3.4.3 Significance of Demonstration Exercises Results

The significance of the results of the DSNA first exercise is considered **low**.

- EXE-PJ38-4-1-Limitation004: As the exercise was conducted in the live trials' modalities, it was not possible to control the operational situations (number of flights and complexity of traffic, workload level, etc.) seen by the FMP controllers. Therefore, the appreciation of the usefulness of the EPP data (of the same data), can vary a lot from one participant to another according to the operational case encountered. Moreover, it was **not possible** to assess the use of the ADS-C/EPP data during **a high traffic period and non-nominal operational situations**

- EXE-PJ38-4-1-Limitation005: A lack of FMP controllers debriefing ("face to face") did not allow **further investigation** of the questionnaires' answer.

A.4 Conclusions

The **technical feasibility** of displaying ADS-C/EPP data for the traffic flow management and arrival sequencing improvements in En-route improvements **has been successfully assessed in the exercise**.

Based on the exercise results, the ADS-C/EPP data **has the potential to improve** the traffic flow management and arrival sequencing.

Overall, the **display** of ADS-C/EPP data on the IODA tool was **appreciated**. Even though the utilization rate of the **IODA EPP** was lower than expected, this exercise helped to **identify the added-value of ADS-C/EPP data for XMAN operations**.

However, considering the limitations of the exercise, this operational improvement would need to be further validated **especially in order to assess in more detail the benefits of each piece of data** on the activity of FMP controllers.

A.5 Recommendations

A.5.1 Recommendations for industrialization and deployment

To further validate the operational benefits of using ADS-C/EPP data for the traffic flow management and arrival sequencing in the next step of the project, it would be important to consider the following improvements in the validation set up:

- **EXE-PJ38-4-1-REC001**: Foresee an exercise allowing the **characterisation of operational situations** encountered by the FMP controllers (number of flight, airspace complexity, number of logged on aircraft, workload level, etc.) in order to broaden the analysis of ADS-C/EPP data use cases on the IODA EPP display.

- **EXE-PJ38-4-1-REC002**: Normalising the training and exposure of the FMP controllers to the IODA and IODA EPP tool in order to reduce learning and use bias.

- **EXE-PJ38-4-1-REC003**: Allow debriefing FMP controllers in order to improve understanding of the use and utility of each IODA EPP data element in the FMP controller activity.

- **EXE-PJ38-4-1-REC004**: Organize trials during high or medium level of Traffic (around summer period)

In order to better assess the operational impact of using the ADS-C/EPP data by the FMP controllers, the number of equipped and logged on aircraft has to be increased:

- **EXE-PJ38-4-1-REC005**: Encourage, beyond the CP1-AF6.1.3 requirement, the airlines to equip the aircraft with the ATS B2 capability to optimise the benefits of the use of ADS-C/EPP data.

- **EXE-PJ38-4-1-REC006**: Generalize the use of the Auto logon functionality for all the ATS B2 equipped aircraft to optimise the benefits of the use of ADS-C/EPP data.

A.5.2 Recommendations on regulation and standardisation initiatives

- **EXE-PJ38-4-1-REC007**: The availability and the use of an ADS-C Common Service should be promoted and recognized as a means of compliance to the AF6 CP1 as the PJ38 has demonstrated the benefits of the use ADS-C Common Service by ANSPs.

Appendix B Demonstration Exercise #02 (EXE-PJ38-4-2 by DSNA) Report

B.1 Summary of the Demonstration Exercise #02 Plan

B.1.1 Exercise description and scope

DSNA second exercise focused on the display of ADS-C/EPP data from revenue flights to Air Traffic Controllers (ATCOs) in En-Route airspace. DSNA aimed at demonstrating operational benefits of ADS-C/EPP data in the provision of ATC service (e.g., optimisation of the vertical profiles).

Live trials were conducted in four ACCs, November 2022 to 20th January 2023, the start date slightly varies depending on the ACC:

- Reims (LFEE) 02/11/2022
- Bordeaux (LFBB) 17/11/2022
- Paris (LFFF) 14/11/2022
- Brest (LFRR) 20/12/2022.

Note: Brest ACC was not initially identified as a participating ACC but this ACC also expressed its desire to participate to the exercise.

To be able to conduct these live trials, DSNA has upgraded its industrial-based platform (4Me) with the integration of ADS-C/EPP data made available via the ADS-C Common Service in the MAP page.

Prior to this exercise, initial thoughts on the use of ADS-C/EPP data in the control position and visualized in 4Me were carried out by reviewing the available ADS-C data with the objective of evaluating which data could be useful and in which operational situations. A CONOPS was thus drafted with the participation of the people in charge of each ACC. As a result, each use case was associated with a data item.

In a second step, in order to evaluate the objectives defined in the DEMOPLAN, a questionnaire was built from the CONOPS inputs. This questionnaire (two pages) presented a list of questions with open and/or closed answer modalities (yes/no, Likert[3]) and it aimed at collecting the controller's perception of the interest of using ADS-C/EPP data (utility) and their impact on the control activity (workload, situational awareness, decision making, future activities, safety, etc.). The same questionnaire was sent to each ACC and available to all controllers who, after having used the 4Me tool, were interested in providing their feedback (without any obligation). This method allowed the qualitative analysis of the first use of the ADS-C/EPP data on the control position.

[3] Likert scales aimed at measuring on a linear continuum, going from negative (1) to positive (5) or from strongly disagree to strongly agree as applicable

B.1.2 Summary of Demonstration Exercise #02 Demonstration Objectives and success criteria

The demonstration objectives for EXE-PJ38-4-2 were to demonstrate that from an operational perspective, the use of ADS-C data:

- **does not add any safety events,**
- **improves the Human Performance of ATCOs** (improved situational awareness, workload within acceptable limits, tasks performed efficiently and effectively, and decisions taken in a timely and optimal manner),
- **improves the Operational performance** (enhanced adherence to the on-board expected vertical profile),
- **is Operationally feasible** beyond what has been demonstrated in PJ31 (display of ADS-C data considered as useful by ATCOs)

From a technical perspective, the objective was to demonstrate that the use of an **ADS-C Common Service** enables the access to data (reliable ADS-C data are received through ADS-C periodic, on event and on-demand contracts)

B.1.3 Summary of Validation Exercise #02 Demonstration scenarios

Revenue Flights non-equipped with ADS-C downlink capabilities are considered as the reference.

During the ADSCENSIO live trials, ADS-C data provided by revenue flights equipped with ATS B2 were displayed on the 4Me HMI to enhance the situational awareness of the ATCOs and permit qualitative analysis of the improvements in the management of these flights compared to the non-equipped ones.

B.1.4 Summary of Demonstration Exercise #02 Demonstration Assumptions

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
PJ38-ASS-01	ADS-C data provision		The ADS-C Common Service (ACS) is available with appropriate functionalities (including TOA Range demand contracts) and performances	Pre-requisite to be able to carry out ANSP validation exercises	High

PJ38-ASS-02	ADS-C data usability		The received ADS-C data are usable (available on time, not corrupted, etc.)	Pre-requisite to be able to use ADS-C data.	High
PJ38-ASS-03	VDL2 performances		VDL2 performances support an efficient downlink of ADS-C data	The same avionics as in PJ31 will be used.	High
PJ38-ASS-04	Future Covid situation		Future Covid situation will not affect the organisation of the exercises (e.g. travel restrictions)	The ACS must ensure that the received data are correctly conveyed to the ANSPs	High

Table 8: Exercise #02 Demonstration Assumptions overview

B.2 Deviation from the planned activities

All the planned activities were conducted, except the use of the on-demand contracts (related to criterion EX1-CRT-38-W3-DEMOP-031) because the ACS did not support on-demand contracts when the exercise platform was developed.

The only variation compared to the Demonstration Plan is related to the planning. The live trials had to be delayed by 6 months because the number of ATS B2 capable flights logged on was ranging from 0 to 2 per day in a given ACC at the time of the initial planned dates. This was identified as risk PJ38-RISK-01 in the Demonstration Plan.

A minimal number of logged on aircraft allowing to conduct the exercise could only be achieved after the implementation of the Auto logon procedure by PJ38 WP2 and WP5 in coordination with the Airspace Users.

Initially, the evaluations were planned for the Paris (LFFF), Reims (LFEE) and Bordeaux (LFBB) but Brest (LFRR) also expressed its desire to participate to the exercise. However, due to the **low number of ADS-C equipped aircraft connected**, the analyses only considered the feedbacks received from Paris (LFFF), Bordeaux (LFBB) and Brest (LFRR).

Concerning the possibility of using some recorded data for quantitative post-exercise analysis, no need was expressed by the ATCOs to support the subjective analysis.

B.3 Demonstration Exercise #02 Results

B.3.1 Summary of Demonstration Exercise #02 Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-38-W3-DEMOP-SAFE-0001	Safety improvement	CRT-38-W3-DEMOP-001	No **safety** event is added by the ADS-C Display	En route	**No safety events were added** by the ADS-C display. ATCOs considered the information to have **no negative impact on safety.**	OK
OBJ-38-W3-DEMOP-HPRF-0002	Human Performance improvement	CRT-38-W3-DEMOP-005	The **situational awareness** is considered improved by the users (e.g. ATCO).	En route	ATCOs considered that the use of the ADS-C/EPP data would **have a positive impact on situational awareness.** ADS-C/EPP data could **enhance the controller's mental model,** allow him/her to **know the aircraft's intentions** and **monitor the compliance with clearances.**	OK
		CRT-38-W3-DEMOP-007	The user's level of **workload** is within acceptable	En route	ATCOs assessed that having access to the ADS-C/EPP data at their discretion has **not negatively**	OK

Co-funded by the European Union

			limits (e.g. ATCO).		affected the **workload**.	
		CRT-38-W3-DEMOP-009	The HMI **design** supports users (e.g. ATCO) in performing their tasks efficiently and effectively.	En route	The tested HMI was appreciated by ATCOs. ADS-C/EPP equipped aircraft were **easily identifiable** and data **understandable**. However, controllers differed on the **choice of displaying ADS-C/EPP data on a secondary screen** (4Me one) from the control screen (radar one).	Partially OK
		CRT-38-W3-DEMOP-010	The use of ADS-C data provides assistance for user decision in a timely and optimal manner.	En route	ATCOs considered that the use of the ADS-C/EPP data **had a positive impact on decision making.** ADS-C/EPP data could improve the **strategic level** and anticipate the decision making.	OK
OBJ-38-W3-DEMOP-OPRF-0003	Operational performance improvement	CRT-38-W3-DEMOP-015	The **adherence to on board expected vertical trajectories** is enhanced thanks to the use (e.g. display) of	En route	ATCOs **did not use the TOD** data to refine their instructions. However, this data was considered useful by the ATCOs in order to reduce	Partially OK

			TOD information.		communication with pilots and save time.	
OBJ-38-W3-DEMOP-OPSF-0004	Operational feasibility	CRT-38-W3-DEMOP-023	Display: the display of ADS-C data is considered **useful** by users (e.g. ATCO).	En route	Overall, ATCOs considered the ADS-C/EPP data useful. **Further studies are needed** to understand more deeply how the limitations encountered in this exercise may have **impacted the assessment of the operational utility of each AD-C/EPP data** and whether this changes by center and/or traffic situation to ensure that all operational needs are addressed.	Partially OK
OBJ-38-W3-DEMOP-TECH-0006	Access to ADS-C data	CRT-38-W3-DEMOP-030	ADS-C periodic, on event contracts are successfully established and maintained by the ADS-C Common Service, and resulting data shared with the clients in due time.	En route	No feedback concerning problems with the connection to the common server was recorded. All **ATCOs were able to visualize and use the ADS-C/EPP data** when needed.	OK
		CRT-38-W3-DEMOP-031	ADS-C on demand contracts are correctly	En route	**No on-demand contracts have been issued** because the	Not covered

			passed through the ADS-C Common Service established on client request, and resulting data shared in due time.		ACS did not support on-demand contracts when the exercise platform was developed.	
		CRT-38-W3-DEMOP-032	Data received via the ADS-C Common Service are reliable (i.e. they faithfully reflect the latest situation provided by the aircraft).	En route	No feedback concerning problems with the connection to the common server was recorded. All **ATCOs were able to visualize and use the ADS-C/EPP data** when needed.	OK

Table 9: Exercise #02 Demonstration Results

B.3.2 Analysis of Exercises Results per Demonstration objective

B.3.2.1 EX2-OBJ-38-W3-DEMOP-SAFE-0001 Results

This objective Demonstrate that the use of ADS-C data **does not degrade safety** (CRT-38-W3-DEMOP-001).

No safety events were added by the ADS-C display.

Globally, as shown in Figure 1, ATCOs considered the information to have **no negative impact on safety** or a **slightly positive impact** because **situational awareness and decision making** would be improved by the availability of more accurate flight intention information (see next sections).

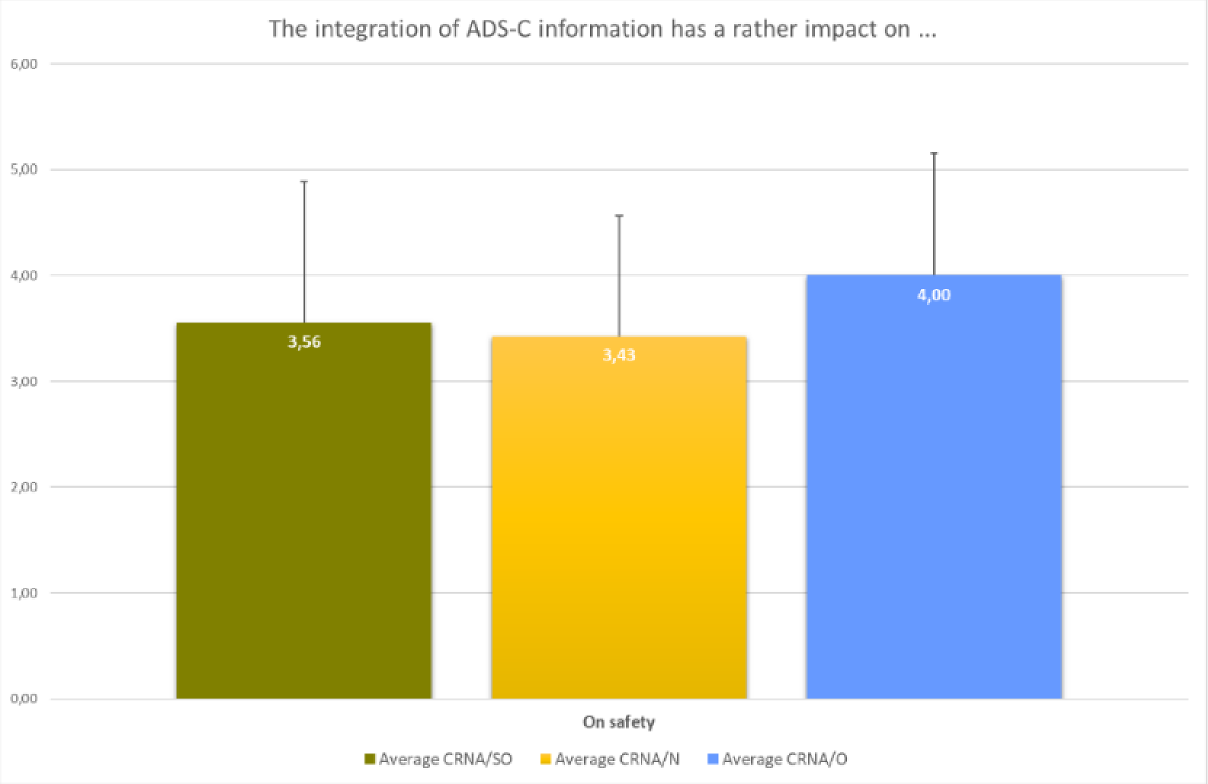


Figure 12 EXE-PJ38-4-2: Impact on safety per ACC.

Subjective analysis showed that the safety improvement from ADS-C information may depend on how such data were presented and used by the controller. In fact, the ATCOs briefing material (one-page presentation or power point presentation, internal note, etc.) providing the exercise scope and the ADS-C/EPP data added to the 4Me display, clearly specified that the MAP page of the 4Me display **is not a control tool** and should only be used if the air traffic situation and the workload level allowed it (see Confidence in the Demonstration Results). For these reasons, the results of this analysis should be taken carefully because the controllers may have answered in very different ways **depending on the use of the ADS-C/EPP data displayed on the 4Me tool.**

However, if ADS-C information is integrated into the radar display of the CWP, the impact on safety should be reassessed.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

B.3.2.2 EX2-OBJ-38-W3-DEMOP-HPRF-0002 Results

This objective aimed to assess whether the use of ADS-C data improves the **Human Performance**.

ATCOs were asked about the type of impact the integration of ADS-C information has on:

- **situational awareness** (CRT-38-W3-DEMOP-005)
- effectiveness of **decision making** (CRT-38-W3-DEMOP-010)
- **workload** (CRT-38-W3-DEMOP-007).

Figure 2 shows that ATCOs (no significant difference between ACC) consider that the use of the ADS-C/EPP data **had a positive impact on situational awareness and decision making** dimensions. However, the **workload** was assessed as **not impacted** by the use of the ADS-C/EPP data in the ATCOs activity.

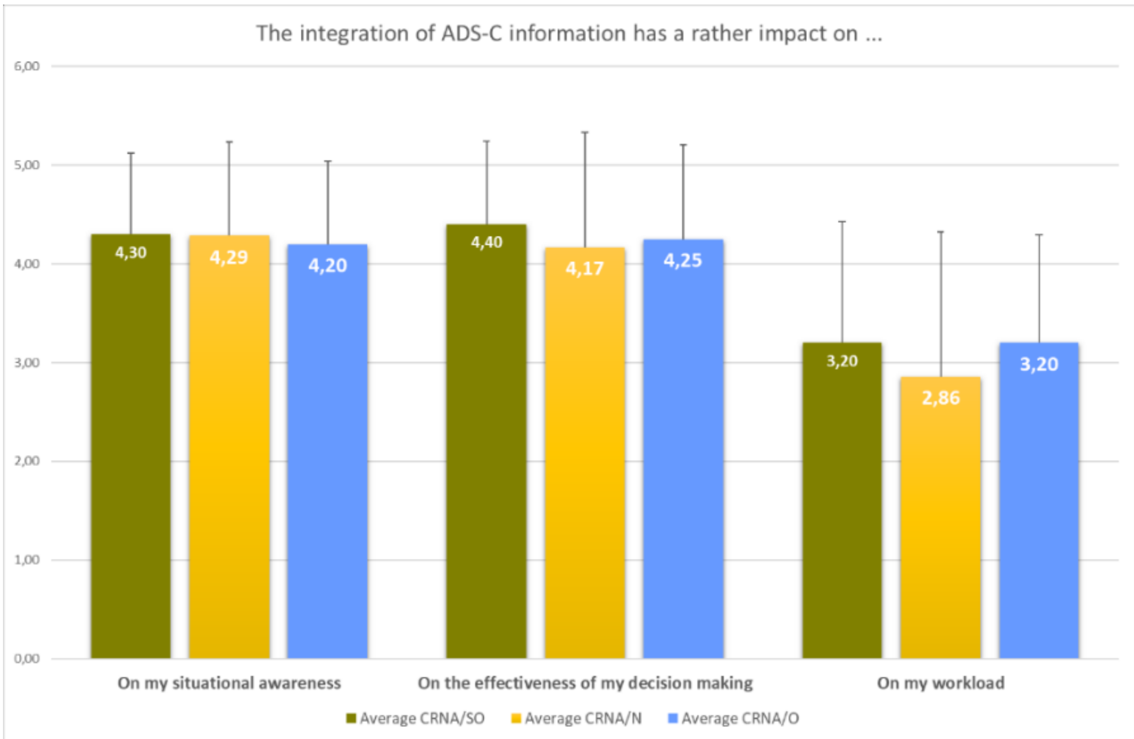


Figure 13 EXE-PJ38-4-2: Impact on human performance per ACC.

Regarding **situational awareness**, qualitative analyses showed that ADS-C/EPP data could **enhance the controller's mental model** of the air traffic situation and allow him/her to **know the intentions** of the aircraft in order to **provide a better service** to pilots and airlines by taking into account the actual aircraft performances. An additional useful aspect of such data is the **monitoring** of the pilot's compliance with clearances. Some controllers indicated that the more complete the information is, the easier it is to **understand** the aircraft's reactions to instructions.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Regarding the **decision making**, the qualitative analyses showed that having more accurate data available would improve decision making at the **tactical level**. This would be characterized by taking into account, the real aircraft's intentions (provided by FMS) when choosing a clearance/instruction. ADS-C/EPP data would allow to **anticipate** the decision making because the controller would **not have to communicate by radio** with the pilot to know what are the speeds that the aircraft can really reach. This would save a lot of time allowing the controller more time for other tasks and, indirectly, a gain in safety (see EX1-OBJ-38-W3-DEMOP-SAFE-0001 results).

It is worth noting that, improvements on these dimensions would **depend on the traffic situation** (number of flights and complexity of traffic) and the induced level of workload of the controllers.

In terms of **workload**, the qualitative analysis revealed that the answers were impacted by the conditions of the exercise and associated limitations (see Confidence in the Demonstration Results). Indeed, as expected, the controllers prioritized control tasks over viewing and using ADS-C/EPP data provided on a secondary display used for non-priority tasks. The consequence was that they only had time to consult the 4Me MAP page to access ADS-C/EPP data when their workload was low.

As a result, the different displays' setup of the CWP (between ACC) could have affected the ease with which the data were consulted on 4Me (see next analysis).

A specific part of the questionnaire was dedicated to the **design** of the tested solution. ATCOs were asked to comment on the ADS-C/EPP data display (CRT-38-W3-DEMOP-009) in order to assess its **usability**. Figure 3 shows a **positive rating for the following** assessed **dimensions:**

- ADS-C aircraft **identification**
- ADS-C/EPP data **presentation**
- ADS-C/EPP data **understanding**.

However, ATCOs confirmed the display on a secondary screen reduces the use of ADS-C information.

Overall, the score **difference between ACCs does not seem significant** and could depend on the limitations and conditions of the exercise, such as the disparity between the number of received questionnaires per ACC (see Confidence in the Demonstration Results).

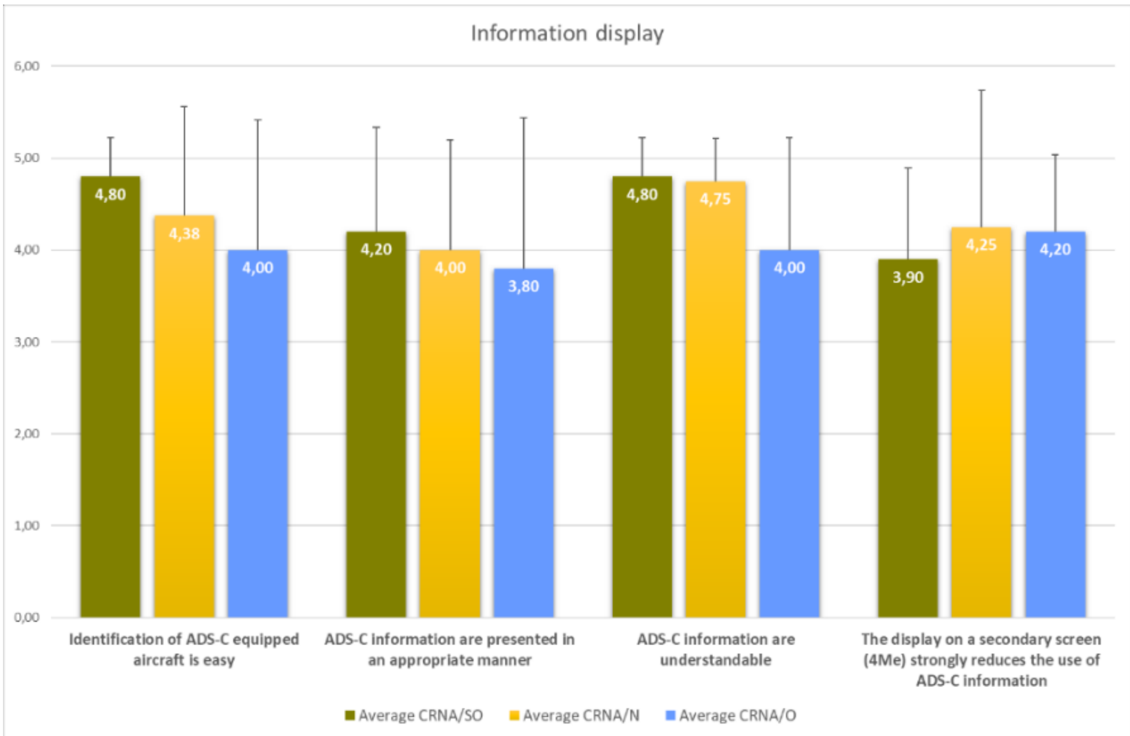


Figure 14 EXE-PJ38-4-2: Information display per ACC.

Regarding strictly design-related topics, the qualitative analysis confirmed that the controllers appreciated the **clear design** chosen to represent the data related to the ADS-C equipped aircraft: aircraft were **easily identifiable** and the **information understandable**, no major problems were reported.

However, controllers differed on **displaying ADS-C/EPP data** on a different screen (4Me one) from the control screen (radar one). The qualitative analysis showed that while a majority of ATCOs would have preferred to have the information directly accessible on the radar screen, others found advantages to presenting the data on a distinct display. This difference depends on several factors such as the appreciation of the usefulness of the data, the way the data were integrated into the control activity, as well as the limitations of the exercise (see Confidence in the Demonstration Results). While displaying the ADS-C/EPP data directly on the radar image might make it easier to use for the main tasks, having it on a side screen would allow freedom of consultation in terms of timing and manner of displaying the data.

Nevertheless, **some points for improvement** were raised, mainly due to displaying the information on the 4Me screen:

- The aircraft concerned by XMAN measures are displayed in red or green and these colours hide the blue used to identify the ADS-C aircraft, the choice of the priorities of the colours should be reviewed in order to allow the identification of the ADS-C aircraft even when concerned by the XMAN measures.

- For operational reason, on the 4Me tool a temporization (not modified by the addition of the ADS-C data) is set inducing to come back automatically on the HOME page regardless of actual consulted page. This can negatively impact the accessibility of the MAP page by increasing the time needed to reach and consult the ADS-C/EPP data even if this feature can be disabled if the MAP page is pinned.
- The general ergonomics of the CWP could have an impact on the accessibility of the data, by reducing the number of actions (mouse clicks) to reach the ADS-C/EPP data and by facilitating the visual access (e.g., position/size of the screen) the controllers would be more inclined to use them.

In conclusion, as long as the ADS-C/EPP data are displayed on a secondary screen and the controller can decide when to consult them, there will be no negative impacts on the primary tasks. However, if in the future these data will be integrated on the radar screen (as wished by a part of the participants), further studies will be necessary to decide when and how to display the ADS-C/EPP data while preserving the controllers' performance.

B.3.2.3 EX2-OBJ-38-W3-DEMOP-OPRF-0003 Results

This objective aimed to assess whether the use of ADS-C data improves the **Operational performance**.

ATCOs were asked if the **TOD** information was relevant to their activity, with the assumption that this information would make it easier for them to identify where the aircraft planned to start the descent and adhere to it if the situation allowed (CRT-38-W3-DEMOP-015). The **relevance of TOD information was questioned** as controllers pointed out cases of vertical discrepancies between the FPL (ground system flight plan), and the FMS FPLN reflected in the ADS-C/EPP. These discrepancies happen either at waypoints in cruise bearing an altitude constraint (even if it is published in the RAD) or when an intermediate FL existing in the FPLN do not correspond to published RAD. It must be noticed that even altitude constraints on cruise waypoints resulting from inter-ACC LOA and published in the RAD are usually missing in the FMS FPLN, despite being integrated in the FPLN transmitted by the AOC to the flight crew. This cause of vertical discrepancies, due to current technical limitations when uploading the AOC FPLN in the FMS, will have to be addressed in future activities.

Discrepancies were also observed between EPP ToC and actually flown cruise FL, in cases when the FMS CRZ FL was not updated in climb following last minute changes (it happens when actually flown cruise FL is below FMS CRZ FL).

Although not trained to use the TOD information, **the ATCOs considered this data potentially useful** in order to reduce communication with pilots and save time (see EX1-OBJ-38-W3-DEMOP-OPSF-0004 Results).

B.3.2.4 EX2-OBJ-38-W3-DEMOP-OPSF-0004 Results

This objective aimed to assess whether the use of ADS-C data is **Operationally feasible** beyond what has been demonstrated in PJ31 (i.e., highlight 2D consistency check discrepancies).

In order to assess how the information displayed might be **useful to the ATCOs' activity** (EX2-CRT-38-W3-DEMOP-023), controllers were asked:

- to comment on whether the information presented had been **useful/relevant** to their activity and
- to evaluate the assumptions made about the type of task each information would support.

Regarding the perceived **relevance**, the following figures show the positive, negative, and missing answers rates for each ADS-C/EPP data. For each ADS-C/EPP data, the empty answer rate could depend on the fact that, depending on the operational situation, not all ADS-C/EPP data was needed by the controller.

Figure 4 shows the scores for all ACC and ranked in order of relevance. The ADS-C/EPP data considered most useful (all ACCs considered) was the **WIND**, followed not far behind by the **TOD** and the **Altitude associated to the waypoints**.

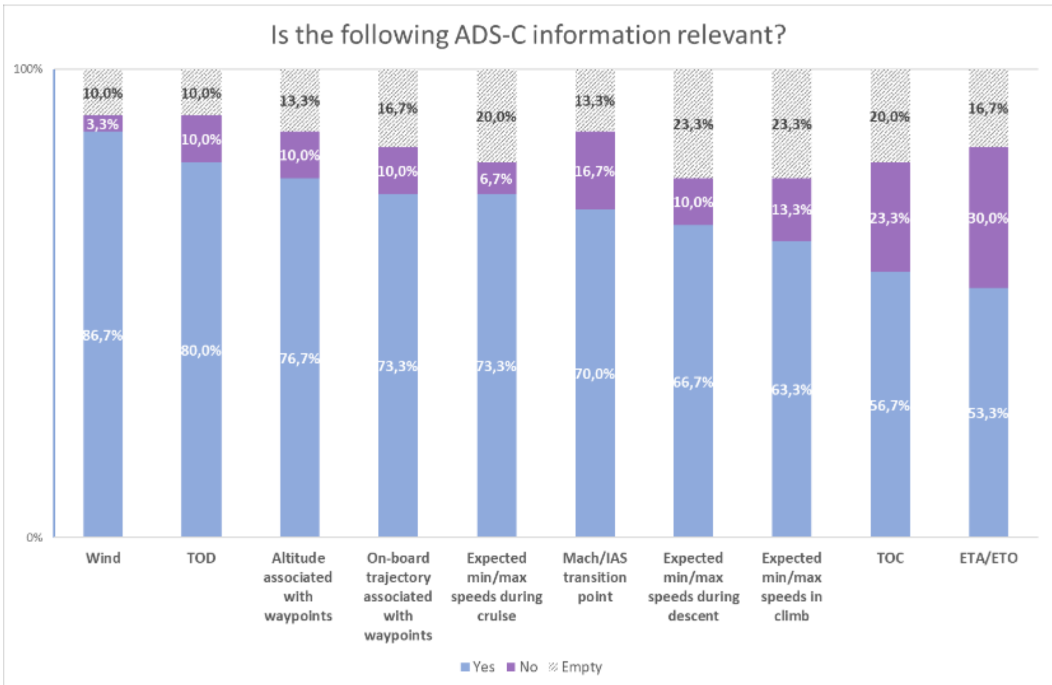


Figure 15 EXE-PJ38-4-2: Relevance - all ACCs combined.

A closer analysis of the data shows that it can be grouped into four classes of relevance:

- over 80%
- between 80% and 70%

- between 70% and 60%
- less than 60%.

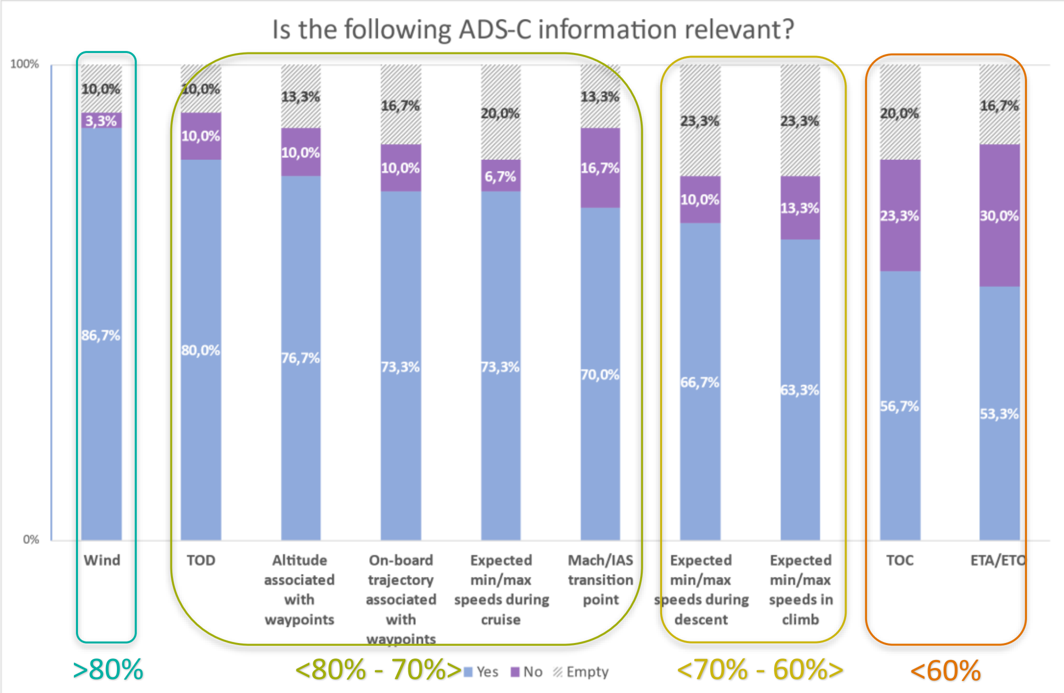


Figure 16 EXE-PJ38-4-2: Relevance - all ACCs combined.

A closer look at the scores per ACC shows that **the ranking and its distribution in the classes are not the same per ACC**.

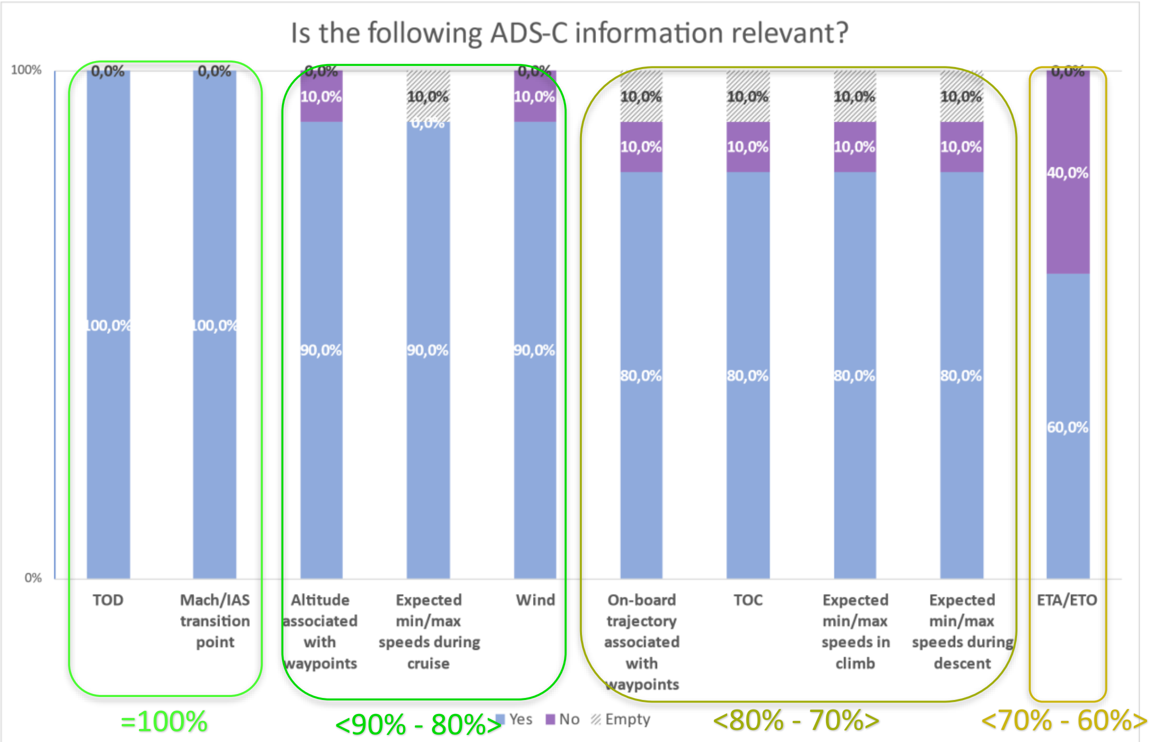


Figure 17 EXE-PJ38-4-2: Relevance - ACC Bordeaux.

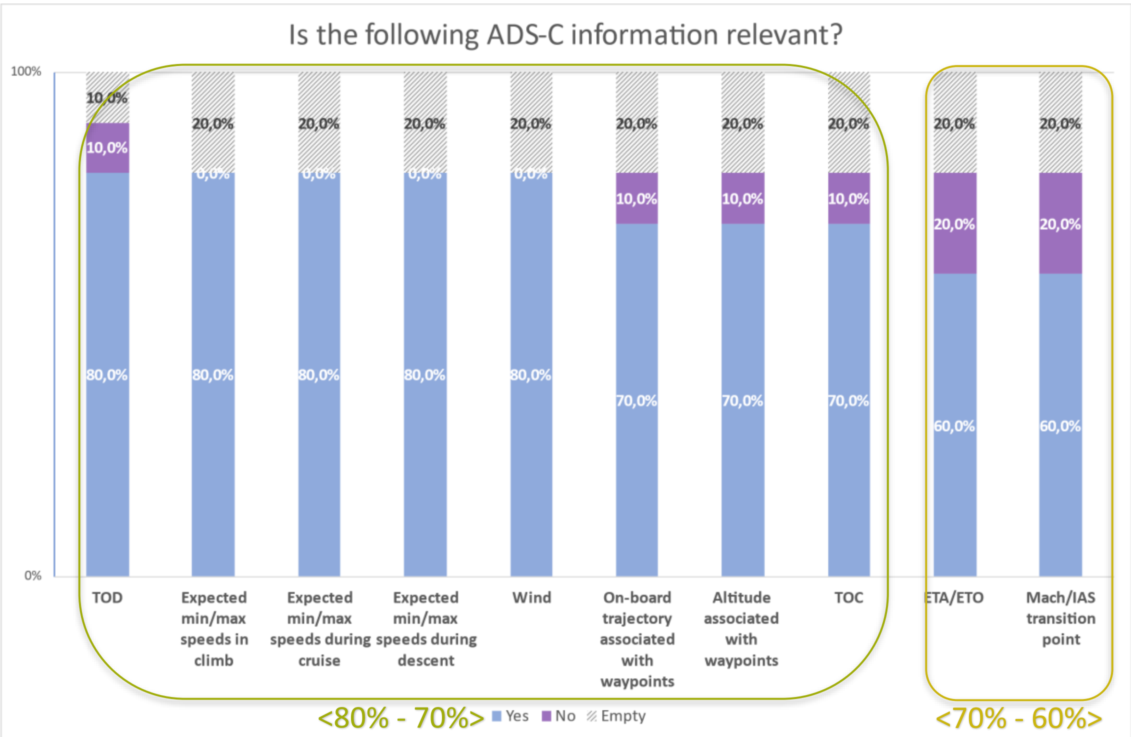


Figure 18 EXE-PJ38-4-2 Relevance - ACC Paris

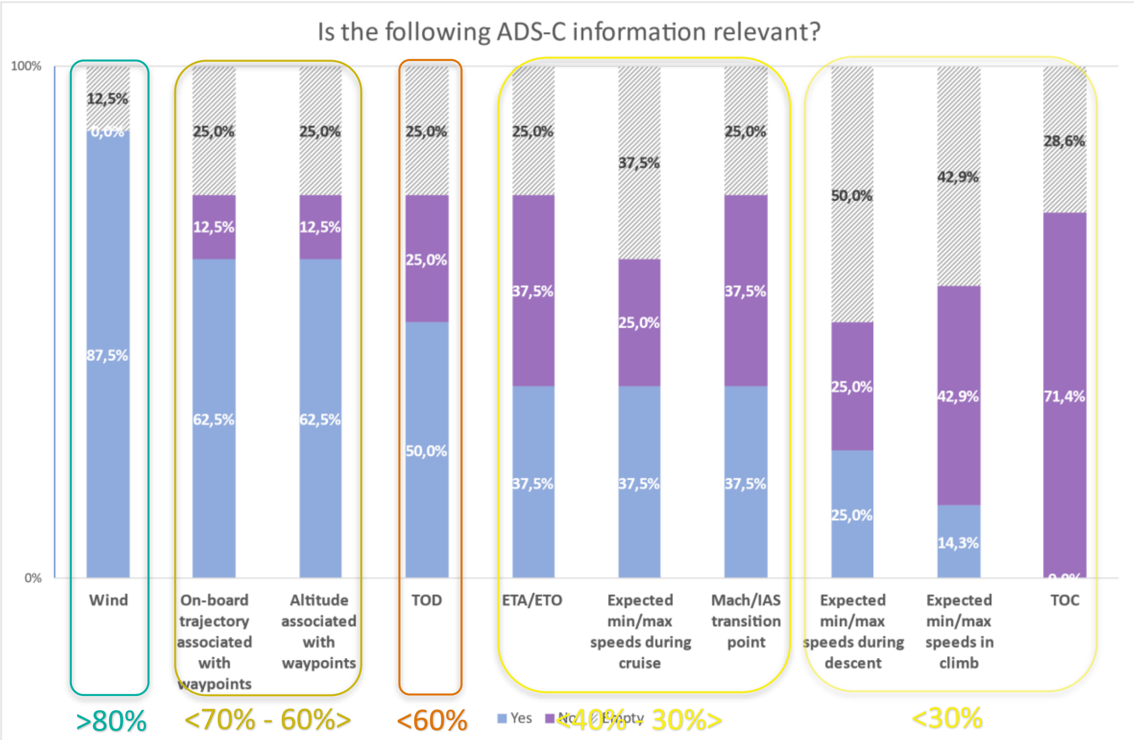


Figure 19 EXE-PJ38-4-2: Relevance - ACC Brest.

Considering the relative **low number of questionnaires** received, the distribution of the answers was **strongly biased** by the (heterogeneous) number of questionnaires per ACC and by the number of incomplete forms. However, what could be inferred from these data is that:

- Almost all data had a **positive perceived relevance** rating.
- Depending on the **operational situations** encountered, the relevance of a specific data may have been perceived as different.
- The **controlled areas** have diverse **configurations and receive different types of traffic** that may have impacted the need to use certain data and, consequently, the perceived relevance.
- The difference in **working methods** between the ACC may have had an impact on the assessment of the relevance of each data.

Overall, the qualitative analysis showed that data such as **Wind**, **TOD**, **Altitude associated with the waypoint**, **Expected speeds** seem useful because they could help the controllers to reduce the time spent on the frequency (asking crews for this parameters), to have a better vision of what the aircraft and crew have planned to fly for the current area and those to come, to know the sectors to be avoided, and to know the passage over the waypoints that are not displayed on the radar image (for more details on the impact on the ATCOs tasks' see OBJ-38-W3-DEMOP-HPRF-0002 Results).

Regarding the second criterion to assess this objective, in the questionnaire **one assumption per ADS-C/EPP data** were presented to ATCOs. All hypotheses were extracted from CONOPS. The purpose of presenting them to the ATCOs was to gather their level of agreement/disagreement on which type of task each ADS-C/EPP data could support (Figure 9).

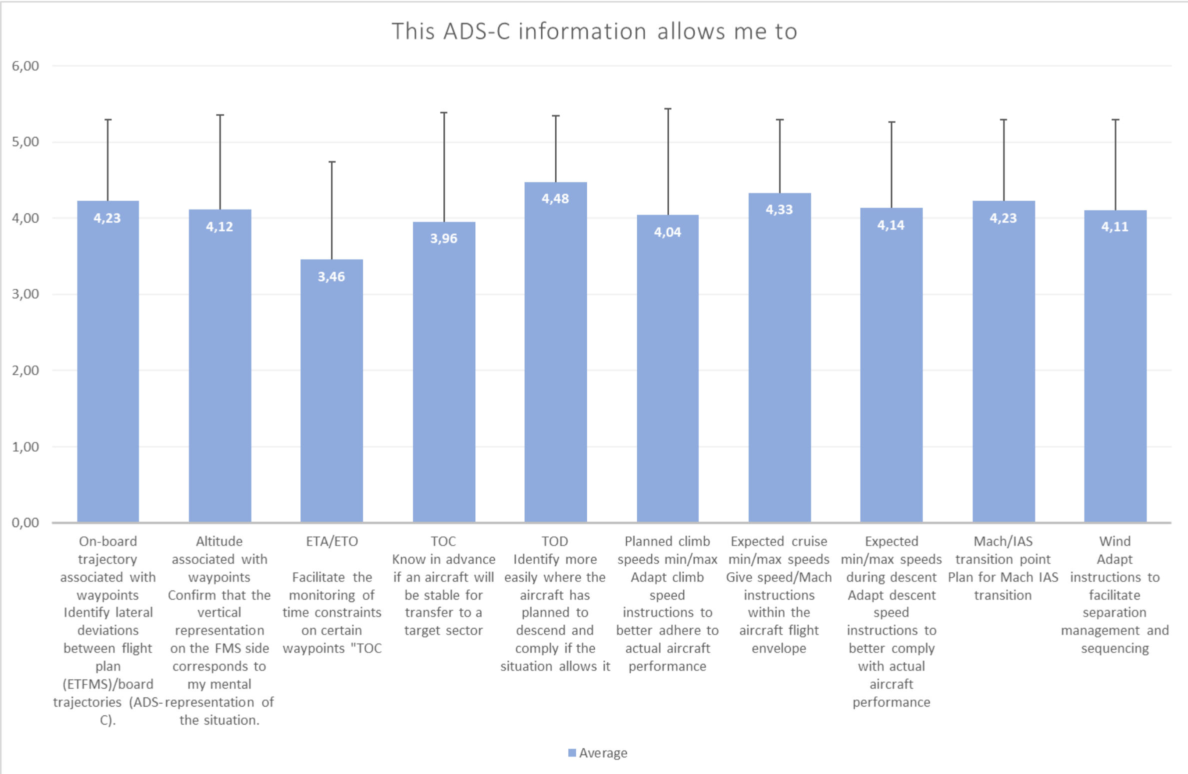


Figure 20 EXE-PJ38-4-2: Agreement/disagreement with the CONOPS assumptions - all ACCs combined.

The analysis of these answers was not easy, on the one hand because of the empty response rate and the low number of questionnaires received, and on the other hand because of the difficulty of the participants to project themselves into a future operational situation (with more aircraft equipped).

Further studies are needed to understand more deeply how the limitations encountered in this exercise may have **impacted the assessment of the operational utility of each ADS-C/EPP data** and whether this changes by center and/or traffic situation to ensure that all operational needs are addressed.

B.3.2.5 EX2-OBJ-38-W3-DEMOP-TECH-0006 Results

This objective aimed to demonstrate that the use of an ADS-C Common Service enables the **access to data**.

The associated criteria (EX1-CRT-38-W3-DEMOP-030 ADS-C periodic, on event contracts are successfully established and maintained by the ADS-C Common Service, and resulting data are received) (EX1-CRT-38-W3-DEMOP-032 Data received via the ADS-C Common Service are reliable) were obtained in a purely **qualitative way in the context of this exercise.** A quantitative assessment of the ADS-C data reliability has been conducted as part of WP3 and the results provided in D3.1 ([28] D3.1 Ed 01.00.00 - PJ38 ADS-C Data Analysis). Indeed, during the exercise, no feedback concerning problems with the connection to the common server was recorded. All ATCOs were able to visualize and use the information displayed on 4Me when needed.

A deviation from the planned activities must be reported for the criterion EX1-CRT-38-W3-DEMOP-031 (ADS-C on demand contracts are correctly passed through the ADS-C Common Service established on client request, and resulting data are received). **No on-demand contracts have been issued** because the ACS did not support on-demand contracts when the exercise platform was developed.

B.3.3 Unexpected Behaviours/Results

Considering the size of the population of ATCOs having potentially access to ADS-C Data during the exercise (around 1200), the number of questionnaires collected is lower than expected

B.3.4 Confidence in the Demonstration Results

B.3.4.1 Level of significance/limitations of Demonstration Exercise Results

As anticipated in the DEMOPLAN, the significance level of the exercise was **negatively impacted** by the low rate of logged on aircraft. The limitations and their consequences for the **quality** and **significance** of the exercise are presented in the following sections.

B.3.4.2 Quality of Demonstration Exercise Results

The quality of the results of the DSNA second exercise is considered **acceptable** and allowed for an acceptable assessment of the HP-related objectives given the maturity of the solution and the limitations of the activity.

The following **limitation** impacted the **quality** of the results:

- EXE-PJ38-4-2-Limitation001: A **very small number of aircraft were equipped and logged on**, especially at the beginning of the exercise. This limitation had an impact on the use of the ADS-C/EPP data on 4Me.

B.3.4.3 Significance of Demonstration Exercises Results

The significance of the results of the DSNA first exercise is considered **low**.

The following **limitations** impacted the **significance** of the results:

- EXE-PJ38-4-2-Limitation002: A **non-uniform number of questionnaires** per ACC was collected and used for the analysis. This complicated the interpretation of the results for the descriptive analysis and **impacted the significance of the results** obtained.

- EXE-PJ38-4-2-Limitation003: As the exercise took place in the control room and during the daily activity, it was not possible to **control the operational situations** (number of flights and complexity of traffic, workload level, etc.) seen by the ATCOs. Therefore, the appreciation of the usefulness of the ADS-C/EPP data (of the same data), can vary a lot from one participant to another according to the operational case encountered. Moreover, it was **not possible** to assess the use of the ADS-C/EPP data during **non-nominal operational situations**.

- EXE-PJ38-4-2-Limitation004: The number and location of the 4Me screen varied between the 4 ACCs. There could be **one display for both ATCOs in the middle** or **one display per ATCO at the edges of the radar display**. This difference could have impacted the **usability** of 4Me and more specifically the accessibility of the ADS-C/EPP data on the MAP page

- EXE-PJ38-4-2-Limitation005: With the format of the Exercise (continuous display of ADS-C Data during live operations on a 2-month period) it was difficult to organize debriefings ("face to face") that would have allowed **further investigation** of the rating of the answer scales.

B.4 Conclusions

The **technical feasibility** of using and integrate the ADS-C/EPP Data of revenue Flights to improve vertical profile on arrival and departure from main surrounding airports **has been assessed in the exercise**.

Based on the exercise results, the **ADS-C/EPP data has the potential to improve** the ATC service provision on selected CWP. Nonetheless, in order for the ATC to take a better advantage of the ToD information, improvements are still needed to reduce current limitations resulting in vertical discrepancies between the FMS FPLN and the ground FPL, when known LOA apply (although published in RAD and thus known by the Airspace Users). Discrepancies were also observed between EPP ToC and actually flown cruise FL, in cases when the FMS CRZ FL was not updated in climb following last minute changes.

Overall, the **display** of ADS-C/EPP data on the 4Me tool was **appreciated**. Even though the utilization rate of **4Me** was lower than expected, this exercise helped to **identify the added-value of ADS-C/EPP data for reducing communication time** (ATCO/pilot), **enhance mental model** of the air traffic situation and provide a **better service to airspace users**.

However, considering the limitations of the exercise, this operational improvement would need to be further validated **especially in order to assess in more detail the benefits of each piece of data** on the activity of ATCOs.

B.5 Recommendations

B.5.1 Recommendations for industrialization and deployment

- **EXE-PJ38-4-2-REC001**: **Further studies are needed** to understand more deeply how the limitations encountered in the exercise may have **impacted the assessment of the operational utility of each ADS-C/EPP data** and whether this changes by ACC and/or traffic situation in order to ensure that all operational needs/issues are addressed.

- **EXE-PJ38-4-2-REC002**: If in the future these data will be integrated on the radar screen (as wished by a part of the participants), **further studies will be necessary to decide when and how to display the ADS-C/EPP data while preserving the ATCOs' performance**.

- **EXE-PJ38-4-2-REC003**: If ADS-C information is integrated into the **CWP radar display**, the **safety impact** should be assessed in order to ensure that **airspace safety is not degraded**.

- **EXE-PJ38-4-2-REC004**: in the deployment phase, foresee sufficient time to train controllers on ADS-C data characteristics to allow a better understanding of the information downlinked via ADS-C and its limitations. In particular, consider limitations concerning altitude constraints on waypoints in cruise, which may result in vertical discrepancies between FMS FPLN and ground FPL.

- **EXE-PJ38-4-2-REC005**: consider the cases when CRZ FL is not updated in climb despite the actual cruise FL being different due to tactical changes (either due to ATC or due to flight crew decision), and find solutions, possibly thanks to procedures and training.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

- **EXE-PJ38-4-2-REC006**: further studies are needed to find ways to better align the FMS FPLN and the ground FPL in case of vertical constraints on waypoints in cruise resulting from known LOA (published in RAD, and integrated in the AOC FPLN, but not considered by the FMS FPLN).

In order to better assess the operational impact of using the ADS-C/EPP data by ATCOs, **the number of equipped and logged on aircraft has to be increased**:

- **EXE-PJ38-4-2-REC007**: Encourage, beyond the CP1-AF6.1.3 requirement, the airlines to equip the aircraft with the ATS B2 capability to optimise the benefits of the use of ADS-C/EPP data.

- **EXE-PJ38-4-2-REC008**: Generalize the use of the Auto logon functionality for all the ATS B2 equipped aircraft to optimise the benefits of the use of ADS-C/EPP data.

B.5.2 Recommendations on regulation and standardisation initiatives

- **EXE-PJ38-4-2-REC006**: The availability and the use of an ADS-C Common Service should be promoted and recognized as a means of compliance to the AF6 CP1 as the PJ38 has demonstrated the benefits of the use ADS-C Common service by ANSPs.

Appendix C Demonstration Exercise #03 (EXE-PJ38-4-3 by skyguide) Report

C.1 Summary of the Demonstration Exercise #03 Plan

C.1.1 Exercise description and scope

The scope of the skyguide exercise was to demonstrate the ATM benefits through the use of ADS-C data (EPP – speed schedule) via:

- the management of ADS-C contracts (via the ADS-C Common Service),
- the collection of ADS-C EPP downlinked data,
- the benefit of using ADS-C data (Speed schedule & EPP) in the Trajectory Prediction tool and in the Conflict Detection & Resolution tools,
- the benefits of improved trajectory display and management (with Speed schedule and EPP) for ATCO situation awareness, predictability, safety, flight efficiency,
- the benefit of improved trajectory management (with Speed schedule and EPP) for 2D and 3D conformance check in term of safety and predictability,
- the relevance of the validation results of the Solutions PJ18-W2.53B and PJ18-W2.56.

The following cases of EPP data usage will be addressed:

- Trajectory Information display,
- A/G Discrepancy Monitoring / 2D-3D conformance Check,
- Ground Trajectory enhancements and Conflict Detection & Resolution tools enhancements,
- Complex / in advance clearances (solution PJ18-W2.56 cases with real flights data (ADS-C EPP equipped)).

In order to measure the benefits of using real ADS-C EPP data and to conduct the demonstration exercises, in addition to systems and software, Skyguide has used two validation platforms:

- A fast time validation platform developed within W3 PJ38 framework to replay ADSCENCIO flights that have crossed skyguide's airspace. The replay of these flights on this platform allowed to obtain the data of the New Trajectory Prediction using EPP data (developed in Solution PJ18-W2.53B), which is currently not implemented in the operational room. In order to ensure the quality of the data, it has been obviously necessary to integrate and synchronize the ADS-C EPP reports and ATC clearances issued in live.

- A real time validation platform (skytics simulation platform) developed within the PJ18-W2 framework (integrating Solutions PJ18-W2.53B and PJ18-W2.56 solutions tools) was used to allow controllers to verify that the operational benefits demonstrated in PJ18-W2 on the basis of simulated ADS-C EPP data are confirmed with the use of real data collected in live conditions (i.e. re-injected in the real time validation platform).

The ADS-C EPP data used in PJ18-W2 were of very high quality thanks to the use of Genetics Traffic generator (developed by Airbus Defense and Space), which integrates algorithms, performance models and communication protocols similar to real aircraft. This high quality of simulated data facilitated the comparison with real data. By demonstrating in W3 PJ38 that real ADS-C EPP data are of similar quality to the simulated data, it has been possible to confirm the usefulness of the ADS-C EPP implementation as well as qualitative and quantitative operational benefits measured in PJ18-W2 framework (Operational acceptability, HP, CAP, SAF, FEFF, PRED), linked to Solutions PJ18-W2.53B and PJ18-W2.56 new tools implementation.

The EXE3-PJ38-4-3 was based on replay of PJ38 flights (ADS-C equipped aircraft) that flew in the skyguide controlled airspace. To do so, all operational data and technical data from the operational system have been recorded for the period January 2022 - November 2022. Also the ADS-C EPP data from these flights have been retrieved from the EUROCONTROL EPP reports storage.

The fast time validation platform has been used to replay the concerned flights with the associated ADS-C EPP reports with the objective to compute the ground trajectory of concerned flights with the new Trajectory Predictor developed for SESAR 2020 Wave 2 PJ18 with the aim to assess the Trajectory Prediction computation using ADS-C EPP data in comparison with the legacy Trajectory Predictor (not using ADS-C EPP data).

Another objective was to assess the use of "real" ADS-C EPP data for the computation performed by the Conflict Detection tools in particular in improving the detection envelope with aircraft performance data.

The real time validation platform (skytics simulation platform) has been used for demonstration to operational staff during specific demonstration sessions.

It concentrated on the En-route part of the flights (Geneva and Zurich En-route ACCs):

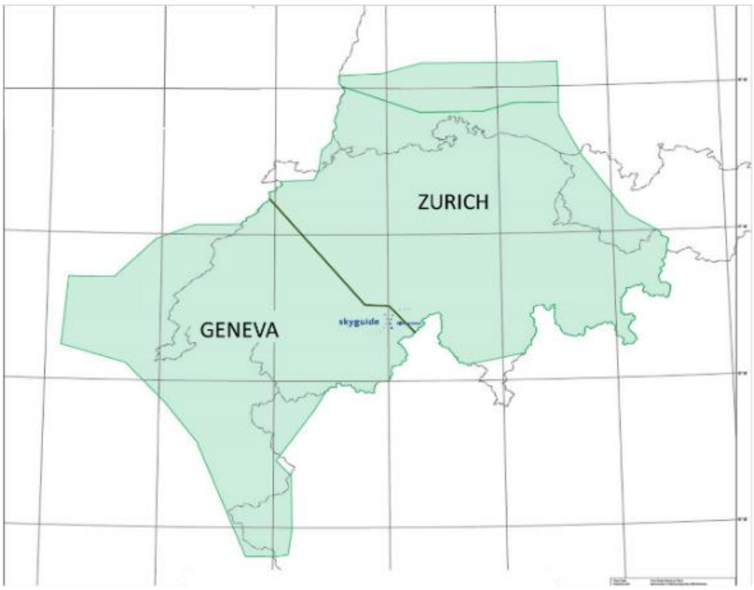


Figure 21: EXE-PJ38-4-3 - skyguide controlled airspace

In term of demonstration to ATCO community, ATCO assessment on the ADS-C EPP has been also performed by presenting:

- Specific use cases have been set-up using some selected ADSCENSIO flights in order to show/demonstrate:
  - the display of EPP trajectory to compare with the ground Trajectory and the potential benefit of route conformance check with the availability of EPP data
  - the use of ADS-C EPP capabilities to enhance clearances capabilities
- Specific scenarios demonstration (based on solution 18-53B and 18-56)

The following paragraphs describe how the airborne data (ADS-C EPP reports) is used in the Trajectory Predictor (legacy v/s new TP) and in CD&R tools.

Legacy vs Skysoft-ATM Trajectory Predictor (New TP)

The following table details the differences between the legacy route prediction and the new trajectory management system developed for the exercise:

	Legacy TP	**Skysoft-ATM TP**
BADA version	3.12	3.12
Performance database	tables	Total energy model parameters
output	Time-Over/Level on waypoints Insertion of TOC TOD	Forecast of Position/level/speed/mass every 4s along the trajectory
Mass injection	NO	YES
Fuel consumption	NO	YES
Speed schedule injection	NO	YES (climb, cruise, decent)
Calibration	NO	YES
Catchup manoeuvre	NO	YES (1000 ft/min, 2*VS)
Cross over injection	NO	YES
Turn	NO	YES (flyby + radius, overfly)
Weather	Static Wind across level	Wind grid modelling through whole airspace and time

Figure 22: EXE-PJ38-4-3 – Comparison Legacy vs Skysoft-ATM Trajectory Predictor

ADS-C equipped aircraft - Calibration

The calibration algorithm is composed of two computation steps triggered by different events:

- On EPP update: Extraction of aircraft performance and Computation of calibration parameter applied to BADA performance to match aircraft performance
- On track or FPL update: Application of calibration parameter on what if or on Medium term and Tactical Conflict Detection Tools trajectory computation

The performance parameter depends on the evolution phase of the flight.

Climb phase

On climb phase, the calibration parameter is a ratio of gross mass.

- Consideration of TOC part of trajectory or SOC (Start Of Climb) to EOC (End Of Climb) part.
- If there is no climb phase in the EPP the calibration is performed based on initial EPP received after takes-off (thanks to ADS-C Common Service contract).
- Extraction of Time to perform the climb to TOC or EOC on the IAS/MACH stable part of the climb.
- Reproduction of the extracted climb part of the route using Skysoft-ATM TP.
- Variation of mass calibration parameter to match aircraft performance.
- If successful, climb calibration is performed and will be used.
- If not successful use non-ADS-C equipped algorithm.

Descent phase

On descent phase, the calibration parameter is an aerodynamic coefficient.

EUROPEAN PARTNERSHIP
Co-funded by the European Union

- Consideration of TOD part of trajectory or SOD (Start Of Descent) to EOC (End Of Descent) part.
- If there is no descent phase the calibration is not possible, keep the previous one or use non-ADS-C equipped aircraft algorithm.
- Extraction of Time to perform the descent from TOD or SOD on the IAS/MACH stable part of the descend.
- Reproduction of the extracted descent part of the route using Skysoft-ATM TP.
- Variation of aerodynamic coefficient parameter to match aircraft performance.
- If successful, descent calibration is performed and will be used.
- If not successful use non-ADS-C equipped aircraft algorithm.

Conflict Detection & Resolution tools:

The following paragraph details how the detection envelope for conflict is computed depending on availability of ADS-C EPP and speed schedule data or not.

Conflict envelopes computation

Conflicts in climb and descent manoeuvres are calculated by means of envelopes that represent the best and the worst case of aircraft performances during the manoeuvre. Intersection of envelopes or levelled trajectories of flights generate a conflict alert. The figures below explain the differences between envelope computation for non-ADS-C equipped flights and for ADS-C EPP equipped flights).

non-ADS-C equipped vs ADS-C equipped aircraft - climb envelope computation

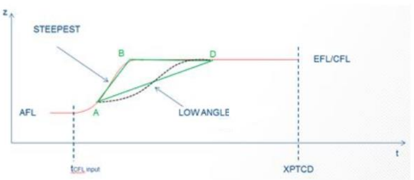
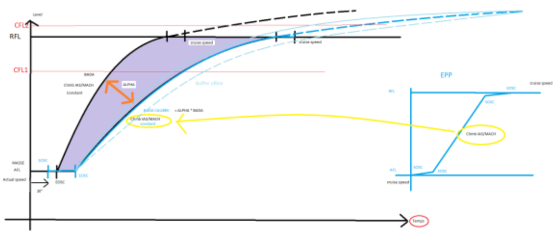
	Non ADS-C equipped aircraft	**Using ADS-C EPP reports**
TP	legacy	Skysoft-ATM
Steepest	4500 ft/min	BADA and BADA calibrated with climb phase EPP (TOC-SOC EOC)
Less Steep	500 ft/min	
		

Figure 23: EXE-PJ38-4-3 – *Climb envelope computation*

non ADS-C equipped vs ADS-C equipped aircraft - descent envelope computation

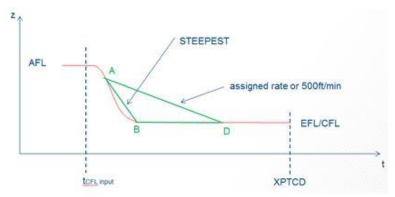
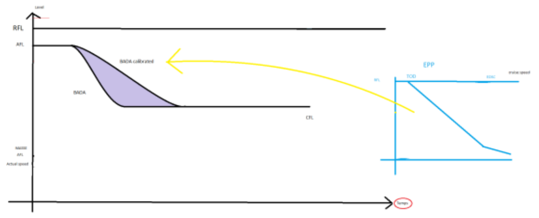
	Non ADS-C equipped aircraft	Using ADS-C EPP reports
TP	legacy	Skysoft-ATM
Steepest	4500 ft/min	BADA and BADA calibrated with descent phase EPP (TOD-SOD EOD)
Less Steep	500 ft/min	
		

Figure 24: EXE-PJ38-4-3 – *Descent envelope computation*

C.1.2 Summary of Demonstration Exercise #03 Demonstration Objectives and success criteria

The following domains have been addressed in order to map with the EXE-PJ38-4-3 Demonstration objectives and success criteria.

- **Safety improvement** (OBJ-38-W3-DEMOP-SAFE-0001): ADS-C data contribute to improve Safety. Checking that there is a reduction of the number of potential infringements, or an earlier resolution.
- **Human Performance improvement** (OBJ-38-W3-DEMOP-HPRF-0002): Demonstrate that the ADS-C changes performed improves the Human Performance compared to current operations. This has been assessed taking into account the results and feedbacks from Solutions PJ18-W2.53B and PJ18-W2.56.
- **Operational Performance improvement** (EX4-OBJ-38-W3-DEMOP-OPRF-0003): Demonstrate that the ADS-C changes performed improves the Operational Performance compared to current operations. This has been assessed taking into account the results and feedbacks from Solutions PJ18-W2.53B and PJ18-W2.56.
- **Operational feasibility** (OBJ-38-W3-DEMOP-OPSF-0004): Demonstrate that the use of ADS-C data is operationally feasible.
- **Access to ADS-C data** (OBJ-38-W3-DEMOP-TECH-0006): Demonstrate that the use of an ADS-C Common Service improves the access to data assessing that the data received via the ADS-C Common service is reliable and it is correctly received.

In addition several KPIs addressing the reliability of the ADS-C EPP data based on all ADSCENSIO flights that crossed Skyguide controlled airspace have been measured:

- **Comparison of EPP waypoint names to FDP route points**
- **EPP stability and precision:**

  - stability of predictions over time, e.g. ETO trends and drifts,
  - altitude trends and drifts

- **Speed schedule variability:**
  - Speed schedule variation during progress of flights
- **TOC and TOD variability:**
  - TOC/TOD Fluctuation in relation with ATC instructions
- **FMS Modes:**
  - usage also in relation to flight phase / flight level, flight situation:
  - Flight modes as % of flight duration aggregated at traffic sample level
- **Comparison/Consistency of EPP prediction with Legacy TP:**
  - Lateral consistency between ADS-C EPP and legacy TP (taking into account ATC clearances).
  - Time accuracy
- **Comparison/Consistency of EPP prediction with New TP:**
  - Lateral consistency between ADS-C EPP and New TP (taking into account ATC clearances).
  - Time accuracy
  - Vertical prediction accuracy
  - Speed accuracy (IAS)
- **Comparison/Consistency of EPP prediction with real flown trajectory:**
  - Lateral consistency (number of points appearing in the EPP that are "really" flown) aggregated at traffic sample level.

Demonstration Objective (as in section 3.3.4)	Demonstration Success criteria (as in section 3.3.4)	Coverage and comments on the coverage of Demonstration objectives (as in section 3.3.4)	Demonstration Exercise #03 Objectives	Demonstration Exercise #03 Success criteria
OBJ-38-W3-DEMOP-SAFE-0001	CRT-38-W3-DEMOP-002	Fully covered	EX3-OBJ-38-W3-DEMOP-SAFE-0001	EX3-CRT-38-W3-DEMOP-002 The envelope detection taking in to account ADS-C data improves CD&R and is

Demonstration Objective (as in section 3.3.4)	Demonstration Success criteria (as in section 3.3.4)	Coverage and comments on the coverage of Demonstration objectives (as in section 3.3.4)	Demonstration Exercise #03 Objectives	Demonstration Exercise #03 Success criteria
				considered safe for service provision according to the ATCOs. (supported by PJ18-W2.53B and PJ18-W2.56 validation results)
OBJ-38-W3-DEMOP-HPRF-0002	CRT-38-W3-DEMOP-005	Fully covered	EX3-OBJ-38-W3-DEMOP-HPRF-0002	EX3-CRT-38-W3-DEMOP-005 The enhanced TP and enhanced CDTs envelope detection has a positive impact on ATCO situation awareness. (supported by PJ18-W2.53B and PJ18-W2.56 validation results)
OBJ-38-W3-DEMOP-HPRF-0002	CRT-38-W3-DEMOP-012	Fully covered	EX3-OBJ-38-W3-DEMOP-HPRF-0002	EX3-CRT-38-W3-DEMOP-012 Thanks to ADS-C EPP and Speed schedule, less spurious conflicts are detected. Accuracy of conflict Detection is improved Validation results from PJ18-W2.53B and PJ18-W2.56 (HP) are confirmed by ATCOs
OBJ-38-W3-DEMOP-HPRF-0002	CRT-38-W3-DEMOP-013	Partially covered	EX3-OBJ-38-W3-DEMOP-HPRF-0002	EX3-CRT-38-W3-DEMOP-013

Demonstration Objective (as in section 3.3.4)	Demonstration Success criteria (as in section 3.3.4)	Coverage and comments on the coverage of Demonstration objectives (as in section 3.3.4)	Demonstration Exercise #03 Objectives	Demonstration Exercise #03 Success criteria
		ADS-C data will be used in replay mode		Thanks to ADS-C EPP 2D route conformance check is improved Validation results from PJ18-W2.53B and PJ18-W2.56 (HP) are confirmed by ATCOs
OBJ-38-W3-DEMOP-OPRF-0003	CRT-38-W3-DEMOP-015	Fully covered	EX3-OBJ-38-W3-DEMOP-OPRF-0003	EX3-CRT-38-W3-DEMOP-015 The adherence to on board expected vertical trajectories is enhanced thanks to the use (e.g. display) of TOD information.
OBJ-38-W3-DEMOP-OPRF-0003	CRT-38-W3-DEMOP-016	Partially covered ADS-C data will be used in replay mode	EX3-OBJ-38-W3-DEMOP-OPRF-0003	EX3-CRT-38-W3-DEMOP-016 The number of trajectory revisions is reduced thanks to the reduction of spurious detection of conflicts. (supported by PJ18-W2.53B and PJ18-W2.56 validation results)
OBJ-38-W3-DEMOP-OPRF-0003	CRT-38-W3-DEMOP-017	Not covered	EX3-OBJ-38-W3-DEMOP-OPRF-0003	EX3-CRT-38-W3-DEMOP-017 Validation results in term of performance from PJ18-W2.53B and

Demonstration Objective (as in section 3.3.4)	Demonstration Success criteria (as in section 3.3.4)	Coverage and comments on the coverage of Demonstration objectives (as in section 3.3.4)	Demonstration Exercise #03 Objectives	Demonstration Exercise #03 Success criteria
				PJ18-W2.56 (PERF) are confirmed for PJ38 flights
OBJ-38-W3-DEMOP-OPRF-0003	CRT-38-W3-DEMOP-018	Partially covered ADS-C data will be used in replay mode. This will allow to confirm of the validation results from PJ18-W2.53B and PJ18-W2.56	EX3-OBJ-38-W3-DEMOP-OPRF-0003	EX3-CRT-38-W3-DEMOP-018 Potential reduction of number of conflicts detected thanks to improved CD&R tool (envelope detection taking into account ADS-C data)
OBJ-38-W3-DEMOP-OPRF-0003	CRT-38-W3-DEMOP-020	Fully covered	EX3-OBJ-38-W3-DEMOP-OPRF-0003	EX3-CRT-38-W3-DEMOP-020 The display of EPP trajectory for 2D consistency check is considered useful
OBJ-38-W3-DEMOP-OPSF-0004	CRT-38-W3-DEMOP-023	Fully covered	EX3-OBJ-38-W3-DEMOP-OPSF-0004	EX3-CRT-38-W3-DEMOP-023 Positive feedback from the ATCOs on the usability of the ADS-C data for display of EPP and TOD (linked to PJ18-W2.56)
OBJ-38-W3-DEMOP-OPSF-0004	CRT-38-W3-DEMOP-026	Partially covered ADS-C data will be used in replay mode. This will allow to confirm of the validation results from PJ18-	EX3-OBJ-38-W3-DEMOP-OPSF-0004	EX3-CRT-38-W3-DEMOP-026 The 2D consistency check information and display with ADS-C data is

Demonstration Objective (as in section 3.3.4)	Demonstration Success criteria (as in section 3.3.4)	Coverage and comments on the coverage of Demonstration objectives (as in section 3.3.4)	Demonstration Exercise #03 Objectives	Demonstration Exercise #03 Success criteria
		W2.53B and PJ18-W2.56		acceptable for the ATCOs. (supported by PJ18-W2.53B and PJ18-W2.56 validation results)
OBJ-38-W3-DEMOP-TECH-0006	CRT-38-W3-DEMOP-032	Fully covered	EX3-OBJ-38-W3-DEMOP-TECH-0006	EX3-CRT-38-W3-DEMOP-032 Will be checked against data received from EUROCONTROL
OBJ-38-W3-DEMOP-TECH-0006	CRT-38-W3-DEMOP-033	Fully covered	EX3-OBJ-38-W3-DEMOP-TECH-0006	EX3-CRT-38-W3-DEMOP-033 Check that ADS Common Server data can substitute EUROCONTROL received data

Figure 25: EXE-PJ38-4-3 – Demonstration Objectives applicable to EXE-PJ38-4-3

C.1.3 Summary of Validation Exercise #03 Demonstration scenarios

The demonstration scenario was based on ADSCENSIO flights equipped with ADS-C EPP downlink capabilities and providing EPP reports (periodic, on contract).

All following data have been recorded over a period from January 2022 until November 2022:

- Flight Plan data (transmitted from NM)
- ADS-C EPP data of equipped flight with trajectories impacting skyguide controlled airspace
- Radar tracks
- ATM system data:
    - Trajectory Predictor (legacy TP)
    - Conflicts Detection output
    - Clearances

Co-funded by the European Union

Reference Scenario

The reference scenario is presented by the set of ADS-C equipped flights that flew through skyguide controlled airspace during the trial period and the system data (operational & technical) recorded for these flights. Therefore, it represents the flown trajectories and the system output data from the current operational system. No use of ADS-C EPP in the operational system.

Solution Scenario

The solution scenario is similar to the Reference scenario but with the use of ADS-C data (Speed schedule and EPP) from ADSCENSIO flights with ADS_C capabilities. Solution scenario have been performed on the specific platform with the new Trajectory Predictor taking into account ADS-C EPP and speed schedule reports data and also controller inputs related to revenue flights equipped with ADS-C.

Specific ADSCENCIO flights have been replayed on the specific platform in order to assess the reliability of the ADS-C EPP data and the new Trajectory Prediction tool as well as the impact on Conflict Detection with the use of ADS-C EPP data.

In addition, as the ADS-C EPP data were not used in real-time in the operational system, KPIs are based on validation results from the Solutions PJ18-W2.53B and PJ18-W2.56 exercises runs. As explained in the ***SESAR Solution 53B VALR – V00.01.00*** and ***SESAR Solution 56 VALR – V00.01.00*** the use of the Genetics traffic generator (from Airbus Defence & Space) based on FMS trajectory computation algorithm and logics offer highly reliable aircraft behaviour and is considered reliable to draw usable results.

C.1.4 Summary of Demonstration Exercise #03 Demonstration Assumptions

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
PJ38-ASS-01	ADS-C data provision		The ADS-C Common Service (ACS) is available with appropriate functionalities (including TOA Range demand contracts) and performances	Pre-requisite to be able to carry out ANSP validation exercises	High

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
PJ38-ASS-02	ADS-C data provision		The received ADS-C data are usable (available on time, not corrupted, etc.)	Pre-requisite to be able to use ADS-C data. The same avionics as in PJ31 will be used. The ACS must ensure that the received data are correctly conveyed to the ANSPs	High
PJ38-ASS-03	VDL2 performances		VDL2 performances support an efficient downlink of ADS-C data	Pre-requisite to be able to downlink the ADS-C data	High
PJ38-ASS-04	Future Covid situation		Future Covid situation will not affect the organisation of the exercises (e.g. travel restrictions)	It is anticipated that the future Covid situation will not be as bad as it was in 2020 and early 2021	High

Figure 26: EXE-PJ38-4-3 – Demonstration Assumptions overview

C.2 Deviation from the planned activities

Due to the amount of data to be treated for the Conflict Detection & Resolution tools analysis, it has been necessary to develop a specific Fast time simulation & replay platform.

As this platform differs from the operational system platform, it would have been necessary to develop additional tools able to interface between CD&R tools and the new Trajectory Predictor. In particular, the new Trajectory Predictor is modular and is developed using recent languages, while the CD&R tools are developed with older languages which makes their integration much more difficult and complex, and hardly feasible in the time available.

Even if technically feasible, the heavy workload needed and the availability of experts developers for this specific development could not be ensured within the timeframe of the project.

Also some data from the Legacy Trajectory Predictor, in particular for the vertical mode computation could not be extracted from the recording, therefore the vertical accuracy (Level error) could not be analysed for comparison with new Trajectory Predictor.

Therefore, as in parallel, the validation platform (skytics) used for validations has been enriched with the new Trajectory Predictor and new CD&R tools detection envelope, the results from validations on CD&T tools using ADS-C EPP and speed schedule data have been used to assess the Conflict Detection & Resolution tools for ADS-C equipped flights.

C.3 Demonstration Exercise #03 Results

In order to assess the results of the Demonstration Exercise #03 it is necessary to detail how the ADS-C EPP and speed schedule have been used in the ground system and in particular in the Trajectory Predictor process and in the CD&R tools process.

First hereafter is the list and brief description of the ***Conflicts detection & Resolution tools (CD&R tools)*** used in the skyguide operational system and improvements with the introduction of ADS-C EPP and speed schedule data and their use in the CD&R tools process.

Four tools are used to detect potential loss of separation:

- **Conflict Detection Tools:**
  - **Medium term and Tactical Conflict Detection Tools**: allow medium term and tactical conflict detection and provides continuous monitoring of conflicts and encounters, supporting the ATCOs in detecting the conflict and solving them. These tools provide conflict data display (e.g. time remaining before separation minima infringement start, expected minimum separation distance, etc.), a graphical display of conflict geometry and coordination functions between EC and PC ATCOs. Detection envelope has been improved thanks to the more accurate Trajectory Prediction and more accurate aircraft behaviour data received via datalink.

    These tools are permanently activated and refreshed at:
    - Each radar track update (4 sec),
    - Each clearance or coordination made,

  - **Cross-border Exit Conditions Analysis Tool:** allows to detect potential conflicts at AoR exit and potential infringement of agreed exit conditions defined in the Letters of Agreement (LOAs). This tool is adapted to FRA and allows to detect problems without any reference to Coordination Points in Exit; however the tool did use not EPP data, this will be addressed in SESAR 3.

  - The **"What if?" tool**: On any aircraft, it is possible to see what potential conflict the action (flight level, speed, heading, waypoints …) will create. It supports planning and tactical actions assessment. Multiple clearances analysis is possible (e.g. route + level changes). It takes benefit of EPP data.

  - **Conflict Detection for Descent When Ready on XPT (System Proposal):** when the aircraft is expected to descend towards destination, the system analyses the predicted trajectory

 Co-funded by the European Union

and the TOD and check if the predicted trajectory is free of conflict, then coordination actions with lower sectors (if required) as well as the DWR clearance proposals to the currently controlling sector are automatically performed by the system . The skip action (lower sectors, if appropriate) and clearance acceptation (currently controlling sector) are manually performed by the ATCOs. manually performed by the ATCO.

The following table details the different CD&R tools (their scope, triggers…)

	Medium Term Conflict Alert	Long Term Conflict Alert	What-if	Cross-border Exit Conditions Analysis Tool
Scope	All airspace	Computed for each opened sector	Only on under-control sector or requested sector	All airspace
Visibility criteria	At least One aircraft Assumed in sector	in the level range of the sector	in the level range of the sector	At least One aircraft Assumed in sector
Trigger	Track update Tactical change FPL change	Track update Tactical change FPL change	Before validation of clearance On coordination or datalink order transmission	Track update Tactical change FPL change
Target level	CFL	CPDLC level coordinated level CFL if assumed EFL (Entry Flight Level) if not	CFL or requested level or coordinated level	XFL
Route	Tactical	CPDLC route Coordinated route Tactical route	CPDLC route Coordinated or requested route Tactical route	Exit Point
Separation	5 NM	7.5 10 15 nm defined by ATCO	for clearances: 5 NM 2 min 30s	According to LOAs

Co-funded by the European Union

	Medium Term Conflict Alert	Long Term Conflict Alert	What-if	Cross-border Exit Conditions Analysis Tool
	2 min 30s	20 min+	for coordination: 7.5 10 15 nm defined by ATCO 20 min+	
Vertical	1000 feet / 2000 feet for non RVSM in RVSM area			
Reference algorithm	Loss of separation between legacy TP segments and non-ADS-C equipped aircraft envelope			
Solution algorithm	Loss of separation between: Non-ADS-C equipped aircraft: legacy segments and non-ADS-C equipped aircraft envelope extrapolated to samples of 4s. ATS-B2 equipped aircraft: Skysoft TP samples and ATS-B2 equipped envelope.			

Figure 27: EXE-PJ38-4-3 – CD&R tools conditions and objectives

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Conflict Detection & Resolution tools have been upgraded with new detection envelopes computation using aircraft performance from ADS-C EPP reports (refer to ***Conflict envelopes computation***).

In prerequisite to the CD&R tools improvement, the ADS-C EPP and speed schedule are used in the ***Trajectory Predictor process*** and for ***Trajectory Management***

A new **Trajectory Predictor** has been developed to take into account ADS-C EPP data received from equipped aircraft

A major improvement is the display of ADS-C EPP trajectory and the display of predicted trajectory with points every 4 seconds and no more based on segment. This permits ATCOs to have a more precise view of the predicted trajectory and therefore to better optimize conflicts resolution when appropriate. Thanks to ADS-C EPP data, the ATCOs were provided with visualization of the aircraft intent/performance (e.g. TOC/TOD, turns, speed…). The FMS mode (Managed, Selected, Manual) has an impact on the accuracy of the EPP downlinked data. Therefore, the calibration process needs to be adapted taking into account the FMS mode.

Taking into account ADS-C EPP data permits to display the right type of turns in trajectory (Fly By or Fly Over).

The Trajectory editor provides several capabilities:

- Display of the initial trajectory (initial planned RBT/RMT when the currently flown trajectory is a revised one i.e. open or close the loop clearance in progress)
- Display of the planned trajectory (taking into account tactical clearances given) with better accuracy thanks to TP taking into account ADS-C EPP data
- Display of EPP trajectory
- Manual Graphic design of trajectory revisions (using the mouse)
- What-if function on trajectory revisions
- Implementation of the trajectory revisions

For details of Trajectory Predictor improvements refer to ***Legacy vs Skysoft-ATM Trajectory Predictor*** in C.1.1.

C.3.1 Summary of Demonstration Exercise #03 Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-38-W3-DEMOP-SAFE-0001	Safety improvement	EX3-CRT-38-W3-DEMOP-002				
		EX3-CRT-38-W3-DEMOP-005				

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
		EX3-CRT-38-W3-DEMOP-012			Results have shown that t	
		EX3-CRT-38-W3-DEMOP-013	Thanks to ADS-C EPP 2D route conformance check is improved. Validation results from PJ18-W2.53B and PJ18-W2.56 (HP) are confirmed by ATCOs		Results from PJ18-W2.53B and PJ18-W2.56 (HP) validations are confirmed by ATCOs. 2D route conformance is improved thanks to ADS-C EPP	OK
OBJ-38-W3-DEMOP-OPRF-0003	Operational performance improvement	EX3-CRT-38-W3-DEMOP-015	The adherence to on board expected vertical trajectories is enhanced thanks to the use (e.g. display) of TOD information.		The information on vertical profile is an important asset of the ADS-C EPP and thanks to improved vertical trajectory computation by the ground system ensure a better adherence to the expected vertical trajectories	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
		EX3-CRT-38-W3-DEMOP-016	The number of trajectory revisions is reduced thanks to the reduction of spurious detection of conflicts. (supported by PJ18-W2.53B and PJ18-W2.56 validation results)		It has been demonstrated that there were less spurious detection of conflicts but impact on trajectory revision may not necessarily be reduced	POK
		EX3-CRT-38-W3-DEMOP-017	Validation results in term of performance from PJ18-W2.53B and PJ18-W2.56 (PERF) are confirmed for PJ38 flights		could not be assessed as the ADSCENSIO flights were controlled as any other flights, not taking into account any ADS-C EPP data, neither new Trajectory Prediction or CD&R tools with new detection envelope calculation	Not Covered
		EX3-CRT-38-W3-DEMOP-018	Potential reduction of number of conflicts detected		Number of conflicts detected thanks to improved	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
			thanks to improved CD&R tool (envelope detection taking into account ADS-C data)		CD&R tool (envelope detection taking into account ADS-C data) is reduced (from PJ18-W2.53B)	
		EX3-CRT-38-W3-DEMOP-020	The display of EPP trajectory for 2D consistency check is considered useful		ATCOs highlighted the usefulness of the visualisation of discrepancy between the ground trajectory and the FMS (EPP) trajectory downlinked	OK
OBJ-38-W3-DEMOP-OPSF-0004	Operational feasibility	EX3- CRT-38-W3-DEMOP-023	Positive feedback from the ATCOs on the usability of the ADS-C data for display of EPP and TOD (linked to PJ18-W2.56)		ATCOs were very positive about the foreseen awareness situation thanks to the display of the EPP trajectory (flight information (TOC, TOD, type of turns etc…).	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
		EX3-CRT-38-W3-DEMOP-026	The 2D consistency check information and display with ADS-C data is acceptable for the ATCOs. (supported by PJ18-W2.53B and PJ18-W2.56 validation results)		The 2D consistency check information and display with ADS-C data is considered acceptable by the ATCOs	OK
OBJ-38-W3-DEMOP-TECH-0006	Access to ADS-C data Data collection improvement	EX3-CRT-38-W3-DEMOP-032	Will be checked against data received from EUROCONTROL		The infrastructure to access to the ADS-C Common Service has been developed, integrated, tested and validated. the reliability of ADS-C EPP has been checked against data received from EUROCONTROL.	OK
		EX3-CRT-38-W3-DEMOP-033	Check that ADS Common Server data can substitute		POK Connection to ADS-C Common Service has successfull	POK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
			EUROCONTROL received data		y been achieved, however ADS-C EPP data have been retrieved from EUROCONTROL	

Figure 28: EXE-PJ38-4-3 – Demonstration Results

The following KPAs were considered: Predictability, Human Performance and Safety. The results from the

Predictability:

This has been assessed in two different ways:

Quantitative (from ADSCENSIO flights):

The ADS-C EPP reports have been retrieved from the EUROCONTROL sharepoint OneSky Teams for all the ADSCENSIO flights that flew through the skyguide controlled airspace. As well all operational data concerning these flights have been recorded from the operational system, which permitted to get the clearances given by the ATCOs, the legacy Trajectory Predictor outputs and the flown tracks (from the radar).

With all these data, several KPIs have been calculated in particular for predictability (refer to C.3.2.5.1 and PJ38-WP4- benefit articulation).

Hereunder, is the number of ADSCENSIO flights that flew in skyguide controlled airspace and the part of these flights that downlinked ADS-C EPP reports.

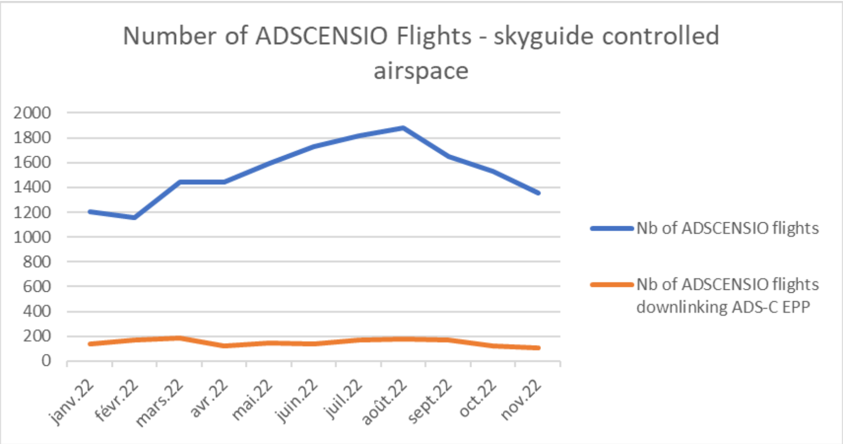


Figure 29: EXE-PJ38-4-3 – Number of ADSCENSIO Flights - skyguide controlled airspace

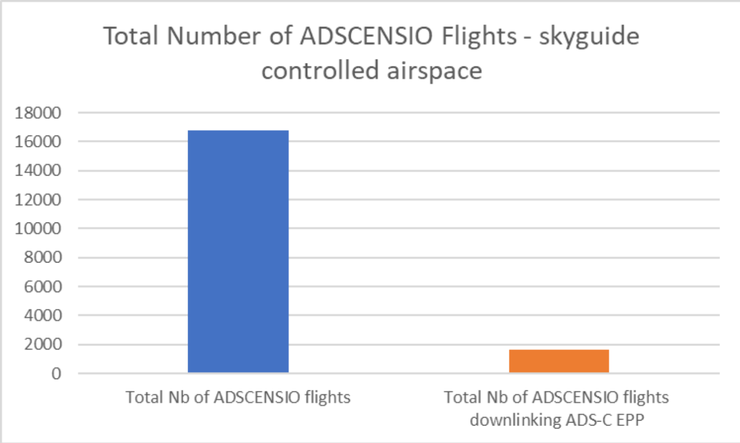


Figure 30: EXE-PJ38-4-3 – Total Number of ADSCENSIO Flights over the period - skyguide controlled airspace

As shown in previous figures, only ~10% of the ADSCENSIO flights that flew in the skyguide controlled airspace were downlinking ADS-C EPPs, therefore the quantitative data have been processed with these flights ADS-C EPPs.

Qualitative (from PJ.38 Ops demonstrations and from :

The impact of the use of ADS-C EPP data for Trajectory Prediction and CD&R Tools and the associated better knowledge of aircraft performance and on Predictability (Figure 23) are considered by ATCOs *very positive*.

As well, the impact of having better knowledge of aircraft performance and intentions and improved CD&R tools on predictabiliy is considered by ATCOs *very positive.*

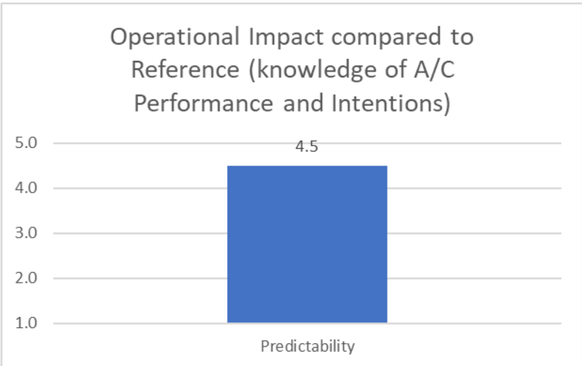


Figure 31: EXE-PJ38-4-3 – Operational impact on predictability

Human Performance:

Refer to C.3.2.4 - EX3-OBJ-38-W3-DEMOP-OPSF-0004 Results**.**

Safety

Refer to C.3.2.1 - EX3-OBJ-38-W3-DEMOP-SAFE-0001 Results

This has been assessed in :

Thanks to ADS-C EPP data used in Trajectory Prediction tool, the knowledge of aircraft performance and intentions is improved and therefore benefit to conflicts detection and resolution.

The impact of CD&R tools using ADS-C EPP data on safety was largely positive as despite very high complex airspace and high traffic load, thanks to the tools and the better knowledge of performance and intentions, ATCOs managed traffic and conflicts without issues.

No separation infringements have been measured in any runs of the validation exercises despite a large increase of traffic and even during the "Very High traffic samples" runs.

C.3.2 Analysis of Exercises Results per Demonstration objective

C.3.2.1 EX3-OBJ-38-W3-DEMOP-SAFE-0001 Results

*"Demonstrate that the use of ADS-C data contributes to improve **Safety**.*

It might either be:

- *a direct improvement of safety level, or*
- *a demonstration that the level of safety is maintained while another aspect of improvement is addressed (Operational efficiency or Human performance)."*

Success Criterion ID		Success Criterion Status
EX3-CRT-38-W3-DEMOP-002		OK

Concerning the use of CD&R tools, it has been intensively assessed during the solutions PJ18-W2.53B and PJ18-W2.56 validation exercises.

The EX3-CRT-38-W3-DEMOP-002 has been assessed (refer to C.3.2.1.1).

Objective Conclusion:

Taking into account the results for criterion EX3-CRT-38-W3-DEMOP-002 (refer to C.3.2.1.1) the objective EX3-OBJ-38-W3-DEMOP-SAFE-0001 is OK.

C.3.2.1.1 EX3-CRT-38-W3-DEMOP-002

Success Criterion ID		Success Criterion Status
EX3-CRT-38-W3-DEMOP-002		OK

The results provided by the solution PJ18-W2.53B validation showed as a summary:

*(For more detail refer to Annex E.3.2 from **SESAR Solution 53B VALR – V00.01.00**, (validation report of solution 18-53B validation exercises) - (OBJ-18-W2-53B-V3-HPAP-003 and OBJ-18-W2-53B-V3-VALP-005)*

- *There is no increase in the number of pre-tactical planned conflicts and of planned tactical taking.*
- *There is no increase in the number of planned tactical conflicts taking into consideration increase in traffic.*
- *There is no increase in the number of imminent separation infringements taking into consideration increase in traffic*
- *The implementation of support tools does not deteriorate human performance impacting safety.*

The detection envelope computed with the use of ADS-C EPP and speed schedule data and the knowledge of aircraft performance in the Trajectory Prediction and aircraft intentions improves the Conflict detection and resolution.

This permits to:

- Improve the reliability of detected conflicts
- Reduce the number of "false" conflicts

In term of safety, it has to be noted that no separation infringements have been measured in any runs of the solution 18-53B and 18-56 validation exercises despite a large increase of traffic and even during the "Very High traffic samples" runs. The safety was not impacted in solution 18-53B and 18-56 scenarios and also in with very high traffic load corresponding to 10 to 15% sector capacity increase.

The CD&R tools as well as the Trajectory Management tools (including route conformance monitoring…) were considered reliable and situation awareness is reported increased by ATCOs.

ADSCENSIO results:

During the **EXE-PJ38-4-3 demonstration sessions**, the participating ATCOs were also very positive about the foreseen awareness situation thanks to:

- reliable trajectory computation using aircraft performance (ADS-C EPP data),
- the display of the trajectory (flight information (TOC, TOD, type of turns etc.…),
- more precise detection envelopes

Success criterion Conclusion: The success criterion EX3-CRT-38-W3-DEMOP-002 is OK.

C.3.2.2 EX3-OBJ-38-W3-DEMOP-HPRF-0002 Results

"

Success Criterion ID	Success Criterion Description	Success Criterion Status
EX3-CRT-38-W3-DEMOP-005		OK
EX3-CRT-38-W3-DEMOP-012		OK
EX3-CRT-38-W3-DEMOP-013	Thanks to ADS-C EPP 2D route conformance check is improved Validation results from PJ18-W2.53B and PJ18-W2.56 (HP) are confirmed by ATCOs	OK

Objective Conclusion:

Taking into account the results for criteria EX3-CRT-38-W3-DEMOP-005 (refer to C.3.2.2.1), EX3-CRT-38-W3-DEMOP-012 (refer to C.3.2.2.2) and EX3-CRT-38-W3-DEMOP-013 (refer to C.3.2.2.3)

the objective EX3-OBJ-38-W3-DEMOP-HPRF-0002 is OK.

C.3.2.2.1 EX3-CRT-38-W3-DEMOP-005

Success Criterion ID	Success Criterion Description	Success Criterion Status
EX3-CRT-38-W3-DEMOP-005		OK

During the validation exercises performed in the frame of solution PJ18-W2.53B, it has been demonstrated that the visualization and knowledge of aircraft intent and performance clearly brings strong benefits in terms of reliability. Being able to see the aircraft's performance in advance thanks to EPP report data makes much easier to give climb or descent clearances. The Situation Awareness was not degraded with the amount of traffic in the PJ18-W2.53B solution scenarios in comparison to reference scenario

The knowledge of turns types (FlyBy / FlyOver) is really useful for conflict detection as types of turns can generate significant deviations.

*(For more detail refer to Annex E.3.2 from **SESAR Solution 53B VALR – V00.01.00**, (validation report of solution 18-53B validation exercises) - (OBJ-18-W2-53B-V3-HPAP-003)*

ADSCENSIO results:

During the EXE-**PJ38-4-3 demonstration sessions to ATCOs**, ATCOs highlighted the usefulness of the visualisation of aircraft intent and performance on the displayed trajectory. This will have a positive impact on situation awareness as trajectory information and Conflict Detection & Resolution tools are enhanced with more accurate and reliable data thanks to ADS-C EPP and speed schedule reports.

Success criterion Conclusion:
The success criterion EX3-CRT-38-W3-DEMOP-005 is OK.

C.3.2.2.2 EX3-CRT-38-W3-DEMOP-012

Success Criterion ID	Success Criterion Description	Success Criterion Status
EX3-CRT-38-W3-DEMOP-012		OK

As explain in the description of ***Conflict envelopes computation*** in C.1.1 the detection envelope for is drastically reduced thanks to data extracted from the ADS-C EPP and speed schedule reports. Therefore, the intersection envelopes of two flights having trajectories possibly interfering is also largely reduced. As a consequence, during the validation exercises performed in the frame of solutions PJ18-W2.53B and PJ18-W2-56, ATCOs reported trajectory predictor and conflict detection tools are more precise, showing less spurious conflicts and therefore bring high benefits and contribute to reduce workload.
The decrease of ratio number of conflict per flight is a clear trend.

*(For more detail refer to Annex E.3.2 from **SESAR Solution 53B VALR – V00.01.00**, (validation report of solution 18-53B validation exercises) - (OBJ-18-W2-53B-V3-VALP-004)*

Success criterion Conclusion:
The success criterion EX3-CRT-38-W3-DEMOP-012 is OK.

C.3.2.2.3 EX3-CRT-38-W3-DEMOP-013

Success Criterion ID	Success Criterion Description	Success Criterion Status
EX3-CRT-38-W3-DEMOP-013	Thanks to ADS-C EPP 2D route conformance check is improved Validation results from PJ18-W2.53B and PJ18-W2.56 (HP) are confirmed by ATCOs	OK

During the validation exercises performed in the frame of solution PJ18-W2.53B and PJ18-W2.56, the visualization and knowledge of aircraft intent and performance clearly brings strong benefits in terms of situation awareness.

The knowledge of turns types (FlyBy / FlyOVer) is really useful for conflict detection as types of turns can generate significant deviations.

*(For more detail refer to Annex E.3.2 from **SESAR Solution 53B VALR – V00.001.00** and Annex F.3.2 from , **SESAR Solution 56 VALR – V00.01.00** (validation report of solution PJ18-W2.53B and PJ18-W2.56 validation exercises) - (OBJ-18-W2-53B-V3-VALP-004, EXE006-OBJ-18-56-V2-VALP-002)*

ADSCENSIO results:

During the EXE-**PJ38-4-3 demonstration sessions to ATCOs**, the 2D Route Discrepancy detection (consistency check) and solving (incl. alerting) was presented with concrete cases (ADSCENSIO flights). ATCOs highlighted the usefulness of the visualisation of discrepancy between the ground trajectory and the FMS (EPP) trajectory downlinked. This visualisation is supported by efficient HMI allowing the ATCO to update easily the trajectory (either airborne trajectory, or ground trajectory). This will have a positive impact on situation awareness as trajectory information and Conflict Detection & Resolution tools are enhanced with more accurate and reliable data thanks to ADS-C EPP and speed schedule reports.

Success criterion Conclusion:

Results from PJ18-W2.53B and PJ18-W2.56 (HP) validations are confirmed by ATCOs

The success criterion EX3-CRT-38-W3-DEMOP-013 is OK.

C.3.2.3 EX3-OBJ-38-W3-DEMOP-OPRF-0003 Results

*"Demonstrate that the use of ADS-C data improves the **Operational performance**"*

Success Criterion ID	Success Criterion Description	Success Criterion Status
EX3-CRT-38-W3-DEMOP-015	The adherence to on board expected vertical trajectories is enhanced thanks to the use (e.g. display) of TOD information.	OK
EX3-CRT-38-W3-DEMOP-016	The number of trajectory revisions is reduced thanks to the reduction of spurious detection of conflicts. (supported by PJ18-W2.53B and PJ18-W2.56 validation results)	POK
EX3-CRT-38-W3-DEMOP-017	Validation results in term of performance from PJ18-W2.53B and PJ18-W2.56 (PERF) are confirmed for PJ38 flights	Not Covered
EX3-CRT-38-W3-DEMOP-018	Potential reduction of number of conflicts detected thanks to improved CD&R tool (envelope detection taking into account ADS-C data)	OK
EX3-CRT-38-W3-DEMOP-020	The display of EPP trajectory for 2D consistency check is considered useful	OK

Objective Conclusion: Taking into account the results for criteria EX3-CRT-38-W3-DEMOP-015 (refer to C.3.2.3.1), EX3-CRT-38-W3-DEMOP-016 (refer to C.3.2.3.2), EX3-CRT-38-W3-DEMOP-017 (refer to C.3.2.3.3), EX3-CRT-38-W3-DEMOP-018 (refer to C.3.2.3.4) and EX3-CRT-38-W3-DEMOP-020 (refer to C.3.2.3.5) the objective EX3-OBJ-38-W3-DEMOP-OPRF-0003 is OK.

C.3.2.3.1 EX3-CRT-38-W3-DEMOP-015

Success Criterion ID	Success Criterion Description	Success Criterion Status
EX3-CRT-38-W3-DEMOP-015	The adherence to on board expected vertical trajectories is enhanced thanks to the use (e.g. display) of TOD information.	OK

The vertical profile computed by the Trajectory Predictor taking into account ADS-C EPP data is more accurate than the vertical profile computed by legacy Trajectory Predictor. The vertical mode selected (managed or unmanaged) does not really impact the Trajectory Prediction as the "catch-up" manoeuvre principle (refer to C.3 (Trajectory Prediction principle description) is taken into account in the Trajectory Predictor. The display of vertical information (FLs, TOD) has been considered very valuable by the ATCOs.

Nevertheless, in order to use the ADS-C EPP TOD for ground Trajectory Prediction, it is mandatory that the FMS Flight Plan integrates LOAs' level constraints and these constraints must be properly flown by the flight management system.

However, the number of ADSCENSIO flights starting descent in the skyguide controlled airspace was quite limited to have quantitative conclusions.

Success criterion Conclusion: The information on vertical profile is an important asset of the ADS-C EPP and thanks to improved vertical trajectory computation by the ground system ensure a better adherence to the expected vertical trajectories The success criterion EX3-CRT-38-W3-DEMOP-015 is OK.

C.3.2.3.2 EX3-CRT-38-W3-DEMOP-016

Success Criterion ID	Success Criterion Description	Success Criterion Status
EX3-CRT-38-W3-DEMOP-016	The number of trajectory revisions is reduced thanks to the reduction of spurious detection of conflicts. (supported by PJ18-W2.53B and PJ18-W2.56 validation results)	POK

As explained in the criteria C.3.2.2.2 EX3-CRT-38-W3-DEMOP-012, with the detection envelope being drastically reduced thanks to data extracted from the ADS-C EPP and speed schedule reports, the number of spurious conflicts detected is reduced.

During the validation exercises performed in the frame of solutions PJ18-W2.53B and P18-W2.56, the results did not show a clear trend / change regarding the number of clearances per flight in solution runs compared to reference runs. The characteristics of Skyguide HMI permits the ATCO to grey out conflicts that he/she considers not appropriate or spurious, therefore thanks to the reduction of spurious detection of conflicts with Trajectory Prediction and CD&R envelope detection taken into account ADS-C EPP and speed schedule data, less conflicts were greyed out by the ATCOs in solutions runs.

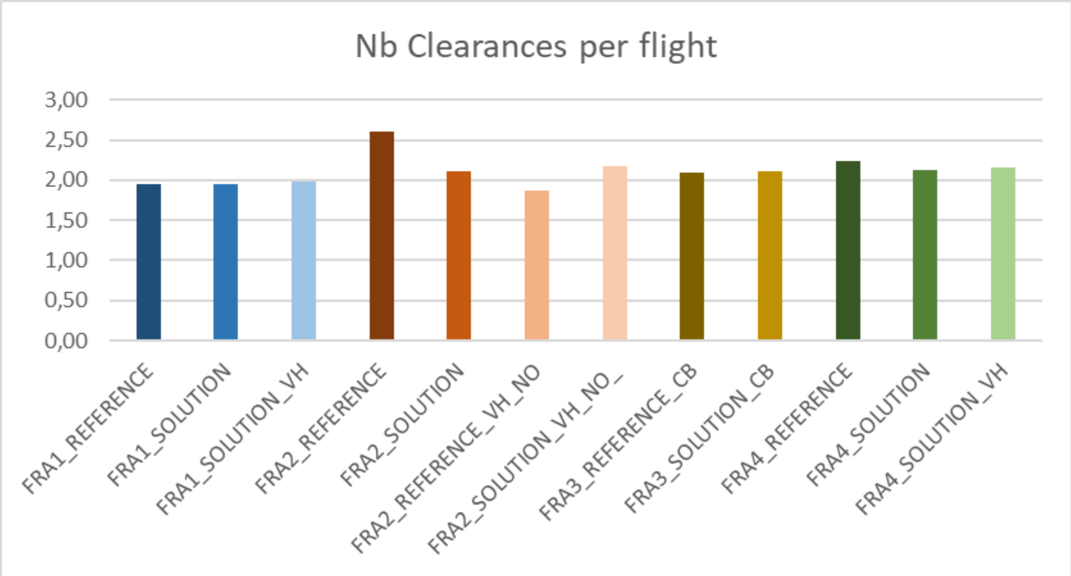


Figure 32: EXE-PJ38-4-3 – Number of clearances per flight

*(For more detail refer to Annex E.3.2 from **SESAR Solution 53B VALR – V00.01.00** and Annex F.3.2 from , **SESAR Solution 56 VALR – V00.01.00** (validation report of solution PJ18-W2.53B and PJ18-W2.56 validation exercises) - (CRT-18-W2-53B-V3-VALP-004, EXE006-OBJ-18-56-V2-VALP-004)*

<u>**Success criterion Conclusion:**</u>

It has been clearly demonstrated that the number of spurious conflicts is reduced with the use of ADS-C EPP and speed schedule, therefore, there are less trajectory revisions linked to these spurious conflicts. However the number of trajectory revisions is not necessarily drastically reduced if the traffic situation requires trajectory revisions due to real conflicts.

The success criterion EX3-CRT-38-W3-DEMOP-016 is POK.

C.3.2.3.3 EX3-CRT-38-W3-DEMOP-017

Success Criterion ID	Success Criterion Description	Success Criterion Status

EX3-CRT-38-W3-DEMOP-017	Validation results in term of performance from PJ18-W2.53B and PJ18-W2.56 (PERF) are confirmed for PJ38 flights	Not Covered

This criterion could not be assessed as the ADSCENSIO flights were controlled as any other flights, not taking into account any ADS-C EPP data, neither new Trajectory Prediction or CD&R tools with new detection envelope calculation.

Success criterion Conclusion:
The success criterion EX3-CRT-38-W3-DEMOP-017 is Not Covered.

C.3.2.3.4 EX3-CRT-38-W3-DEMOP-018

Success Criterion ID	Success Criterion Description	Success Criterion Status
EX3-CRT-38-W3-DEMOP-018	Potential reduction of number of conflicts detected thanks to improved CD&R tool (envelope detection taking into account ADS-C data)	OK

Following is a reminder on envelope detection without and with ADS-C EPP data.

non ADS-C equipped vs ADS-C equipped aircraft - climb envelope computation

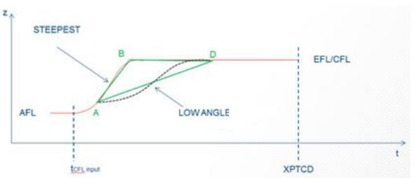
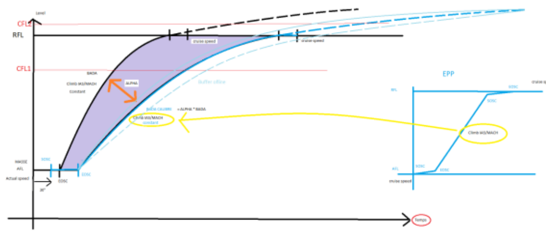
	non ADS-C equipped	ADS-C + ATS-B2 equipped
TP	legacy	Skysoft-ATM
Steepest	4500 ft/min	BADA and BADA calibrated with climb phase EPP (TOC-SOC EOC)
Less Steep	500 ft/min	
		

Figure 33: EXE-PJ38-4-3 – climb enveloppe computation

non ADS-C equipped vs ADS-C equipped aircraft - descent envelope computation

	non ADS-C equipped	ADS-C + ATS-B2 equipped
TP	legacy	Skysoft-ATM

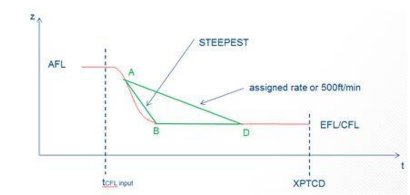
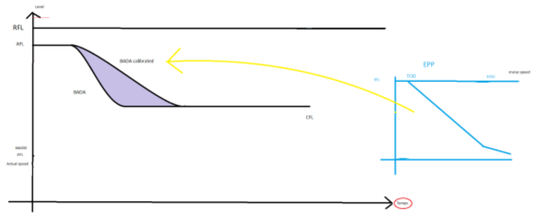
	non ADS-C equipped	ADS-C + ATS-B2 equipped
Steepest	4500 ft/min	BADA and BADA calibrated with descent phase EPP (TOD-SOD EOD)
Less Steep	500 ft/min	
		

Figure 34: EXE-PJ38-4-3 – descent envelope computation

non ADS-C equipped vs ADS-C equipped aircraft - when ready envelope computation

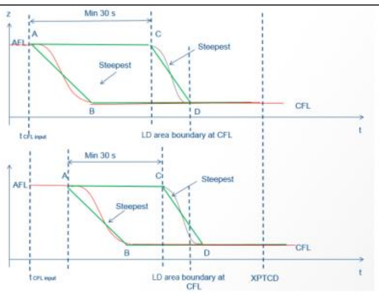
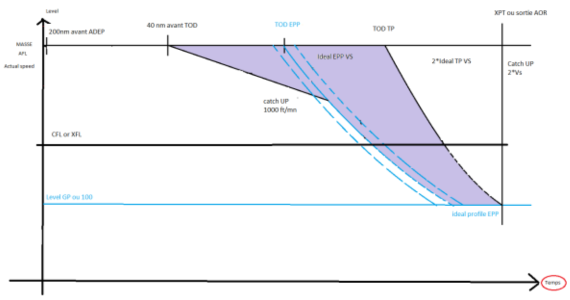
	non ADS-C equipped	ADS-C + ATS-B2 equipped
TP	legacy	Skysoft-ATM
Steepest 1	4500 ft/min	Catch-up manoeuvre: - 40 NM before TOD, 1000 ft/min - After TOD, 2*VS optimal received via EPP
Steepest 2	4500 ft/min from exit of area boundary	
		

Figure 35: EXE-PJ38-4-3 – when ready envelope computation

As demonstrated with the new detection envelope calculation (taking into account aircraft performance extracted from the ADS-C EPP and speed schedule data), the intersection of the detection envelopes is therefore reduced. Consequently the number of conflicts for a same traffic is reduced with the use of ADS-C data.

Success criterion Conclusion:

The potential number of conflicts detected thanks to improved CD&R tool (envelope detection taking into account ADS-C data) is reduced. The success criterion EX3-CRT-38-W3-DEMOP-018 is OK.

C.3.2.3.5 EX3-CRT-38-W3-DEMOP-020

Success Criterion ID	Success Criterion Description	Success Criterion Status
EX3-CRT-38-W3-DEMOP-020	The display of EPP trajectory for 2D consistency check is considered useful	OK

In the frame of solutions PJ18-W2.53B and PJ18-W2.56 trajectory management tools have been upgraded with the use of ADS-C data.

First the new Trajectory Predictor taking into account ADS-C EPP data for calibration and also other parameters for computation and display (e.g. TOC, TOD, type of turns...). The displayed trajectory is no more based on segment but on point every 4 seconds and takes into account the additional information such as TOC, TOD, and type of turns.

The ground trajectory and the ADS-C EPP trajectory can be displayed and the ground system is systematically checking on reception of an ADS-C EPP the consistency between the ground 2D trajectory and the ADS-C EPP trajectory.

This has been considered very positive by the ATCOs during the PJ18-W2.53B and PJ18-W2.56 validation exercises as well as during different sessions of ADSCENSIO presentations to ATCOs

The impact of better knowledge of aircraft performance and intentions (enabled by better trajectory visualization and EPP reports) is considered by ATCOs *positive* for 2D flight efficiency and *positive* to *very positive* by ATCOs.

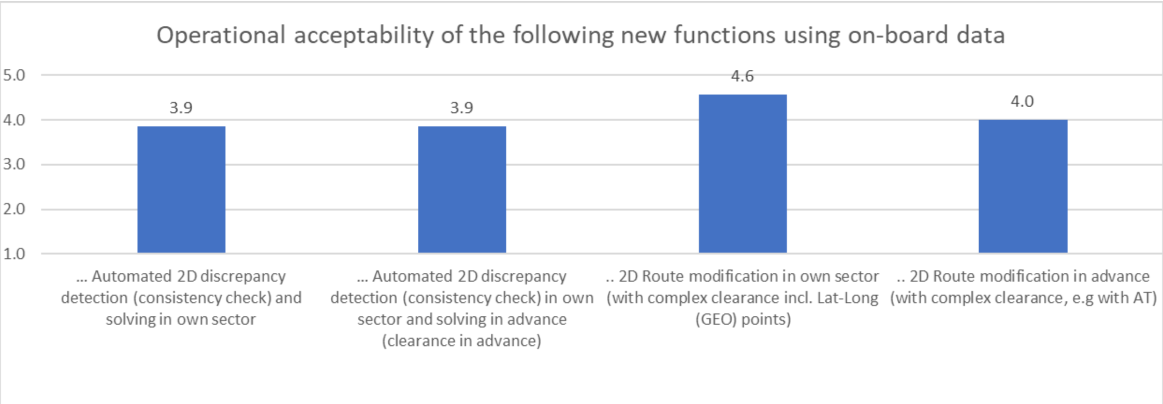


Figure 36: EXE-PJ38-4-3 – Operational acceptability of new functions related to Automated Ground Based Flight Conformance and Intent Monitoring support (from PJ18-W2.56 validation)

The levels of acceptability of all the functions have been rated as high (= acceptable with minor improvements to acceptable with no improvement).

The visualization and knowledge of aircraft intent and performance clearly brings strong benefits in terms of situation awareness. Being able to see the aircraft's performance in advance with the EPP makes it much easier to give climb or descent clearances, especially when other aircraft have to be crossed during the evolution.

2D automated detection of discrepancies is considered really useful. Today, Route Adherence Monitoring function exists but it takes more time to see the problem (only when a deviation is in progress), compared to the discrepancy warning (immediately detected). Moreover, the discrepancy automated detection also allows to quickly see if a clearance has not been properly understood/implemented by the Flight Crew.

*(For more detail refer to Annex E.6.2 from , **SESAR Solution 56 VALR – V00.01.00** (validation report of solution PJ18-W2.56 validation exercises) - (CRT-18-56-V2-VALP-002-001, CRT-18-56-V2-VALP-002-003)*

ADSCENSIO results:

During the EXE-PJ38-4-3 demonstration sessions to ATCO, the 2D Route Discrepancy detection (consistency check) was presented with concrete cases (ADSCENSIO flights). ATCOs highlighted the usefulness of the visualisation of discrepancy between the ground trajectory and the FMS (EPP) trajectory downlinked.

Success criterion Conclusion:

The display of EPP trajectory for 2D consistency check associated with the 2D automatic detection of discrepancies has been considered useful

The success criterion EX3-CRT-38-W3-DEMOP-020 is OK.

C.3.2.4 EX3-OBJ-38-W3-DEMOP-OPSF-0004 Results

*"**Operational feasibility**"*

Success Criterion ID	Success Criterion Description	Success Criterion Status
EX3-CRT-38-W3-DEMOP-023	Positive feedback from the ATCOs on the usability of the ADS-C data for display of EPP and TOD (linked to PJ18-W2.56)	OK
EX3-CRT-38-W3-DEMOP-026	The 2D consistency check information and display with ADS-C data is acceptable for the ATCOs. (supported by PJ18-W2.53B and PJ18-W2.56 validation results)	OK

during the validation exercises performed in the frame of solution PJ18-W2.53B and PJ18-W.56, explained in C.3.2.2.1 EX3-CRT-38-W3-DEMOP-005 *(For more detail refer to Annex E.3.2 from **SESAR Solution 53B VALR – V00.01.00**, (validation report of solution 18-53B validation exercises) – (OBJ-18-W2-53B-V3-HPAP-002 CRT-18-W2-53B-V3-HPAP-002-003) and refer to Annex E.6.2 from , **SESAR Solution 56 VALR – V00.01.00** (validation report of solution PJ18-W2.56 validation exercises) - (CRT-18-56-V2-VALP-003-004, CRT-18-56-V2-VALP-002-003)*

Objective Conclusion:

Taking into account the results for criteria EX3-CRT-38-W3-DEMOP-023 (refer to C.3.2.4.1) and EX3-CRT-38-W3-DEMOP-026 (refer to C.3.2.4.2)

the objective EX3-OBJ-38-W3-DEMOP-OPSF-0004 is OK.

C.3.2.4.1 EX3-CRT-38-W3-DEMOP-023

Success Criterion ID	Success Criterion Description	Success Criterion Status
EX3-CRT-38-W3-DEMOP-023	Positive feedback from the ATCOs on the usability of the ADS-C data for display of EPP and TOD (linked to PJ18-W2.56)	OK

This has been assessed in :

The task performance was assessed at the end of each day of simulation by asking the controllers to answer the following question: How would you rate your task performance linked to the following tasks during the Solution Runs in comparison to the Reference runs.

The following tasks were assessed:

- Optimizing vertical evolution (3D) A/C through sector (DWR)
- Clearing an A/C through the sector
- Anticipating and monitoring A/C performance
- Solving conflicts
- Solving exit conflicts

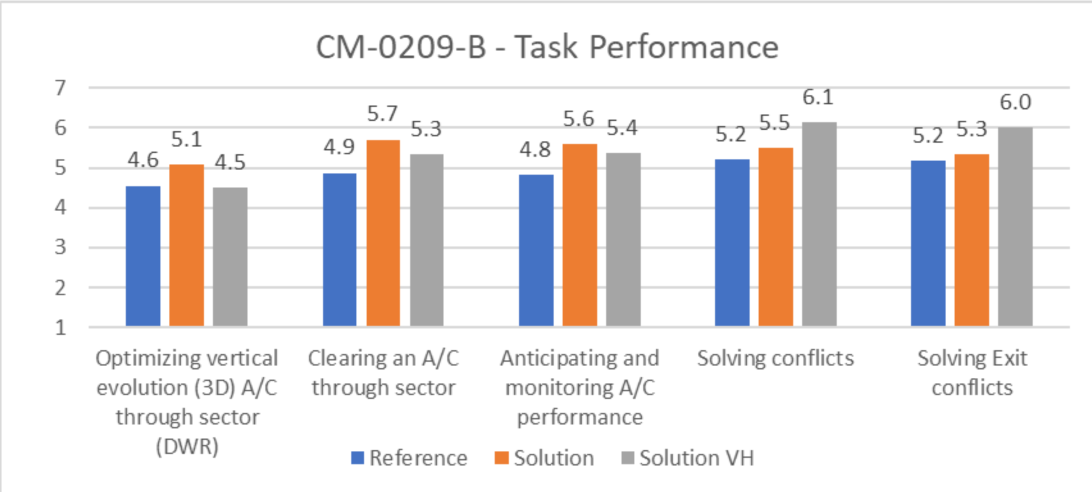


Figure 37: EXE-PJ38-4-3 – Task performance

Results in Figure 29 show an increase of Task Performance for all function in scenarios with ADS-C EPP taken into account compared to Reference scenarios (no ADS-C EPP).

Solving Conflicts in Very High traffic scenarios was rated as performant, meaning that the CD&R tools taking into account ADS-C EPP data are highly performing. It has also an impact on the number of false conflicts that were noted by the ATCOs, therefore improving performance as the ATCOs could more rely on detected conflicts and then solve them more efficiently.

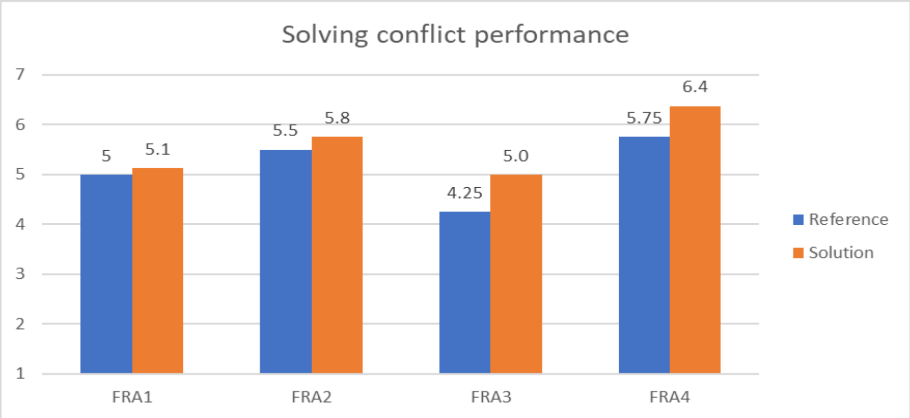


Figure 38: EXE-PJ38-4-3 – Solving conflict performance

Figure 30 shows a *high level* performance (orange) of CD&R tools supporting the use of ADS-C EPP data in the CD&R detection envelopes computation.

In addition, the usefulness/usability of CD&R tools was assessed.

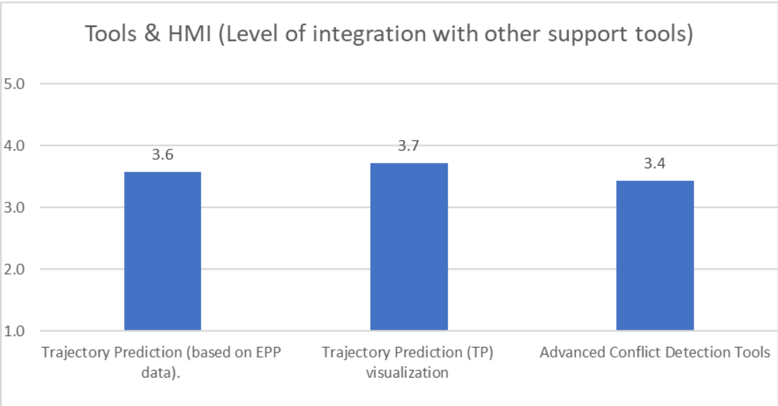


Figure 39: EXE-PJ38-4-3 – HMI Usability of CD&R tools and Trajectory Prediction

Figure 33 shows the HMI usability of CD&R tools and Trajectory Management tools (Prediction, visualisation (trajectory, EPP…), it has been rated with high score.

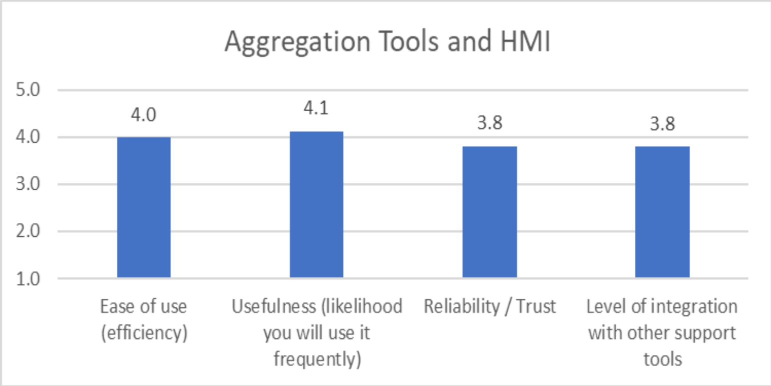


Figure 40: EXE-PJ38-4-3 – Usefulness of the CD&R tools and Trajectory Management

The Figure 32 presents the results for the tools *Trajectory Prediction (based on EPP data) and CD&R tools* for the four aspects of usability. This has been rated with high score strengthens the use of ADS-C EPP data in ground tools.

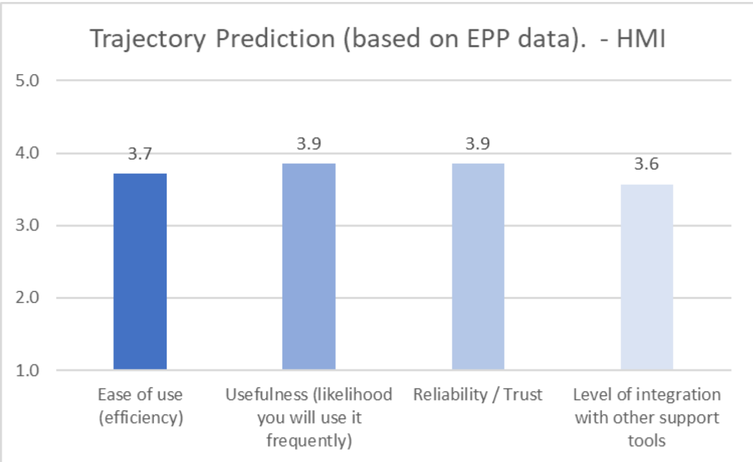


Figure 41: EXE-PJ38-4-3 – Trajectory Prediction (based on ADS-C EPP data) – HMI

The Figure 33 presents the results for the tool *Trajectory Prediction (based on EPP data)* for the four aspects of usability This has been rated with high score strengthens the use of ADS-C EPP data in Trajectory Prediction.

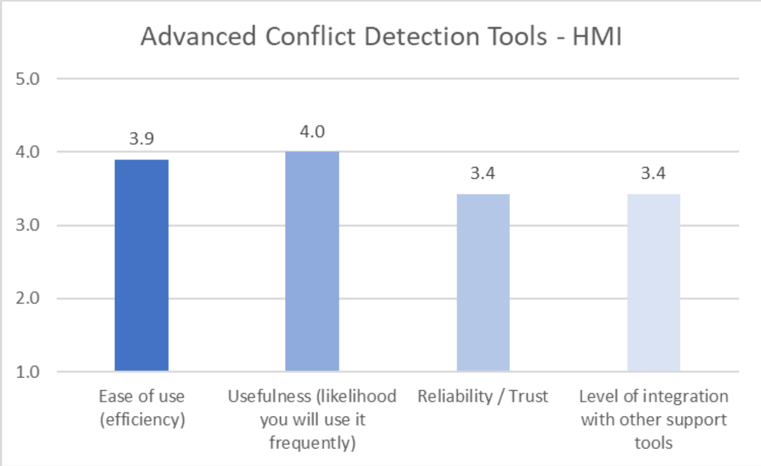


Figure 42: EXE-PJ38-4-3 – Advanced Conflict Detection Tools – HMI

The level of usefulness of the CD&R and Trajectory Management tools was satisfactory with an average score from 3,4 to 4,0 corresponding to the value *Medium to High.*

The TOD information is considered useful by the ATCOs, however, the TOD information can only be reliable is the Flight Plan (in the FMS) takes into account LOAs' level constraints. This is crucial for the associated tools such as Descent When ready "automatically generated" clearances.

*(For more detail refer to Annex E.3.2 from **SESAR Solution 53B VALR – V00.01.00**, (validation report of solution 18-53B validation exercises) – (OBJ-18-W2-53B-V3-HPAP-002 CRT-18-W2-53B-V3-HPAP-002-003) and refer to Annex E.6.2 from , **SESAR Solution 56 VALR – V00.01.00** (validation report of solution PJ18-W2.56 validation exercises) - (CRT-18-56-V2-VALP-003-004, CRT-18-56-V2-VALP-002-003)*

ADSCENSIO results:

During the **EXE-PJ38-4-3 demonstration sessions**, the participating ATCOs were very positive about the foreseen awareness situation thanks to the display of the EPP trajectory (flight information (TOC, TOD, type of turns etc.…).

Success criterion Conclusion:

Display of EPP and TOD is considered useful by the ATCOs and increase situation awareness and predictability. However, to have reliable TOD information, it is mandatory that the Operational Flight Plan (in the FMS) takes into account LOAs' level constraints.

The success criterion EX3-CRT-38-W3-DEMOP-023 is OK.

C.3.2.4.2 EX3-CRT-38-W3-DEMOP-026

Success Criterion ID	Success Criterion Description	Success Criterion Status
EX3-CRT-38-W3-DEMOP-026	The 2D consistency check information and display with ADS-C data is acceptable for the ATCOs.	OK

	(supported by PJ18-W2.53B and PJ18-W2.56 validation results)	

In the frame of solutions PJ18-W2.53B and PJ18-W2.56 the 2D conformance/consistency check has been tested and evaluated.

The ground trajectory and the ADS-C EPP trajectory can be displayed and the ground system is systematically checking on reception of an ADS-C EPP the consistency between the ground 2D trajectory and the ADS-C EPP trajectory.

When a discrepancy between the ground trajectory and the ADS-C EPP trajectory was detected, an indication was displayed in the label of the concerned aircraft ("TRAJ" in orange). The discrepancy is displayed and the ATCO can either accept the airborne trajectory or uplink the round trajectory to the aircraft.

Following graph shows the rating of the 2D route discrepancy detection from the PJ18-W2.53B and PJ18-W2.56 validations.

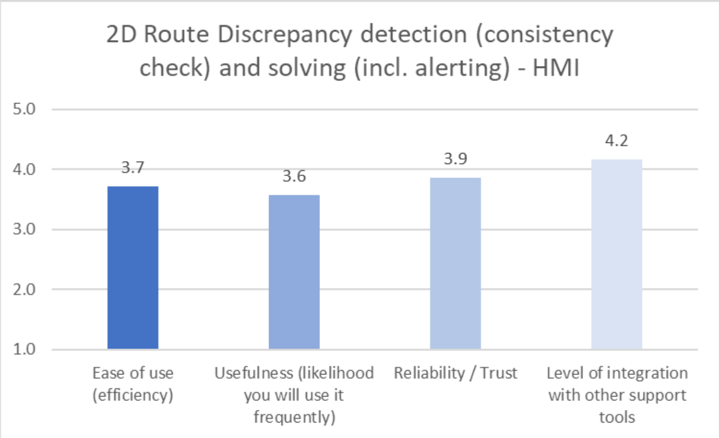


Figure 43: EXE-PJ38-4-3 – 2D Route Discrepancy detection and solving

This functionality has been considered largely positive by the ATCOs during the PJ18-W2.53B and PJ18-W2.56 validation exercises as well as during different sessions of ADSCENSIO presentations to ATCOs.

ADSCENSIO results:

During the EXE-PJ38-4-3 demonstration sessions, use cases demonstrating the 2D consistency check and solving with ADS-C data have been presented to the ATCOs and their feedback was very positive.

Success criterion Conclusion:

Thanks to PJ18-W2.53B and PJ18-W2.56 validation results, 2D consistency check information and display with ADS-C data is considered acceptable by the ATCOs

The success criterion EX3-CRT-38-W3-DEMOP-026 is OK.

C.3.2.5 EX3-OBJ-38-W3-DEMOP-TECH-0006 Results

*"**Access to ADS-C data** - Data collection improvement"*

Success Criterion ID	Success Criterion Description	Success Criterion Status
EX3-CRT-38-W3-DEMOP-032	Data received via the ADS-C Common Service are reliable (i.e. they faithfully reflect the latest situation provided by the aircraft). Will be checked against data received from EUROCONTROL	OK
EX3-CRT-38-W3-DEMOP-033	Check that ADS Common Server data can substitute EUROCONTROL received data	POK

The infrastructure to access to the ADS-C Common Service has been developed, integrated, tested and validated.

Nevertheless, as no ADS-C EPP data have been used in "live" (ADS-C EPP data have been retrieved from EUROCONTROL sharepoint OneSky Teams and stored for analysis on skyguide server), the reliability of ADS-C EPP has been checked against data received from EUROCONTROL.

Objective Conclusion:

Taking into account the results for criterion EX3-CRT-38-W3-DEMOP-032 (refer to C.3.2.5.1)

the objective EX3-OBJ-38-W3-DEMOP-TECH-0006 is OK.

C.3.2.5.1 EX3-CRT-38-W3-DEMOP-032

Success Criterion ID	Success Criterion Description	Success Criterion Status
EX3-CRT-38-W3-DEMOP-032	Data received via the ADS-C Common Service are reliable (i.e. they faithfully reflect the latest situation provided by the aircraft). Will be checked against data received from EUROCONTROL	OK

For the Demonstration Exercise #03 (EXE-PJ38-4-3), the ADS-C EPP data were not used in realtime but replayed. All operational data from the operational system and all ADS-C EPP data retrieved via the EUROCONTROL have been recorded and stored locally.

This has been used for replay session in the dedicated PJ38 platform in order to validate the use of ADS-C with the new Trajectory Predictor that has been developed.

The access to ADS-C Common Service has been validated in the frame of PJ38.

The ADS-C Common Server client has been developed and validated in order to connect to and receive ADS-C EPP data using ADS-C Common Service with the aim to:

- In a first step: collecting ADS-C Data (EPP, speed schedule) that have been used in skyguide systems

- At a second step: establishing specific ADS-C contracts with aircraft via the ADS-C Common service, however, this second step has not been validated in the frame of EXE-PJ38-4-3.

The infrastructure developed for the ADS-C Common Server client has been verified.

Verification results are:

- Count of messages received during verification time frame. Compared with messages stored on ECC sharepoint OneSky Teams
- Verified the messages sent per flight, compared the timestamp with the messages
- Content of example messages verified by comparing with messages received by Skyguide internal equipment. Data from 20211104, 14:00 until 14:24 UTC, example flight BAW518

Following Use Cases have been tested with following results:

- **Use Case 1** – Subscribe by ICAO is implemented with the prototype.
  - ***result:*** Implemented is the technical variant a) the client connects to a preconfigured endpoint
- **Use Case 2** – Subscribe to all aircraft:
  - ***result:*** Implemented (Use Case 2 is very similar to Use Case 1)
- **Use Case 3** – Demand Contract Request:
  - ***result:*** Not implemented
- **Use Case 4**- Service Status Monitoring:
  - ***result:*** As status info is not configurable at this stage, no individual subscription management is needed. Therefore, it is automatically included in Use Case 1)
- **Use Case 5** – Subscribe to aircraft fleet:
  - ***Result:*** this Use case is mainly intended for airline users. Not implemented

Trajectory Predictor output have been used for data analysis in particular to perform following analyses:

- Comparison of EPP waypoint names to FDP route points
- EPP stability and precision
- TOC and TOD variability
- FMS Modes
- Comparison/Consistency of EPP prediction with real flown trajectory

C.3.2.5.1.1 Number of ADSCENSIO Flights per phase in the skyguide controlled airspace

The following graphs presents the repartition of the flights that have flown in the skyguide controlled airspace per phase of flight.

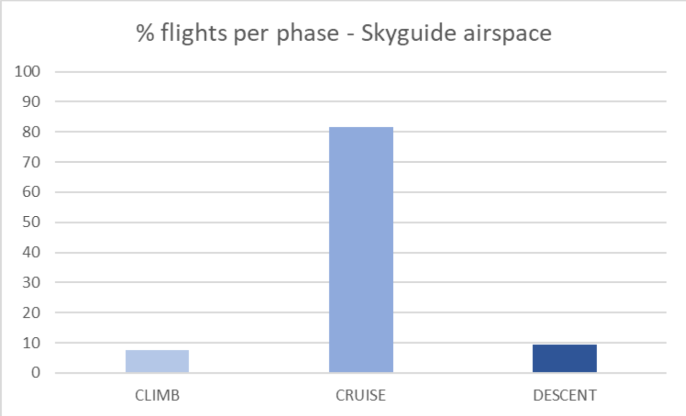


Figure 44: EXE-PJ38-4-3 – % flights per phase – skyguide airspace

Large majority of flights (81.7%.) were in cruise phase, 7.6% had a climb phase and 9.3% had a descent phase in the skyguide controlled airspace.

C.3.2.5.1.2 Comparison of EPP waypoint names to FDP route points

The list of waypoints in the ATFN Flight Plan has been compared with the list of waypoints in the EPP within the AOI of skyguide.

For FPL data, the last AFTN FPL message received has been taken into account and for ADS_C EPP, the last ADS-C EPP received at the activation of the flight before entering the AOR of skyguide.

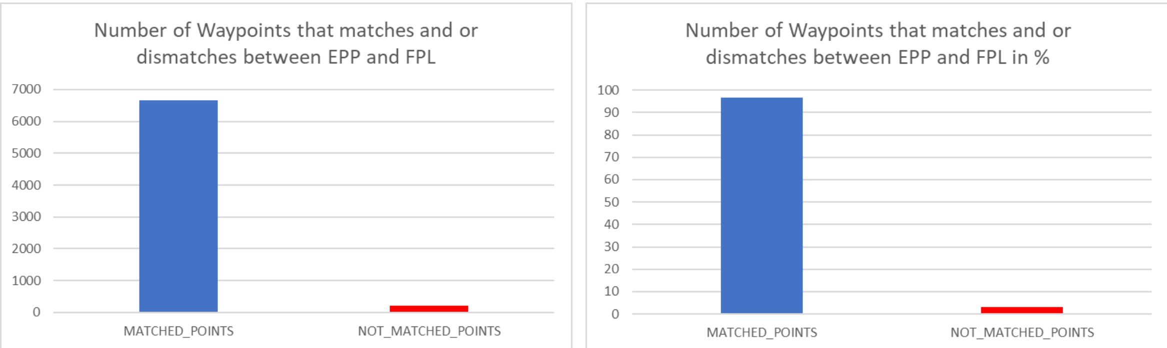


Figure 45: EXE-PJ38-4-3 – Number of Waypoints that matches and or mismatches between EPP and FPL

Results show that a marginal % of waypoints that do not match between FPL and ADS-C EPP.

It shows that the route information in the ADS-C EPP is reliable based on the Flight Plan route sent by NM and taken into account in the ground Flight Data Processing system.

The reliability of the ADS-EPP route data in regard to FPL data is high.

C.3.2.5.1.3 ADS-C EPP stability and precision

ADS-C EPP variability of a specific EPP estimate (e.g a specific named waypoint estimated time or level or speed) in a flight, is defined as the variation of the estimate value considering all EPPs for this flight. The following approach has been adopted:

The variability of ADS-C EPP data on a waypoint has been measured by grouping and comparing for each flight, all successive EPPs corresponding to the same ATC clearance.

It has been measured mainly using the Standard Deviation (StDev) metric. Standard Deviation is a measure of the amount of variation of dispersion of a set of values. A low standard deviation indicates that the values tend to be close to the mean of the set, while a high standard deviation indicates that the values are spread out over a wider range; in a normal (Gaussian) distribution, 68% of the data lies within one StDev value range around the mean value, and 98% of the data within two StDev values range around the mean value. The Interquartile Range (IQR) has also been computed, to measure how much is the variability when the median is used instead of the mean to show the central tendency.

C.3.2.5.1.3.1 EPP time estimates variability

mean StDev Time	Median StDev Time	mean IQR Time	Max StDev Time	Min StDev Time	Mean 20% outliers
7.78	3.50	10.13	64.45	0.00	5.67

Table 10: EXE-PJ38-4-3 – EPP time estimates variability

The average Standard deviation in time is 7.78 sec. It has to be noted that the average value is better when removing the 20% outliers estimations which lead to 5.67 sec. Indeed, maximum standard deviations of 64.45 sec is observed and explained by the fact that some type of turns on waypoints are changing in successive EPP reports (i.e. Fly by with change of Fixed Radius Turns values).

The Median Standard deviation value of 3.5 sec is meaningful and shows a good stability.

Globally, the stability of the time estimates is quite good (i.e. low variability).

C.3.2.5.1.3.2 EPP Flight Level estimates variability

mean StDev Flight Level (ft)	Median StDev Flight Level (ft)	mean IQR Flight Level (ft)	Max StDev Flight Level (ft)	Min StDev Flight Level (ft)	Mean 20% outliers
4.51	0.00	5.36	321.50	0.00	0.00

Table 11: EXE-PJ38-4-3 – EPP Flight Level estimates variability

The average Standard deviation in Flight Level is 4.51 ft.

The Median Standard deviation value of 0 ft.

Globally, the stability of Flight Level estimates is excellent.

C.3.2.5.1.4 ADS-C speed schedule variability

ADS-C speed schedule variability has been assessed from the downlinked speed schedule data for each ADSCENSIO downlinking ADS-C EPP reports.

Figure 46: EXE-PJ38-4-3 – Speed variability – Climb phase (kts and Mach) – standard deviation

Results show very low standard deviation of speed in climb phase (either speed (kts) before transition level or after transition level (Mach), in particular when removing 20% outliers. Speed variability in climb is very low.

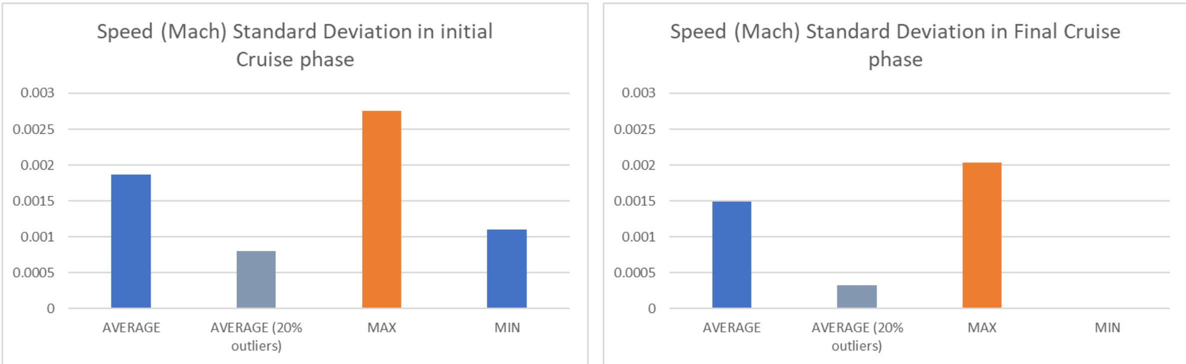


Figure 47: EXE-PJ38-4-3 – Speed variability – Cruise phase (initial and final) – standard deviation

Results show very low standard deviation of speed in cruise phase (either initial (after TOC) or final before (TOD)), in particular when removing 20% outliers. Speed variability in cruise is very low.

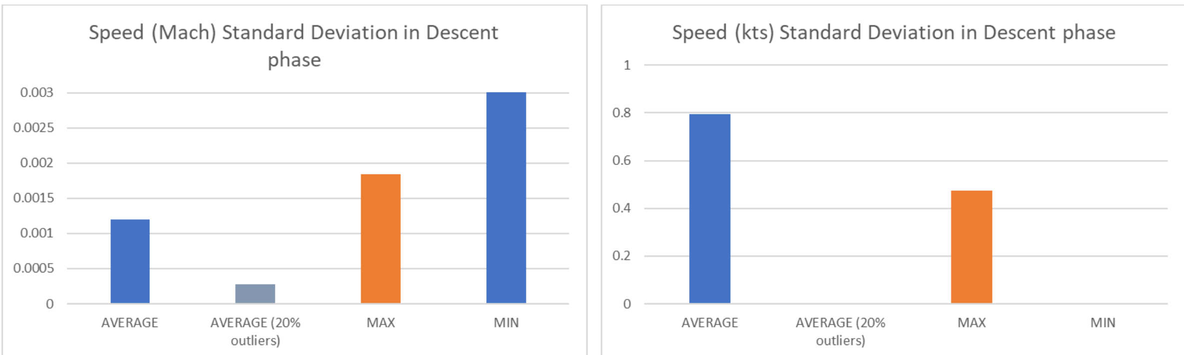


Figure 48: EXE-PJ38-4-3 – Speed variability – Descent phase (Mach and kts) – standard deviation

Results show very low standard deviation of speed in descent phase (either speed (Mach) before transition level or after transition level (kts), in particular when removing 20% outliers. Speed variability in descent is very low.

ADS-C speed schedule variability can be considered very low.

C.3.2.5.1.5 TOC and TOD variability

TOC and TOD variability has been measured for flights reaching TOC or starting Descent in the skyguide controlled airspace. The number of flights in the sample is relatively limited. ATCO clearances are taken into account.

C.3.2.5.1.5.1 TOC variability

mean StDev Time (sec)	Median StDev Time (sec)	mean IQR Time (sec)	Max StDev Time (sec)	Min StDev Time (sec)	Mean 20% outliers
91.25	*10.50*	*138.83*	*422.56*	*1.70*	*61.03*

Table 12: EXE-PJ38-4-3 – TOC variability

No conclusion can be drawn, as only very few ADSCENSIO flights were climbing in skyguide controlled airspace. The variability is quite big as the climbing flights are always influenced by the clearances given by ATC from previous ACC during the climb phase, which were not taken into account as data was not available.

C.3.2.5.1.5.2 TOD variability

mean StDev Time (sec)	Median StDev Time (sec)	mean IQR Time (sec)	Max StDev Time (sec)	Min StDev Time (sec)	Mean 20% outliers
1.17	0.00	1.17	0.00	0.50	3.00

Table 13: EXE-PJ38-4-3 – TOD variability

TOD variability is very low but it has to be noted that this statistic is not fully relevant due to the limited number of ADS-C EPPs considered, indeed, majority of ATC clearances have an impact on TOD (limiting the number of comparable ADS-C EPPs) and the number of ADSCENSIO flights descending within skyguide airspace was very low.

C.3.2.5.1.6 FMS Modes

Following graphs present the % of flights in Managed or Selected mode per phase.

Climb phase

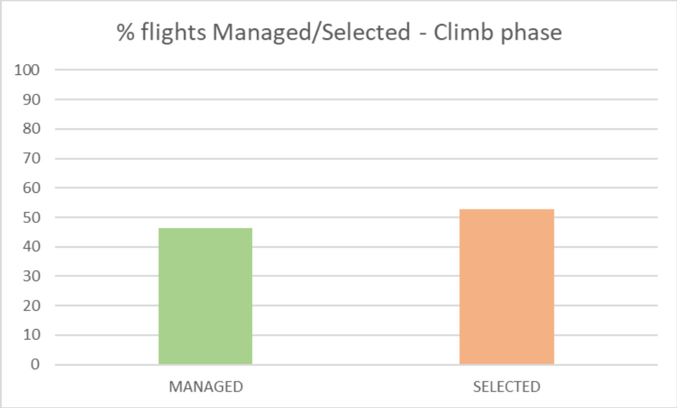


Figure 49: EXE-PJ38-4-3 – % flights Selected mode - Climb phase

A little more than 50% of flights in Climb phase are not in Managed mode. This may impact ground Trajectory Prediction in vertical mode, however, the climb performance in the ground Trajectory Prediction are based on calibration taking into account ADS-C EPP data and speed schedule. It also takes into account the ATCO clearances that may impact vertical profile (e.g. Rate of Climb, intermediate Flight Level…).

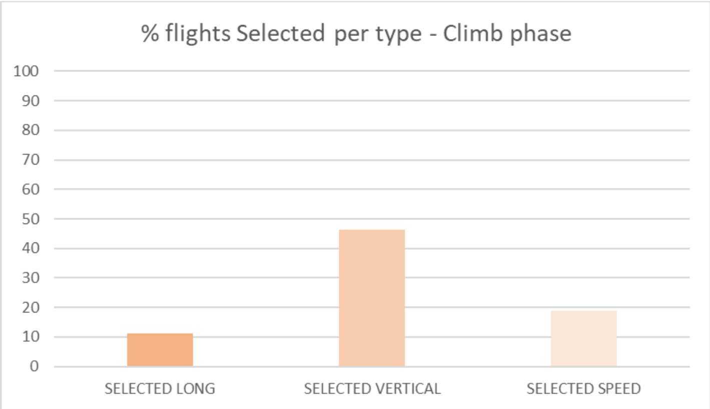


Figure 50: EXE-PJ38-4-3 – % flights Selected mode per type - Climb phase

As shown in the graph above, when in Selected mode, most of the flights are in vertical mode selected when climbing which may influence vertical predictions.

Cruise phase

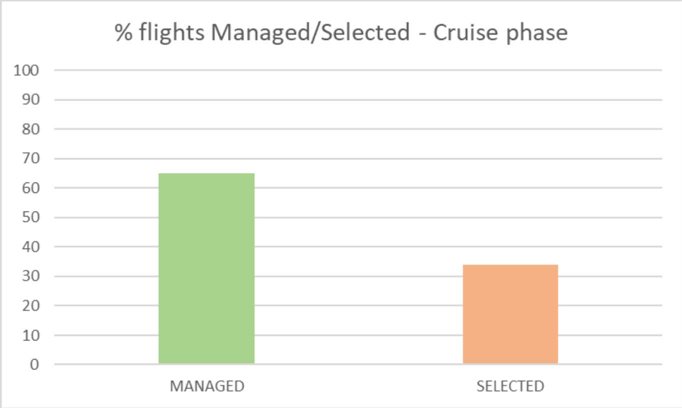


Figure 51: EXE-PJ38-4-3 – % flights Selected mode - Cruise phase

In cruise phase, a large majority of flights (65%) are in Managed mode.

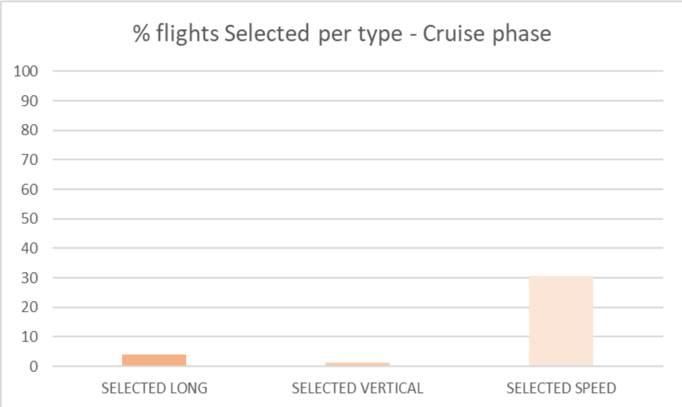


Figure 52: EXE-PJ38-4-3 – % flights Selected mode per type - Cruise phase

When in Selected mode in cruise, majority of flight (31%) are in Selected speed. When flights are in Selected Heading, the ADS-C EPP 2D trajectory, airborne Trajectory Prediction is no more accurate.

Descent phase

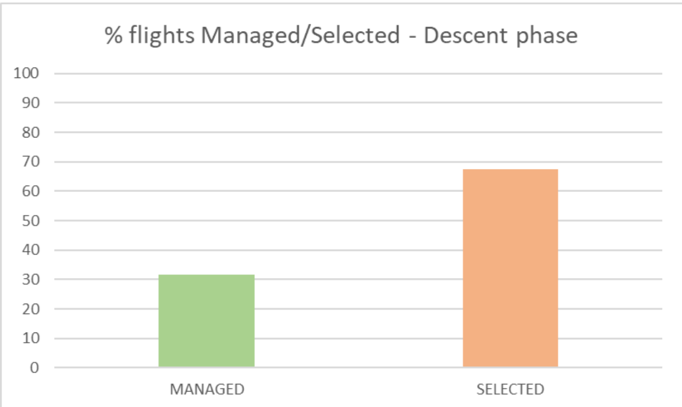


Figure 53: EXE-PJ38-4-3 – % flights Selected mode - Cruise phase

It is during the Descent phase that most of the "selected mode" is used, a large majority of flights (67%) are in Selected mode which may influence vertical predictions.

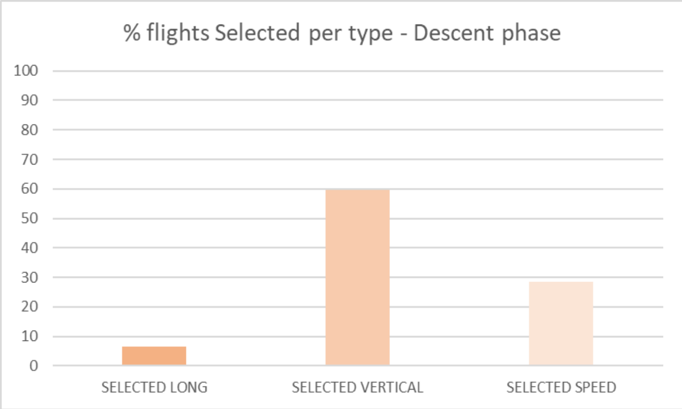


Figure 54: EXE-PJ38-4-3 – % flights Selected mode per type - Descent phase

As shown in the graph above, when in Selected mode, most of the flights are in vertical mode selected when descending.

C.3.2.5.1.7 Comparison/Consistency of ADS-C EPP prediction with Legacy TP

To compare ADS-C EPP prediction and legacy TP predictions, the following approach has been adopted:

ADS-C EPP and legacy TP data have been compared by comparing respective predictions. Logically the accuracy of predictions is linked to the remaining distance before a named waypoint overfly. Therefore, predictions errors are measured in sec/NM.

Comparison is based on average error prediction on each waypoint (time, FL, speed).

C.3.2.5.1.7.1 Average Time Error on Waypoints (sec/Nm)

Following table contains the Time Error on Waypoints:

Min	1st Qu.	Median	**Mean**	3rd Qu.	Max
0.000	0.0384	0.0727	**0.205**	0.129	73.504

Table 14: EXE-PJ38-4-3 – Average Time Error on Waypoint (sec/NM) – Legacy TP

Co-funded by the European Union

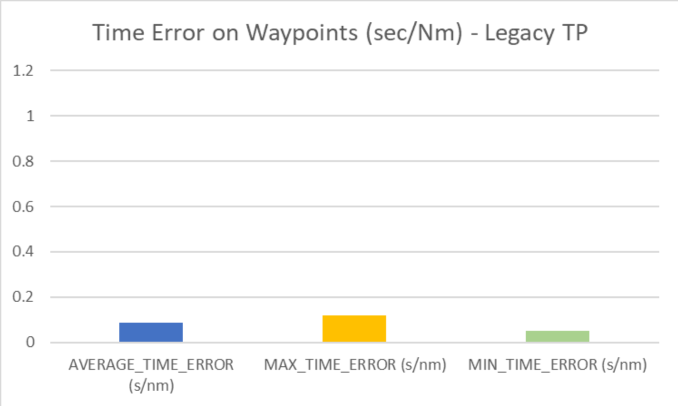


Figure 55: EXE-PJ38-4-3 – Time error on Waypoint (sec/NM) – Legacy TP

Statistical results show that the average Time Error on waypoints (within skyguide controlled airspace) is acceptable, meaning that the time accuracy of the ADS-EPP report data compared with the predicted trajectory computed by the legacy TP is good. This average time error is used for comparison with the same metric computed with new Trajectory Predictor data (see graphic for New TP - ***Average Time Error on Waypoints (sec/Nm)***).

C.3.2.5.1.7.2 Average Level Error on Waypoints (ft/Nm)

With the Legacy Trajectory Predictor, it was not possible to assess the error on Flight Level. The legacy Trajectory Predictor, despite computing vertical profile does not have the capability to export Flight Levels on navpoints of the legacy trajectory.

C.3.2.5.1.8 Comparison/Consistency of ADS-C EPP prediction with New TP

To compare ADS-C EPP prediction and new TP predictions, the following approach has been adopted:

ADS-C EPP and legacy TP data have been compared by comparing respective predictions. Logically the accuracy of predictions is linked to the remaining distance before a named waypoint overfly. Therefore, predictions errors are measured in sec/NM, ft/NM, kts/NM and Mach nb/NM.

Comparison is based on average error prediction on each waypoint (time, FL, speed).

C.3.2.5.1.8.1 Average Time Error on Waypoints (sec/Nm)

Following table contains the Time Error on Waypoints:

Min	1st Qu.	Median	**Mean**	3rd Qu.	Max
0.000	0.0466	0.0890	**0.127**	0.160	1.830

Table 15: EXE-PJ38-4-3 – Average Time Error on Waypoint (sec/NM) – New TP

The table shows that stability in time is high. The accuracy of EPP data and Trajectory Prediction in time is high.

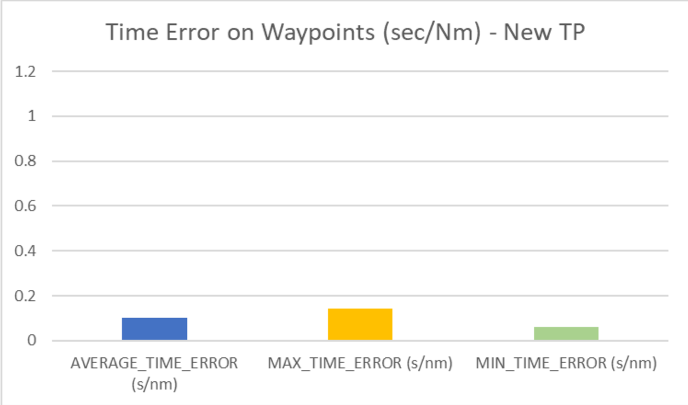


Figure 56: EXE-PJ38-4-3 –Time error on Waypoint (sec/NM) – New TP

Statistical results show that the average Time Error on waypoints (within skyguide controlled airspace) is small, meaning that the time accuracy of the ADS-EPP report data compared with the predicted trajectory computed by the new TP is high. The use of the ADS-EPP report data and the calibration is able to improve the estimation of the time over the waypoint and to obtain more stable estimates The Trajectory Prediction can be considered reliable in regards with the ADS-C EPP trajectories. The average Time Error on waypoints is much lower compared to the average Time Error on waypoints measured with the Legacy TP (see graphic for Legacy TP - *Average Time Error on Waypoints (sec/Nm)*). It has to be noted also that the legacy TP is using ad-hoc computing method (wind accuracy in ground speed) that will be implemented in a next iteration of the new TP, this will even increase precision in time computation.

C.3.2.5.1.8.2 Average Level Error on Waypoints (ft/Nm)

Following table contains the Level Error on Waypoints (standard deviation)

Min	1st Qu.	Median	Mean	3rd Qu.	Max
0.000	0.000	0.210	8.277	0.563	341.415

Table 16: EXE-PJ38-4-3 – Average Level Error on Waypoint (ft/NM) – New TP

The table shows that stability in Flight Level is very high. The accuracy of EPP data and Trajectory Prediction in FL is high. The large extreme max value can be explained by the fact that EPPs have not been updated with clearances (probably loss of connection).

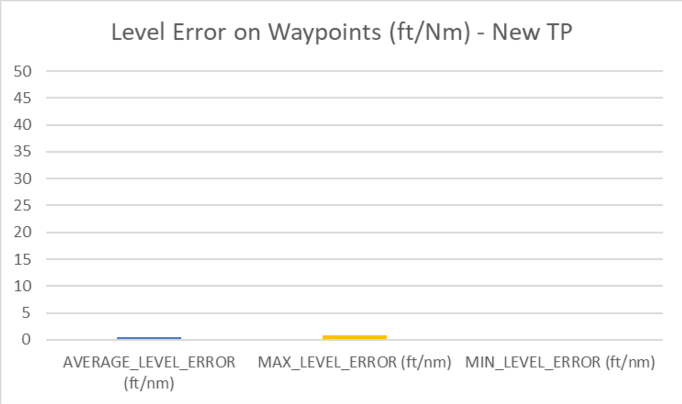


Figure 57: EXE-PJ38-4-3 – Level error on Waypoint (ft/NM) – New TP

Statistical results show that the average Level Error on waypoints (within skyguide controlled airspace) is small, meaning that the Flight Level accuracy of the ADS-EPP report with regards to the predicted vertical profile (from new TP) can be considered .

C.3.2.5.1.8.3 Average Speed Error on Waypoints (IAS kts)

Following table contains the Speed Error (IAS) on Waypoints (standard deviation)

Min	1st Qu.	Median	Mean	3rd Qu.	Max
0.000	5.558	0.000	15.761	16.518	32.191

Table 17: EXE-PJ38-4-3 – Average Speed (IAS) Error on Waypoint (kts/NM) – New TP

The table shows that stability in speed (IAS) is good. The accuracy of EPP data and Trajectory Prediction in speed is good. The large extreme max value can be explained by the fact that EPPs have not been updated with clearances (probably loss of connection).

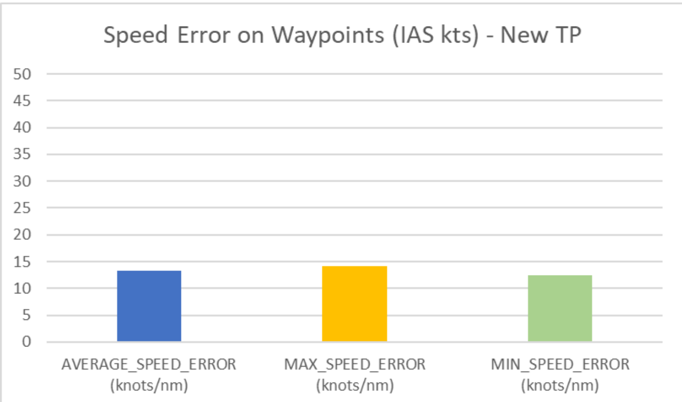


Figure 58: EXE-PJ38-4-3 – Speed (IAS) error on Waypoint (kts/NM) – New TP

Statistical results show that the average Speed (IAS) error on waypoints (within skyguide controlled airspace) is quite small, meaning that the speed accuracy of the ADS-EPP report data with regards to the predicted speeds (new TP) is good.

Following table contains the Speed Error (Mach) on Waypoints (standard deviation)

Min	1st Qu.	Median	Mean	3rd Qu.	Max
0.0012	0.0003	0.0013	0.0014	0.0016	0.0990

Figure 59: EXE-PJ38-4-3 –Speed (Mach) error on Waypoint (Mach nb/NM) – New TP

Same results as for IAS speed.

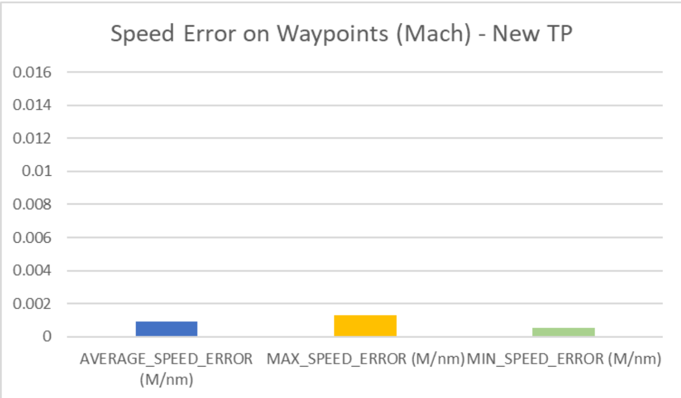


Figure 60: EXE-PJ38-4-3 –Speed (Mach) error on Waypoint (kts/NM) – New TP

C.3.2.5.1.9 Comparison/Consistency of EPP prediction with real flown trajectory

To compare EPP prediction with real flown trajectory, the following approach has been adopted:

EPP data on waypoints have been compared with real flown trajectory by grouping and comparing for each flight, all successive EPPs corresponding to the same ATC clearance.

Comparison is based on average error prediction on each waypoint (time, FL, speed).

C.3.2.5.1.9.1 Overflown waypoints

The criteria taken into account is the overfly of the EPP waypoints taking into account the impact of the turn (flyby turns).

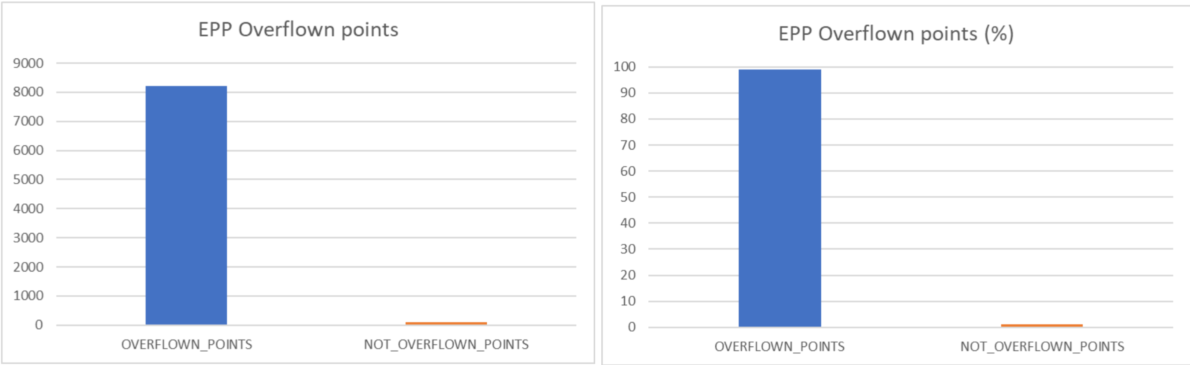


Figure 61: EXE-PJ38-4-3 – EPP overflown waypoints

99% of the waypoints have been overflown by the flights.

C.3.2.5.1.9.2 Average Time Error on Waypoints (sec/Nm)

Following table contains the time Error on Waypoints

Min	1st Qu.	Median	Mean	3rd Qu.	Max
0.01	0.06	0.10	0.12	0.18	3.50

Table 18: EXE-PJ38-4-3 – Average Time Error on Waypoint (ft/NM) – tracks

The table shows that stability in time is high. The accuracy of EPP data compared to flown trajectory in time is high.

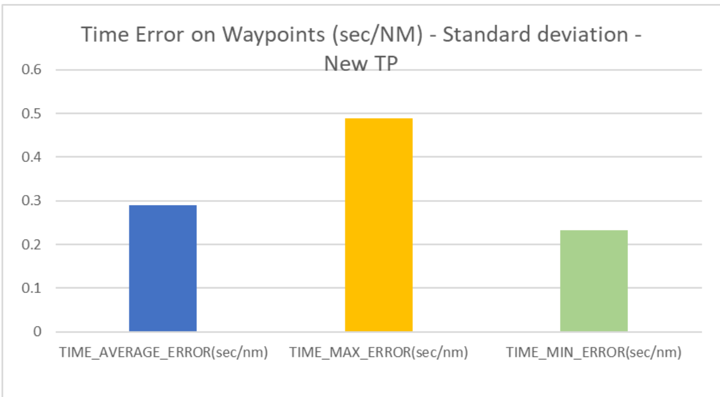


Figure 62: EXE-PJ38-4-3 – Standard Deviation – Time error on Waypoint (sec/NM) – tracks

Statistical results show that the average Time Error on waypoints (within skyguide controlled airspace) is small, meaning that the time accuracy of the ADS-EPP report data is high.

C.3.2.5.1.9.3 Average Level Error on Waypoints (ft/Nm)

Following table contains the Level Error on Waypoints

Min	1st Qu.	Median	Mean	3rd Qu.	Max
0	0.00	0.28	0.42	0.68	177.08

Table 19: EXE-PJ38-4-3 – Average Level Error on Waypoint (ft/NM) – tracks

The table shows that stability in Flight Level is very high. The accuracy of EPP data and Trajectory Prediction in FL is high. The large extreme max value can be explained by the fact that EPPs have not been updated with clearances (probably loss of connection).

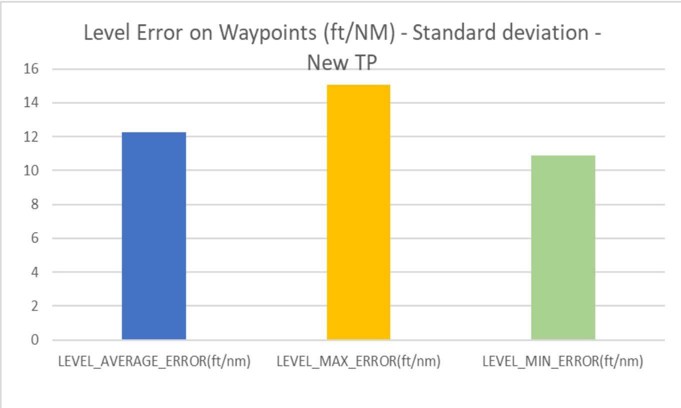


Figure 63: EXE-PJ38-4-3 – Standard Deviation – Level error on Waypoint (ft/NM) – tracks

Statistical results show that the average Level Error on waypoints (within skyguide controlled airspace) is small, meaning that the Flight Level accuracy of the ADS-EPP report data is high.

Success criterion Conclusion:

The objective to retrieve ADS-C EPP data via the ADS-C Common Service has been successfully validated, despite some functions that were not yet available but do not impact the objective of the ADS-C Common Service. Requirements have been updated and will be taken into account in the deployment of the ADS-C Common Service.

The success criterion EX3-CRT-38-W3-DEMOP-032 is OK.

C.3.2.5.2 EX3-CRT-38-W3-DEMOP-033

Success Criterion ID	Success Criterion Description	Success Criterion Status
EX3-CRT-38-W3-DEMOP-033	Check that ADS Common Server data can substitute EUROCONTROL received data	POK

Connection to the ADS-C Common Server has been established and technically tested, however, ADS-C EPP data have been retrieved from the EUROCONTROL sharepoint OneSky Teams storage.

Operational substitution of EUROCONTROL data with ADS Common Server data has not been assessed.

Success criterion Conclusion:
Operational substitution of EUROCONTROL data with ADS Common Server data has not been assessed.
The success criterion EX3-CRT-38-W3-DEMOP-033 is POK.

C.3.3 Unexpected Behaviours/Results

For the data analysis with ADSCENSIO flights EPP, it has been found that some information (Estimated Time Over waypoint) was missing in some downlinked EPP of a same flight. It may affect the quality and reliability of the calculations taking into account ADS-C EPP data.

C.3.4 Confidence in the Demonstration Results

C.3.4.1 Level of significance/limitations of Demonstration Exercise Results

Significance of results

Operational environment

ATCOs and OPS experts have been involved in the assessment of the use of ADS-C APP and speed schedule in the Trajectory Prediction and in CD&R tools.

For all ADSCENSIO flights entering the skyguide airspace, data have been retrieved and recorded. This was recorded from 01 January 2022 until 1 November 2022. The data concerned:

- ADS-C report (EPP, speed schedule)
- Flight Plan Data
- Radar tracks data
- Ops system data:
    - Legacy Trajectory Predictor data
    - Clearances

Quantitative assessment

In order to complete the data from the ADSCENSIO flights, as ATCOs were not benefiting from EPP reports during the live trials (no possible impact on their decisions), results from solutions PJ18-W2.53B and PJ18-W2.56 have been also taken into account.

From the ADCSENSIO flights (~16815 – period 01/22-11/22) that have flown in the skyguide controlled airspace, 2930 have downlinked ADS-C EPP reports.

The number of ADCSENSIO flights downlinking ADS-C EPP is quite low, however it permitted to get sufficient data to compare EPP data with Legacy Trajectory Prediction tool, new Trajectory Prediction tool and tracks. Only limited results have been obtained in vertical profile analysis as few ADSCENSIO flights were climbing or descending in skyguide controlled airspace.

From PJ18-W2.53B and PJ18-W2.56 validations, an assessment of Fuel efficiency can be considered reliable as Genetics traffic generator based on FMS trajectory computation algorithm and logics offer highly reliable aircraft behaviour. *(For more detail refer to Annex E.3.2 from **SESAR Solution 53B VALR – V00.01.00** and Annex F.3.2 from , **SESAR Solution 56 VALR – V00.01.00** (validation report of solution*

PJ18-W2.53B and PJ18-W2.56 validation exercises) - (OBJ-18-W2-53B-V3-VALP-002, EXE006-OBJ-18-56-V2-VALP-005)

Predictability has been only assessed at local level and mainly on a basis of qualitative results basis, quantitative results being less relevant for several reasons explained in dedicated section.

Qualitative assessment

Human Factors results have been collected from different ATCOs within EXE-PJ38-4-3 demonstration sessions.

As for quantitative assessment, results from solutions PJ18-W2.53B and PJ18-W2.56 have been also taken into account and confirmed by EXE-PJ38-4-3 demonstration sessions.

Limitations and mitigations

For data analysis perspective, the number of ADSCENSIO ADS-C connected (Logon) flights and downlinking ADS-C EPP reports was limited due to the COVID period and the limited number of participating aircraft.

This impacted more the statistic side of the Demonstration rather than the operational use of ADS-C EPP data in the ground system.

For the operational objectives, results from solutions PJ18-W2.53B and PJ18-W2.56 have been taken into account.

Conclusion

With the results from solutions PJ18-W2.53B and PJ18-W2.56 being taken into account in addition to the results from PJ38 (statistical analyses, replay and ops demonstrations), the level of significance of results can be considered satisfying regarding the use of ADS-C EPP in the ground system.

C.3.4.2 Quality of Demonstration Exercise Results

Qualitative data (from PJ38 local demonstrations and from solutions PJ18-W2.53B and PJ18-W2.56 validations) were sufficient to draw realistic conclusions.

Number of quantitative data (ADS-C EPPs and operational data) were sufficient to draw realistic conclusions.

Participating ATCOs to PJ38 local demonstration showed great interest in the ADS-C EPP content and the possibilities of its operational use (new Trajectory Prediction, trajectory visualisation (type of turns, TOC, TOD, aircraft performance…), improved CD&R tools (enhanced detection envelopes), Route Conformance monitoring…)

Participating ATCOs considered that the validation platform level of performance was really good during the measured runs (from solutions PJ18-W2.53B and PJ18-W2.56 validations).

The confidence in the validation results is satisfying, since the data come from various sources (real ADS-C EPPs, operational recordings, ATCO feedback from demonstrations, simulation logs, observations, questionnaires and interviews (from solutions PJ18-W2.53B and PJ18-W2.56 validations)).

C.3.4.3 Significance of Demonstration Exercises Results

Trajectory Prediction tool, Trajectory Management tools and Conflict Detection & Resolution tools have been largely evaluated in PJ18-W2.53B and PJ18-W2.56 by the participants and also via operational demonstrations allowing valuable insight into the concept of using ADS-C EPP data in the ground tools (Trajectory Predictor, CD&R tools, Trajectory management tools e.g. Trajectory editor, trajectory information display, 2D route discrepancy check, Route adherence Monitoring, 3D conformance monitoring).

The amount of ADS-C EPP received from ADSCENSIO flights entering the skyguide controlled airspace is sufficient to obtain statistically significant results.

Overall, it can be assumed that the PJ38 demonstration with the complement of PJ18-W2.53B and PJ18-W2.56 validation exercises provided a good level of operational realism, the level of significance of the results is considered satisfying.

C.4 Conclusions

The amount of ADS-C EPP received from ADSCENSIO flights entering the skyguide airspace permitted to draw sufficient statistical analysis on the ADS-C EPP reliability and on the use of it in the operational system (trajectory Prediction, CD&R tools, 2D route discrepancy check, Route Conformance monitoring…)

The content of the EPP and the triggers need some modifications and this will impact the standards in some cases.

ATCOs showed great interest in the ADS-C EPP content and the possibilities of its operational use:

- new Trajectory Prediction,
- trajectory visualisation (type of turns, TOC, TOD, aircraft performance…),
- improved CD&R tools (enhanced detection envelopes),
- 2D route discrepancy check
- Route Conformance monitoring
- 3D conformance monitoring
- Foreseen capabilities with combination of ADS-C EPP and ATS-B2 CPDLC

The benefits of using ADS-C EPP data has been demonstrated from an operational point of view, however the proportion of ADS-C equipped flights has a substantial impact of the potential benefits (performance).

C.5 Recommendations

C.5.1 Recommendations for industrialization and deployment

The results show that the use of airborne data (ADS-C EPP and speed schedule) in the ground system greatly improve ground tools. Operational benefits from ATC part and also from airborne part can be achieved in the short/medium term. However, it relies on a minimum airborne equipage rate that shall be sufficient for operational benefits.

EXE-PJ38-4-3-REC-01: It is therefore recommended that the airborne equipage forecast shall be evaluated quickly in order to enable efficient deployment planning. This has to be taken into account in regulations (CP1) in order to ensure a minimum critical mass for quick return on investments and maximised operational benefits.

EXE-PJ38-4-3-REC-02: Use of FMS modes to be harmonised and more reliable. The use of ADS-C EPP reports is affected by the FMS mode in use (Managed, Non-Managed).

EXE-PJ38-4-3-REC-03: The status of certain items (mandatory/non mandatory) (e.g. Estimated Time Over waypoints) has to be analysed in order to ensure an optimal use of ADS-C EPP reports in the ground system.

EXE-PJ38-4-3-REC-04: A more detailed study of ADS-C contracts to be established and reliability / usability of downlinked data must be carefully assessed.

EXE-PJ38-4-3-REC-05: Calibration process requires vertical and horizontal performance of the aircraft. When a flight is entering. There is a need for ground system of a crossed ANSP airspace to get the vertical performance data of the aircraft even if the flight is entering the airspace in cruise in order to calibrate and predict potential vertical evolution in the crossed airspace (need for What-if function). This can be solved by the ADS-C Common Service enabling any ANSPs to get ADS-C EPP reports when flight is in climb phase (for vertical profile calibration).

EXE-PJ38-4-3-REC-06: Currently, the CP1/AF6 mandates the ADS-C equipage only for new airframes. To be beneficial, the capability to retrofit the current airframes with ATS B2 should be envisaged and promoted.

C.5.2 Recommendations on regulation and standardisation initiatives

EXE-PJ38-4-3-REC-07: It is therefore recommended that the airborne equipage forecast shall be evaluated quickly in order to enable efficient deployment planning. This has to be taken into account in regulations (CP1)

EXE-PJ38-4-3-REC-08: The use of FMS modes has to be harmonised and more reliable. The use of ADS-C EPP reports is affected by the FMS mode in use (Managed, Non-Managed). Potential regulation and standardisation shall address operational procedures (airborne, ground) to ensure the optimal use of ADS-C EPP and speed schedule reports.

EXE-PJ38-4-3-REC-09: The use of ADS-C common server has to be promoted and be part of a regulation with a short/medium term timeframe to get benefit of the use of ADS-C as soon as possible.

Appendix D Demonstration Exercise #04 (EXE-PJ38-4-4 by MUAC) Report

D.1 Summary of the Demonstration Exercise #04 Plan

D.1.1 Exercise description and scope

Maastricht UAC will make use of the platform developed for PJ31 and further evolve it to enhance the ATCO experience with updates coming from ATCOs' feedback collected during PJ31.

MUAC exercise focused on evolving the platform developed for PJ31 to enhance the ATCO experience and made it more suitable for the operational use. The updates implemented were coming from ATCOs' feedback collected during PJ31.

The main purpose was to demonstrate that the changes better support the operational and human performance by reducing the number of nuisance alerts being displayed and improving the readability of the ADS-C data thanks to additional information, while maintaining at least the safety level observed during PJ31.

D.1.2 Summary of Demonstration Exercise #04 Demonstration Objectives and success criteria

MUAC exercise addresses the following objectives:

- **Safety improvement** (OBJ-38-W3-DEMOP-SAFE-0001): ADS-C data contribute to improve Safety. Checking that there is a reduction of the number of potential infringements, or an earlier resolution.
- **Human Performance improvement** (OBJ-38-W3-DEMOP-HPRF-0002): Demonstrate that the ADS-C changes performed improves the Human Performance compared with PJ31.
- **Operational Performance improvement** (EX4-OBJ-38-W3-DEMOP-OPRF-0003): Demonstrate that the ADS-C changes performed improves the Operational Performance compared with PJ31.
- **Operational feasibility** (OBJ-38-W3-DEMOP-OPSF-0004): Demonstrate that the use of ADS-C data is operationally feasible beyond what has been demonstrated in PJ31.
- **Access to ADS-C data** (OBJ-38-W3-DEMOP-TECH-0006): Demonstrate that the use of an ADS-C Common Service improves the access to data assessing that the data received via the ADS-C Common service is reliable and it is correctly received.

D.1.3 Summary of Validation Exercise #04 Demonstration scenarios

The reference scenario is the standard operational environment within Maastricht UAC.

At the beginning, only the selected group of controllers participating in PJ31 will have the ADS-C information available on the screen, but before the exercise concludes it is intended that all controllers will be trained and will have the ADS-C functionality available with the enhancements proposed during PJ31.

D.1.4 Summary of Demonstration Exercise #04 Demonstration Assumptions

There were no specific assumptions for this exercise other than the general demonstration ones provided in section 5.5 of the PJ38W3 Demonstration Plan Release 2.

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
PJ38-ASS-01	ADS-C data provision		The ADS-C Common Service (ACS) is available with appropriate functionalities (including TOA Range demand contracts) and performances	Pre-requisite to be able to carry out ANSP validation exercises	High
PJ38-ASS-02	ADS-C data usability		The received ADS-C data are usable (available on time, not corrupted, etc.)	Pre-requisite to be able to use ADS-C data. The same avionics as in PJ31 will be used. The ACS must ensure that the received data are correctly conveyed to the ANSPs	High
PJ38-ASS-03	VDL2 performances		VDL2 performances support an efficient downlink of ADS-C data	Pre-requisite to be able to downlink the ADS-C data	High
PJ38-ASS-04	Future Covid situation		Future Covid situation will not affect the organisation of the exercises (e.g. travel restrictions)	It is anticipated that the future Covid situation will not be as bad as it was in 2020 and early 2021	High

Table 20: Exercise #04 Demonstration Assumptions overview

D.2 Deviation from the planned activities

At MUAC we are currently having our own connection with the aircraft to establish ADS-C contracts and to receive the ADS-C reports. However, our intention is to move to the ADS-C Common Service once it is deployed.

In that context, and even if the core part of our exercise was to focus on the evolution and enhancements of PJ31 ADS-C implementation before full operational deployment, our initial intention was to use PJ38 as an opportunity to build a basic ADS-C Common Service (ACS) Client to early test the future setup. However, this was not finally possible because of the challenging schedule of the project and the workload the MUAC team in charge of the development.

It was already identified as a risk within the demonstration plan the possibility of not being able to accommodate the development of the ACS Client in the timeframe of the PJ38. This risk became a reality despite the mitigation actions in place as it was not possible to deconflict the priorities of the development team before the end of the year. EX4-OBJ-38-W3-DEMOP-TECH-0006 could not be demonstrated.

D.3 Demonstration Exercise #04 Results

D.3.1 Summary of Demonstration Exercise #04 Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-38-W3-DEMOP-SAFE-0001	Safety improvement	EX4-CRT-38-W3-DEMOP-043	Reduction of potential infringements (caused by discrepancies air/ground) or resolved earlier thanks to the availability of EPP information (via controllers' feedback)	En-Route	Positive feedback from Controllers about the reduction of potential infringements. Thanks to ADS-C, controllers can be aware of the aircraft intents even before assume and they can take early action to resolve discrepancies with the aircraft intent is discrepant with the plan on the ground avoiding possible incidents.	OK
OBJ-38-W3-DEMOP-HPRF-0002	Human Performance improvement	EX4-CRT-38-W3-DEMOP-009	The additional EPP information provided improves the readability of	En-Route	MUAC Controllers confirmed that the changes performed in the system to	OK

			the ADS-C data displayed and supports ATCOs better in performing their tasks compared with PJ31 implementation.		enhance the ADS-C information display adding additional information improved the readability of the information and helped them perform their tasks better than the PJ31 solution.	
OBJ-38-W3-DEMOP-HPRF-0002	Human Performance improvement	EX4-CRT-38-W3-DEMOP-013	The number of nuisance 2D discrepancy alerts displayed to the ATCOs is reduced compared with PJ31 implementation. (via controllers' feedback)	En-Route	The feedback received from the controllers was very positive. They consider that the changes performed during PJ38 in relation with the display and filtering of some of the discrepancy alerts reduced the number of nuisance 2D discrepancy warnings compared with PJ31.	OK
OBJ-38-W3-DEMOP-OPRF-0003	Operational performance improvement	EX4- CRT-38-W3-DEMOP-020	EX4-CRT-38-W3-DEMOP-013 The number of nuisance 2D discrepancy alerts displayed to the ATCOs is reduced compared with PJ31 implementation. (via controllers' feedback)	En-Route	The feedback received from the controllers was very positive. The reduction of the nuisance alerts due to the changes performed during PJ38, help improve the Operational performance compared with PJ31.	OK
OBJ-38-W3-DEMOP-OPRF-0003	Operational performance improvement	EX4- CRT-38-W3-DEMOP-020	The number of nuisance 2D discrepancy alerts displayed to the ATCOs is	En-Route	MUAC controllers confirmed that the EPP additional information provided helped	OK

			reduced compared with PJ31 implementation . (via controllers' feedback)		improving the readability of the data displayed and supports ATCOs better in performing their tasks than the solution of PJ31.	
OBJ-38-W3-DEMOP-OPSF-0004	Operational feasibility	EX4-CRT-38-W3-DEMOP-023	Positive feedback from the ATCOs on the usability of the ADS-C TOD information (potentially to be linked to fuel consumption benefits analysis under PJ18-W2.56)	En-Route	The ATCOs gave positive feedback on the usability of the EPP TOD information being downlinked by the aircraft. It has been proven to be reliable as long as both the air and ground share the same view related to constraints. The use of the preferred TOD can delay the start of the descent.	OK
OBJ-38-W3-DEMOP-OPSF-0004	Operational feasibility	EX4-CRT-38-W3-DEMOP-023	The additional EPP information provided improves the readability of the ADS-C data displayed and supports ATCOs better in performing their tasks compared with PJ31 implementation .	En-Route	MUAC controllers confirmed that the EPP additional information provided helped improving the readability of the data displayed and Operational feasibility compared with PJ31.	OK
OBJ-38-W3-DEMOP-TECH-0006	Access to ADS-C data	EX4-CRT-38-W3-DEMOP-032	Assess that the data received via the ADS-C Common Service are reliable.	En-Route	The ACS Client could not be developed within the timeframe of the project; therefore, this objective could not be demonstrated.	Not covered

OBJ-38-W3-DEMOP-TECH-0006	Access to ADS-C data	EX4-CRT-38-W3-DEMOP-033	Assess that the ADS-C data is correctly received by our system (test platform).	En-Route	The ACS Client could not be developed within the timeframe of the project; therefore, this objective could not be demonstrated.	Not covered

Table 21: Exercise #04 Demonstration Results

The following KPAs were considered: Predictability, Human Performance and Safety.

Predictability – Similar conclusions to those of PJ31 were obtained, the controllers did not consider that the predictability of the equipped flights showed any big improvement over the non-equipped. However, the confirmation of the routing via ADS-C acted as an assurance that the trajectory prediction was indeed where the aircraft was intending to fly.

In this respect the confirmation increased the confidence level of the controllers and hence the trust in predictability was increased.

Moreover, the trust in predictability was also increased thanks to the use of the TOA Range demand contract. This contract can be used for instance when an aircraft intends to cross a military area which is about to be activated. The aircraft will downlink a the time interval as response to the contract and the controllers can be confident whether the aircraft is able to be out the military area before its activation.

Human Performance –The CBT and the ADS-C briefing material created for the training of all MUAC ATCOs was considered to be sufficient and similar to PJ31 no additional comments were received relating to the roles, responsibilities, structures or communications during this project.

The comments received during PJ31 relating to the HMI display were not received this time. The implementation of the enhancements proposed in PJ31 made the HMI evolved to a state where the users considered it to be suitable for the use in the online environment.

Safety – The discrepancy indication is considered to be a safety improvement in the same way as the display of the aircraft selected altitude via Mode S in the vertical plane. While no discrepancies were seen the controllers stated that it was good to know that an additional check was being made. Additionally, the FIM tabular display containing the EPP information was also considered as a safety improvement assuring the controllers that a CPDLC route clearance given to an aircraft was properly understood and correctly implemented in the FMS by the aircrew.

D.3.2 Analysis of Exercises Results per Demonstration objective

D.3.2.1 EX4-OBJ-38-W3-DEMOP-SAFE-0001 Results

The discrepancy indication is considered to be a safety improvement. The controllers stated that it was good to know that an additional check was being made between the ground and air trajectories. The 2D checking is performed before the aircraft is under control by MUAC and the controllers can be aware of discrepancies earlier and solve them as soon as the aircraft is transferred to MUAC. For instance, the ADS-C information provides awareness of last minute flight plan changes not received by ATC system and gives the possibility to the ATCOs to react early.

The automatic 2D discrepancy check and the ADS-C information being displayed are also perceived as a way of saving time on voice frequency and helping reduce the likelihood of mistakes. The EPP information assures the controllers that a CPDLC route clearance given to an aircraft was properly understood and correctly implemented in the FMS by the aircrew and if it is not the case, the controllers can immediately see it on the EPP information downlinked and displayed and they can quickly react to correct the situation.

Another situation where the ADS-C information is helping is detecting early start of turns for large heading changes. Controllers have a greater awareness of whether or not an early turn can take an aircraft into an active danger area. ADS-C can also help the controller to be sure an aircraft crossing a military area can exit it before it gets active.

From all what has been said it can be concluded that the ADS-C data and the 2D discrepancy check performed by the systems contribute to an improvement on Safety.

D.3.2.2 EX4-OBJ-38-W3-DEMOP-HPRF-0002 Results

The list of enhancements performed in the CWP HMI during PJ38 regarding the display of the ADS-C information and the filtering of the nuisance 2D discrepancy warnings were successful. The ATCOs saw an improvement compared with PJ31 implementation.

The number of nuisance alerts being displayed to the ATCOs has been reduced to the minimum and the additional columns included in the FIM EPP window giving information about the lateral/vertical types of the waypoint are helping the ATCOs to understand why those latlongs waypoints are there. The ADS-C changes performed have improved the Human Performance compared with PJ31 implementation.

D.3.2.3 EX4-OBJ-38-W3-DEMOP-OPRF-0003 Results

The ATCOs feedback is that the additional EPP information provided (additional columns included in the FIM EPP window) improved the readability of the ADS-C data displayed compared with PJ31. However, additional enhancements are being proposed to fine tune further the display of the latlong waypoints in the FIM EPP window:

- They would like to have the option to decide whether to filter the latlongs out or display them in the EPP window.
- Additionally, they would also like to have a highlight function from the EPP window to see where a given latlong waypoint is located graphically along the EPP Leg.

The new filtering rules of the 2D discrepancies reduced the nuisance warnings to the minimum. The ATCOs provided positive feedback and considered it improved the operational performance compared with PJ31 implementation.

D.3.2.4 EX4-OBJ-38-W3-DEMOP-OPSF-0004 Results

The ATCOs gave positive feedback on the usability of the EPP TOD information being downlinked by the aircraft. It has been proven to be reliable as long as both the air and ground share the same view related to constraints e.g. applicable LOAs included in the FMS, or when there is no restriction on the ground.

In the cases above, if traffic allows, the ATCOs will try to adhere to the aircraft preferred TOD. This is usually translated in a delay of the start of the descent, which will mean that the aircraft will be more NM in average in cruise.

As an example, in some specific flows studied it has been observed that during the day, if the traffic situation permits, the TOD can be delayed on 20-30 NM in average and during night or during low traffic periods, it can be delayed to 30-40 NM on average.

D.3.2.5 EX4-OBJ-38-W3-DEMOP-TECH-0006 Results

This Objective couldn't be demonstrated by MUAC because the initial intention to develop a basic ACS Client to connect to the ADS-C Common Service and assess the correct reception of ADS-C data could not be materialized. See explanation in section D.2 Deviation from the planned activities.

D.3.3 Unexpected Behaviours/Results

There are no others unexpected behaviours observed than those already reported during PJ31. See Appendix F section F3.3.

D.3.4 Confidence in the Demonstration Results

D.3.4.1 Level of significance/limitations of Demonstration Exercise Results

This exercise was executed with the FANS C equipped aircrafts from the same six Airspace Users (Air France, British Airways, EasyJet, IBERIA, Novair and Wizz Air) participating in PJ31 DIGITS. It is important to mention that the a/c equipment is fully certified and complies with the applicable ATS-B2 standard as released in March 2016 (EUROCAE ATS B2 standards Rev A). The flights considered during MUAC exercise were all normal commercial flights during a period of almost two years (mid December 2020 to September 2022) and they were controlled during different weather conditions and different traffic situations.

At MUAC the ATS B2 flights were processed by the operational system, but we can differentiate two different setups. From mid-December 2020 until end May2022 only a sub-set of the controllers had the specific "ADS-C functionality" available on the CWP HMI, while as from the 31st of May 2022, this functionality was made available to all MUAC controllers. It is important to mention, that before making the new functionality available to all MUAC controllers there were changes implemented in both FDPS and CWP HMI systems and that all controller followed a training on ATS B2 functionality. The changes made were in accordance with the results and recommendations obtained during PJ31 DIGITS demonstration.

Additionally, to the ADS-C functionality, MUAC has also implemented the upgrade of CPDLC for ATS B2 (CPDLC v2), being able to use CPDLC v1 with ATN B1 aircrafts and CPDLC v2 with ATS B2 aircrafts. CPDLC v2 message set is currently used with the FANS C equipped aircrafts (ATS B2) included in MUAC B2 list. The selection of the correct CPDLC version to use with each flight is transparent for both the controller and the pilot. This mechanism is performed during the Logon process, it is done by the FDPS systems and agreed with the aircraft avionics and this proves the backwards compatibility.

D.3.4.2 Quality of Demonstration Exercise Results

From all what has been said in the previous section, we can claim that both the avionics as well as MUAC ground system are fully operational and ATS B2 compliant also showing the readiness of the standards for the CP1 maturity gate.

D.3.4.3 Significance of Demonstration Exercises Results

During the 20 months this demonstration has lasted, 28,800 ATS B2 flights have been controlled by MUAC ATCOS sending a total of 419,163 ADS-C reports. Those flights were operating under a variety of weather, traffic conditions and under different AU-operating policies from which we can conclude the statistical relevance of the exercise.

D.4 Conclusions

PJ38 MUAC exercise builds on the work initiated in SESAR 1 with I4D and continued during PJ31 DIGITS VLD. The exercise is based on real operations. An operational ground system controlling mix traffic of both ATN B1 and ATS B2 certified aircrafts. This exercise also provides a real insight of the challenges and benefits of deploying ATS B2.

The main conclusions of this exercise are:

- The current implementation of the ATS B2 standards in both air and ground systems are good and proven to be ready for deployment. MUAC ground system is fully operational as from the end of May 2022 and since then the ADS-C information and 2D discrepancy indication is available to all ATCOs. Therefore, it can be claimed that MUAC ground system is ready to comply with the CP1/AF6 mandate.

  Note that at the moment MUAC is establishing the ADS-C contracts directly and receiving the reports with the a/c via the DLFEP and not via the ADS-C Common Service (ACS). MUAC will make the transition to the ACS once it is deployed.

- The enhancements performed in the CWP HMI during PJ38 regarding the display of the ADS-C information and the filtering of the nuisance 2D discrepancy warnings were successful. The ATCOs saw an improvement compared with PJ31 implementation.

  There are much less nuisance alerts being displayed to the ATCOs and the additional columns included in the FIM EPP window giving information about the lateral/vertical types of the waypoint are helping the ATCOs to understand why those latlongs waypoints are there. However, there are situations for instance after a far DCT clearance, where there are many latlongs displayed on the EPP FIM window (e.g. ABEAM waypoints) and the controllers would like to have the option to decide whether to filter them out or display them. Additionally, they would also like to have a highlight function from the EPP window to see where a given latlong waypoint is located along the EPP Leg.

  Other enhancements ATCOs expect to have in the future are:

  - Use/Display of the intent status information and/or displaying the EPP information in a different way depending on the mode the aircraft is flying.
  - Display of a warning when the Requested Flight Level of the FPL and the EPP one differ.
  - Display of the speed schedule
  - Vertical discrepancies alerts

The last two proposal above will be implemented in the operational system depending on the PJ18 validations results.

These and other future changes requested by the OPS room will be implemented and incorporated in MUAC's CWP HMI and/or FDPS as part of the normal evolutions of the operational system.

- The ATCOs gave positive feedback on the usability of the EPP Top Of Descent (TOD) information being downlinked by the aircraft. It has been proven to be reliable as long as both the air and ground share the same view related to vertical constraints e.g. applicable LOAs included in the FMS, or when there is no vertical restriction on the ground.

  If that is the case and when traffic allows, the controller can see the optimum TOD computed by the aircraft and will adhere try to it. This will be translated into better descend profiles, the start of the descent will start a number of nautical miles later, which can be translated into fuel saving and reduction of CO_2 emissions.

Figure 64: EXE-PJ38-4-4 –Optimum TOD Indication in the EPP

- The ADS-C can bring immediate benefits to the airlines, not only by having later descends, but also by getting early and better direct routings and possible reduction of re-routings due to for instance military area activations. This can be achieved thanks to better controller awareness on the flight's trajectory. These path reductions will contribute to less nautical miles flown and less fuel consumption.

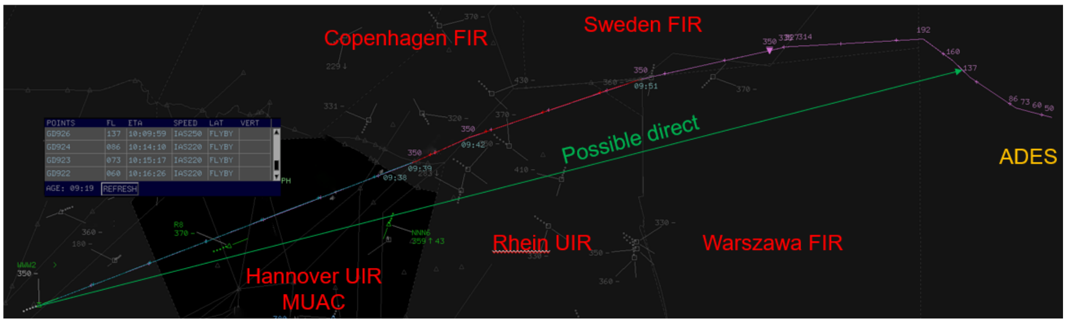
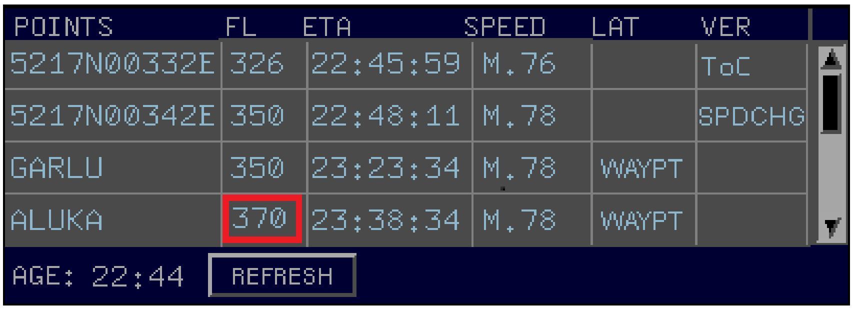


Figure 65: EXE-PJ38-4-4 –Example of possible better direct clearance thanks to EPP

Additionally, the better controller awareness on the flight's intent can result in earlier climbs to optimal levels during cruise as controllers are more aware of the climb intent without the pilot intervention.



POINTS	FL	ETA	SPEED	LAT	VER
5217N00332E	326	22:45:59	M.76		ToC
5217N00342E	350	22:48:11	M.78		SPDCHG
GARLU	350	23:23:34	M.78	WAYPT	
ALUKA	370	23:38:34	M.78	WAYPT	

AGE: 22:44 REFRESH

Figure 66: EXE-PJ38-4-4 –RFL intent in the EPP

- ADS-C is a major step towards trajectory-based operations, offering controllers a clearer picture of aircraft intentions, that could help to better predict sector loads and that is being seen as one of the first steps towards future automation.

D.5 Recommendations

D.5.1 Recommendations for industrialization and deployment

Recommendation 1

- ANSPs should try to join the ACS and comply with the CP1/AF6 mandate as early as possible. An early deployment of ADS-C along Europe can bring more benefits not only to the ANSP, AOs, but to the whole network as this technology will contribute to TBO and greener flights. The implementation of ADS-C via ACS instead of having an own link established would make the deployment quicker and easier for the ground systems.

Recommendation 2

- Current operations have demonstrated that CPDLC version 2 brings benefits when it is used in combination with ADS-C. As TBO enabler, CPDLC v2 allows ATCOs to uplink more complex clearances with lat/long coordinates and vertical constraints with extended messages integration in avionics. For instance, the route clearances are directly loadable by pilots into the FMS, which reduces the workload of the flight crew and minimised human errors. Additionally, the subsequent ADS-C/EPP downlinked data can be used to check that the pilot has implemented the data in the FMS. Being able to uplink lat/long coordinates enables a better use of the airspace, which at the end can result in less miles flown for the aircraft. MUAC will recommend the ground systems to use CPDLC v2 in combination with ADS-C to make use of all the ATS B2 potential and support future ATC automation.

Recommendation 3

- Currently, the CP1/AF6 mandates the ATS B2 equipage only for new airframes, but MUAC considers that encouraging retrofitting the current airframes with ATS B2 would be beneficial and in the interest of the whole network. As the retrofit option is more costly and therefore less interesting for the AOs, SDM and EC should try to give some incentives to encourage AOs to also retrofit their fleet.

Recommendation 4

- It would be recommended to evolve in the next ADS-C steps needed towards TBO. Some guidelines on common direction beyond the CP1/AF6 functionality should be provided for the ground system exploring additional functionalities to enhance the use of ADS-C data.

D.5.2 Recommendations on regulation and standardisation initiatives

Even if Rev A has been proved to be matured and ready for standardisation, MUAC would recommend that the airborne manufacturers move towards future versions of the standards when possible. The current ED standards are satisfying and provide significant added value for ground usage, but it is expected that the future versions (e.g. Rev B to start with) of the standards will contain many of the improvements requested by the ANSPs participants of PJ31 DIGITS VLD (see PJ31 Demo Report V2 section 5.2.2.). Those improvements will add possibilities to enhance the ground prediction tools and some of them will provide additional information and flexibility to the ADS-C Common Service (ACS) deployment.

On the ground, the systems should be prepared to already support a mix fleet, ATS B2 equipped aircrafts with RevA and RevB (as the standard under discussion today) and future standards. The implementation of new contract types or triggers would only require low evolutions.

However, from an avionic perspective, we can identify two different situations. Those of the manufacturers who at the moment do not have an ATS B2 product certified and those who already have it, as Airbus.

For the first case, it is recommended that the future updates of ED-228A/ED-229A standards are immediately taken on board before certification, as the new revision will bring additional benefits to the ground.

In the second case, the updates of ED-228A/ED-229A (Rev B) standards will be more complicated, as they would have an impact on the manufacturer product line, because the implementation of the new revision will require new evolutions of ATSU, FMS or both. For instance, in the case of Airbus, their FANS C product is based on ED-228A/ED-229A and it is already certified. Therefore, the upgrades of Rev B will require consequent process of development, verification and validation before being recertified against the RevB new standard. The recommendation in this case would be to try to accommodate to update of their product whenever possible.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Appendix E Demonstration Exercise #05 (EXE-PJ38-4-5 by DFS) Report

E.1 Summary of the Demonstration Exercise #05 Plan

E.1.1 Exercise description and scope

This demonstration exercise led by DFS has been collecting, processing and analysing ADS-C data downlinked from revenue flights within the German airspace in the area of responsibility of Karlsruhe Upper Area Centre (EDUU).

The ADS-C data flows towards the ATM system are realised by means of the ADS-C Common Service (ACS).

Based on the results of PJ31 the DFS iCAS IBP has been further developed to support investigations in the following areas:

- Improvement of ATCOs situational awareness due to
  - Provision of ADS-C data to the ATCO
  - Automated 2D conformance checks comparing the airborne and ground planned trajectories
- Improvement of ATM ground systems Trajectory Prediction (TP) based on the usage of ADS-C EPP data
- Potential positive effects on Medium Term Conflict Detection by using ADS-C improved TP
- Verification of the ADS-C common service client interface

E.1.2 Summary of Demonstration Exercise #05 Demonstration Objectives and Success Criteria

The following objectives were addressed by the DFS Exercise:

- **Safety improvement** (OBJ-38-W3-DEMOP-SAFE-0001): Demonstrate that the use of ADS-C data contributes to improve Safety: A demonstration that the level of safety is maintained while another aspect of improvement is addressed (Operational efficiency or Human performance).
- **Human Performance improvement** (OBJ-38-W3-DEMOP-HPRF-0002): Demonstrate that the use of ADS-C data improves the Human performance.
- **Operational Performance improvement** (EX4-OBJ-38-W3-DEMOP-OPRF-0003): Demonstrate that the ADS-C changes performed improves the Operational Performance and creates Operational Benefits
- **Operational feasibility** (OBJ-38-W3-DEMOP-OPSF-0004): Demonstrate that the use of ADS-C data is Operationally feasible beyond what has been demonstrated in PJ31 (i.e., highlight 2D consistency check discrepancies)

- **Access to ADS-C data** (OBJ-38-W3-DEMOP-TECH-0005/0006): Demonstrate a reliable and robust collection infrastructure to set up ADS-C contract and process data. And demonstrate that the use of an ADS-C Common Service improves the access to data.

The summary of Success Criteria can be found in Table 15 below in chapter E.3.1.

E.1.3 Summary of Demonstration Exercise #05 scenarios

The reference scenario is based on real flights within the Karlsruhe Upper Area Control Centre (EDUU) area of responsibility, which have no ADS-C capabilities.

The solution scenario comprises ADS-C capable revenue flights within the Karlsruhe Upper Area Control Centre (EDUU) area of responsibility. The ADS-C data is used to improve the ground system.

The demonstration is carried out with a mix of the following methods, supporting the different verification objectives:

- Shadow demonstration with live ADS-C traffic
- Simulated ADS-C traffic

The overall demonstration has involved two technical sites, which are the DFS SESAR iCAS IBP in Langen, Germany, and Indra demonstration platform in Torrejon, Spain.

The execution timeframe of the demonstration exercise has been Q4 2023. Both operational personnel (ATCOs) and Engineering personnel has been involved and assessed the demonstration objectives according to the respective criteria.

Due to the thematic areas addressed in the demonstration (among them discrepancy monitoring, CD&R and Trajectory improvements) the demonstration exercise has been carried out in close cooperation with PJ18 Sol 53B and Sol 56. Specifically, the same ATS system prototypes have been used and parts of the exercises and assessments were carried out in a combined effort. A key element and contribution of PJ38 in this cooperation has been the usage real life data from revenue flights in the flight trials and the consumption of this data via the ADS-C Common Service developed in PJ38.

In the reporting of the following sections, results in exercise conditions are reported in different levels of details. For thematic areas which have been focused in detail via PJ18, the reader is referred to corresponding VALR to avoid duplication. A higher level of detail is applied in the reporting for objectives which are exclusive to PJ38 (here in particular technical objectives, related to the coupling of the ATS platform with the ADS-C Common Service).

E.1.4 Summary of Demonstration Exercise #05 Demonstration Assumptions

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
PJ38-ASS-01	ADS-C data provision		The ADS-C Common Service (ACS) is available with appropriate functionalities (including TOA Range demand contracts) and performances	Pre-requisite to be able to carry out ANSP validation exercises	High
PJ38-ASS-02	ADS-C data usability		The received ADS-C data are usable (available on time, not corrupted, etc.)	Pre-requisite to be able to use ADS-C data. The same avionics as in PJ31 will be used. The ACS must ensure that the received data are correctly conveyed to the ANSPs	High
PJ38-ASS-03	VDL2 performances		VDL2 performances support an efficient downlink of ADS-C data	Pre-requisite to be able to downlink the ADS-C data	High
PJ38-ASS-04	Future Covid situation		Future Covid situation will not affect the organisation of the exercises (e.g. travel restrictions)	It is anticipated that the future Covid situation will not be as bad as it was in 2020 and early 2021	High

Table 22: Exercise #05 Demonstration Assumptions overview

All Assumptions pre-exercise became TRUE before the start of the exercise, such fulfilling the preconditions for a series of successful exercise runs.

E.2 Deviation from the planned activities

Deviating from the original assumption on exercise execution, the parts of the exercise where live ADS-C data was directly consumed from the ADS-C Common Service was executed at Indra Premises, not at DFS premises. The decision was made for cybersecurity reasons and constraints, which prevented connection of the DFS platform to the ACS interface exposed via public internet in an adequate way. The decision did not affect the exercise execution in content, notably identical software and system architecture was used at DFS and Indra premises and the functionality demonstrated was not affected.

Also deviating from the plan, it was considered that the offline recorded data replay modus was fully substituted with the live data and live traffic activities during the two Exercise days at Indra premises and so it was omitted.

E.3 Demonstration Exercise #05 Results

First an overview/summary is given in table form, details per objective and success criteria are then reported and analysed thereafter.

E.3.1 Summary of Demonstration Exercise #05 Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results (per criteria)	Demonstration Objective Status
OBJ-38-W3-DEMOP-SAFE-0001	Safety improvement	CRT-38-W3-DEMOP-002	The CD&R tools enhanced by the use of additional data with more reliability is adequate for safe service provision according to the ATCOs.	OK	OK
OBJ-38-W3-DEMOP-HPRF-0002	Human Performance improvement	CRT-38-W3-DEMOP-005	The situation awareness is considered improved by the users (e.g. ATCO).	OK	Partially OK
		CRT-38-W3-DEMOP-006	The use of ADS-C data leads to a reduced ATCO workload due to reduced radio conversation asking for the aircraft intention.	Not validated	

		CRT-38-W3-DEMOP-012	The number of spurious detection of conflicts is reduced thanks to enhanced CD&R tool.	OK	
OBJ-38-W3-DEMOP-OPRF-0003	Operational performance improvement	CRT-38-W3-DEMOP-015	The adherence to on board expected vertical trajectories is enhanced thanks to the use (e.g. display) of TOD information.	Partially OK	Partially OK
		CRT-38-W3-DEMOP-018	CD&R: The reduced detection uncertainty buffers of the improved CD&R tool MTCD lead to a higher operational performance due to a higher reliability of the planned trajectories.	OK	
OBJ-38-W3-DEMOP-OPSF-0004	Operational feasibility	CRT-38-W3-DEMOP-023	Display: the display of ADS-C data is considered useful by users (e.g. ATCO).	OK	OK
		CRT-38-W3-DEMOP-024	The CD&R tools enhanced by ADS-C data are acceptable for the ATCOs.	OK	
		CRT-38-W3-DEMOP-025	The system enhancement allows to establish trust in the system	OK	

		CRT-38-W3-DEMOP-026	The consistency check with ADS-C data in 2 dimensions is acceptable for the ATCOs.	OK	
OBJ-38-W3-DEMOP-TECH-0005	Data collection improvement	CRT-38-W3-DEMOP-029	Provision of regular statistics about the traffic of ADS-C datalink exchanges.	OK	OK
OBJ-38-W3-DEMOP-TECH-0006	Access to ADS-C data	CRT-38-W3-DEMOP-030	ADS-C periodic, on event contracts are successfully established and maintained by the ADS-C Common Service, and resulting data shared with the clients in due time.	OK	OK
		CRT-38-W3-DEMOP-031	ADS-C on demand contracts are correctly passed through the ADS-C Common Service established on client request, and resulting data shared in due time.	OK	
		CRT-38-W3-DEMOP-032	Data received via the ADS-C Common Service are reliable (i.e. they faithfully reflect the latest situation provided by the aircraft).	OK	

		CRT-38-W3-DEMOP-033	The ACS successfully receives, processes and distributes ADS-C data to multiple clients via SWIM in real time.	OK	
		CRT-38-W3-DEMOP-034	The ACS successfully collects ADS-C data in live flight trials	OK	
		CRT-38-W3-DEMOP-036	The ACS data provision satisfies the operational needs of the clients	OK	
		CRT-38-W3-DEMOP-037	The ACS saves A/G bandwidth with regards to an architecture of local ADS-C data acquisition	OK	

Table 23: Exercise #05 Demonstration Results

E.3.2 Analysis of Exercises Results per Demonstration Objective

In this chapter the relevant demonstration exercise observations towards the individual Objectives and the associated Success Criteria are reported.

Criteria assessed in a Combined Effort (CE) with PJ18 Solution 53B and Solution 56 exercises are tagged with the label [CE Sol 53/56 PJ38].

E.3.2.1 EX1-OBJ-38-W3-DEMOP-SAFE-0001 Results

Safety Improvement Objective:

Demonstrate that the use of ADS-C data contributes to improve Safety. It might either be:

- *a direct improvement of safety level, or*
- *a demonstration that the level of safety is maintained while another aspect of improvement is addressed (Operational efficiency or Human performance).*

[CE Sol 53/56 PJ38]

Criteria CRT-38-W3-DEMOP-002: *OK*

The CD&R tools enhanced by the use of additional data with more reliability is adequate for safe service provision according to the ATCOs.

- EX009-OBJ-18-W2-53B-V3-VALP-005 (CRT 1) - The impact of enhanced CD&R tools using aircraft data on safety was assessed. There is no increase in the number of pre-tactical planned conflicts taking into consideration increase in traffic. The improved TP as such reduces false alarms and reveals undetected conflicts. There is no evidence that additional pre-tactical conflicts are generated by this approach.
- EX009-OBJ-18-W2-53B-V3-VALP-005 (CRT 2) - To assess the impact of enhanced CD&R tools using aircraft data on safety. There is no increase in the number of planned tactical conflicts taking into consideration increase in traffic. There is no evidence that additional planned tactical conflicts are generated by the improved TP using ADS-C EPP.
- EX009-OBJ-18-W2-53B-V3-VALP-005 (CRT 5) - The impact of enhanced CD&R tools using aircraft data on safety was assessed. The implementation of CD&R support tools does not deteriorate human performance impacting safety. Reduction of false alerts and identification of undetected conflicts could potentially increase situational awareness while reducing the workload for unnecessary checking for false alerts. There is no indication that human performance is deteriorated by this observation, especially no negative effect on Safety.

E.3.2.2 EX1-OBJ-38-W3-DEMOP-HPRF-0002 Results

Human Performance Improvement Objective:

Demonstrate that the use of ADS-C data improves the Human Performance.

[CE Sol 53/56 PJ38]

Criteria CRT-38-W3-DEMOP-005: *OK*

The situation awareness is considered improved by the users (e.g. ATCO).

- EX05-CRT-18.56-V2-VALP-003-001 - The participating controllers estimate a positive impact on Situation Awareness.

  However, there are doubts about the systems behaviour under specific conditions, like e.g. heavy weather where many aircraft will divert from their originally planned routes. Such situations might end up in a degradation of the situational awareness and need to be further investigated by succeeding V3 validation activities.

Criteria CRT-38-W3-DEMOP-006: *Not validated*

The use of ADS-C data leads to a reduced ATCO workload due to reduced radio conversation asking for the aircraft intention.

This criterion is not covered by solution PJ18-56 or by PJ38 findings. However, it was emphasised by the ATCOs that the provision of the aircraft intent via ADS-C EPP can lead to less radio conversation due to the availability of the data.

Criteria CRT-38-W3-DEMOP-012: *OK*

 Co-funded by the European Union

The number of spurious detection of conflicts is reduced thanks to enhanced CD&R tool.

- EX009-OBJ-18-W2-53B-V3-HPAP-002 - It was presumed that the number of previously unidentified conflicts could increase, and the number of false alerts would decrease. As a result, workload could be reduced, and situational awareness might be increased. ATCO feedback on CD/R impact of improved TP revealed that a resulting higher accuracy of conflict detection will support the ATCOs in carrying out their tasks.

- EX009-OBJ-18-W2-53B-V3-HPAP-001 - Impact of enhanced CD&R support tools using aircraft data on controllers' tasks and operating methods was assessed. Participants see a positive impact of ADS-C EPP enabling TP improvement.

- EX009-OBJ-18-W2-53B-V3-VALP-004 (CRT 1) - The impact of the use of aircraft data in TP and CD&R on technical performance was assessed. The number of false conflict notification is reduced with the use of enhanced CD&R tools using aircraft data.

E.3.2.3 EX1-OBJ-38-W3-DEMOP-OPRF-0003 Results

Operational Performance Improvement Objective:

Demonstrate that the use of ADS-C data improves the Operational performance.

[CE Sol 53/56 PJ38]

Criteria CRT-38-W3-DEMOP-015: Partially OK

The adherence to on board expected vertical trajectories is enhanced thanks to the use (e.g. display) of TOD information.

- It was recognised by the ATCOs that the provision of the aircraft intent via ADS-C EPP can be used to provide a better service to the airspace users because of the availability of the data, whenever the situation allows.

  However, the complexity of the DFS airspace and the traffic flows often prevent the ATCOs from clearing the optimum vertical profile as downlinked.

Criteria CRT-38-W3-DEMOP-018: OK

CD&R: The reduced detection uncertainty buffers of the improved CD&R tool MTCD lead to a higher operational performance due to a higher reliability of the planned trajectories.

- EX009-OBJ-18-W2-53B-V3-VALP-004 (CRT 2) - The impact of the use of aircraft data in TP and CD&R on technical performance was assessed. Uncertainty in trajectory prediction is reduced when using aircraft data. It can be concluded that undisturbed climb procedure can be more accurately predicted when using ADS-C EPP information and correct weather information.

- EX009-OBJ-18-W2-53B-V3-VALP-004 (CRT 1) - The impact of the use of aircraft data in TP and CD&R on technical performance was assessed. The number of false conflict notification is reduced with the use of enhanced CD&R tools using aircraft data. Potentially, the adjustment of the tolerances might be necessary to bring the full benefit.

Co-funded by the European Union

E.3.2.4 EX1-OBJ-38-W3-DEMOP-OPSF-0004 Results

Operational Feasibility Objective:

Demonstrate that the use of ADS-C data is Operationally feasible beyond what has been demonstrated in PJ31 (i.e. highlight 2D consistency check discrepancies).

[CE Sol 53/56 PJ38]

Criteria CRT-38-W3-DEMOP-023: *OK*

Display: the display of ADS-C data is considered useful by users (e.g. ATCO).

- EX05-CRT-18.56-V2-VALP-002-003-01 - The downlink of Top of Climb (ToC) and Top of Descent (ToD) allowed the controllers to anticipate the pilot's intention to operate the flight. Especially, the ToC information was found useful by the ATCOs because it has an impact on the controlling sector list and the knowledge about this trajectory point helps to reduce the R/T communication because the controller does not need to ask the pilot whether he manages to reach a certain flight level or not.

Criteria CRT-38-W3-DEMOP-024: *OK*

The CD&R tools enhanced by ADS-C data are acceptable for the ATCOs.

- EX009-OBJ-18-W2-53B-V3-HPAP-001 - Impact of enhanced CD&R support tools using aircraft data on controllers' tasks and operating methods was assessed. Participants see a positive impact of ADS-C EPP enabling TP improvement.

Criteria CRT-38-W3-DEMOP-025: *OK*

The system enhancement allows to establish trust in the system

- EX05-CRT-18.56-V2-VALP-003-005 - The level of trust in automation was assessed and found acceptable by the controllers.

Criteria CRT-38-W3-DEMOP-026: *OK*

The consistency check with ADS-C data in 2 dimensions is acceptable for the ATCOs.

- EX05-CRT-18.56-V2-VALP-002-003-04 - The automated display of 2D discrepancies between air and ground planned trajectory was found very useful to support the controllers. It could help to discover aircraft deviations from the ground planned trajectory at an early stage.

  The controllers saw the advantage of using the 2D conformance monitoring for the synchronisation of the air and ground planned trajectory. Either, by aligning the ground trajectory with the air trajectory (implement a part of the route in the ground planned trajectory) or vice versa (uplink the ground route to the aircraft). The required functionality was not available in the prototype. This functionality will be required to be implemented for future V3 validations be the controllers.

- EX009-OBJ-18-W2-53B-V3-HPAP-001 - Impact of enhanced CD&R support tools using aircraft data on controllers' tasks and operating methods was assessed. Participants see a positive impact of ADS-C EPP enabling TP improvement.

E.3.2.5 EX1-OBJ-38-W3-DEMOP-TECH-0005 Results

Data Collection Improvement Objective:

Demonstrate a reliable and robust collection infrastructure to set up ADS-C contract and process data.

Criteria CRT-38-W3-DEMOP-029: OK

Provision of regular statistics about the traffic of ADS-C datalink exchanges.

A reliable and robust infrastructure for ADS-C data collection has been demonstrated by means of the ADS-C Common Service instance run by DFS/ESSP. The ACS prototype has been demonstrated for more than a year in 24/7 operations with live revenue flights.

Reliability could be demonstrated

- by dedicated system verification tests before deployment of the ACS,
- by analysis of the data recordings/collections from the ACS, and
- by practical use of the ACS in operational demonstration exercises.

For more details on the technical data analysis, see Appendix M.

E.3.2.6 EX1-OBJ-38-W3-DEMOP-TECH-0006 Results

Access to ADS-C data Objective:

Demonstrate that the use of an ADS-C Common Service improves the access to data.

Criteria CRT-38-W3-DEMOP-030: OK

ADS-C periodic, on event contracts are successfully established and maintained by the ADS-C Common Service, and resulting data shared with the clients in due time.

The following activities were performed for the demonstration of this objective:

- ACS Demonstrator developed together with Airtel, based on PJ38 WP5 requirements (see Appendix N)
- Hosting together by DFS/ESSP, DFS running the Data Collection and ESSP the SWIM Data Distribution
- From the verification and demonstration activities plus data analysis it could be shown
  - Periodic and event contracts are successfully established and maintained with commercial aircraft (subject to existing ATN coverage at the a/c position)

- Resulting data is shared with the clients via SWIM interface in due time (several clients, starting from EIH test client, via iTEC Platform of DFS/PANSA, to other PJ38 partners like DSNA, which used this service in their operational exercises)

Criteria CRT-38-W3-DEMOP-031: *OK*

ADS-C on demand contracts are correctly passed through the ADS-C Common Service established on client request, and resulting data shared in due time.

- ADS-C demand contracts have been successfully demonstrated with real world traffic, although on a smaller scale than default periodic/event contracts data collection
- Test means at DFS has been mainly EIH test client for demand contracts (Other ANSP partners have developed additional clients and successfully connected to the demand contract interface of the ACS demonstrator of DFS/ESSP)
- Demand contracts are successfully processed and passed through the service, resulting data is shared on the same distribution channel as periodic/event contracts, according to the agreed PJ38 ICD (see appendix N.3 – ADS-C Common Service SWIM ICD).

Exercise Procedure and Demonstration Method in support of CRT-38-W3-DEMOP-032,033,034,036,037

The ATC prototype system at Indra facilities was configured to connect to the ADS-C Common Service (ACS) hosted by DFS and ESSP and to subscribe to the needed ADS-C/EPP services for the time of the live demonstration activities on 30th of November and 1st of December 2022.

In addition an independent tool at Indra subscribed to the services of ACS in order to monitor the continuous ADS-C flights data stream and in an early stage find and filter out ADS-C broadcasting Aircraft ID’s (partly even before actual Take-Off) of those flight profiles which would enter the EDUU (Karlsruhe/Rhein ACC; KUAC) air space volume under test/demonstration. It acted technically as a completely own service subscriber/client.

Upon early identification of such a live flight, the related EPP data was taken out and input into a NM/IFPS mocking tool which was used to feed the KUAC ATC system with an initial flight plan (IFPL/ADEXP) so to generate a System Flight Plan (SFPL) in status “PASSIVE” (waiting for a radar track).

In parallel the EPP data was used to “arm” the flight in the Indra traffic simulator with a 4-D flight profile and a starting 4-D point (3D plus time).

This real flight progress was then observed by the test operator via sources of ADS-B data as well as by the live continuously incoming periodic ADS-C reports from CS.

Once the flight approached the “start” waypoint of the route close before entry to KUAC AOR at the given time (in EPP), the Indra flight track simulator (iSim) set the flight to “go” and radar tracks was provided to the KUAC ATC system prototype where the “waiting” SFPL switched to status ACTUAL.

From that moment on a correlated radar track would appear on the CWP (Controller Working Position) of the ATC system prototype in "advanced" status. Once this is achieved, any incoming ADS-C report for this flight will be associated with the aircraft. Therefore it can take a few minutes (within periodic time interval) until also EPP data is available for the "Controller" in the test set up.

Once the first EPP since switch to ACTUAL has been received, two general access methods are available on the CWP/HMI:

- Direct readable access to selected EPP data in a table form
- Indications on the symbol and label (upon a click) – according to Project 18, Solution 56 specifications

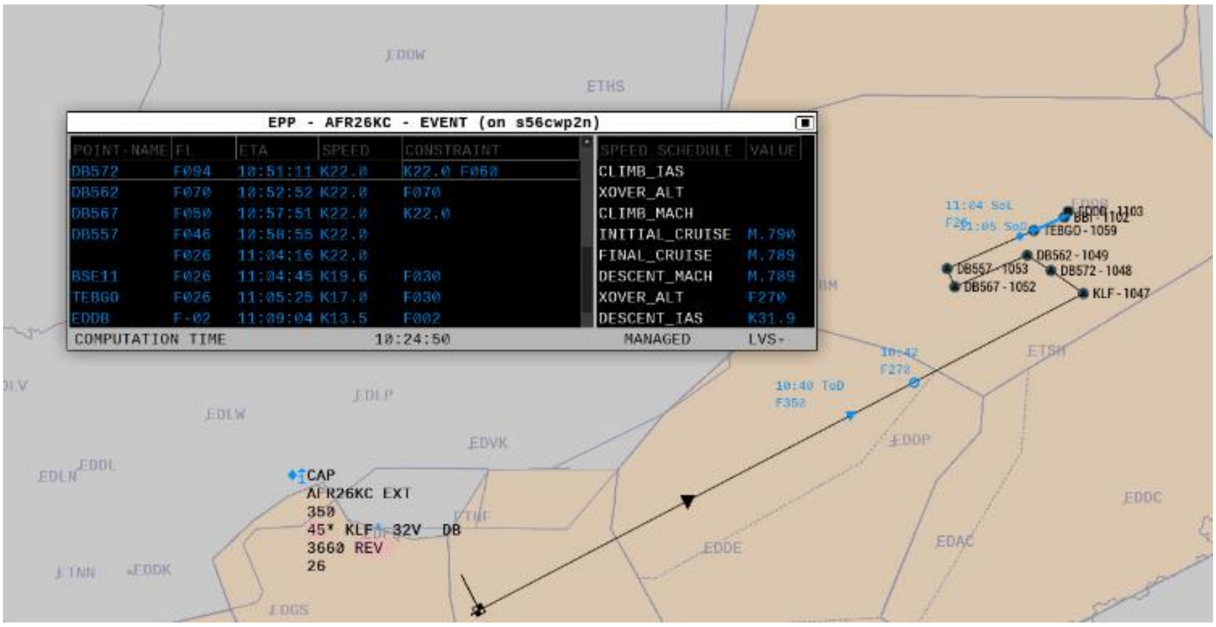


Figure 67 On request display of EPP "numerical" data

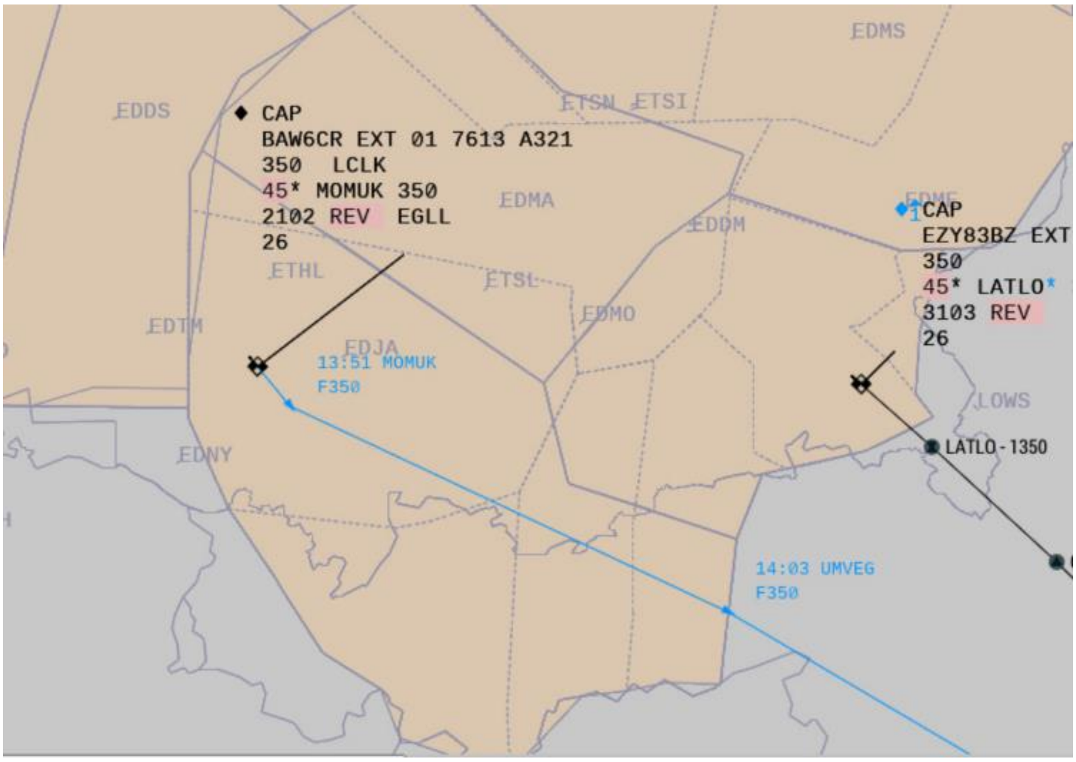


Figure 68 Display of EPP triggered indications (blue)

The access to latter is greatly enhanced once the flight is in ASSUMED state. As mentioned above (deviations from the plan) it was not possible to staff the part of the demonstration activities at Indra with real world controllers, instead engineering controllers substituted them. The further "work" with the flight was trying as best as possible to mimic the obvious controller-clearances in the real world in shadow mode. Due to the missing direct communication link to the Control Centre in Karlsruhe (KUAC) and to any legacy radar data access (like in a real shadow mode demonstration), it was done in low latency time reverse-engineering mode by observation:

- of common ADS-B data streams
- of (ACS provided) periodic ADS-C reports, or on-event ADS-C reports. (On-demand reports were not triggered by the test set-up).

I.e. if we saw in the EPP data that a new clearance was given (either Levels or more easy Direct Routings) the corresponding Controller clearance was entered in the system under test/demonstration.

<u>Criteria CRT-38-W3-DEMOP-032:</u> OK

> *Data received via the ADS-C Common Service are reliable (i.e. they faithfully reflect the latest situation provided by the aircraft).*

The demonstration activities covered a full and a half day and have demonstrated by operation and on-the-fly observation of the whole demonstration set-up environment that the ACS services provided reliably good data from real-world aircraft which have been a) equipped with ADS-C and b) logged on (either by manual logon of the pilots or by the Airline participation to Autologon procedure). It was observed that then the data came continuously while crossing the KUAC airspace, that they reflected the given, re-routings (Directs) or Flight Level changes, or Times At in real world. Obviously, the secondary real world reference was the reference via ADS-B reception for the immediate picture (much more frequent than ADS-C). In EPP data the continuous flight progress was visible by disappearing of overflown points with a new incoming periodic report (dt 5min in the demonstration).

As far as observable in the given demonstration setup, the provision and reception of ADS-C data was complete and indeed reflected the real flight progress with all its changes due to directs or cleared climb/descend profiles.

Criteria CRT-38-W3-DEMOP-034: *OK*

The ACS successfully collects ADS-C data in live flight trials.

Criteria CRT-38-W3-DEMOP-033: *OK*

The ACS successfully receives, processes and distributes ADS-C data to multiple clients via SWIM in real time.

Criteria CRT-38-W3-DEMOP-036: *OK*

The ACS data provision satisfies the operational needs of the clients.

One advantage of going to the Indra Industry site was that it hosted in fact twin prototype systems, i.e. two test strings for two ANSPs: DFS (Karlsruhe ACC) and NATS (Swanwick ACC) which were both run actively during some hours of the demonstration. The latter fully independently subscribing to and consuming ACS data. This was realised because of the still limited availability of real-world EPP downlinking flights and those were mainly from airlines operating from/to England (Easy Jet, British Airways) or Hungary (Wizz Air), which resulted in KUAC mostly overflights in cruise levels. By using also the Swanwick (NATS) prototype system more ADS-C flights could be demonstrated and with climbing/descending profiles in addition.

In the Demonstration setup, while at a time only one or maximum two real flights were really in air in the test AOR, the ACS was always providing updates (of EPP) in regular manner as expected and could be continuously presented to the test operators.

Once a flight was synchronised with the real world flight, it was easily visible that the ADS-C data received triggered correctly, as functionally expected, indications or warnings on the Controller HMI, similar as to the offline simulation exercises in PJ18 Solution 56/53.

In parallel to the DFS demonstration, DSNA has been performing a long period validation exercise in their platform subscribed continuously to the same ACS service instance. And finally the Indra tool described above was technically a fourth client to the ACS services.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

It can such be summarised - by observation during two live demonstration days that ADS-C data from real-world flights was successfully received in real-time simultaneously by four ACS clients without an observed interruption or hick-up. It can therefore be indirectly deduced that also the ACS system was successfully receiving data from the "Collector" complete and in real-time.

Criteria CRT-38-W3-DEMOP-037: OK

The ACS saves A/G bandwidth with regards to an architecture of local ADS-C data acquisition.

The saving of bandwidth is evident with the chosen ACS architecture based on the following argument:: the ACS maintains only one A/G connection and has been shown in this Demo to successfully share the data with multiple clients. The degree to which the ACS concept/architecture saves A/G bandwidth depends on the number of parallel clients using the data. The average number of parallel clients to be expected in deployment cannot be fully predicted (not in the scope of the demo) but it is certain that in core European airspace this will be several ANSPs, Arrival Manger, NM and other users at once. So the ACS Distribution architecture will indeed save bandwidth with regards to local ADS-C connections, it is fully scalable and capable of distributing ADS-C data to a theroretically unlimited number of ground clients, without duplicating A/G connections.

E.3.3 Unexpected Behaviours/Results

No unexpected behaviours were observed.

E.3.4 Confidence in the Demonstration Results

The validation exercises was conducted with high-fidelity industrial prototypes and high attention to achieving good representativeness of experimental conditions, generally supporting high confidence in the validation results. The following limitations however existed for the different exercise parts and are to be taken into account:

E.3.4.1 Level of significance/limitations of Demonstration Exercise Results

[CE Sol 53/56 PJ38]

[Sol 53B]

- For ADS-C EPP related improvements, we are always relying on Airbus aircraft types except for simulated flights.
- All recorded real flights (including both PJ.31 DIGITS and future revenue flight) are subject to ATC practices, which includes tactical actions preventing the aircraft to fly the FMS profile. The operational uncertainty existing on those flight segments (aircraft flying on selected mode instead of full-managed mode) limits the TP accuracy validation. This matter should be taken into account when interpreting the results.

[Sol 56]

The following limitations of the exercise do exist:

- Number of controllers
  There were only four active controllers participating to the validation exercises.

- Simplified environment
  The V&VI did not support CPDLC.

- Non-nominal conditions were not considered

Considering the V2 maturity level of the solution, the RTS mainly focused on concept acceptability, feasibility, and its impact on Human Performances.

The reduced number of participating ATCOs (4 controllers from Karlsruhe) and the reduced time for the RTS (3 RTS with one day each) limited the possibility to gain realistic experience with the system under test. This had an impact on representativeness of the results.

The quantitative measures of the questionnaire could not be analysed statistically. Therefore, the results were assessed

- *OK* if all participants provided affirmative answers, i.e. all agreed to a statement,

- *Not OK* if all participants disagreed to a statement.

- *Partially OK* in any other case, i.e. some participants agreed and some disagreed.

There was no direct comparison between a reference scenario and the solution scenario possible (see E.2). The controllers compared the solution scenario with their current system in Karlsruhe.[PJ38]

- Shadow mode flights (radar tracks and transponder data) cannot be influenced or cleared for dedicated test purposes. While test subjects can manipulate system inputs, they cannot control directly the course of the flight.

- Shadow Mode had no R/T from KUAC OPS room, so no possibility to listen to ATCO/clearances

- Limited number of actually airborne A/C types (A320 family), limited A/C Frames&Airlines

E.3.4.2 Quality of Demonstration Exercise Results

[CE Sol 53/56 PJ38]

[SOL53B]

Several aspects degraded the quality in the comparison of TPs for real flight scenarios:

- ATC instructions were present but were not considered.

- Pilot strategies like flying in a selected vertical guidance with a constant climb rate were not identified and could also not be considered.

- The weather prediction uncertainty was not considered and may have had an influence on the quality of the TP.

[SOL56]

Despite the limitations mentioned above, the obtained results are considered of sufficient quality for the following reasons:

- Involvement and strong motivation of active controllers participating in the validation who expressed their feedback on the overall concept
- Suitability of qualitative and quantitative data collection methods/material (questionnaires, debriefings, observations) during the ground real time simulation
- Use of realistic simulated environment e.g. ground real time platform iTEC V3, current KUAC sector and traffic samples.

[PJ38]

Together with the positive aspects from above, the obtained results during real live traffic demonstrations the observations and activities (actions on HMI) lead to a positive reception of quality of the ACS service due to:

- Timely reception of ADS-C data on test site to build up a shadow track simulation and AFTN and OLDI messages to “arm” the system under test
- Regular updates of EPP related indications on the radar track information (label and symbol) representing the real traffic changes (monitored by “live” ADS-B)
- Correct indication of changes, vertical data (TOD, TOC), warning of 2-D deviations from filed plan, etc.
- Good “raw EPP” data monitored in the related on-demand display on the CWP/HMI.

E.3.4.3 Significance of Demonstration Exercises Results

[CE Sol 53/56 PJ38]

[SOL56]

Due to the reduced number of participating ATCOs and the reduced time for the RTS no statistical analysis could be performed.

Due to the use of realistic simulated environment (e.g. ground real time platform iTEC V3, current KUAC sector and traffic samples) the operational significance could be achieved.

[PJ38]

In the real-world demonstration unfortunately no ATCOs could participate.

Nevertheless since the demonstration could not be run in real shadow mode (which would imply an direct observation channel to real OPS rooms) this limitation does not reduce the significance of the intended results (mainly the usability of "live" ADS_C Common Services based on live ADS-C contracting and data).

In the real world only up to a maximum of three airframes were in flight at a time in the controlled airspace volume, which actually established an ADS-C Contract. This established fully trust to the ADS-C CS on a functional level and for those also on a Continuity of service level. On a Capacity level no statements can be given by the demonstration. It should be complemented by architectural analysis (for scalability etc.) under the assumption of a fully mandated ADS-C environment (all flights, all ATSUs at ECAC region).

E.4 Conclusions

[CE Sol 53/56 PJ38]

[Sol53B]

- It can be concluded that undisturbed climb procedure can be more accurately predicted when using ADS-C EPP information and correct weather information.
- It is assumed that the TP improvement leads to a more accurate conflict detection. With this assumption, the improved TP has notable effect on the CD/R detection. Additional conflict partners were identified, or different conflict types were detected by the improvement.
- Potentially, the adjustment of the conflict tolerances might be necessary to bring the full benefit.

[Sol56]

- The usage of Flight Conformance and Intent Monitoring tools or functionalities are compatible with procedures and working methods to controllers in En-Route airspace.
- There was no clear conclusion how ATC procedures and workings methods have to be optimised to make the best use of ADS-C EPP data for 3D Flight Conformance and Intent monitoring.
- Ground Based Flight Conformance and Intent Monitoring support in En-Route by means of ADS-C EPP data is suitable to support controllers.
    - The processing and display of the downlinked Top of Climb and Top of Descent is useful. Especially, the Top of Climb because of its impact on the controlling sector list.
    - The automated display of 2D discrepancies supports controllers.
    - The automated display of missing or wrong level constraints in the frame of 3D conformance monitoring is helpful for controllers.

- The automated display of 3D discrepancies potentially supports controllers.

[PJ38]

- The exercise demonstrated the successful consumption and use of live ADS-C data from the ADS-C Common Service in the ATS System. This included functionality for EPP display, 2D and 3D discrepancy monitoring and TP improvements.
- Both periodic and event contract data were successfully and reliably consumed from the ACS by the ATS platform. (Execution of Demand Contracts was verified by a separate test tool)
- Data received was reliable, shared in due time and satisfied the operational needs of the client. Multiple clients (four) were shown to be served at the same time.
- The ACS architecture served the need to save A/G bandwidth with regards to an architecture of local ADS-C data acquisition.

E.5 Recommendations

E.5.1 Recommendations for industrialization and deployment

[SOL56]

Based on the validation results DFS recommends the following:

- ATC procedures and working methods need to be further worked out to make an optimal use of ADS-C EPP data.
- In case of 2D discrepancy the system under test shall provide the controller with the capability to synchronise the air and ground route. Either by,
  - taking over the airborne route as stated by ADS-C EPP or by
  - uplinking a route clearance for the deviating part of the route by means of CPDLC.
- Specific conditions, like e.g. heavy weather where many aircraft will divert from their planned route, need to be further investigated with regard to situational awareness.
- It needs to be further validated whether the infringement of level (3D conformance monitoring) and/or speed constraints is reported via ADS-C EPP early enough, so that the data is useful for the controller.

  Note: In revision B of the datalink standards ED-228 and ED-229 new events will be introduced which trigger the downlink of an ADS-C EPP report, when level and/or speed constraints are infringed.

- A validation of the usage of ADS-C EPP data could be extended to lower airspace and TMA.
- HMI design in terms of usability needs to be improved.

E.5.2 Recommendations on regulation and standardisation initiatives

The exercise has successfully demonstrated several ADS-C applications in the IBP connected to live traffic from the ADS-C Common Service. The design and architecture has been shown to be technically feasible and operationally appropriate. It is recommended to pass on the PJ38 ADS-C Common Service Requirements and SWIM ICD Definition (see Appendix N) to the standardization process foreseen via OEP WST 12.2. (A first transfer was already made with DEMOR R1, an update shall be provided with this DEMOR R2).

Appendix F Demonstration Exercise #06 (EXE-PJ38-4-6 Plan by ENAV) Report

F.1 Summary of the Demonstration Exercise #06 Plan

As planned in the D1.5 Edition 02.00.00 - PJ38 ADSCENSIO DEMOP Release 2 [ref.], the exercise was performed by ENAV and LEONARDO, with the support of DEEP BLUE, and focused on the assessment of Conflict Detection tool enhanced through EPP trajectory information downlinked via ADS-C.

The exercise was conducted at ENAV's premises in Rome in the end of October and the beginning of November 2022.

F.1.1 Exercise description and scope

ENAV, with the support of the industrial partner LEONARDO, performed a shadow mode demonstration including ADS-C live aircraft data injected in a test environment similar to the one used in PJ18 Sol53A EXE001.

The PJ18-W2.53A EXE 001 upgraded platform was used for subscription to the ACS to receive real ADS-C data.

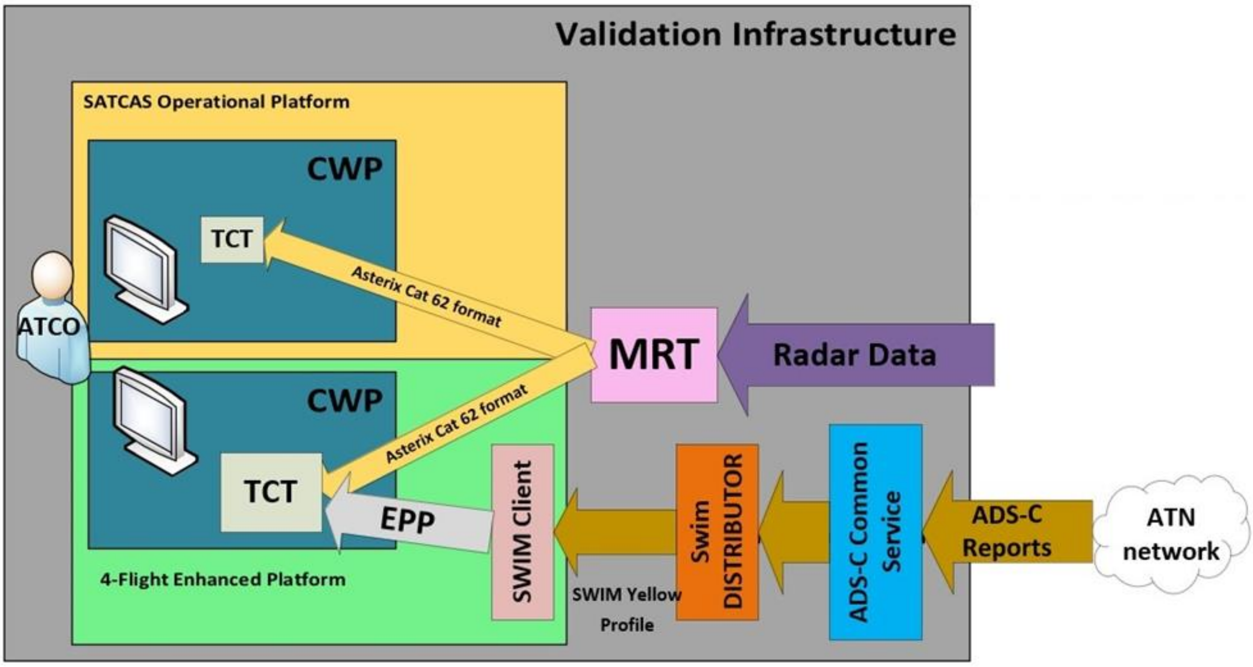


Figure 69: PJ38 EXE006 schematic diagram of validation infrastructure

The EXE assessed the operational benefits resulting from the use of ADS-C data integrated into controller end systems. ADS-C data were retrieved by subscribing the ATC test platform to "use interfaces" of the ACS distribution module.

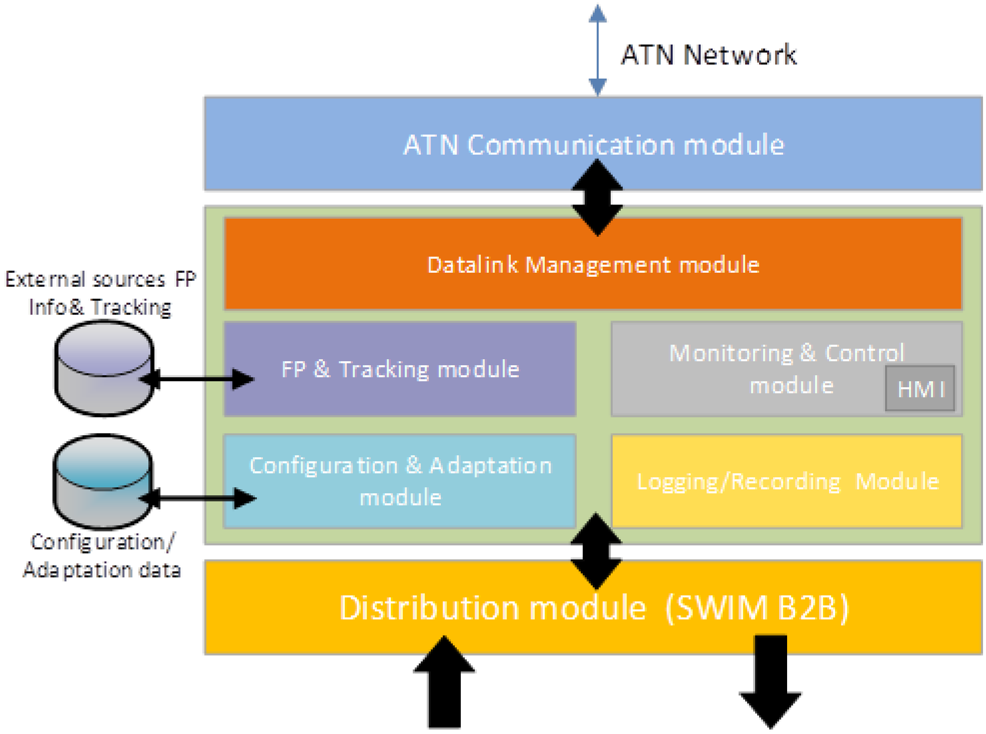


Figure 70: High-level logical architecture of a single ADS-C service

CD&R tools were used to increase the ATCO awareness of potential conflicts to assess the use of EPP data showed to ATCOs on the CWPs. ATCOs were requested to provide their feedback in regard to the operational benefits of the data provided. In detail, the ATCO Situational Awareness was investigated based on live-recorded data.

A modified version of the PJ18-W2.53A EXE 001 platform was used for this exercise .

The operational data collected during the demonstration exercise have been further analysed in order to characterise the anticipated operational benefits generated from more accurate airborne data received via ADS-C.

F.1.2 Summary of Demonstration Exercise #06 Demonstration Objectives and success criteria

Safety improvement (OBJ-38-W3-DEMOP-SAFE-0001): ADS-C data contribute to improve Safety. Checking that there is a reduction of the number of potential infringements, or an earlier resolution.

Human Performance improvement (OBJ-38-W3-DEMOP-HPRF-0002): Demonstrate that the ADS-C changes performed improve Human Performance compared with PJ31.

Operational Performance improvement (EX4-OBJ-38-W3-DEMOP-OPRF-0003): Demonstrate that the ADS-C changes performed improve Operational Performance compared with PJ31.

Operational feasibility (OBJ-38-W3-DEMOP-OPSF-0004): Demonstrate that the use of ADS-C data is operationally feasible beyond what was demonstrated in PJ31.

Data collection improvement (OBJ-38-W3-DEMOP-TECH-0005): Demonstrate a reliable and robust collection infrastructure to set up ADS-C contract and process data.

Access to ADS-C data (OBJ-38-W3-DEMOP-TECH-0006): Demonstrate that the use of an ADS-C Common Service improves the access to data assessing that the data received via the ADS-C Common service is reliable and it is correctly received.

F.1.3 Summary of Validation Exercise #06 Demonstration scenarios

The area considered for the exercise was Padua ACC real traffic scenario filtered over the ADS-C equipped A/Cs and shadow mode recorded in Rome.

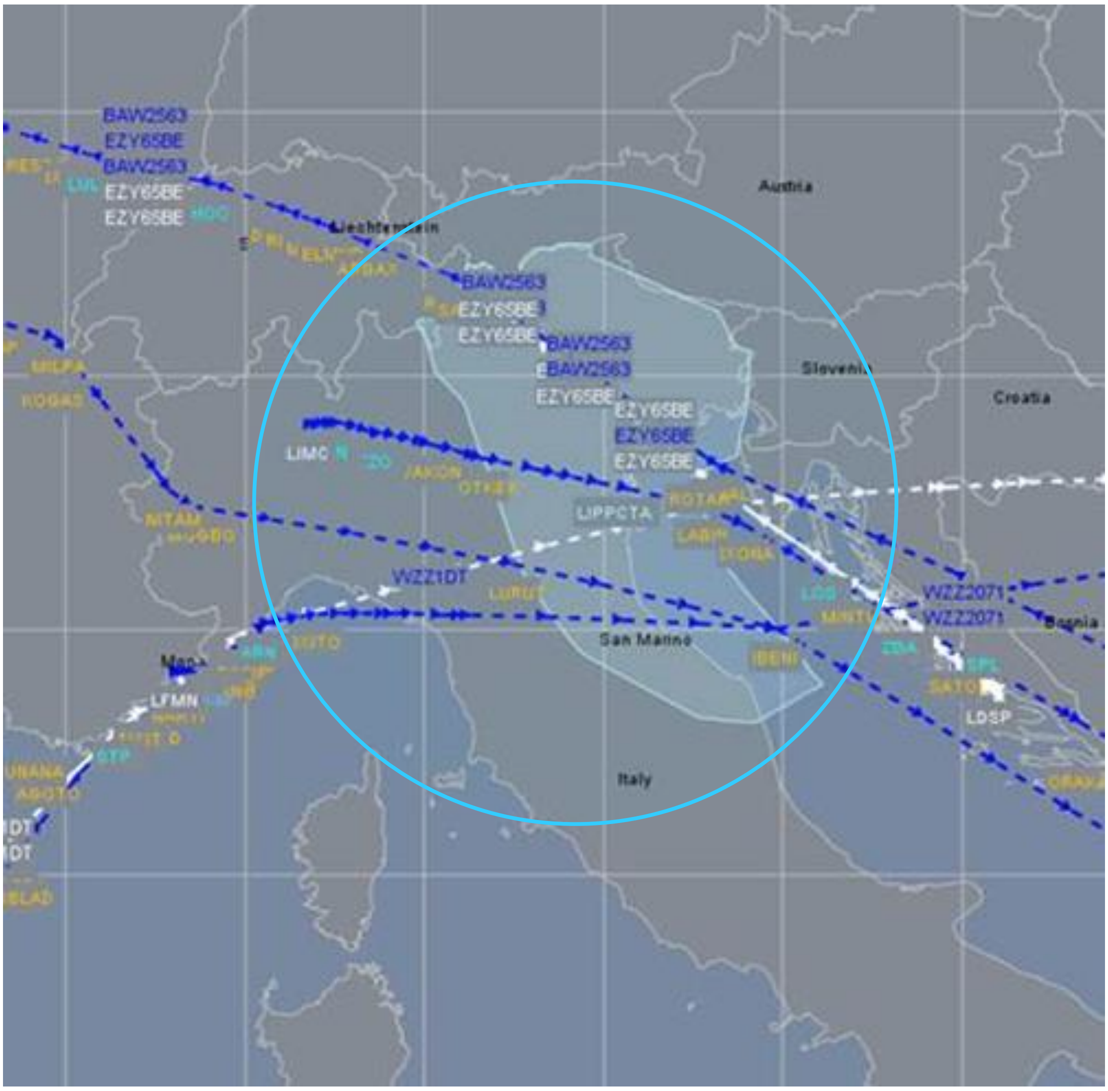


Figure 71: Padua Area considered in the EXE006 scenario

The reference scenario is the current operational environment, with current ATM system (SATCAS) and conflict detection tools (TCT) not integrating ADS-C/EPP data. Several Controllers have operated during the acquisition period, some of these controllers have been involved to request the ADS-C A/C pilots to make the initial log-on. The Padua area ADS-C/EPP traffic was mirrored on a prototypal platform based on 4-Flight system with: real tracks and real ADS-C data.

The solution scenario was based on the current operational environment, with a new ATM system (4Flight prototype platform PJ18 Solution 53 A EXE001 legacy) and the downloaded ADS-C/EPP data. Two Controllers have been involved in processing the recorded operations playback for analysis of the results.

ENTRY	ARCID	ATYP	ADEP	ADES	RM2
07:14E	**WZZ162**	A321	LIME	LATI	HALTI
08:07E	**BAW401**	A21N	HECA	EGLL	GNEOZ

10:09E	**EZY13GY**	A20N	LDDU	EGKK	GUZHX
10:39E	**WZZ1495**	A21N	EPWA	GCTS	HALVH
10:57E	**EZY85PT**	A20N	LICC	EGGW	GUZLB
11:30E	**AFR85WY**	A321	LFPG	LGAV	FGTAY
11:30E	**WZZ1056**	A21N	LOWW	LFMN	HALVK
12:01E	**WZZ1AD**	A20N	LIRP	LATI	HALJB
12:57E	**EZY48PB**	A20N	LGIR	EGKK	GUZLA
13:27E	**WZZ9AW**	A20N	LIBD	LIML	HALJB
13:44E	**EJU79GH**	A21N	LIMC	LLBG	OEISC
13:54E	**WZZ835**	A21N	LFMN	LOWW	HALVK
14:06E	**EZY26LH**	A20N	LGIR	EGGP	GUZLD
14:12E	**WZZ2071**	A21N	LFMN	LROP	HALVF
14:37E	**WZZ4837**	A20N	LIBD	LIPX	HALJE

Table 24:example of EPP equipped flights on LIPP area on 16th October 2022

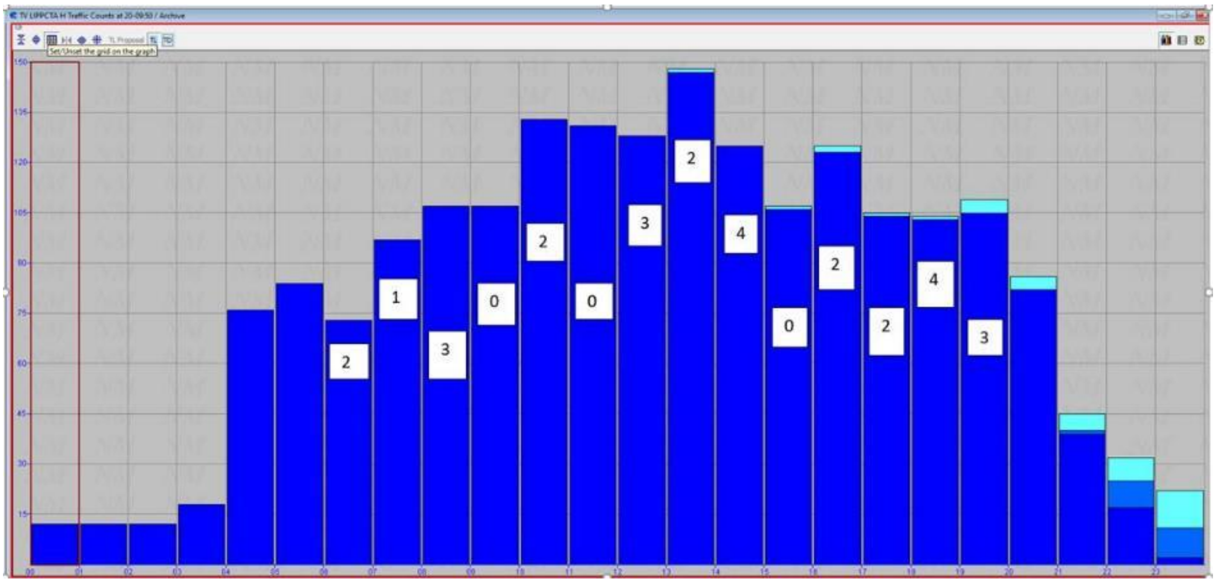


Figure 72: example of daily traffic load with hourly distribution (UTC) in LIPP on 19th October 2023 with EPP equipped flights per column

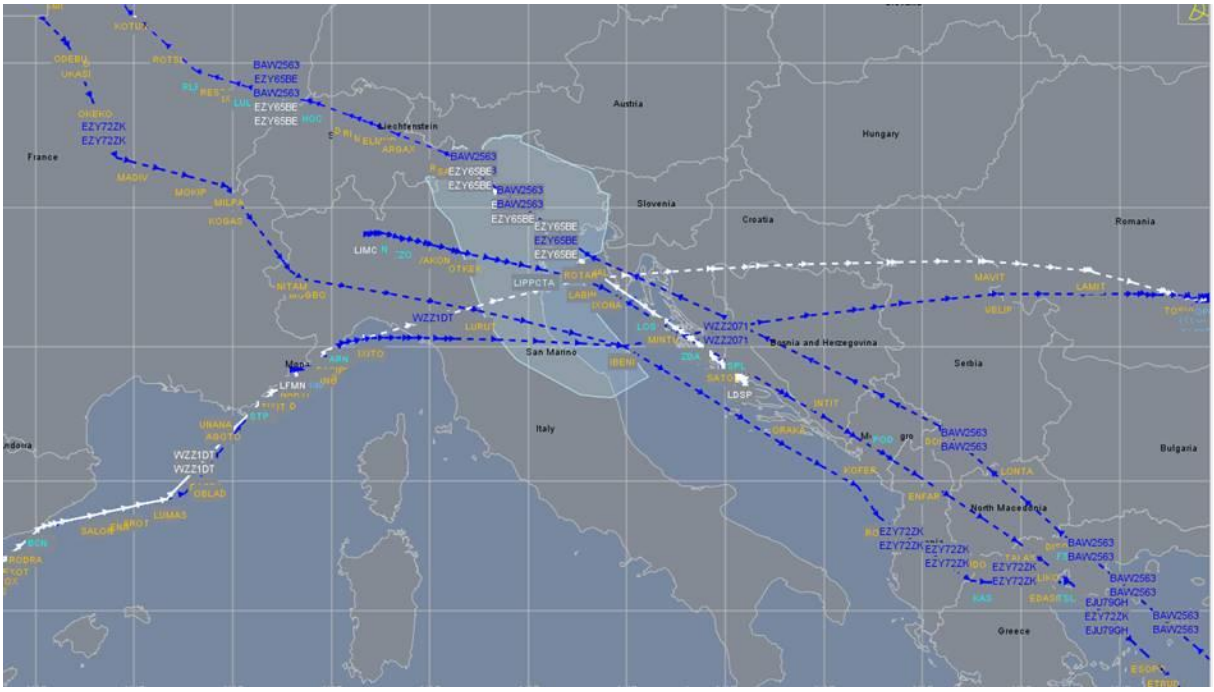


Figure 73: Actual vs Estimated trajectories gap

In the table below daily lists of equipped A/C considered are shown, for the period between 24th October andthe 18th November 2022.

ENTRY	ARCID	ATYP	ADEP	ADES	RM2
07:10E	BAW599	A21N	LIPZ	EGLL	GNEOU
09:15C	WZZ2866	A21N	EHEH	LIRF	HALVK
09:15C	AFR15XJ	A319	LFPG	LGAV	FGRXK
09:27E	WZZ1475	A20N	LIBD	EGKK	HALJA
11:07E	EZY53QZ	A21N	LGAV	EGKK	GUZMI
11:45E	EJU37PG	A21N	LFPG	LLBG	OEISE
13:16E	AFR99RA	A319	LGAV	LFPG	FGRXK
13:30C	EJU3EF	A21N	LLBG	LIMC	OEISB
13:34E	WZZ1657	A20N	EGKK	LIBD	HALJA
13:40E	WZZ4089	A321	LATI	LIPX	HALTI
14:54E	EZY9936	A21N	LCPH	EGKK	GUZMJ
15:14E	WZZ407	A321	LIPX	LATI	HALTI

Table 25: EPP equipped flights on LIPP area on 24th October 2022

Here below the daily traffic load:

- in the blue columns, actual traffic or the already active flights for control traffic purposes are shown,
- in the cyan columns planned flights, not yet airborne, are shown

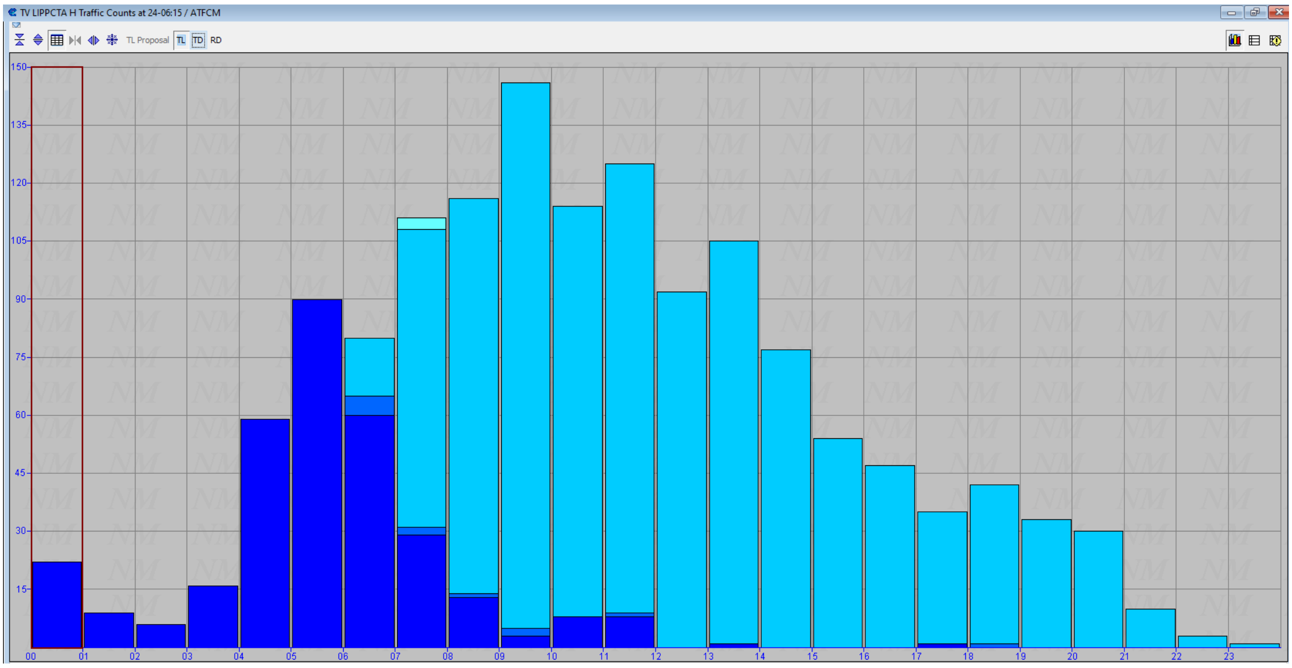


Figure 74: traffic load with hourly trend(UTC) in LIPP on 24th October 2022 with EPP equipped flights

ENTRY	ARCID	ATYP	ADEP	ADES	RM2
08:56A	EZY65BE	A20N	LDSP	EGCC	GUZHZ
09:17A	WZZ1DT	A21N	LEVC	LROP	HALVF
12:22E	EJU79GH	A21N	LIMC	LLBG	OEISC
13:41E	BAW2563	A21N	LTBS	EGLL	GNEOW
14:26E	WZZ2071	A21N	LFMN	LROP	HALVE
14:38E	EZY72ZK	A20N	EGKK	LTFE	GUZLD

Table 26: EPP equipped flights on LIPP area on 25th October 2022

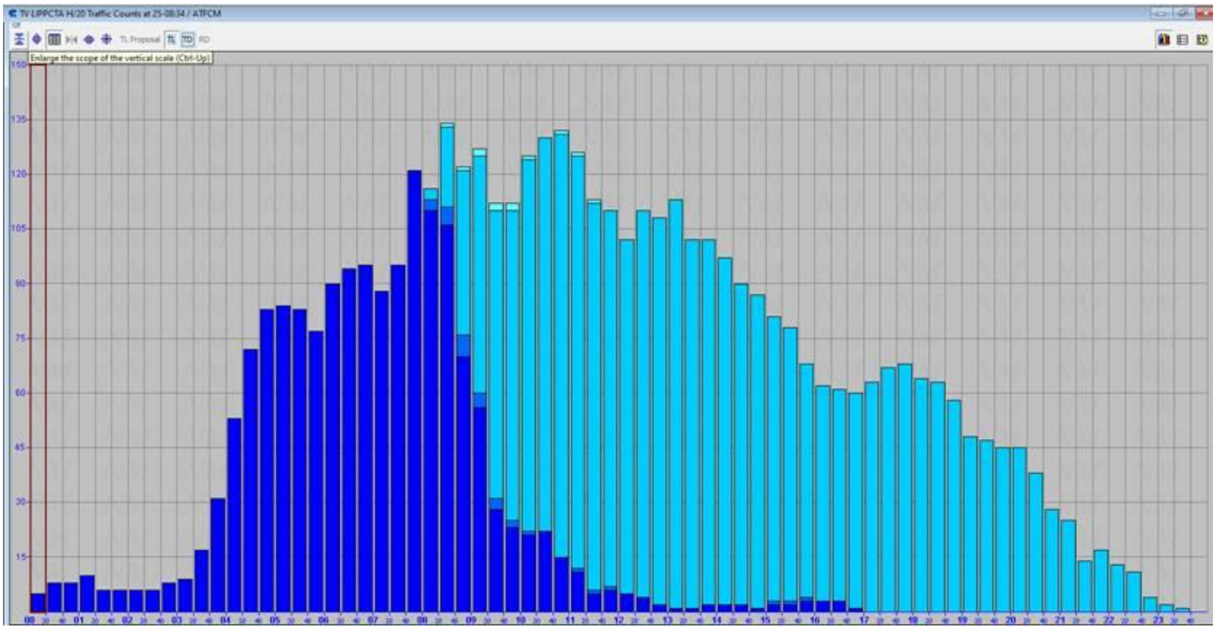


Figure 75: traffic load with hourly trend (UTC) in LIPP on 25th October 2022 with EPP equipped flights

ENTRY	ARCID	ATYP	ADEP	ADES	RM2
06:07E	EJU79GH	A21N	LIMC	LLBG	OEISB
Route: N0429F290 VAKON9Q VAKON Q702 OTKEK/N0438F310 DCT LABIN/N0445F350 DCT IXONA DCT MINTU DCT INTIT DCT POD DCT ENFAR DCT TALAS UN130 ETRUD/N0446F370 UN130 MES UL609 ALKIS DCT APLON DCT PIKOG L609 ZUKKO					
06:10C	EZY89TR	A21N	EGKK	LGZA	GUZMJ
06:22C	EZY37HK	A20N	EGKK	LGKR	GUZLL
07:10C	EZY75AU	A20N	EGGD	LDDU	GUZLB
08:17E	BAW401	A21N	HECA	EGLL	GNEOR
09:09C	EZY41KT	A21N	EGKK	LGSA	GUZMH
09:19E	AFR25NU	A320	LFPG	LIPZ	FHEPJ
09:42E	WZZ89	A20N	LIBD	LIPZ	HALJA
09:50E	EZY21QM	A20N	LDDU	EGGD	GUZLB
10:00E	EZY63CA	A20N	LGKR	EGKK	GUZLL
10:02E	BAW62T	A21N	LGAV	EGLL	GNEOP
10:34E	EZY65WC	A21N	LGZA	EGKK	GUZMJ
10:56E	AFR87PK	A320	LIPZ	LFPG	FHEPJ
10:56E	WZZ217	A20N	LIPZ	LIBD	HALJA
11:12E	EZY26ET	A20N	LGTS	EGCC	GUZHW
11:28E	AFR85WY	A321	LFPG	LGAV	FGTAZ
11:42E	WZZ8798	A21N	LROP	LIPE	HALVC
11:46E	EJU37PG	A21N	LFPG	LLBG	OEISE
11:55E	EZY34QN	A20N	LGKR	EGGW	GUZHX

12:00E	WZZ1670	A21N	LROP	LIRP	HALVF
12:49E	EZY53DT	A21N	LGSR	EGKK	GUZMI
13:03E	WZZ1255	A21N	LIPE	LROP	HALVC
13:16C	EZY41PA	A20N	LTBS	EGCC	GUZLA
13:52E	EZY64EW	A21N	LGSA	EGKK	GUZMH
13:56C	EJU8MN	A21N	LLBG	LIMC	OEISB
13:57E	WZZ1096	A21N	LIRP	LROP	HALVF
14:23E	WZZ369	A321	LATI	LIPE	HALTI
14:48C	BAW665Y	A21N	LCLK	EGLL	GNEOS
15:38E	EJU83GD	A21N	LIMC	LGAV	OEISB

Table 27:EPP equipped flights on LIPP area on 26th October 2022

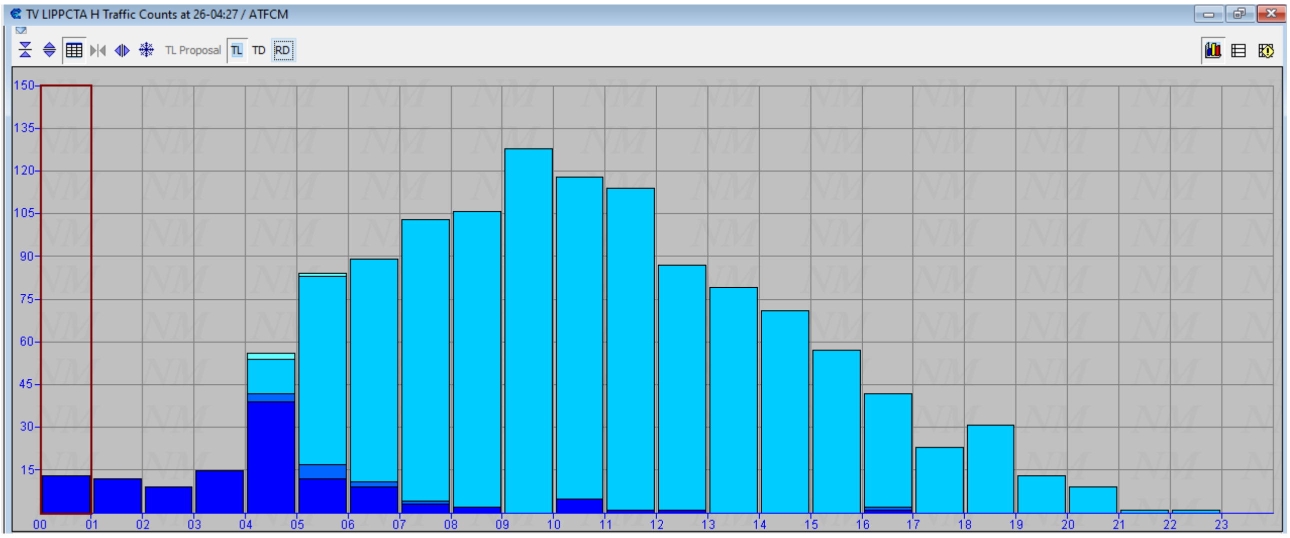


Figure 76: traffic load with hourly trend (UTC) in LIPP on 26th October 2022 with EPP equipped flights

ENTRY	ARCID	ATYP	ADEP	ADES	RM2
07:13E	WZZ162	A321	LIME	LATI	HALTI
08:16A	BAW401	A21N	HECA	EGLL	GNEOP
08:38E	IBE3242	A20N	LEMD	LIPZ	ECNJY
08:42A	AFR1053	A320	UGTB	LFPG	FHEPK
09:32E	BAW62T	A21N	LGAV	EGLL	GNEOX
09:41E	WZZ6773	A21N	LEBL	LROP	HALVC
09:43E	WZZ89	A20N	LIBD	LIPZ	HALJA
10:03E	EZY63CA	A21N	LGKR	EGKK	GUZMJ
10:33E	EZY93TH	A21N	LGTS	EGKK	GUZMH
10:56E	WZZ217	A20N	LIPZ	LIBD	HALJA
11:44E	AFR84YX	A320	LFPG	LIPZ	FGKXZ
13:19E	EJU79GH	A21N	LIMC	LLBG	OEISB

13:28E	EZY18UW	A20N	LGMK	EGKK	GUZLD
13:28E	WZZ9AW	A20N	LIBD	LIML	HALJA
13:48C	WZZ3428	A21N	LROP	LPPT	HALVM
13:48E	EZY96YL	A20N	LGIR	EGCC	GUZHZ
15:03E	WZZ95EK	A21N	LROP	LEMD	HALVC
15:09E	WZZ1084	A21N	EPWA	LEBL	HALVD
15:21E	WZZ3XB	A20N	LIML	LIBD	HALJA

Table 28: EPP equipped flights with FPs on LIPP area on 27th October 2022

ENTRY	ARCID	ATYP	ADEP	ADES	RM
08:03A	BAW401	A21N	HECA	EGLL	GNEOV
08:48A	AFR15XJ	A320	LFPG	LGAV	FHEPG
09:08A	BAW62T	A21N	LGAV	EGLL	GNEOT
09:36E	WZZ1475	A20N	LIBD	EGKK	HALJA
09:37E	WZZ1972	A21N	LEZG	LROP	HALVE
10:19E	WZZ2852	A321	LATI	LIMJ	HALTI
10:59E	EZY53QZ	A21N	LGAV	EGKK	GUZMI
11:14E	EZY93QG	A20N	LGKF	EGCC	GUZLA
11:29E	AFR98QN	A319	LYBE	LFPG	FGRXK
11:46E	AFR84YX	A320	LFPG	LIPZ	FHEPF
12:16C	WZZ1670	A21N	LROP	LIRP	HALVM
12:30C	EZY17XV	A20N	LGKO	EGGD	GUZLB
12:34E	WZZ8ZM	A21N	EGKK	LIPZ	HALVK
13:09E	EZY37BE	A21N	LTBS	EGKK	GUZMH
13:21E	AFR69CU	A320	LIPZ	LFPG	FHEPF
13:30E	WZZ1657	A20N	EGKK	LIBD	HALJA
13:34E	EZY34ZM	A21N	LTFE	EGKK	GUZMJ
13:34E	EZY26ET	A20N	LGTS	EGCC	GUZHZ
13:54E	AFR99RA	A320	LGAV	LFPG	FHEPG
13:57E	WZZ1096	A21N	LIRP	LROP	HALVM
14:16E	WZZ6381	A21N	LIPZ	LIRN	HALVK

Table 29: EPP equipped flights on LIPP area on 28th October 2022

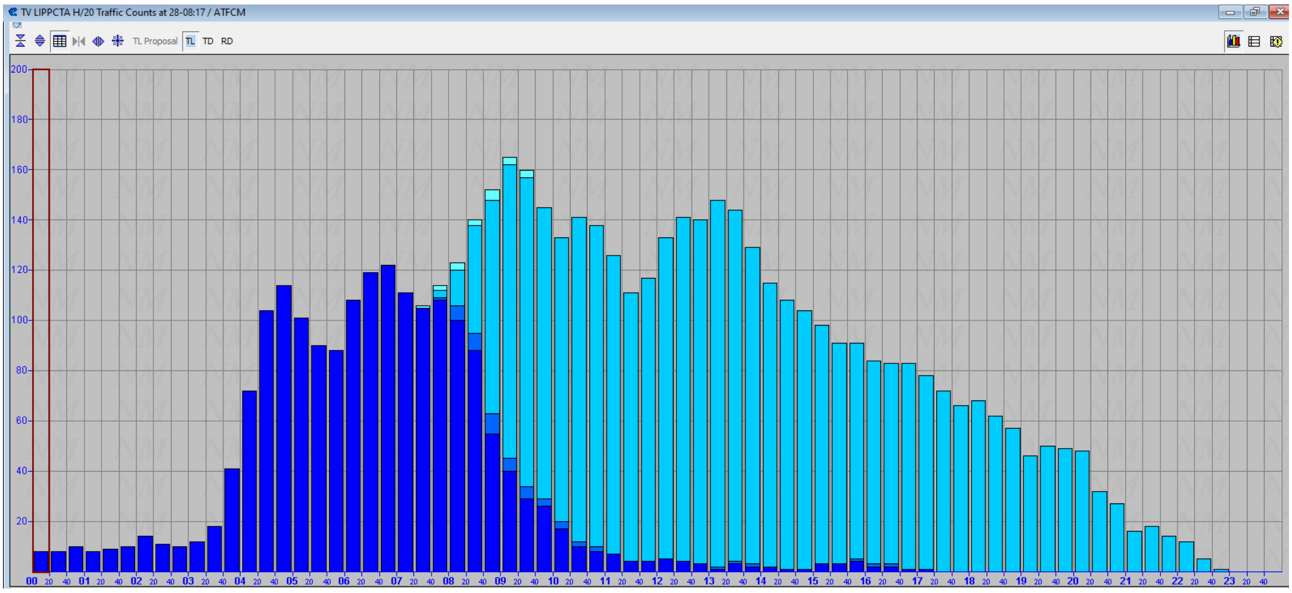


Figure 77: traffic load with hourly trend (UTC) in LIPP on 28th October 2022 with EPP equipped flights

ENTRY	ARCID	ATYP	ADEP	ADES	RM
07:37A	EJU71LD	A21N	LIMC	HESH	OEISD
07:52A	BAW63VP	A21N	LGAV	EGLL	GNEOY
07:56A	WZZ9409	A21N	LROP	LFLL	HALVF
08:29A	BAW401	A21N	HECA	EGLL	GNEOT
09:22E	WZZ8521	A20N	LIMC	UGKO	HALJE
09:29E	WZZ100J	A21N	LEBL	LROP	HALVM
09:54E	AFR46QB	A321	LFPG	LGAV	FGTAY
10:06E	WZZ83XW	A20N	LIBD	EGKK	HALJA
10:20E	WZZ3866	A21N	LFLL	LROP	HALVF
12:05E	WUK64AA	A320	LWSK	EGGW	GWUKD
12:46E	WZZ66	A21N	EPKK	LIMC	HALVH
13:32E	WZZ150	A21N	LIMC	OJAI	HALVK
14:35E	WZZ46	A21N	LIMC	EPKK	HALVH
14:42E	WZZ204	A20N	EGKK	LIBD	HALJA
14:44E	AFR15UL	A321	LGAV	LFPG	FGTAY
14:52C	WZZ2231	A21N	LROP	LPPT	HALVM

Table 30: EPP equipped flights on LIPP area on 2nd November 2022

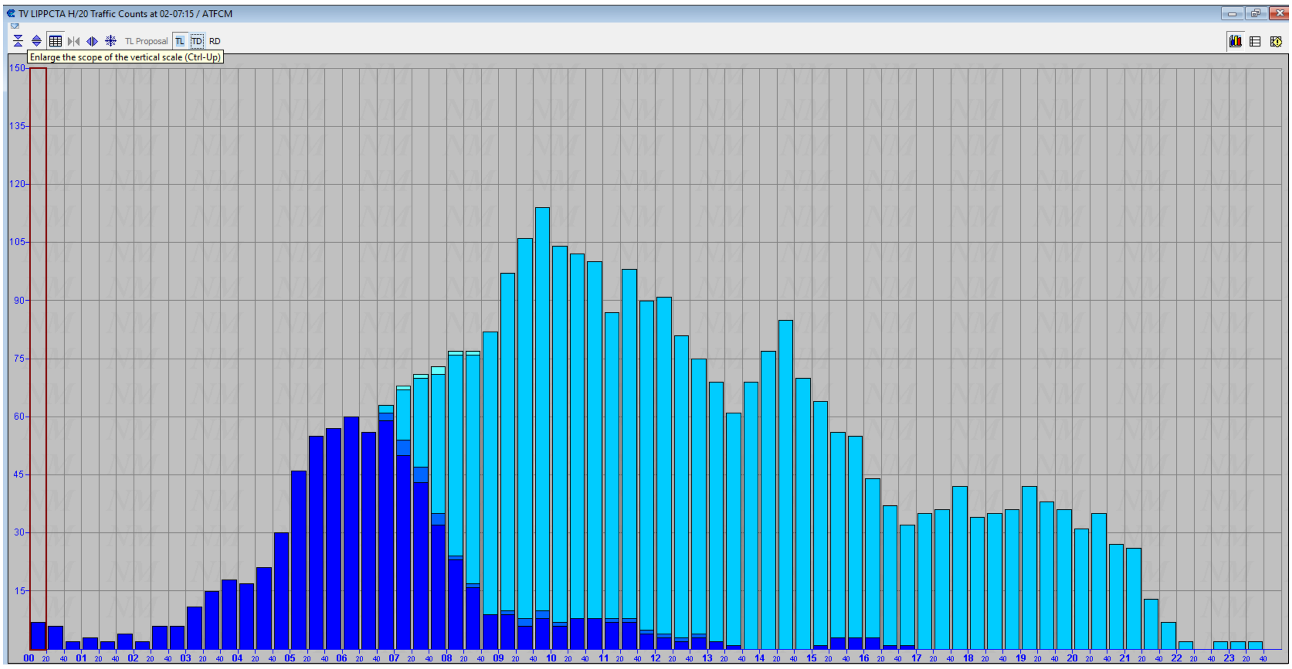


Figure 78: traffic load with hourly trend (UTC) in LIPP on 2nd November 2022 with EPP equipped flights

ENTRY	ARCID	ATYP	ADEP	ADES	RM2
08:16A	BAW401	A21N	HECA	EGLL	GNEOV
08:20A	WUK2	A321	EGGW	LGAV	GWUKG
08:39E	WZZ1313	A321	LIMC	LATI	HALTI
08:44E	WZZ177	A20N	LIBD	LIML	HALJA
09:34C	IBE31ZM	A20N	LEMD	LOWW	ECNJY
12:12E	WZZ2134	A21N	LROP	LFMN	HALVI
12:31E	IBE32EG	A20N	LEMD	LHBP	ECNFZ
12:35E	WZZ833	A20N	LIPX	LIBD	HALJA
13:08E	AFR76VU	A319	LFPG	LIPZ	FGRXK
13:10E	WZZ9358	A21N	LROP	LIPE	HALVF
14:10E	BAW66GA	A21N	LGAV	EGLL	GNEOP
14:15E	WZZ1101	A21N	LIMC	LYPG	HALVK
14:26E	EJU3EF	A21N	LLBG	LIMC	OEISC
14:39E	WZZ6869	A21N	LFMN	LROP	HALVI
14:43E	WZZ347	A21N	LIPE	LROP	HALVF
15:19E	WZZ5505	A20N	LIMF	LIBD	HALJA

Table 31: EPP equipped flights on LIPP area on 3rd November 2022

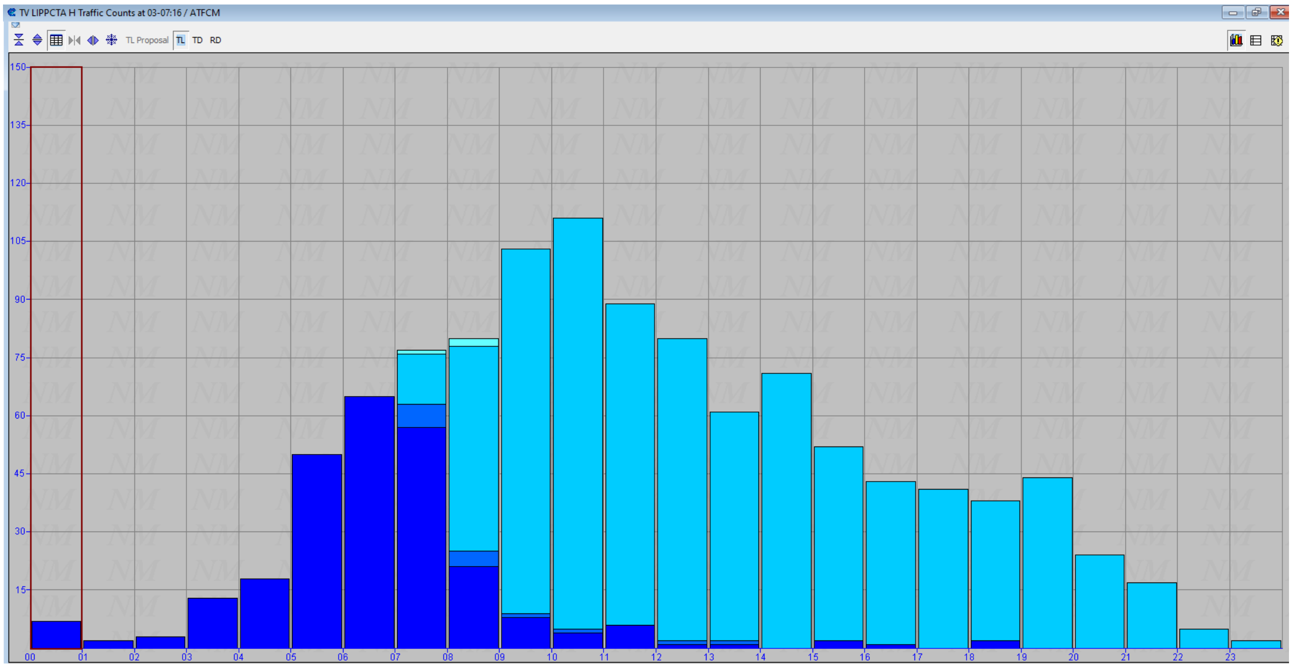


Figure 79: traffic load with hourly trend (UTC) in LIPP on 3rd November 2022 with EPP equipped flights

ENTRY	ARCID	ATYP	ADEP	ADES	RM2
06:42A	EJU12CD	A21N	LIMC	LLBG	OEISD
06:47A	WZZ6993	A21N	LROP	LEVC	HALVM
06:52E	WZZ6101	A321	LATI	LFLL	HALTI
06:53A	AFR1391	A321	LTFM	LFPG	FGTAU
07:25E	WZZ1BG	A21N	LROP	LIME	HALVF
07:34E	EZY63MY	A20N	EGKK	LGIR	GUZHZ
08:13E	WZZ90XY	A21N	LIRF	LKPR	HALVD
08:36E	WZZ83XW	A20N	LIBD	EGKK	HALJA
08:48E	BAW5RI	A21N	EGLL	LGAV	GNEOP
08:58E	WZZ1430	A21N	LIME	LROP	HALVF
09:19E	WZZ3866	A21N	LFLL	LROP	HALVI
09:47E	WZZ3698	A321	LFLL	LATI	HALTI
10:14E	AFR46QB	A320	LFPG	LGAV	FGKXU
10:59E	WZZ623	A21N	LKPR	LIRF	HALVD
11:40E	BAW406	A21N	EGLL	HECA	GNEOU
13:21E	WZZ204	A20N	EGKK	LIBD	HALJA
14:33E	EJU3EF	A21N	LLBG	LIMC	OEISD
15:50E	EZY62KL	A21N	EGKK	LGSR	GUZMH

Table 32: EPP equipped flights on LIPP area on 4th November 2022

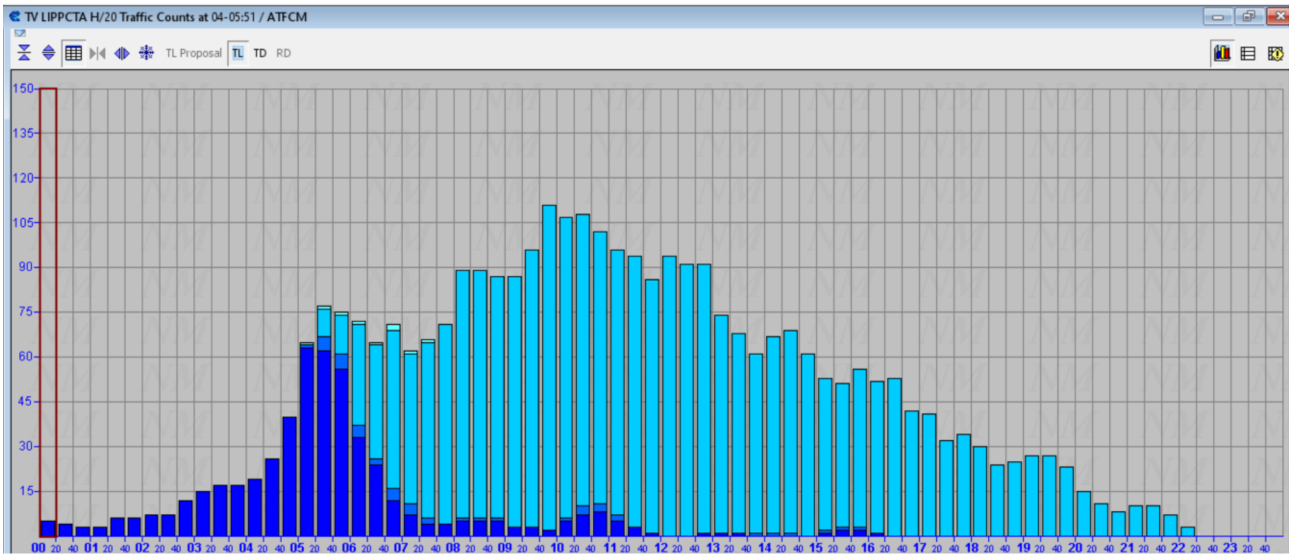


Figure 80: traffic load with hourly trend (UTC) in LIPP on 4th November 2022 with EPP equipped flights

ENTRY	ARCID	ATYP	ADEP	ADES	RM
09:58E	WZZ83XW	A20N	LIBD	EGKK	HALJA
10:34E	WZZ9339	A21N	LEBL	EPKK	HALVH
14:25E	BAW66GA	A21N	LGAV	EGLL	GNEOT
14:59E	WZZ204	A20N	EGKK	LIBD	HALJA

Table 33: EPP equipped flights on LIPP area on 7th November 2022

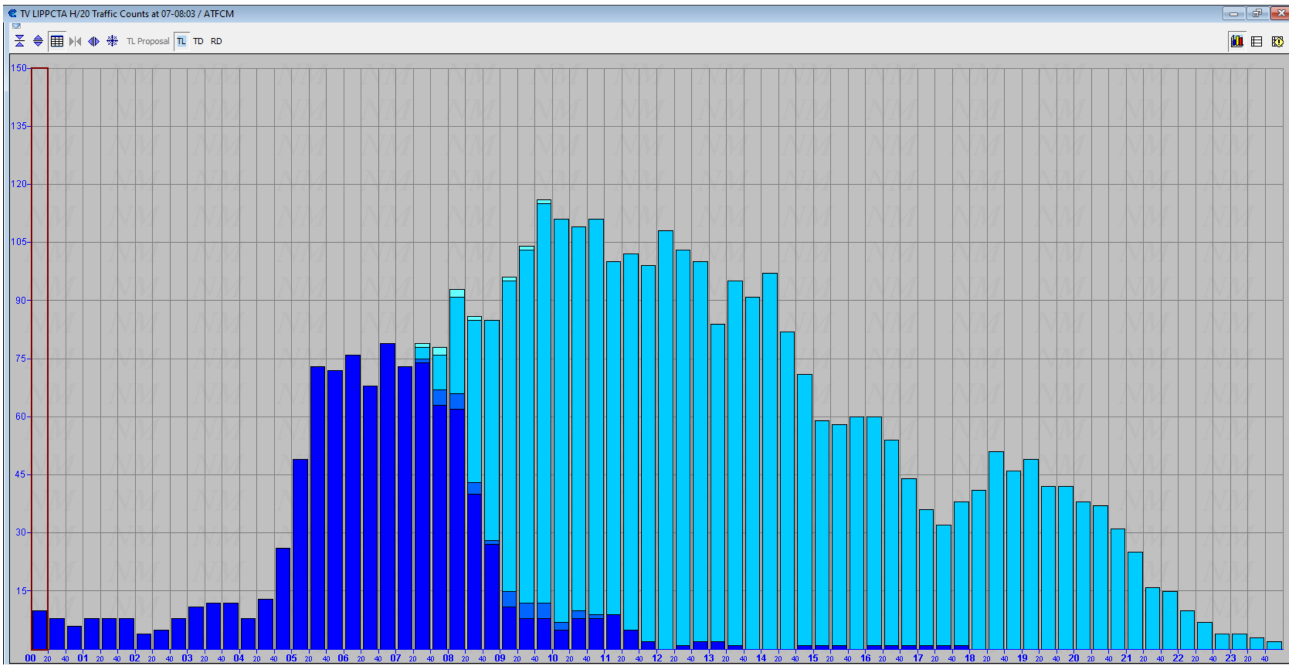


Figure 81: traffic load with hourly trend (UTC) in LIPP on 7th November 2022 with EPP equipped flights

ENTRY	ARCID	ATYP	ADEP	ADES	RM2
07:39E	EJU12CD	A21N	LIMC	LLBG	OEISD
07:46E	WZZ833	A20N	LIPX	LIBD	HALJA
07:48E	EZY93FB	A21N	EGKK	LGKR	GUZMH
11:20E	EZY98DA	A21N	LGKR	EGKK	GUZMH
13:05E	WUK2457	A321	LGAV	EGGW	GWUKJ
14:08E	EZY95JR	A21N	LGIR	EGKK	GUZMI
14:42E	WZZ5JH	A21N	EPWA	LEMG	HALVG
15:01E	WZZ1270	A20N	LHBP	LPPR	HALJB
15:40E	EJU3EF	A21N	LLBG	LIMC	OEISD
15:58E	EZY6575	A20N	LCPH	EGKK	GUZHZ

Table 34: EPP equipped flights on LIPP area on 8th November 2022

Table 35: EPP equipped flights on LIMM and LIPP areas on 8th November 2022

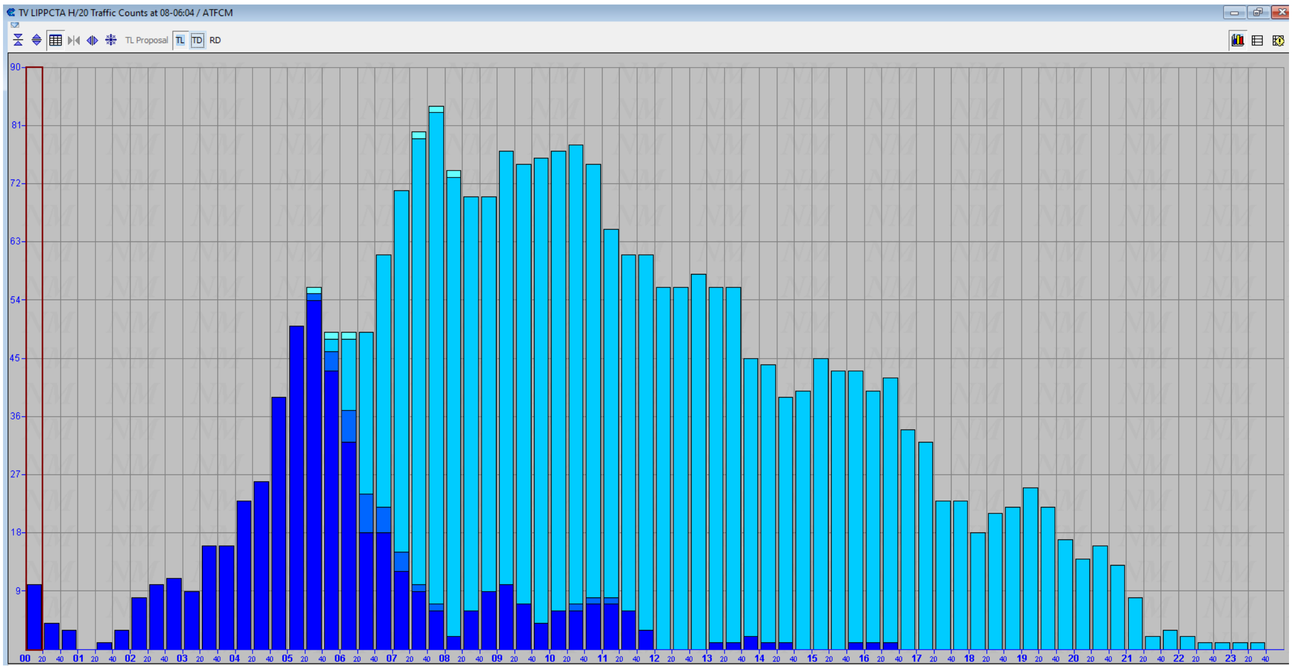


Figure 82: traffic load with hourly trend (UTC) in LIPP on 8th November 2022 with EPP equipped flights

ENTRY	ARCID	ATYP	ADEP	ADES	RM2
07:55A	BAW63VP	A21N	LGAV	EGLL	GNEOU
08:31E	WZZ8279	A321	LIRP	LATI	HALTI
08:35A	BAW401	A21N	HECA	EGLL	GNEOP

09:29E	WZZ1778	A20N	LIML	LIBD	HALJA
14:35E	WZZ46	A21N	LIMC	EPKK	HALVK

Table 36: EPP equipped flights on LIPP area on 9th November 2022

ENTRY	ARCID	ATYP	ADEP	ADES	RM2
08:10A	BAW401	A21N	HECA	EGLL	GNEOZ
09:29A	WZZ1778	A20N	LIML	LIBD	HALJA
10:03A	AFR46QB	A320	LFPG	LGAV	FHEPG
12:53E	WZZ1HL	A21N	EPKT	GCTS	HALVI
13:08E	AFR76VU	A320	LFPG	LIPZ	FGKXP
14:04E	AFR13VF	A320	LIPE	LFPG	FHEPJ
14:07E	BAW66GA	A21N	LGAV	EGLL	GNEOT
14:19E	EZY95JR	A20N	LGIR	EGKK	GUZHZ
14:36E	AFR44MR	A320	LIPZ	LFPG	FGKXP
14:39E	AFR15UL	A320	LGAV	LFPG	FHEPG
14:58E	EZY68QA	A21N	LTAI	EGKK	GUZMI
15:17E	EZY78GC	A20N	LCPH	EGKK	GUZLL
15:51E	WZZ92NE	A21N	LIMC	HESH	HALVK

Table 37: EPP equipped flights on LIPP area on 10th November 2022

ENTRY	ARCID	ATYP	ADEP	ADES	RM2
07:15E	WZZ4UR	A21N	LIPH	LROP	HALVC
07:41E	WZZ1GK	A20N	LIPX	LATI	HALJA
08:18A	BAW401	A21N	HECA	EGLL	GNEOY
08:54E	AFR66GP	A320	LIPE	LFPG	FHEPJ
08:57E	WZZ1HH	A20N	LIRF	LHBP	HALJB
13:13E	WZZ9414	A21N	EPWA	GMMX	HALVG
13:37E	BAW66GA	A21N	LGAV	EGLL	GNEOZ
15:25C	WZZ2231	A21N	LROP	LPPT	HALVD

Table 38: EPP equipped flights on LIPP area on 11th November 2022

ENTRY	ARCID	ATYP	ADEP	ADES	RM2
07:44E	WZZ1885	A20N	LIPE	LATI	HALJA
07:46E	WZZ1GK	A20N	LIPX	LATI	HALJB
08:53E	EZY36RK	A20N	EGKK	LCPH	GUZLL
08:54E	AFR66GP	A320	LIPE	LFPG	FHEPD
09:24E	WZZ3866	A21N	LFLL	LROP	HALVC
09:55E	AFR46QB	A320	LFPG	LGAV	FHEPJ
10:17E	EZY24NL	A20N	EGKK	LGTS	GUZLC

10:41C	WZZ9339	A21N	LEBL	EPKK	HALVK
14:08E	WZZ6313	A321	LATI	LIMF	HALTI
14:10E	EJU79GH	A21N	LIMC	LLBG	OEISD
14:11E	EZY53EN	A20N	LGTS	EGKK	GUZLC
14:45E	AFR15UL	A320	LGAV	LFPG	FHEPJ
15:15E	EZY78GC	A20N	LCPH	EGKK	GUZLL
15:31E	WZZ6101	A20N	LATI	LFLL	HALJA
15:33E	WZZ2231	A21N	LROP	LPPT	HALVC
15:57E	WZZ65	A21N	LROP	LEMD	HALVF
16:37E	WZZ92	A321	LIMF	LATI	HALTI

Table 39: EPP equipped flights on LIPP area on 14th November 2022

ENTRY	ARCID	ATYP	ADEP	ADES	RM2
07:27E	EJU12CD	A21N	LIMC	LLBG	OEISD
07:46E	WZZ1GK	A20N	LIPX	LATI	HALJB
08:22E	WZZ9534	A21N	LSGG	LROP	HALVD
08:31E	WZZ1313	A20N	LIMC	LATI	HALJA
09:57E	AFR96MU	A319	LFPG	LIPZ	FGRXM
09:58E	AFR46QB	A320	LFPG	LGAV	FHEPI
11:26E	AFR87CV	A319	LIPZ	LFPG	FGRXM
14:40E	WZZ5JH	A21N	EPWA	LEMG	HALVH
14:56E	EZY12DP	A20N	LTBS	EGCC	GUZLD
15:32E	EJU3EF	A21N	LLBG	LIMC	OEISD

Table 40: EPP equipped flights on LIPP area on 15th November 2022

ENTRY	ARCID	ATYP	ADEP	ADES	RM2
07:05E	WZZ4UR	A21N	LIPH	LROP	HALVI
07:26A	EJU71LD	A21N	LIMC	HESH	OEISE
08:00E	WZZ1GK	A20N	LIPX	LATI	HALJA
08:28E	WZZ1313	A20N	LIMC	LATI	HALJB
09:29E	BAW5RI	A21N	EGLL	LGAV	GNEOU
10:07E	AFR46QB	A320	LFPG	LGAV	FHEPK
11:12E	BAW406	A21N	EGLL	HECA	GNEOS
13:07E	WZZ9358	A21N	LROP	LIPE	HALVI
14:20E	WZZ6313	A321	LATI	LIMF	HALTI
14:25E	BAW66GA	A21N	LGAV	EGLL	GNEOU
14:31E	EZY81MJ	A21N	LGAV	EGKK	GUZMH
14:38E	WZZ347	A21N	LIPE	LROP	HALVI
14:56E	WZZ2231	A21N	LROP	LPPT	HALVF
15:18E	EZY78GC	A20N	LCPH	EGKK	GUZLL

Table 41: EPP equipped flights on LIPP area on 16th November 2022

ENTRY	ARCID	ATYP	ADEP	ADES	RM2
08:58E	WZZ1DE	A20N	LIME	LATI	HALJB
09:14A	BAW5RI	A21N	EGLL	LGAV	GNEOP
11:18E	BAW406	A21N	EGLL	HECA	GNEOR
12:29E	AFR1390	A321	LFPG	LTFM	FGTAY
14:28E	BAW66GA	A21N	LGAV	EGLL	GNEOP
14:30E	EJU3EF	A21N	LLBG	LIMC	OEISD
15:19E	EZY78GC	A20N	LCPH	EGKK	GUZLL
16:50E	EJU573U	A21N	LIMC	LIBR	OEISD

Table 42: EPP equipped flights on LIPP area on 17th November 2022

ENTRY	CALLSIGN	TYPE	DEP	DEST	RM
07:23	WZZ1AC	A321	LATI	LIPH	HALTI
08:17E	WZZ1313	A20N	LIMC	LATI	HALJA
08:57E	WZZ3538	A321	LIPH	LATI	HALTI
09:19C	WZZ3866	A21N	LFLL	LROP	HALVC
09:40C	WZZ3698	A20N	LFLL	LATI	HALJB
09:53E	AFR46QB	A320	LFPG	LGAV	FGKXZ
11:29E	BAW406	A21N	EGLL	HECA	GNEOY
13:00E	WZZ25GN	A20N	LATI	LIPE	HALJB
14:22E	WZZ1885	A20N	LIPE	LATI	HALJB
14:43E	EJU3EF	A21N	LLBG	LIMC	OEISD
15:01E	BAW58EW	A21N	EGLL	LIPZ	GNEOT
15:06E	EZY13TC	A21N	EGKK	LGAV	GUZMH
15:12E	WZZ122	A20N	LATI	LIPR	HALJA
16:27E	WZZ3GP	A21N	LROP	LEBL	HALVD
16:30E	WZZ3XE	A20N	LIPR	LATI	HALJA
16:51E	EJU573U	A21N	LIMC	LIBR	OEISD
16:58E	BAW53FT	A21N	LIPZ	EGLL	GNEOT

Table 43: EPP equipped flights on LIPP area on 18th November 2022

F.1.4 Summary of Demonstration Exercise #01 Demonstration Assumptions

There are no specific assumptions for this exercise. The general demonstration assumptions are provided in section 5.5 of the D1.5 DEMOP.

F.2 Deviation from the planned activities

The exercise scenario area chosen was the PADUA ACC, as opposed to MILAN ACC which was indicated in the original Demonstration Plan. This was due to the availability of operational tactical resolution tool over the PADUA ACC, such tool not being available over MILAN ACC yet.

Regarding the exercise data collection platform, acquired tracks were not provided with complete flight plans information.

The recording window was initially foreseen to last one week during October 2022. Due to the issues described in F.3.3, it was decided to prolong the duration of data recording period first to two weeks, and finally to a total of 3 weeks (from 24th October to 18th November 2022).

During that period, the exercise figures could be summarised as follows:

- three weeks of shadow mode acquisition,
- 18 days recording data,
- 226 ADS-C equipped flights considered,
- of which, 54 A/Cs performed the log-on.

F.2.1.1 EX6- OBJ-38-W3-DEMOP-HPRF-0002 deviations

Demonstration Objective ID	Success Criterion ID	Success Criterion	Deviation from the DEMOP
OBJ-38-W3-DEMOP-HPRF-0002	EX6- CRT-38-W3-DEMOP-006	The use of ADS-C data leads to a reduced ATCO R/T usage (e.g.: asking for the aircraft intention) and reduced workload. (Subjective data only)	
	EX6- CRT-38-W3-DEMOP-009	The ADS-C/EPP display supports ATCOs in performing their tasks efficiently and effectively. (Subjective data only).	
	EX6-CRT-38-W3-DEMOP-010	The use of ADS-C data provides assistance to support ATCO decision-making. (Subjective data only)	
	EX6-CRT-38-W3-DEMOP-011	Actual conflicts are detected earlier thanks to enhanced CD tool.	
	EX6-CRT-38-W3-DEMOP-013	2D Consistency check and Conformance monitoring is considered improved by ATCOs. (Subjective data only)	

F.2.1.2 EX6- OBJ-38-W3-DEMOP-OPRF-0003 deviation

Demonstration Objective ID	Success Criterion ID	Success Criterion	Deviation from the DEMOP
OBJ-38-W3-DEMOP-OPRF-0003	EX6-CRT-38-W3-DEMOP-015	Adherence to on board expected vertical trajectories is enhanced thanks to the use (e.g. display) of TOD information.	Vertical A/C information not available on the HMI
OBJ-38-W3-DEMOP-OPRF-0003	EX6-CRT-38-W3-DEMOP-020	Enhancement of EPP data display for 2D Consistency check.	EPP data not available on the reference CWP for a real time consistency check
OBJ-38-W3-DEMOP-OPRF-0003	EX6-CRT-38-W3-DEMOP-021	Evidence of operational benefits brought by using ADS-C data elements to enhance ground air traffic flow management operations	

F.2.1.3 EX6- OBJ-38-W3-DEMOP-OPSF-0004 deviation

Demonstration Objective ID	Success Criterion ID	Success Criterion	Deviation from the DEMOP
OBJ-38-W3-DEMOP-OPSF-0004	EX6-CRT-38-W3-DEMOP-023 Same as CRT-38-W3-DEMOP-023	Assess that the display of ADS-C data is considered useful by users (e.g. ATCO).	ATCOs were generally favourable about the usefulness of the EPP data displayed, though no specific measurement or assessment were performed

F.2.1.4 EX6- OBJ-38-W3-DEMOP-TECH-0006 deviation

In the timeframe of the PJ38, with the EXE006 platform performances, was not possible to measure the ACS A/G bandwidth saving and was not possible to demonstrate EX6-CRT-38-W3-DEMOP-037 of the EX4-OBJ-38-W3-DEMOP-TECH-0006.

Demonstration Objective ID	Success Criterion ID	Success Criterion	Deviation from the DEMOP
OBJ-38-W3-DEMOP-TECH-0006	EX6-CRT-38-W3-DEMOP-037	The ACS saves A/G bandwidth with regards to an architecture of local ADS-C data acquisition	Not applicable to the demonstration exercise platform

	Same as CRT-38-W3-DEMOP-037		

F.3 Demonstration Exercise #01 Results

F.3.1 Summary of Demonstration Exercise #01 Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-38-W3-DEMOP-SAFE-0001		EX6- CRT-38-W3-DEMOP-041	The working of enhanced CD tool was appropriate and supported safe service provision. (Subjective data only)	En-Route	EX6- CRT-38-W3-DEMOP-041 assessment can be referred to.	
OBJ-38-W3-DEMOP-HPRF-0002		EX6- CRT-38-W3-DEMOP-006	The use of ADS-C data leads to a reduced ATCO R/T usage (e.g.: asking for the aircraft intention) and reduced workload. (Subjective data only)	En-Route		
OBJ-38-W3-DEMOP-HPRF-0002	Human Performance improvement	EX6- CRT-38-W3-DEMOP-009	The ADS-C/EPP display supports ATCOs in performing their tasks efficiently and effectively. (Subjective data only).	En-Route		
OBJ-38-W3-DEMOP-HPRF-0002	Human Performance improvement	EX6-CRT-38-W3-DEMOP-010	The use of ADS-C data provides	En-Route		

			assistance to support ATCO decision-making. (Subjective data only)			
OBJ-38-W3-DEMOP-HPRF-0002	Human Performance improvement	EX6-CRT-38-W3-DEMOP-011	Actual conflicts are detected earlier thanks to enhanced CD tool.	En-Route		
OBJ-38-W3-DEMOP-HPRF-0002	Human Performance improvement	EX6-CRT-38-W3-DEMOP-013	2D Consistency check and Conformance monitoring is considered improved by ATCOs (Subjective data only)	En-Route		
OBJ-38-W3-DEMOP-OPRF-0003	Operational performance improvement	EX6-CRT-38-W3-DEMOP-015	Adherence to on board expected vertical trajectories is enhanced thanks to the use (e.g. display) of TOD information.	En-Route		
OBJ-38-W3-DEMOP-OPRF-0003	Operational performance improvement	EX6-CRT-38-W3-DEMOP-020	Enhancement of EPP data display for 2D Consistency check.	En-Route		
OBJ-38-W3-DEMOP-OPRF-0003	Operational performance improvement	EX6-CRT-38-W3-DEMOP-021	Evidence of operational benefits brought by using ADS-C data elements to enhance ground air traffic flow management operations	En-Route		

OBJ-38-W3-DEMOP-OPSF-0004	Operational feasibility	EX6-CRT-38-W3-DEMOP-023 Same as CRT-38-W3-DEMOP-023	Assess that the display of ADS-C data is considered useful by users (e.g. ATCO).	En-Route		Not covered
OBJ-38-W3-DEMOP-TECH-0005	Data collection improvement	EX6-CRT-38-W3-DEMOP-029 Same as CRT-38-W3-DEMOP-029	Provision of regular statistics about the traffic of ADS-C datalink exchanges.	En-Route	Data collection performed; no statistical analysis performed	Partial OK
OBJ-38-W3-DEMOP-TECH-0006	Access to ADS-C data	EX6-CRT-38-W3-DEMOP-033 Same as CRT-38-W3-DEMOP-033	Assess that the ADS-C data is correctly received by our system (test platform).	En-Route	As shown in the tables above (see F.1.3) data were properly acquired and recorded daily	OK
OBJ-38-W3-DEMOP-TECH-0006	Access to ADS-C data	EX6-CRT-38-W3-DEMOP-036 Same as CRT-38-W3-DEMOP-036	The ACS data provision satisfies the operational needs of the clients	En-Route	During the training period, ACS data provision has been considered satisfactory for the exercise purposes	OK
OBJ-38-W3-DEMOP-TECH-0006	Access to ADS-C data	EX6-CRT-38-W3-DEMOP-037 Same as CRT-38-W3-DEMOP-037	The ACS saves A/G bandwidth with regards to an architecture of local ADS-C data acquisition	En-Route		Not covered

Table 44: Exercise 1 Demonstration Results

F.3.2 Results per KPA

- ***Safety:***

The safety assessment aspects were somewhat limited because of:

- the ATCO analysis were based on live-recorded data in the Padua ACC with the ADS-C/EPP traffic remotely mirrored on a prototypal platform based on 4-Flight system. For the nature of shadow mode analysis of the operational activities, with the playback assessment performed on the recorded traffic, it was not possible to introduce safety issues by means of the exercise tools.

- the solution scenario was based on the actual operational environment, with an ATM system (4-Flight prototype platform) and the downloaded ADS-C/EPP data. As the platform used for this exercise was derived from PJ18-W2.53A EXE 001, readers can refer to EXE001 report for aspects regarding safety assessment of the platform.

- ***Human Performance:***

As the ATCOs have not considered the number of instances between logged-on A/Cs ADS-C equipped as applicable and sensible for carrying out an effective HP assessment, as well as carrying out a relevant statistical analysis of the exercise, it was decided to not hand the questionnaires out or record HP issues For such a reason, the HM perspectives were considered as not applicable to the #6 demonstration activities.

F.3.3 Analysis of Exercises Results per Demonstration objective

F.3.3.1 EX6- OBJ-38-W3-DEMOP-TECH-0005 Result

Overall conclusion:

This Validation Objective status is OK:

The exercise run system received data with the following provision calendar:

- three weeks of shadow mode acquisition,
- about 12 flights per day,
- overall 226 ADS-C equipped flights considered,
- of which, 54 A/Cs performed the log-on.

As shown in the tables above (F.1.3), data were properly acquired and recorded daily, statistical analysis cannot be performed (see F.3.41 and F.3.43).

F.3.3.2 EX6- OBJ-38-W3-DEMOP-TECH-0006 Result

Overall conclusion:

This Validation Objective status is OK.

OBJ-38-W3-DEMOP-TECH-0006	Access to ADS-C data	EX6-CRT-38-W3-DEMOP-033 Same as CRT-38-W3-DEMOP-033	Assess that the ADS-C data is correctly received by our system (test platform).	En-Route	As shown in the tables above (see F.1.3) data were properly acquired and recorded daily	OK
OBJ-38-W3-DEMOP-TECH-0006	Access to ADS-C data	EX6-CRT-38-W3-DEMOP-036 Same as CRT-38-W3-DEMOP-036	The ACS data provision satisfies the operational needs of the clients	En-Route	During the training period, ACS data provision has been considered satisfactory for the exercise purposes	OK

In the timeframe of the PJ38, the EX6-CRT-38-W3-DEMOP-037 cannot be applied with the EXE006 platform performances.

F.3.4 Unexpected Behaviours/Results

In the first place, a proportion of 10%÷15% of the entire air traffic flying over LIPP in a day was made up of ADS-C equipped A/Cs, meant a limited amount of available data and potential trajectories conflicting in tactical events to be considered for the analysis. Besides, out of the above proportion, only roughly 25% of A/Cs actually made a successful log-on and then downloaded the EPP data. The final result is a tiny proportion of about 3%÷4% in comparison to the total number of movements per day.

An unexpected experience was that sometimes, even if the ATCOs requested a log-on on purpose, the pilots did not perform the log-on as instructed either because they were not aware of the ADS-C capability of the A/C equipment or because they were not willing to perform the log-on in that phase of the flight. There is no significant evidence that, in the area considered for the demonstration scenario, the auto-logon procedure offered any particular support towards acquiring more data.

F.3.5 Confidence in the Demonstration Results

F.3.5.1 Level of significance/limitations of Demonstration Exercise Results

The demonstration results obtained by the exercise could have relied on data samples of useful events which were too small in comparison with the whole traffic of the monitoring period, in fact only seven different instances were detected, not sufficiently representative to carry out a statistical analysis. Some limitations are reported hereafter for considerations about the results interpretation:

- only a small sample of the A/C population provided input data for the present demonstration activity,
- in only seven different instances, with the needed layout, events of tactical conflict advisory alert took place during the whole recording campaign; such limited amount of data were not considered to represent a satisfactory amount of occurrences for statistical significance.

F.3.5.2 Quality of Demonstration Exercise Results

As it was pointed out in the previous section, we can claim that it was not possible to describe all issues concerning the quality of the results achieved in the Demonstration Exercise #06, either regarding the accuracy of results or the confidence in the outcomes, which might have been influenced by the limited number of available events useful for the objectives of the exercise.

F.3.5.3 Significance of Demonstration Exercises Results

During the 3 weeks of the demonstration campaign, 226 flights were controlled by ENAV ATCOs, identifying a total of seven instances of tactical conflict advisory alert between ADS-C equipped and logged-on A/Cs. From such a result, it can be concluded that the exercise did not provide data with applicable statistical relevance.

F.4 Conclusions

The identification of tactical conflicts, usable and relevant to the demonstration activity ends, took place in only seven different instances and, unfortunately, the sizes of recorded samples were not sufficient to carry out a statistical analysis.

Tactical conflicts triggered by EPP tracks were observed but the separation resolution did not yield conclusive evidence for the what-if analysis based on PJ18 platform features.

At the present stage, the lack of useful instances as input to the statistical analysis can be considered one of the triggering points for the ineffectiveness of the demonstration assessment. Further developments and refinements planned in the HERON project, with future traffic scenarios and a higher proportion of ADS-C equipped A/Cs, should likely provide more usable data based on ADS-C EPP trajectories., possibly running new exercises on longer time scales.

F.5 Recommendations

F.5.1 Recommendations for industrialization and deployment

The ENAV PJ38 platform was developed including the whole ATN Stack enabling the use of ADS-C data downloaded from the equipped aircrafts flying within the European airspace. In line with PJ38 architecture the platform provides the ADS-C service for the real-time distribution of related information, which is expected to streamline the deployment of the ADS-C capabilities of ground ATM Systems.

In line with the original plan, the platform was integrated with the ESSP one through a VPN link enabling service continuity in the event of a master ADS-C server (currently hosted in DFS) outage. In addition, the link enables the ESSP center to monitor the status of the ENAV platform ensuring higher reliability-availability of the PJ38 solution.

Based on the experience and on the above described architecture, a distributed implementation seems to be the best option to ensure the requested level of availability and continuity of the service, also in case of disaster recovery situations.

Hence a final recommendation is to further develop the architecture for future activities related to ACS.

F.5.2 Recommendations on regulation and standardisation initiatives

Not addressed in the present EXE006 exercise

Appendix G Demonstration Exercise #07 (EXE-PJ38-4-7 by NATS) Report

G.1 Summary of the Demonstration Exercise #07 Plan

G.1.1 Exercise description and scope

The NATS demonstration exercise is primarily focussed on data collection, processing and analysis of the TOARange ETA min/max ADS-C data group, with subsequent offline benefit assessment. The original intention of the exercise was to establish ADS-C demand contracts, initially directly through the existing NATS PJ31 test platform and then at a later phase via the ADS-C Common Service (ACS). However, the PJ31 platform was unable to support the establishment of demand contracts. It should also be noted that ACS support for the TOA Range data group was initially facilitated by Periodic Contract rather than Demand contract.

The offline assessment of the downlinked ADS-C data aimed to evaluate the stability and accuracy of the ADS-C ETA min/max predictions for the estimated time of arrival against a set of specific London TMA specific arrival waypoints.

The exercise also demonstrated an ANSP developed prototype ACS client submitting Demand Contract Requests and subscribing to ADS-C data reports established by the prototype ACS.

G.1.2 Summary of Demonstration Exercise #07 Demonstration Objectives and success criteria

From an operational perspective, the objective of EXE-PJ38-4-7 is to demonstrate that the use of ADS-C data facilitated by the ADS-C Common Service (ACS) can improve the performance of ground air traffic flow management operations through improved predictions enhanced by ADS-C data elements of EPP and TOA Range ETA Min/Max.

From a technical perspective, the objective of EXE-PJ38-4-7 is to demonstrate that the use of the ACS server-client architecture enables the timely reception and robust access to reliable ADS-C data to support operational benefits.

G.1.3 Summary of Validation Exercise #07 Demonstration scenarios

The aircraft with no ATS B2 ADS-C capability and the subsequent ground trajectory data derived from them, are considered as the reference for this exercise, as current queue management tools and procedures within NATS do not have access to ATS B2 ADS-C data.

The solution scenario involves the ADS-C Common Service (ACS) establishing contracts requesting the TOA Range ETA min/max data for specific London TMA arrival waypoints.

G.1.4 Summary of Demonstration Exercise #07 Demonstration Assumptions

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
PJ38-ASS-01	ADS-C data provision		See section 3.3.4	See section 3.3.4	High [Not realised]
PJ38-ASS-02	ADS-C data usability		See section 3.3.4	See section 3.3.4	High [Not realised]
PJ38-ASS-03	VDL2 performances		See section 3.3.4	See section 3.3.4	High [Not realised]
PJ38-ASS-04	Future COVID situation		See section 3.3.4	See section 3.3.4	High [Not realised]

Table 45: Exercise #07 Demonstration Assumptions overview

G.2 Deviation from the planned activities

The original intention of the exercise was to establish ADS-C Periodic and Demand contracts to the DIGITS' equipped fleet directly from the existing NATS PJ31 test platform while the ACS platform was being developed. This initial phase of the data collection could not be accommodated as the test and development connection point to the SITA ATN backbone was re-prioritised to support operational sustainment activities and the PJ31 platform was unable to support the establishment of demand contracts.

With regards to the second data collection phase, the original intention of the exercise was to establish ADS-C Demand contracts via a NATS developed Client connected to the ACS. However, it should also be noted that ACS support for the TOA Range data group was initially facilitated by Periodic Contract rather than Demand contract. This minor deviation still enabled the data collection for the characterisation of the ETA Min/Max data, although it removed the capability to analyse multiple arrival waypoints on a route.

As the ADS-C data NATS would collect via the ACS would be common with EIH (with the exception of Demand Contracts), it was recognised there would be little benefit in duplicating general ADS-C analysis undertaken by EUROCONTROL in support of EX7-CRT-38-W3-DEMOP-030. As such this criterion was not directly covered by NATS.

As described above, the second phase of the data collection was planned to make use of the ACS platform for the provision of ETA Min/Max data for operational assessment, with the data received through a subscription from a NATS developed ACS client. Due to unexpected resource constraints, NATS encountered a severe delay in establishing a network connection to the ESSP managed ACS distribution server, which was eventually established in January 2023. The provision of TOA Range ETA Min/Max data for the operational assessment was instead provided by ESSP as recorded on their ACS client connected to their ACS distribution server. Furthermore, this delay impacted NATS ability to use its client to collect statistics on datalink exchanges, however due to the nature of the ACS these statistics would be identical to other clients regardless.

The other main aspect of the original exercise plan that could not be realised due to various constraints, was to make use of a prototype AMAN to provide a quantitative assessment of operational benefits of ETA Min/Max within a queue management support tool. Instead, the characterisation and stability analysis of the ETA Min/Max data provided, was used to facilitate an expert judgement group to determine the benefits of the data in facilitating arrival streaming.

G.3 Demonstration Exercise #07 Results

G.3.1 Summary of Demonstration Exercise #07 Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
EX7-OBJ-38-W3-DEMOP-OPRF-0003	Demonstrate that the use of ADS-C data improves the Operational performance	EX7-CRT-38-W3-DEMOP-021	Evidence is produced of practical cases of operational benefits brought by using ADS-C data elements (both EPP and ETA min/max predictions) to enhance ground air traffic flow management operations. Examples of such operational benefits can be: improvement of predictability, reduction of holding times, reduction of tactical interventions, improvement of fuel efficiency. (Evidence might be qualitative and/or quantitative)	En-route	Based on the TOA Range data (ETA, earliest time – ETA min, and latest time – ETA max) analysis, it has been demonstrated that the majority of flights can reduce the holding time by losing between 30s and 90s during the cruise phase. This was calculated based on the TOA Range values indicated when the flights were around 35 minutes away from their COP. This conclusion provides a confirmation that the 60 seconds delay during cruise phase (which is currently built into the XMAN tool) can be achieved by most	OK

					aircraft with some of them being able to lose up to 250 seconds. This was a qualitative assessment due to the deviation mentioned in section G.2 due to the lack of an AMAN prototype for quantitatively assessing the improvement within a queue management support tool from using the TOA Range data.	
EX7-OBJ-38-W3-DEMOP-TECH-0005	Demonstrate a reliable and robust collection infrastructure to set up ADS-C contract and process data	EX7-CRT-38-W3-DEMOP-028	When an ADS-C ETA min/max contract is established, 80% of the ADS-C reports emitted by the A/C provide useful information (not frozen) as agreed through the contract.	En-route	On average 90% of the total periodic reports for each flight are providing the TOA Range data. 104 flights (i.e. 14.1%) of all flights provided TOA data in less than 80% of their periodic reports, with almost 40% of these flights having a rate of TOA data provision more than 70%.. . Regarding demand contracts, the average is around 91% of the demand reports per flight providing the	OK

					requested data Only 28 flights (i.e. 15% of all flights) provided TOA data in less than 80% of their demand reports with 42% of these flights having a rate of TOA data provision higher than 70%. Given the high rate of TOA Range provision, a combination of periodic and demand contracts can be used to support the ATC operational needs.	
EX7-OBJ-38-W3-DEMOP-TECH-0006	Demonstrate that the use of an ADS-C Common Service improves the access to data	EX7-CRT-38-W3-DEMOP-030	Provision of regular statistics about the traffic of ADS-C datalink exchanges.	En-route	Due to delays in implementing NATS ACS client, this success criteria could not be addressed by NATS, however due to the nature of the ACS the statistics on datalink exchanges collected would be identical to other clients regardless.	Not covered
EX7-OBJ-38-W3-DEMOP-TECH-0006	Demonstrate that the use of an ADS-C Common Service	EX7-CRT-38-W3-DEMOP-031	ADS-C on demand contracts are correctly passed through the ADS-C Common Service established on client	En-route	Although measured at the Client, the deltas between the Demand Request sent from the ACS and the Demand	OK

	improves the access to data		request, and resulting data shared in due time.		Report received by the ACS can be indicative of the airborne ADS-C performance. The 7080 eligible messages resulted in a long-tail distribution with large outliers, however the average delta was measured at 4.658 seconds, with 95% of deltas measuring under 12 seconds, as expected by the ATS B2 performance specification.	
EX7-OBJ-38-W3-DEMOP-TECH-0006	Demonstrate that the use of an ADS-C Common Service improves the access to data	EX7-CRT-38-W3-DEMOP-032	Data received via the ADS-C Common Service are reliable (i.e. they faithfully reflect the latest situation provided by the aircraft).	En-route	Individual flights have been reviewed to check that the data provided via the ACS reflects the aircraft planned route and TOA Range estimations. To be noted that the ACS data reviewed has not been collected by NATS and that it has been recorded by ESSP and shared with NATS for the WP4 Operational Analysis activities.	OK

EX7-OBJ-38-W3-DEMOP-TECH-0006	Demonstrate that the use of an ADS-C Common Service improves the access to data	EX7-CRT-38-W3-DEMOP-033	The ACS successfully receives, processes and distributes ADS-C data to multiple clients via SWIM in real time.	En-route	7215 Demand Contract Requests made by the Client and were facilitated by the ACS which was also connected to other Clients.	OK

Table 46: Exercise #07 Demonstration Results

EUROPEAN PARTNERSHIP

Co-funded by the European Union

G.3.2 Analysis of Exercises Results per Demonstration objective

G.3.2.1 EX7-OBJ-38-W3-DEMOP-OPRF-0003 Results

G.3.2.1.1 ADS-C TOA Range predictions assessment

G.3.2.1.1.1 Introduction to the analysis

The analysis of the ADS-C TOA Range data focused on the data collected by ESSP through the periodic reports established by the ADS-C Common Service Prototype between mid-May ’22 and 1st week of December ’22. The objective of this analysis is to characterise the data by looking at its variability when compared to the Actual Time of Arrival (ATO) as well as its stability over time by looking at how this variability evolved as the aircraft providing TOA Range data is getting closer to the target waypoint.

> **Note:** As ATC instructions given to the flight following the downlink of the TOA range information are not available for correlation, the variability stated in this analysis should be viewed as an indicative observation only as the min/max predictions are only truly applicable at the time they were computed. This analysis should therefore not be seen as a measure of the performance of the TOA Range function.

Due to the limited dataset and due to the difficulties NATS encountered in deploying its ACS client, the analysis focused on the dataset that was relevant for the NATS operational exercise which is aimed at assessing the use of the TOA Range data (ETA, Min & Max) for extended-AMAN operations. Therefore, the dataset is comprised of UK inbound flights heading into London Heathrow and London Gatwick airports and targeting Coordination Points (COP) and Initial Approach Fix (IAF) waypoints specific to each airport. The number of reports recorded for the NATS TOA range analysis is 18248. However, after discussions with AMAN SMEs, it has been agreed to remove from the dataset the very short flights i.e. UK domestic flights as well as inbounds from the Paris area to ensure the analysis results are not skewed due to receiving information from flights while still being on the ground or during the climb phase. The reason being there is a known prediction instability of AMAN for streaming purposes when considering flights that are not in cruise phase.

The detailed distribution of the datapoints based on the TOA target waypoint and split by airport is given below in the Figure 83. The filtering undertaken for this analysis as described above is detailed below in terms of the number of reports.

Total number of reports in the dataset= 18248

- Reports from Gatwick inbounds = 12934
- Reports from Heathrow inbounds = 4889
- Reports from Heathrow inbounds & Outbound from ‘Other airports’ data points = 185
- Reports from UK domestic flights = 240
- Reports coming from UK inbound flights selected for analysis = 18008

Airport	WP Flag	WP names						
Destination ↓	↓	IAF					COP	
		OCK	LAM	BIG	TIMBA	WILLO	REVTU	KESAX
Gatwick (EGKK): 12934	IAF (961)	X	X	X	598	363		
	COP (11973)						7737	4236
Heathrow (EGLL) : 4889	IAF (919)	650	253	16	X	X		
	COP (3970)						3970	X

Airport	WP Flag	WP names						
Origin - Destination ↓	↓	IAF					COP	
		OCK	LAM	BIG	TIMBA	WILLO	REVTU	KESAX
LFPG → Gatwick (EGKK): 12934	IAF (961)	X	X	X	598	363		
	COP (11973)						7737	4236
LFPG → Heathrow (EGLL) : 4889	IAF (919)	650	253	16	X	X		
	COP (3970)						3970	X

Figure 83: TOA range datapoint description

Note: in the figure above, the cross [“X”] is used to indicate that there were no reports associated with a specific waypoint for each of the two target airports.

List of definitions for the ADS-C TOA analysis:

- Message time = Time stamps when the ADS-C report is received on the ground.
- TOA Earliest = Earliest time at which an aircraft can arrive with 95% confidence at a waypoint when the aircraft is flying at highest speed while taking into account wind and temperature uncertainties and any altitude as well as speed restrictions inserted in the flight plan.
- TOA Latest = Latest time of arrival with 95% confidence that an aircraft to a waypoint when the aircraft is flying at slowest speed while taking into account wind and temperature uncertainties and any altitude as well as speed restrictions inserted in the flight plan.
- TOA ETO/ETA = Estimated Time Over/of Arrival of an aircraft to a waypoint from the ADS-C report.
- ATO = Actual time of arrival of an aircraft to a waypoint based on radar data.
- Time to metering point = The time remain in minutes to reach a target waypoint.

The analysis and therefore the results are split by the target airport (with EGLL being London Heathrow and EGKK being London Gatwick) as well as by their relevant target TOA waypoints as presented in Figure 83.

For the accuracy analysis, this has been achieved by calculating what we call a time delta between an ADS-C TOA estimation and the ATO obtained from the radar data. This approach was used to calculate the time delta for the TOA ETO, TOA earliest (or MIN as referred to in the analysis results section) and latest time (or MAX as referred to in the analysis results section). To be noted that for the radar ATO

EUROPEAN PARTNERSHIP

Co-funded by the European Union

value, the closest radar point in terms of distance (based on lat/long coordinates) from the target TOA waypoint has been used. Given the radar track update rate of 4 seconds, the deltas to be considered are within +/- 2 seconds. The results for this accuracy analysis have been presented in the upcoming section G.3.2.1.1.2 by plotting how each TOA estimation for each flight evolved with each ADS-C report received. This is referred to below as a step plot.

However, due to the high density of TOA estimations being plotted for each waypoint, there was a need to zoom in into the estimations without compromising on the results. In order to accommodate this, we captured the TOA estimations for each flight that are valid (the latest ADS-C report received before each selected timestamp) at a certain time before these reach each target waypoint. In other words, we have taken a snapshot in time for every 10 minutes up to an hour before the aircraft reached the target waypoint followed by 4 other snapshots at 90, 120, 150 and 180 minutes and have only used the ADS-C report valid for each timestamp to generate the distribution plots as well as the box plots. The idea of 10 minutes intervals closer to the target waypoint is to understand how good the TOA accuracy is when the ADS-C reports are sent closer to the waypoint.

For describing the results in much more depth and therefore when commenting on the plots, where this is needed, a Z-score is used to indicate how much a given value differs from the standard deviation. For calculating outliers, we have used the Z-score of 3 which refers to 3 standard deviations. That would mean that more than 99% of the population was covered by the z score.

To be noted that each vertical blue line within the plots provided in section G.3.2.1.1.2 represents one of the timestamps listed above while the datapoints are marked to indicate the frequency of each valid ADS-C TOA report at that particular timestamp.

Box plots are also used to represent the graphical representation of time deltas for the TOA ETA, earliest and latest estimations based on the minimum, first quartile, median, third quartile, and maximum values recorded at each timestamp. The vertical blue lines have the same meaning as explained above.

It’s important to note that for the step plot and for the datapoint frequency plots, the time axis is provided in seconds while for the boxplot this has been provided in minutes.

Figure 84 below shows the TOA range datapoints distribution used to plot different step plots and box plots at the different TOA waypoints based on the arrival airports. As explained above, the dataset distribution only considers the ADS-C TOA reports that are valid for each timestamp at 10, 20, 30, 40, 50, 60, 90, 120, 150 and 180 minutes.

Airport	WP Flag	WP names						
Destination ↓	↓	IAF					COP	
		OCK	LAM	BIG	TIMBA	WILLO	REVTU	KESAX
Gatwick (EGKK): 2738	IAF (331)	X	X	X	168	163		
	COP (2407)						1495	912
Heathrow (EGLL) : 1308	IAF (287)	204	83	1	X	X		
	COP (1021)						1021	X

Airport	WP Flag	WP names						
Origin - Destination ↓	↓	IAF					COP	
		OCK	LAM	BIG	TIMBA	WILLO	REVTU	KESAX
LFPG → Gatwick (EGKK): 2738	IAF (331)	X	X	X	168	163		
	COP (2407)						1495	912
LFPG → Heathrow (EGLL) : 1308	IAF (287)	204	83	1	X	X		
	COP (1021)						1021	X

Figure 84: TOA range datapoint distribution for box plot

G.3.2.1.1.2 Analysis results by TOA target waypoint

G.3.2.1.1.2.1 EGKK – REVTU (COP)

The analysis data contains 1495 ADS-C reports from 64 flights. Firstly, the outliers are removed from the plot for better visibility of the core datapoints. Also, this analysis only considers the reports that have been sent up to 180 minutes before the waypoint is reached. The analysis data includes 64 flights going through the REVTU waypoint as shown in Figure 85 below. Based on the 64 aircraft flying through REVTU, there is a clear trend for the TOA ETOs being stable from the 90 minutes timestamp with all values being between -192s and + 326s of the ATO with all the upcoming deltas being within ~520s variation excluding the outliers. For the 60 minutes mark there is a bit more variation in the recorded data going between -170s and +233 therefore the ADS-C TOA overestimates the ETO. Similarly, for 30 minutes time interval the TOA values converging to between -98s and 105s.

Also, from the chart we can observe that the spread of the plots gets narrower and the accuracy improves as we move more closer to the REVTU waypoint. For example, the reports sent at 10 minutes before the waypoint achievement are within an accuracy of 120 seconds (-57 to 77 seconds) window removing outliers based on the z-score calculation in comparison to the 30 and 60 minutes time interval calculation above.

- ETO assessment

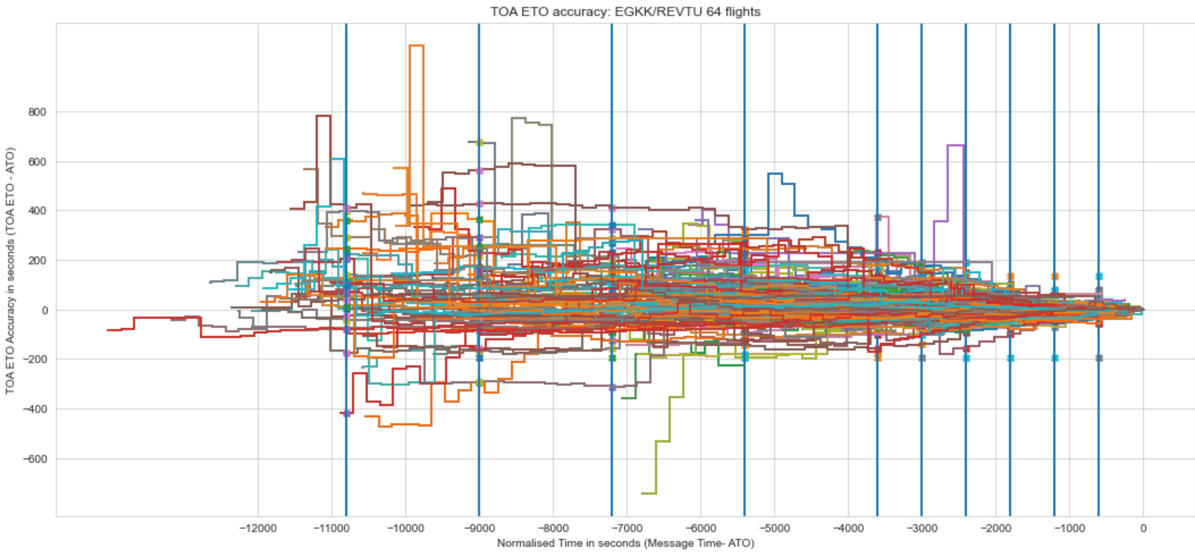


Figure 85: TOA ETO EGKK/REVTU step plot

As observed in the two plots below, the data distribution becomes denser and contained within the 120 seconds time interval as it nears 20 minutes and 10 minutes in comparison to the other time interval durations.

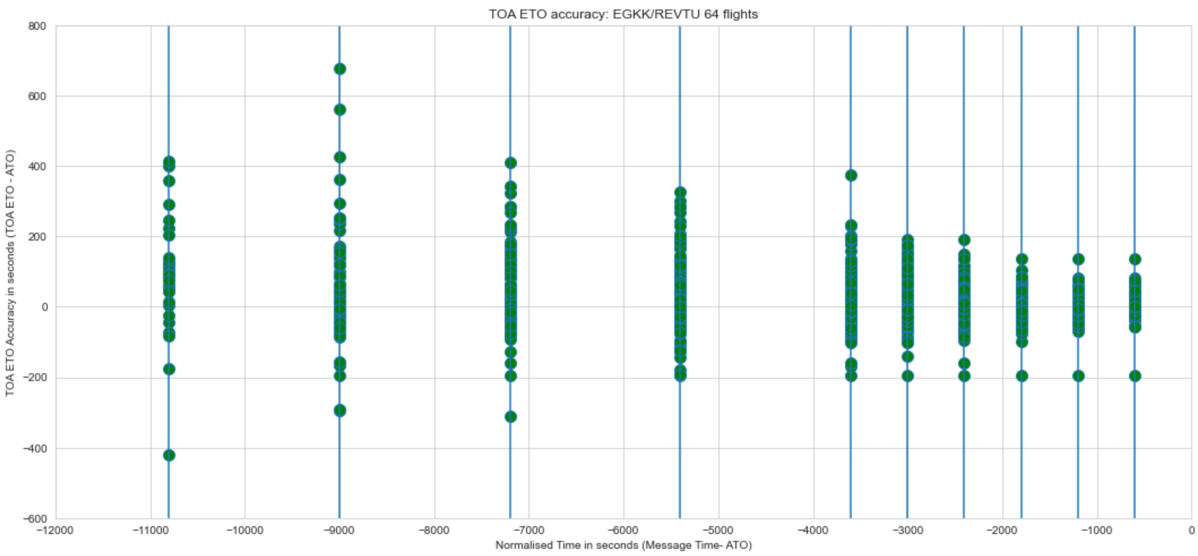


Figure 86: TOA ETO EGKK/REVTU distribution plot

- TOA MIN assessment

In terms of the TOA MIN values for the flights going through REVTU, it can be observed that it has a similar pattern to the TOA ETO values however with a slightly bigger variation near the 30-, 20- and 10-minutes interval. This is somewhat expected given the TOA MIN values are meant to give an indication of how much the aircraft can speed up. Therefore, at the 60 minutes mark, the TOA MIN deltas varied between -253 and +195s with the two extreme values corresponding to the flights where the TOA ETA deltas were -170s and, 233s respectively. As the aircraft are getting closer to REVTU, the variation interval starts to reduce reaching values between -145s and +136s at the 30 minutes timestamp while at the 10 minutes mark this has been between -111s and +83s, again excluding the outliers using the z-score calculation.

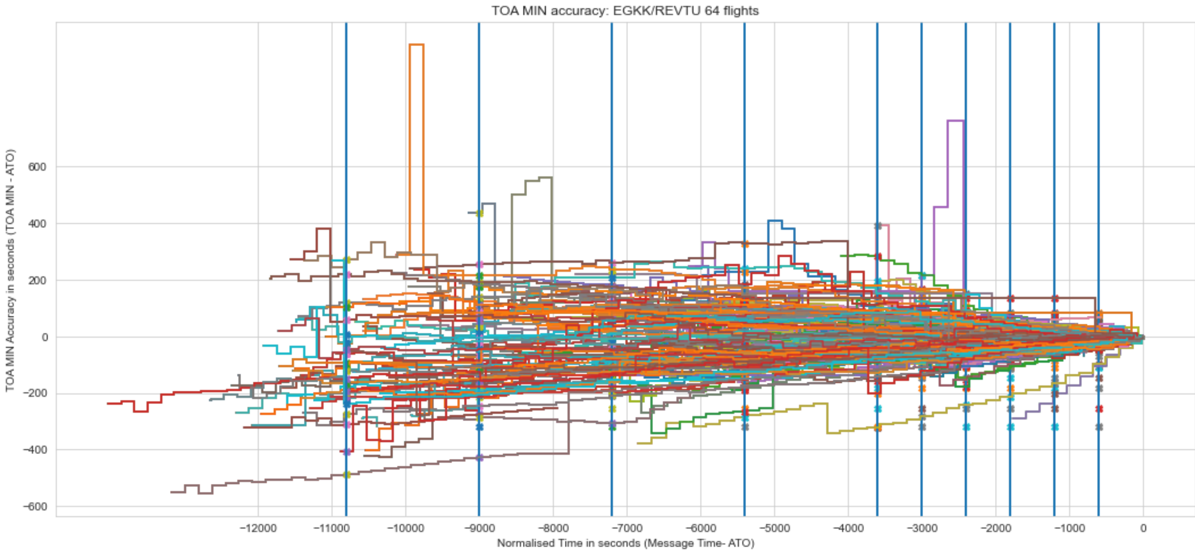


Figure 87 : TOA MIN EGKK/REVTU step plot

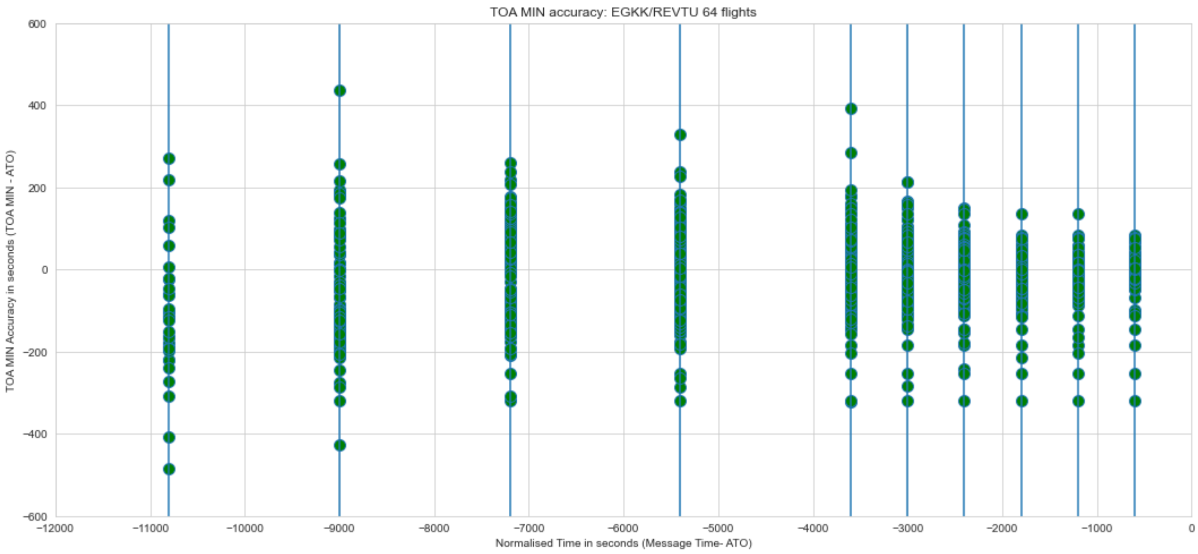


Figure 88: TOA MIN EGKK/REVTU distribution plot

- TOA MAX assessment

As expected, TOA MAX predictions overestimate compared to the ATO, with all values except for the outliers exhibiting similar behaviour. Furthermore, the TOA MAX estimations also get closer to the ATO as the aircraft are getting closer to REVTU, with all flights showing TOA MAX deltas reducing as they move from 60 minutes timestamp all the way through to the 10 minutes timestamp. This is an expected behaviour given the TOA MAX estimations represent the latest time an aircraft can reach a waypoint by slowing down, with the opportunity to diverge from the ATO diminishing with reduced track distance to the waypoint.

The step plot for the ETA max seem to be more skewed to the positive side of the time window in comparison to the ETA min plot.

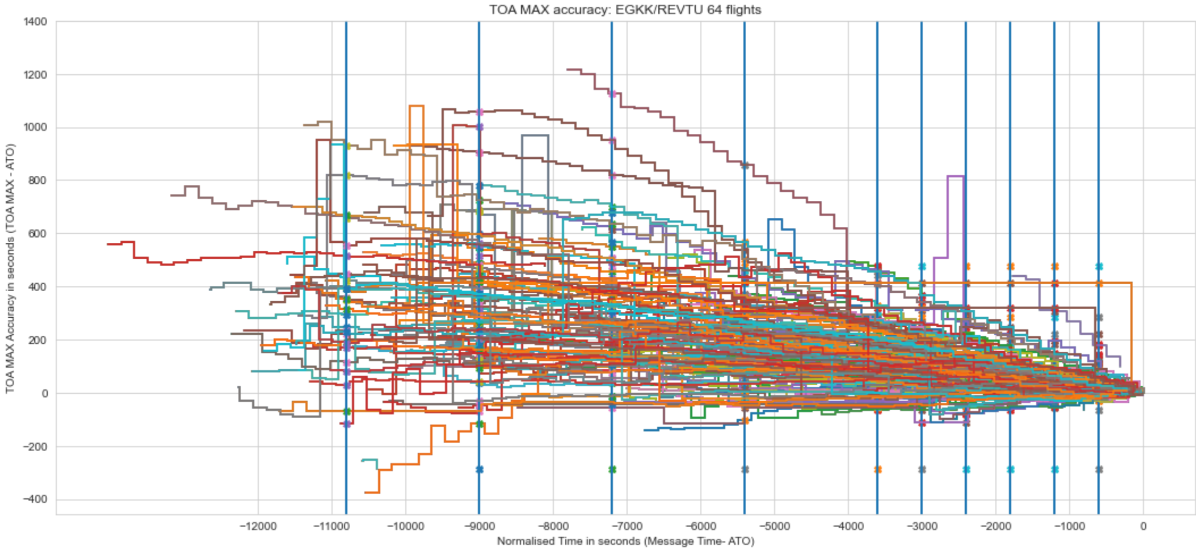


Figure 89: TOA MAX EGKK/REVTU step plot

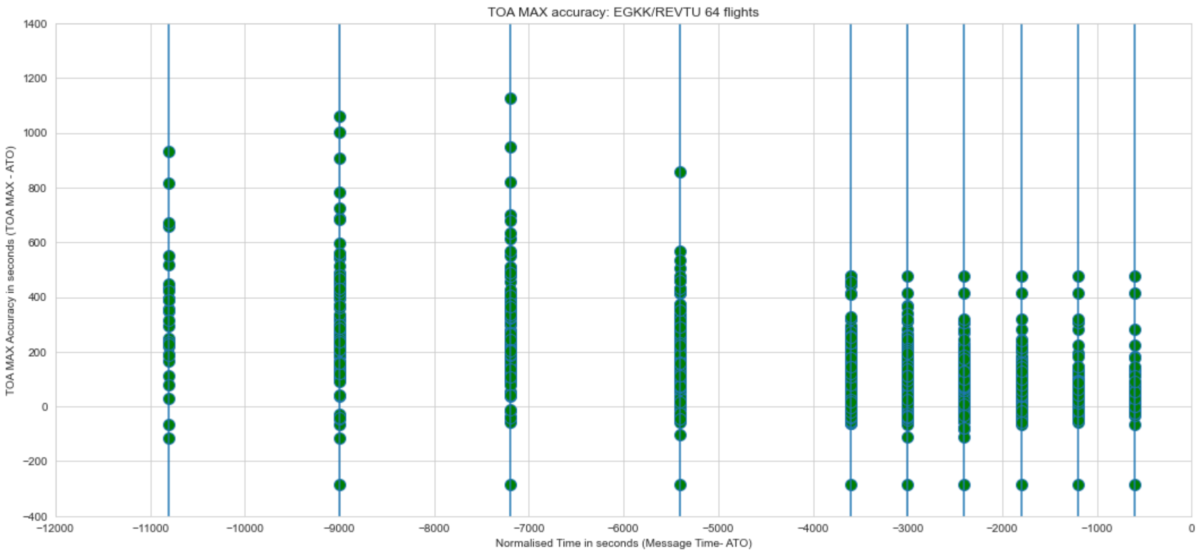


Figure 90: TOA MAX EGKK/REVTU distribution plot

- TOA ETO/MAX/MIN overall box plot

Box plots show groups of time delta score versus the time to metering point before approaching the waypoint. In this figure, 3 different box plots have been generated for different times to the waypoint. The different parameters used for the box plot analysis are TOA ETO/MIN/MAX.

It can be observed from the timestamp distribution plots for TOA ETO, MIN and MAX, starting from the 180 minutes mark, the TOA estimations for the flights going through REVTU are consistent and converging towards the ATO of each flight. The TOA ETO values are closer to the TOA MIN values therefore indicating aircraft are flying closer to their high speed and could therefore accommodate a speed reduction if needed for ATC queue management purposes.

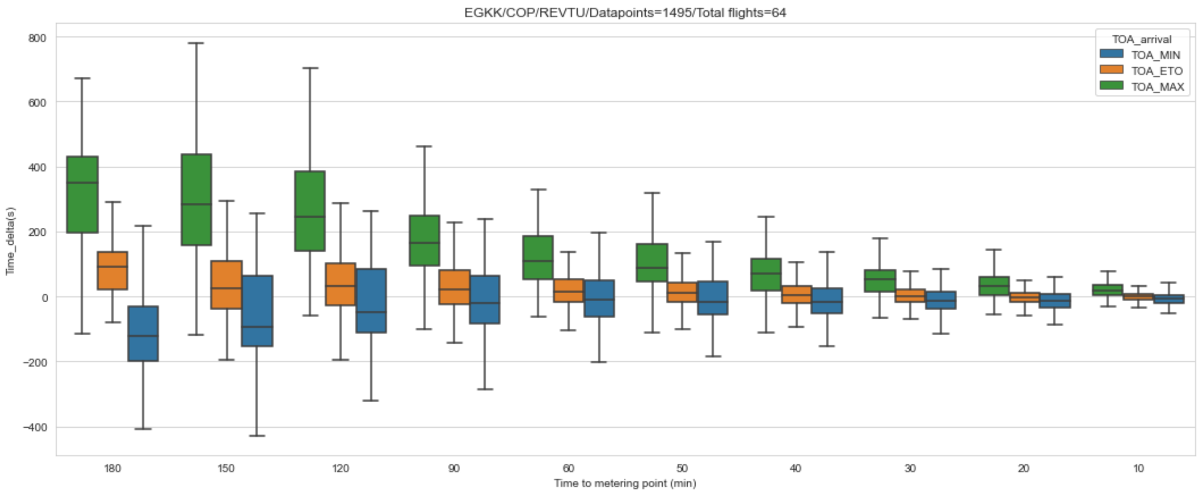


Figure 91 : TOA MIN/ETO/MAX EGKK/REVTU boxplot

G.3.2.1.1.2.2 EGKK – KESAX (COP)

- TOA ETO accuracy

The analysis data contains 912 ADS-C reports from 58 flights. This analysis considers the reports that were sent up to 180 minutes before the waypoint was reached. There is a noticeable trend for the TOA ETOs being stable between 120 – 10 minutes timestamp with all values being between -214s and + 312s of the ATO with all the upcoming deltas being within ~526s variation (excluding the outliers). The TOA ETO accuracy for KESAX seems to follow a constant pattern for a longer duration with a number of datapoints densely distributed across the 500s time interval window which can be seen in the charts below.

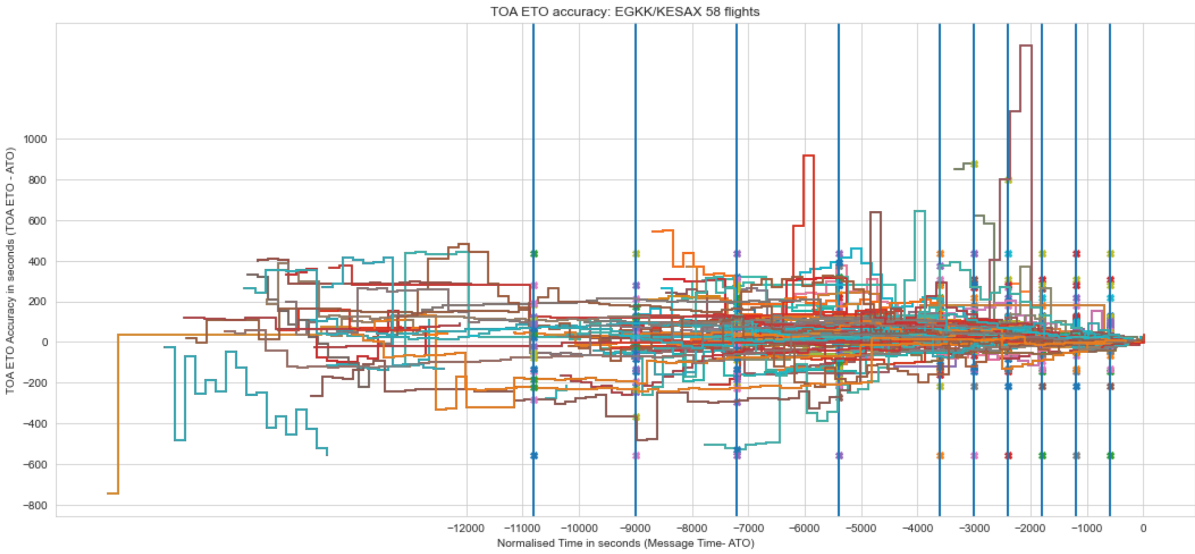


Figure 92 : TOA ETO EGKK/KESAX distribution plot

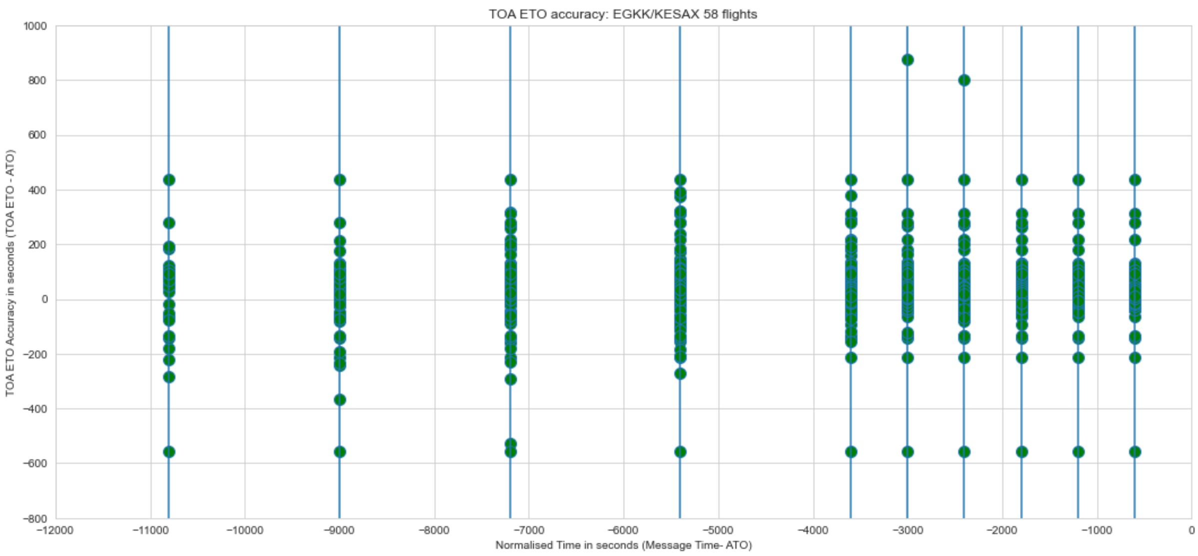


Figure 93: TOA ETO EGKK/KESAX distribution plot

- TOA MIN accuracy

The TOA MIN values for the flights going through KESAX, follow a similar pattern to the TOA ETO. At the 60 minutes mark, the TOA MIN deltas varied between -253 and +195s with the two extreme values corresponding to the flights where the TOA ETA deltas were -214s and, 312s respectively. As the aircraft are getting closer to KESAX, the variation interval remains the same until at the 30 minutes timestamp. While at the 10 minutes mark this is between -134s and +200s which is 120s better prediction than the earlier time stamps, excluding the outliers using the z-score calculation. For the time stamps 180 – 120 minutes away from the target waypoint, the TOA accuracy interval is broad and stable but as the aircraft are getting closer to KESAX, the variation interval starts to reduce.

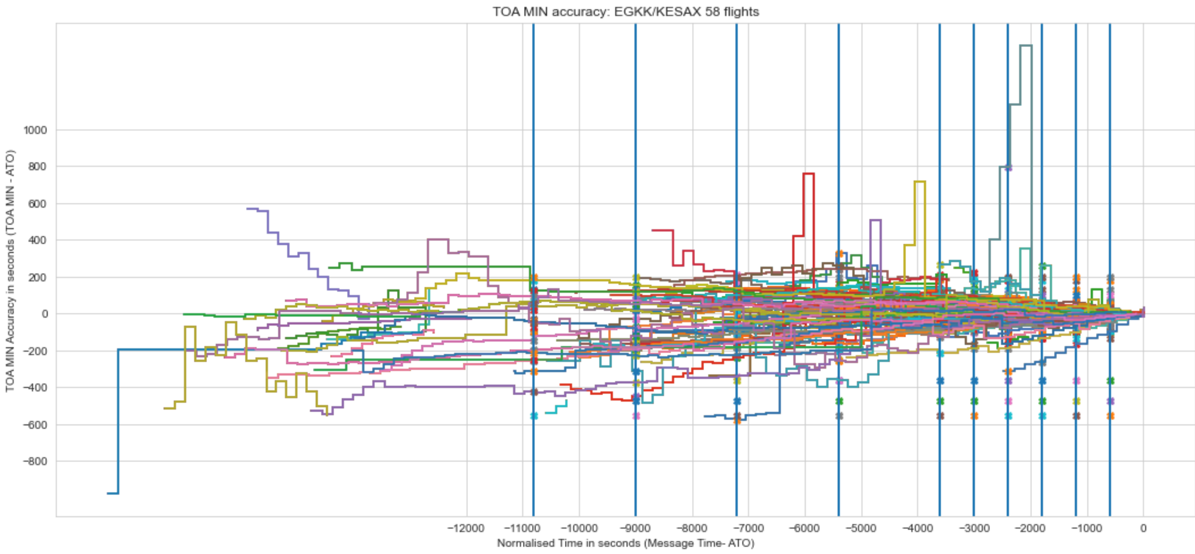


Figure 94: TOA MIN EGKK/KESAX step plot

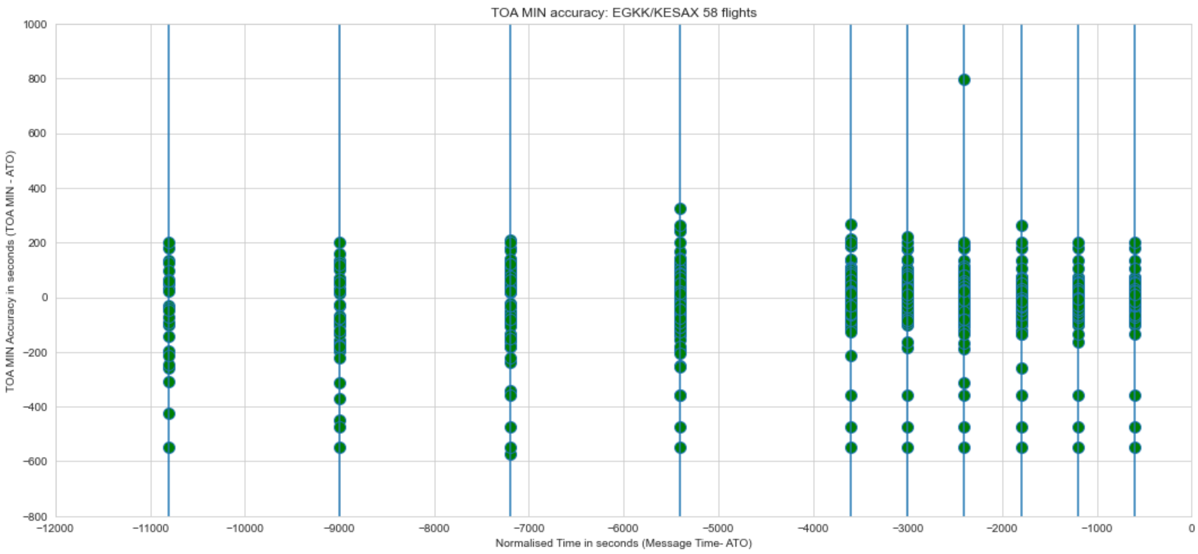


Figure 95: TOA MIN EGKK/KESAX distribution plot

- TOA MAX accuracy

As expected, given the nature of the TOA MAX function, it can be observed from both charts below that the TOA MAX predictions generally overestimate when compared to the ATO, (excluding outliers), providing a skew to the positive side of the y-axis. All TOA MAX deltas consistently get narrower from 60 minutes through to the 10 minutes timestamp. This is an expected behaviour and indicates there is capacity for speeding up the aircraft e.g. if needed for traffic streaming purposes.

As the aircraft are getting closer to the KESAX waypoint, the variation interval remains similar from 60-10 minutes timestamp. Again, as flights approach the waypoint the variance from the ATO reduces, whereas for earlier time stamps the variation is quite distributed but stable as shown in the below two charts.

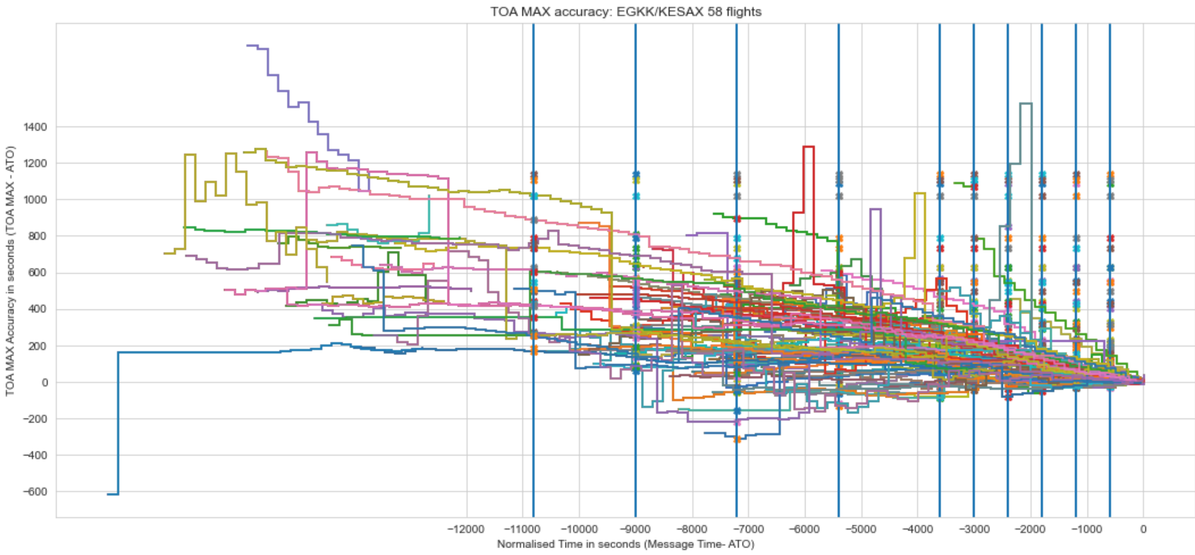


Figure 96: TOA MAX EGKK/KESAX step plot

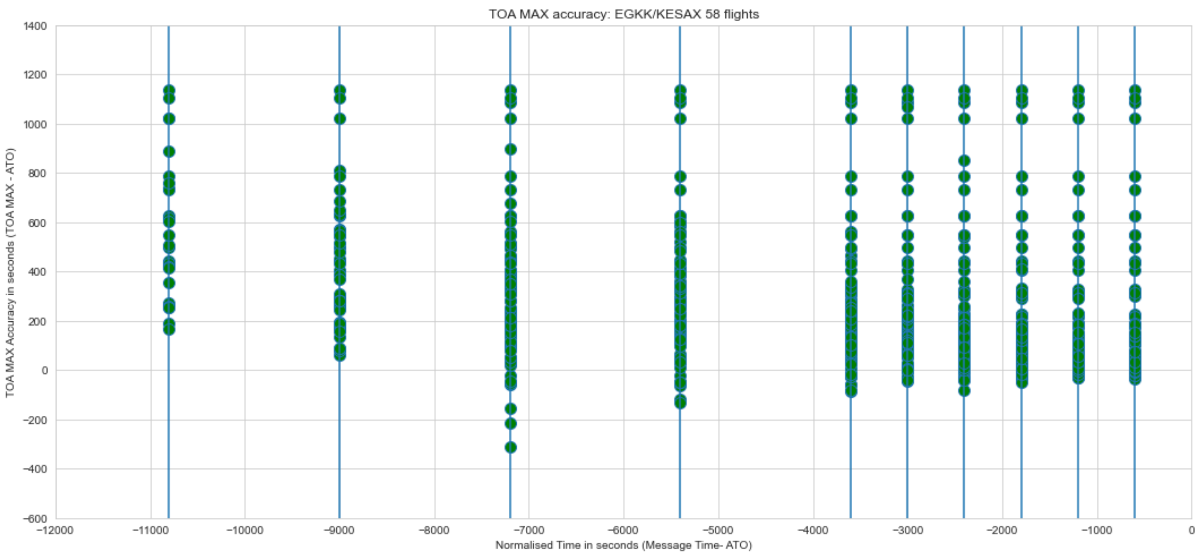


Figure 97: TOA MAX EGKK/KESAX distribution plot

- TOA ETO/MAX/MIN overall box plot

It can be observed from the timestamp distribution plots for TOA ETO, MIN and MAX, starting from the 180 minutes mark, the TOA estimations for the flights going through the KESAX waypoint are consistent. Also, the TOA MIN plots converge towards the TOA ETO. The closer TOA MIN plot indicates that aircraft are flying closer to their high-speed and could accommodate some more time to be added to the flight via speed reduction if needed for ATC operational purposes.

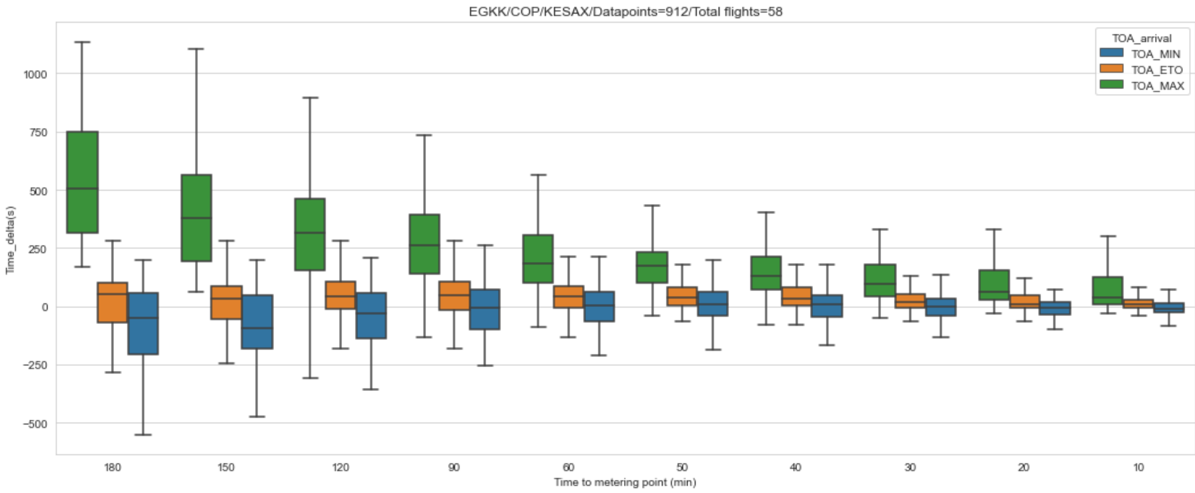


Figure 98: TOA MIN/ETO/MAX EGKK/KESAX boxplot

G.3.2.1.1.2.3 EGKK – TIMBA (IAF)

- TOA ETO accuracy

The analysis dataset includes 51 flights that passed through the TIMBA IAF waypoint, furthermore the timestamps in the plots stop at the 60 minutes mark because the ADS-C Periodic Contract can only support a single waypoint on an aircraft route, with COP's taking precedence. Based on the 51 aircraft flying through TIMBA, there is a clear trend for the TOA ETOs being stable from the 60 minutes timestamp with all values being between -3s and + 86s of the ATO, with all the upcoming deltas being within 89s variation excluding the outliers. For the 30 minutes mark there is a bit more variation in the recorded data going between -77s and +215s, suggesting the ADS-C TOA overestimates the ETO.

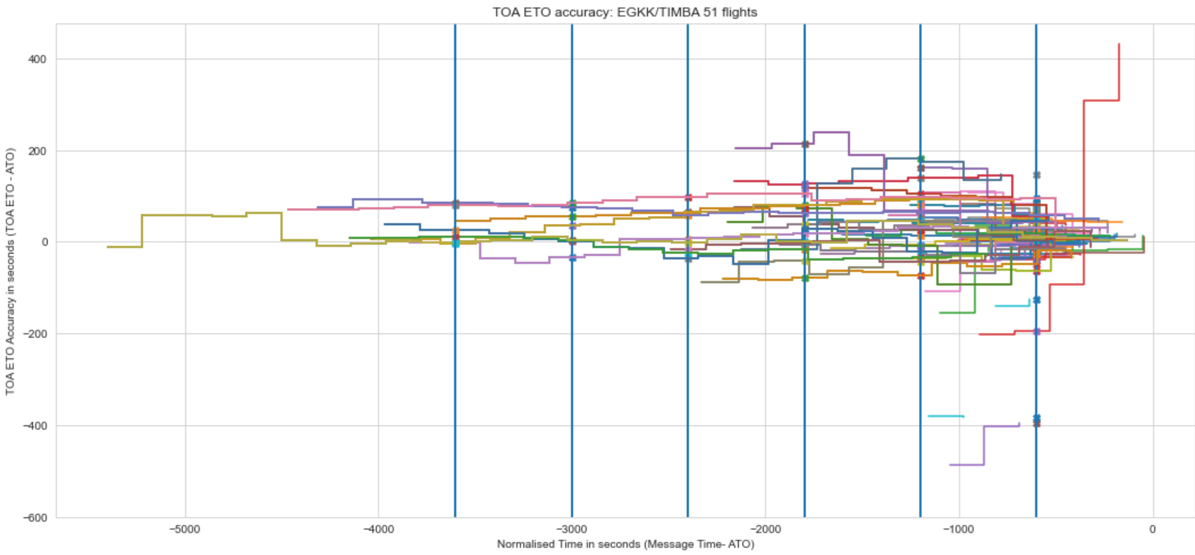


Figure 99: TOA ETO EGKK/TIMBA step plot

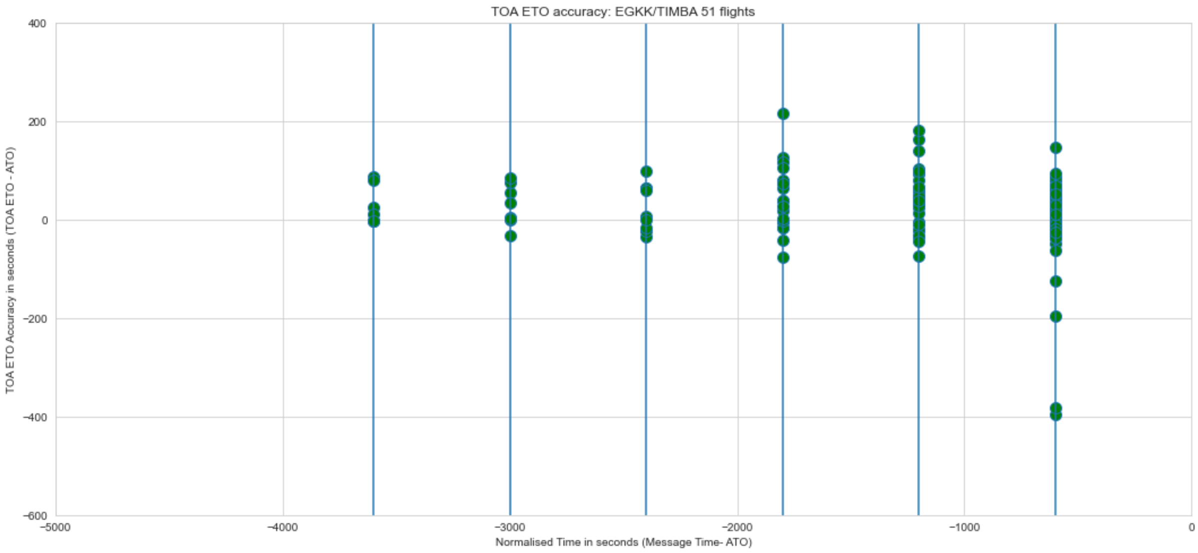


Figure 100: TOA ETO EGKK/TIMBA distribution plot

- TOA MIN accuracy

In terms of the TOA MIN values for the flights passing through TIMBA, a slightly larger variation to the TOA ETO values can be observed. The overall TOA MIN plot can be seen skewed to the negative axis indicating TOA MIN predictions underestimate compared to the ATO, with all values except for the outliers, showing the same behaviour. At the 60 minutes mark, the TOA MIN deltas varied between -213s and +129s with the two extreme values corresponding to the flights where the TOA ETA deltas were -3s and + 86s respectively. As the aircraft get closer to TIMBA the variation interval starts to skew more on the negative scale, reaching values between -326s and +34s at the 30 minutes timestamp, while at the 10 minutes mark this has been between -201s and +90s, again excluding the outliers.

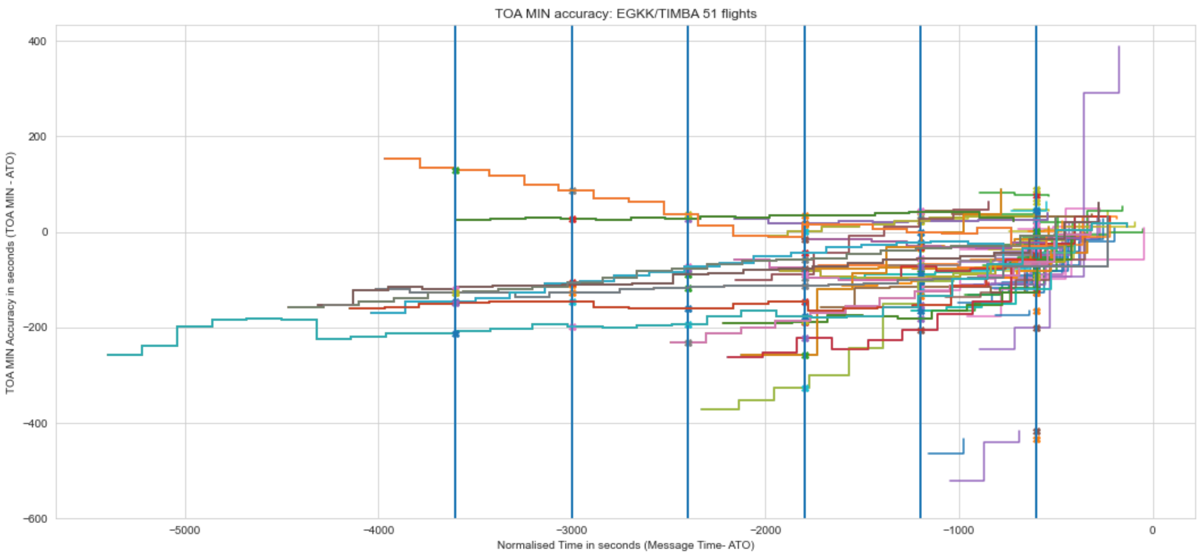


Figure 101: TOA MIN EGKK/TIMBA step plot

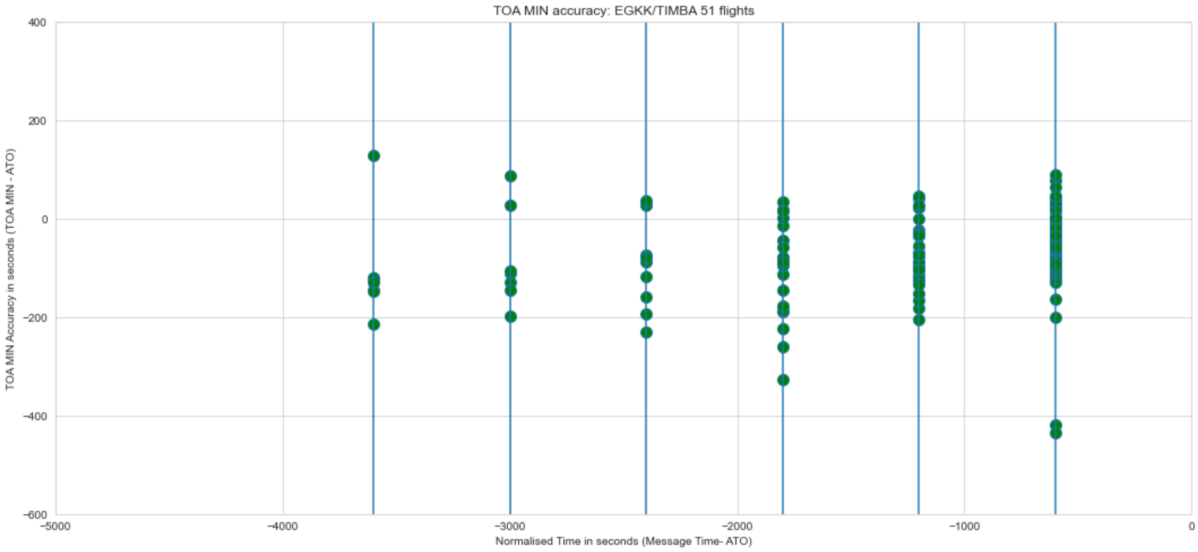


Figure 102: TOA MIN EGKK/TIMBA distribution plot

- TOA MAX accuracy

Looking at the TOA MAX time deltas, it can be observed from both plots below that the TOA MAX predictions show a similar pattern to the TOA ETO values however with a slightly bigger variation. This is somewhat expected given the TOA MAX values provide an indication of how much the aircraft could slow down.

At the 60 minutes mark, the TOA MAX deltas varied between -74s and +308s with the two extreme values corresponding to the flights where the TOA ETA deltas were -3s and 86s respectively. As the aircraft get closer to TIMBA, an overestimating behaviour is seen for the TOA which are -76s and 362s, similar to the TOA ETO deltas which were -77s and +215s at the 30 minutes timestamp, again excluding the outliers.

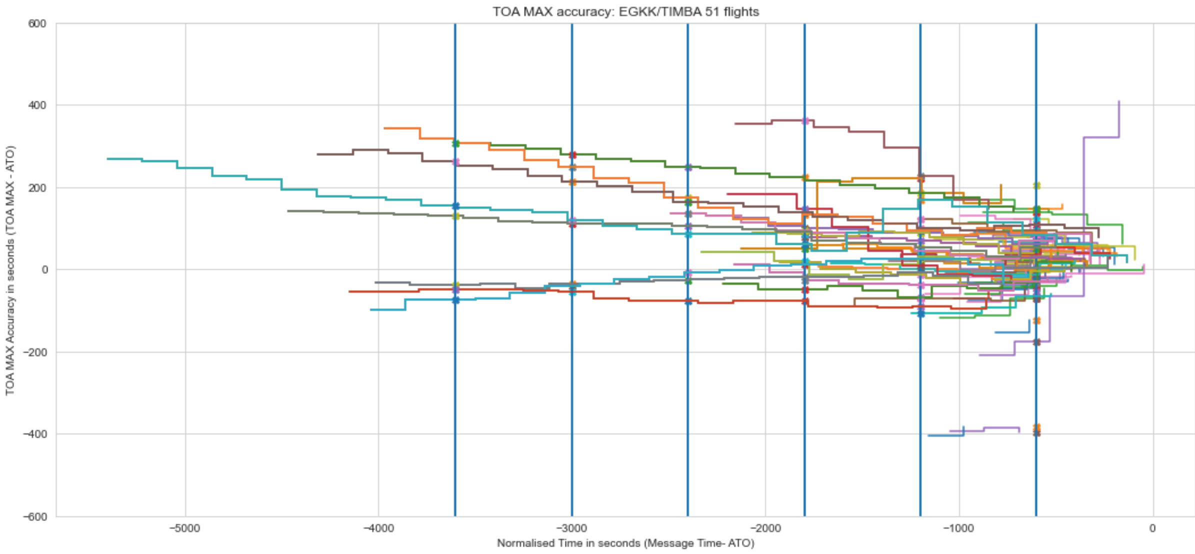


Figure 103: TOA MAX EGKK/TIMBA step plot

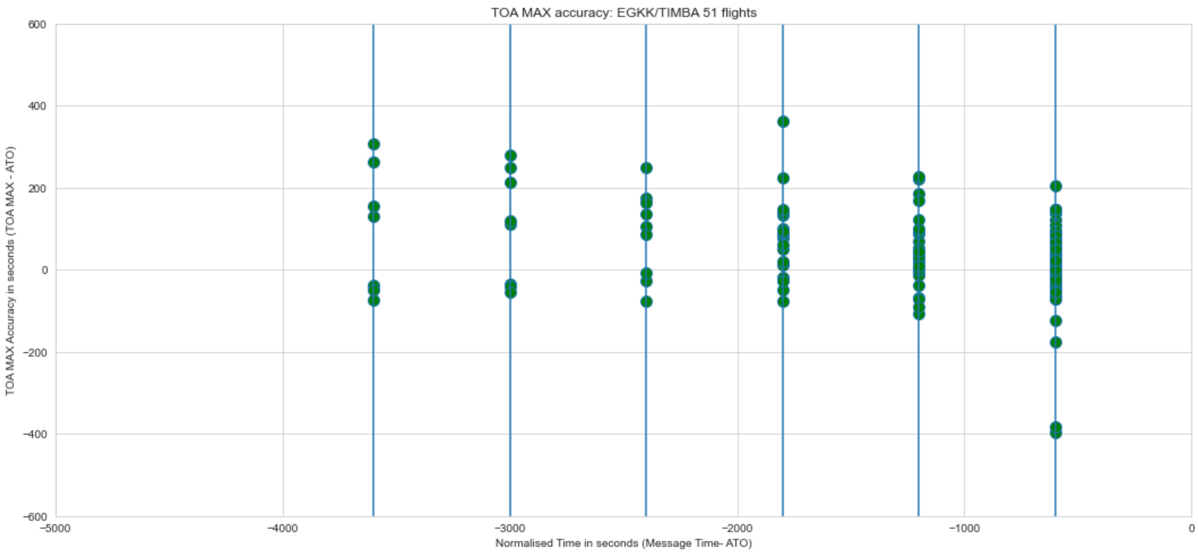


Figure 104: TOA MAX EGKK/TIMBA distribution plot

- TOA ETO/MAX/MIN overall box plot

It can be observed from the timestamp distribution plots for TOA ETO, MIN and MAX that the MIN plots are skewed more to the negative side of the scale indicating underestimating time deltas. However, there is a consistency in the pattern between the TOA ETO and MAX plots. The TOA MAX also converges to the TOA ETO, indicating the aircraft are flying closer to their slower speed indicating they could accommodate a speed up instruction if needed for ATC operational purposes.

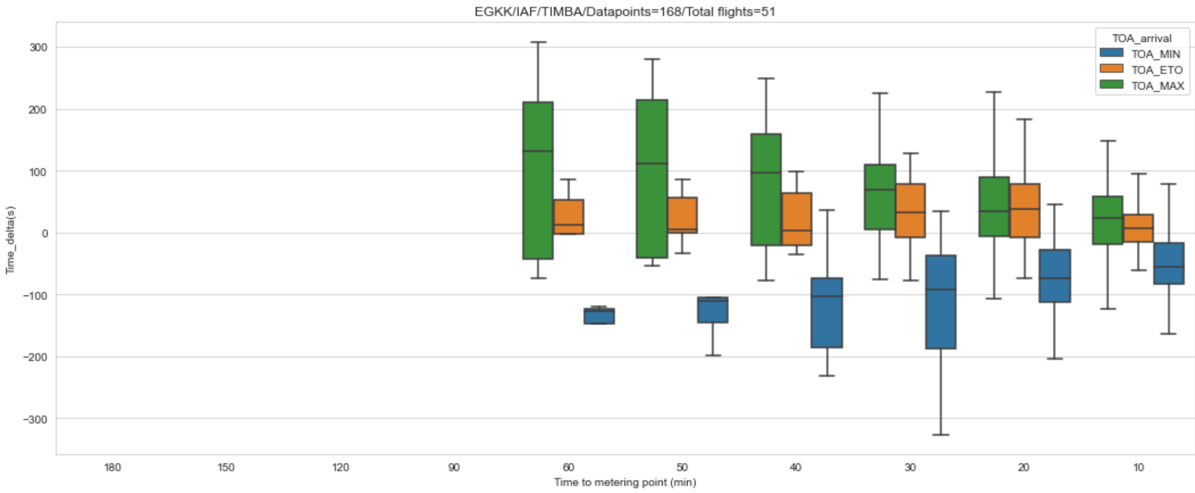


Figure 105: TOA MIN/ETO/MAX EGKK/TIMBA boxplot

G.3.2.1.1.2.4 EGKK – WILLO (IAF)

- TOA ETO accuracy

The analysis data contains 164 ADS-C reports from 52 flights. The WILLO IAF datapoints start to show from about 50 minutes before the flights reached this waypoint. The main reason again why the timestamps in the plots stopped at the 50 minutes mark because for the IAF's the ADS-C reports are sent when the aircraft passes the COP.

The values for the TOA ETO time deltas for the 50 - 30 minutes timestamps are very limited with only 2, 2, and 6 flights respectively providing data for these timestamps. Starting from the 20 minutes timestamp, there seems to be two flows of traffic that provides TOA estimations until closer to WILLO with time deltas around 0s. Looking at the flights providing data for more or less 20 minutes prior to WILLO, the TOA ETO estimations vary between -259s and +476s at the 20 minutes mark. While the 10 minutes timestamp sees time deltas between -208s and 325s, when removing the outliers via the Z-calculation.

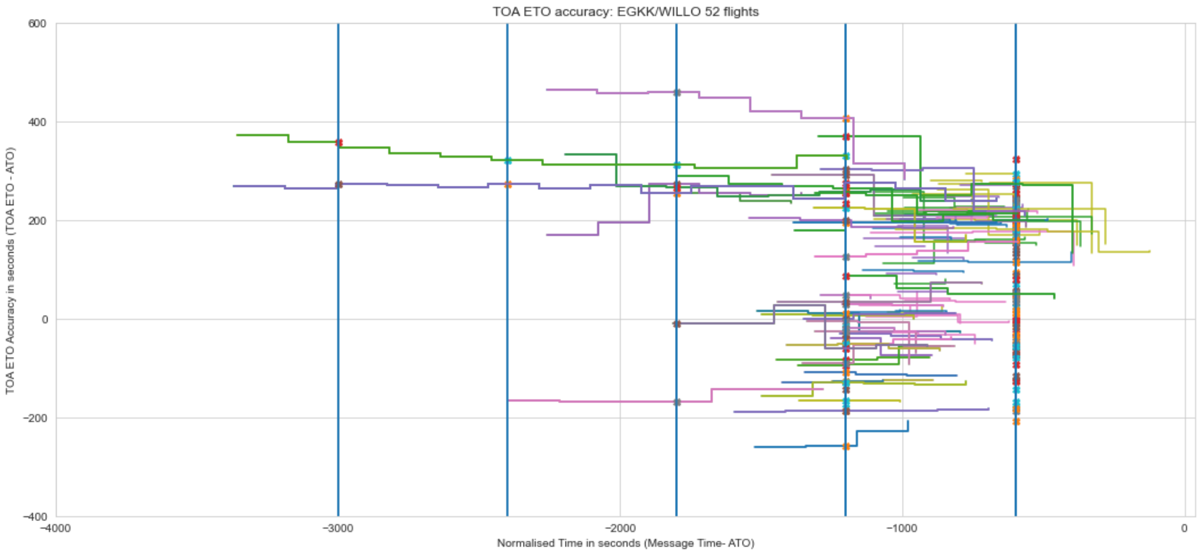


Figure 106: TOA ETO EGKK/WILLO step plot

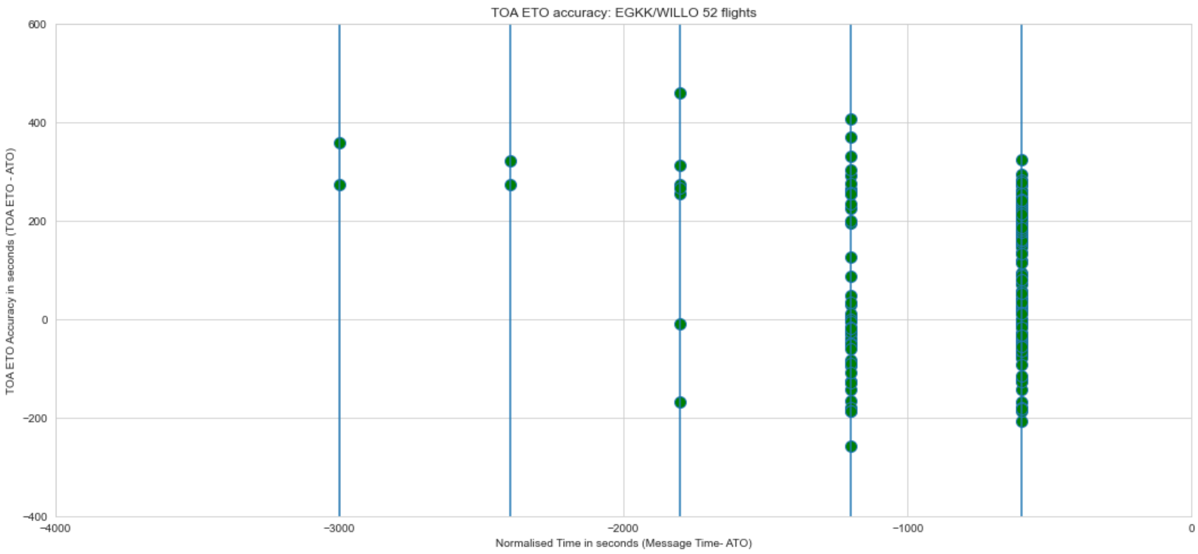


Figure 107: TOA ETO EGKK/WILLO distribution plot

- TOA MIN accuracy

The TOA MIN time deltas provided through the flights going through the WILLO waypoint follow a similar pattern to the TOA ETO data provided in the sense that the 50 - 30 minute timestamps are very limited with only 2, 2, and 6 flights respectively, making these snapshots not statistically relevant.

Similar to the TOA ETO results, the flow of traffic can be observed converging to 0 for the TOA MIN time deltas.

More reports are received for the 20 minute timestamps and onwards. However, the TOA MIN time deltas are still widely spread, covering a range between -264s and +329s for the 20 minutes mark, and a range of -242s and +320s for the 10 minutes mark. The slight increase in the variation of the TOA MIN time deltas from the 20 minutes timestamp to the 10 minutes one can be explained by the additional aircraft which have been considered for the latter timestamp.

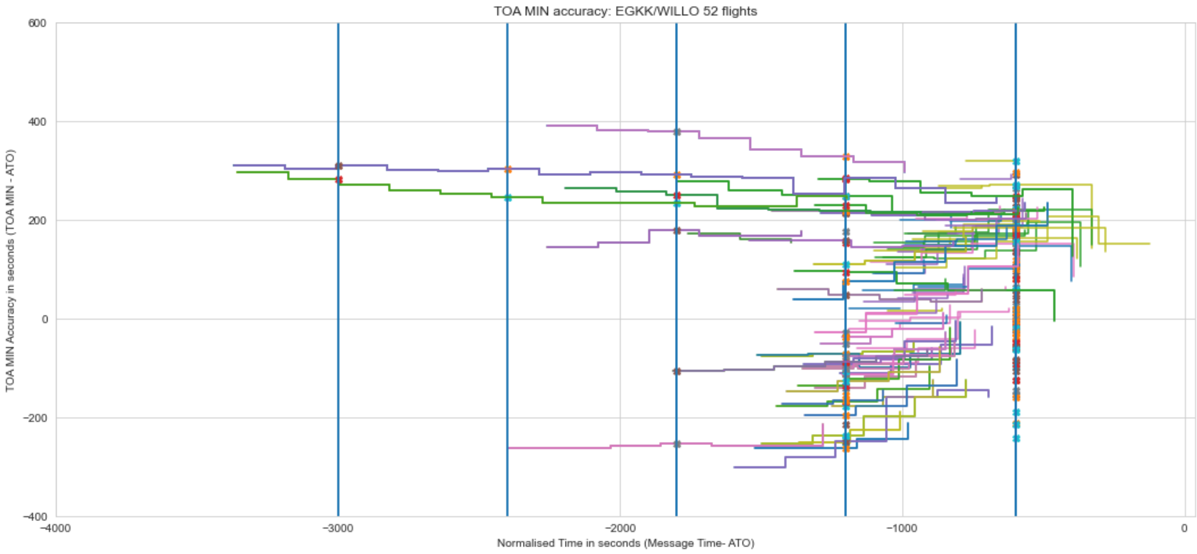


Figure 108: TOA MIN EGKK/WILLO step plot

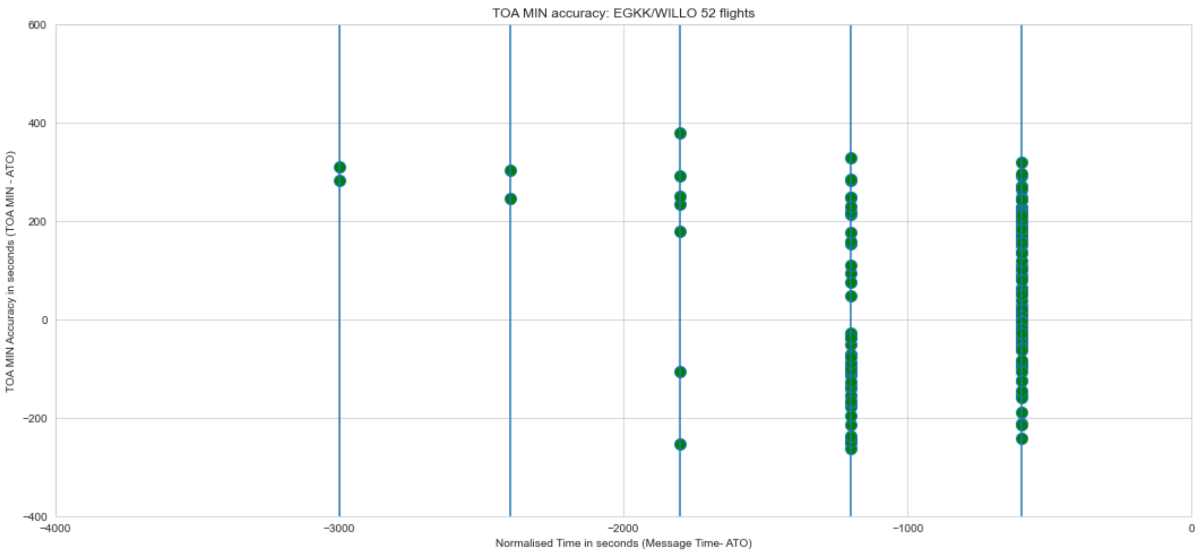


Figure 109: TOA MIN EGKK/WILLO distribution plot

- TOA MAX accuracy

Looking at the TOA MAX time deltas for WILLO, it can be observed from both plots below that the TOA MAX predictions have been overestimating given the information is very limited at time intervals of 10 and 20 minutes. It can also be observed that the TOA MAX estimations are also getting closer to the

ATO and MIN as the aircraft are getting closer to the WILLO waypoint starting from the 20 minutes timestamp all the way through to the 10 minutes timestamp.

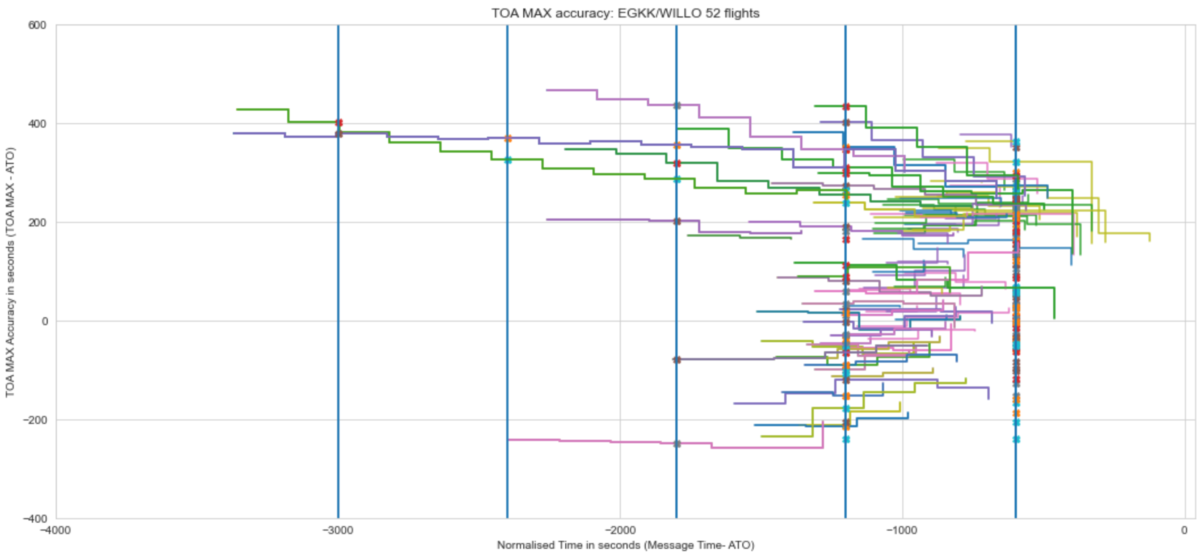


Figure 110: TOA MAX EGKK/WILLO step plot

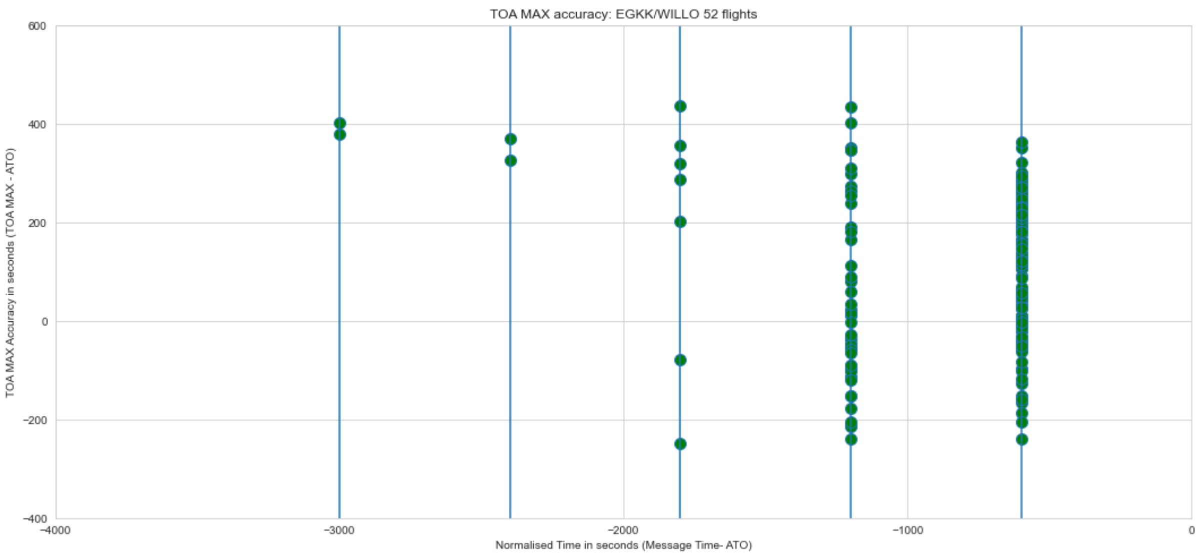


Figure 111: TOA MAX EGKK/WILLO distribution plot

- TOA ETO/MAX/MIN overall box plot

The boxplot below shows that the flights going through the WILLO waypoint can be seen with ADS-C reports as far as 50 minutes prior to reaching the waypoint.

It can be observed from the timestamp distribution plots for TOA ETO, MIN and MAX, the 50 and 40 minute timestamps are limited in terms of data points, therefore could not considered for this analysis. The TOA MIN/MAX estimations for the flights going through the WILLO waypoint are consistent in the plot and they are converging towards the ETO at 10 minutes time interval. It can also be observed that the TOA ETO values are closer to the TOA MIN/MAX values indicating a space of improvement/reduction of flight speed if needed for ATC operational purposes.

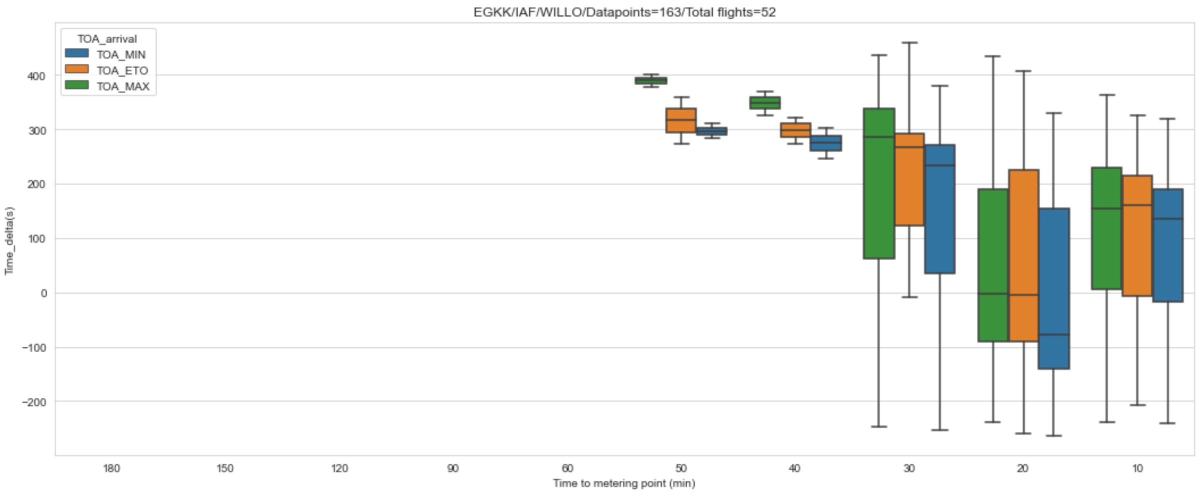


Figure 112: TOA MIN/ETO/MAX EGKK/WILLO boxplot

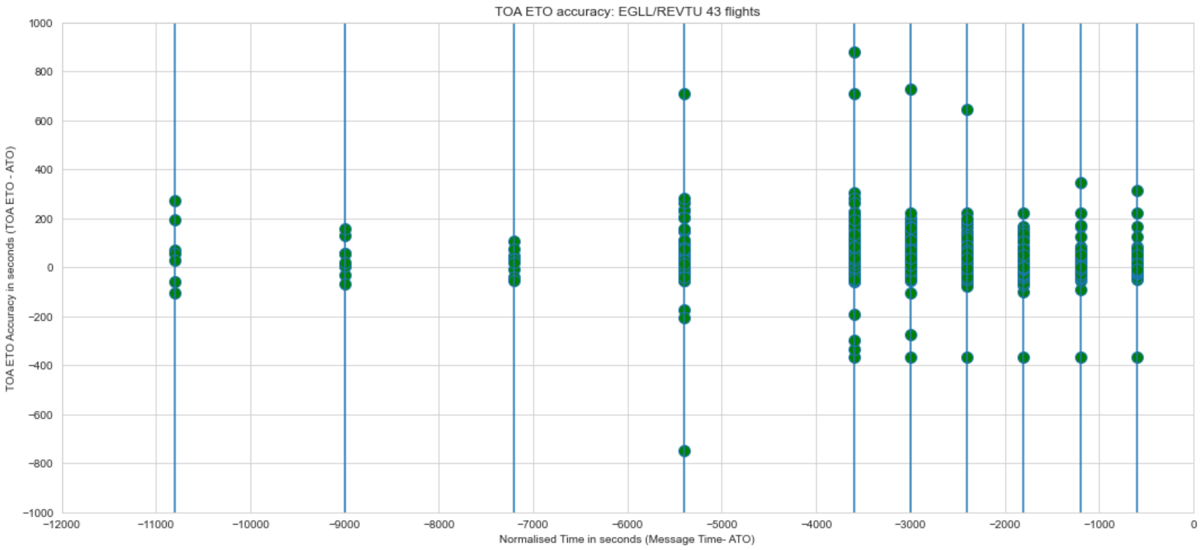
G.3.2.1.1.2.5 EGLL – REVTU (COP)

- TOA ETO accuracy

At the 180 minutes timestamp, the TOA ETO estimations are consistent with the trends noted above having a variation -106s and +271s however it should be noted that only 7 reports have been recorded for this timestamp. Interestingly, going forward through the 150 and 120 minute timestamps, there is a convergence trend towards 0, where the 120 minute timestamp exhibits a much smaller variation in the time deltas going between -45s and +77 seconds. From this point forwards, a lot more flights start to provide data and therefore the variation in data starts to widen as described below.

The TOA ETO time deltas for the flights going through REVTU and heading into Heathrow airport show a consistent behaviour just before the flights reach 90 minutes prior to the waypoint all the way through to the 40 minutes timestamp. The variation of the time deltas is therefore almost constant with a slight decreasing pattern going between -50s and +235s with a slight decreasing trend reaching an upper limit of +200s at the 40 minutes mark.

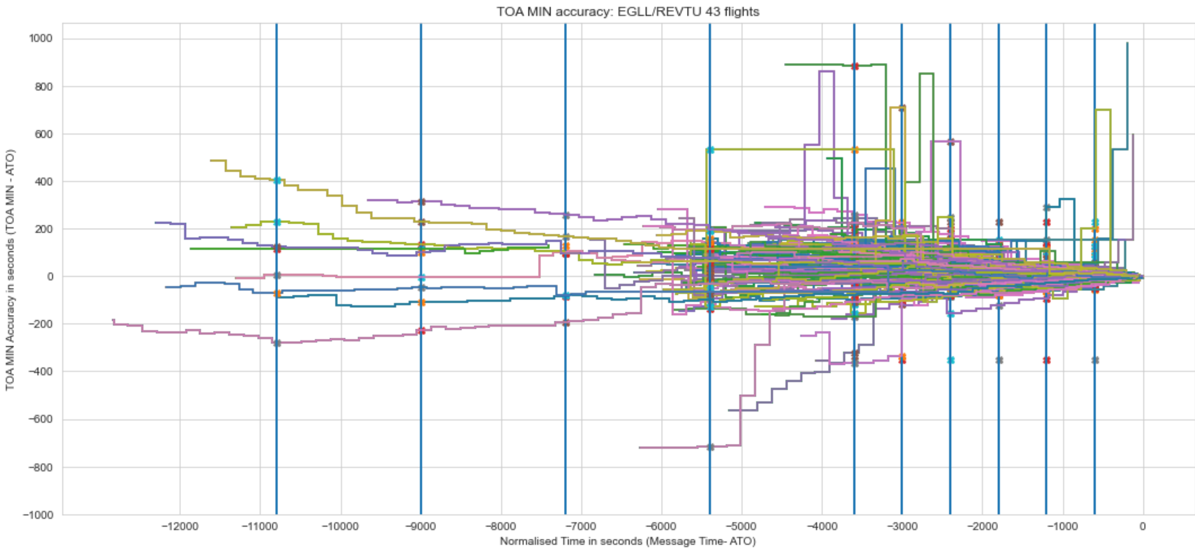
From the 30 minutes timestamp onwards the variation in TOA ETO time deltas is starting to decrease. However, it is to be noted that the time deltas remain consistently positive until after the 10 minutes timestamp with about 75% of the values throughout the last 30 minutes prior to the REVTU waypoint showing an overestimation.

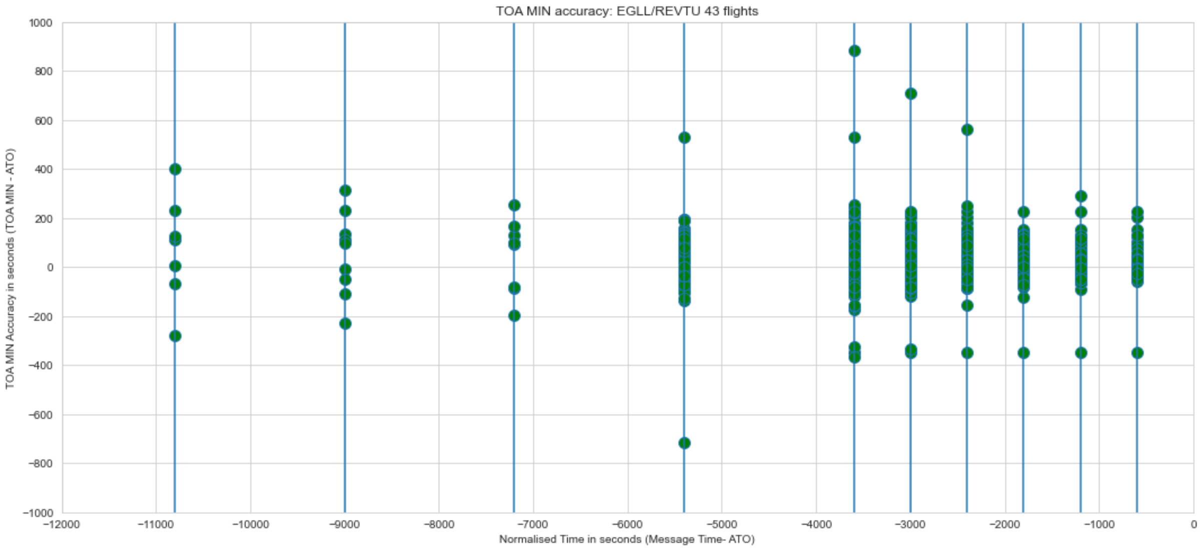


- TOA MIN accuracy

The TOA MIN time deltas analysis show a similar pattern to the TOA ETO one though with a wide variation in the observed results. Starting from the 180 minutes timestamp where the variation is between -281s and +400s followed by a converging trend up to the 90 minutes timestamp where the variation of the time deltas goes between -130s and + 190s. From this point forward, the TOA MIN time deltas present a consistent behaviour with some small variation of +/- 10 seconds all the way through to the 40 minutes timestamp. During this timeframe, there are a lot more flights providing data and also there are a few TOA MIN estimates which are vastly different when compared to the ATO. However, the average time delta remains constant around 30/35s.

As expected, after the 30 minutes timestamp the variation starts converging towards with the 10 minutes timestamp showing a variation between -50s and +100s. It is however important to note that the data shows a constant overestimation of the TOA MIN values with only about 25% of the total values estimating earlier in time than the ATO. This behaviour is also consistent throughout the entire dataset for the REVTU waypoint when used for Heathrow inbounds.





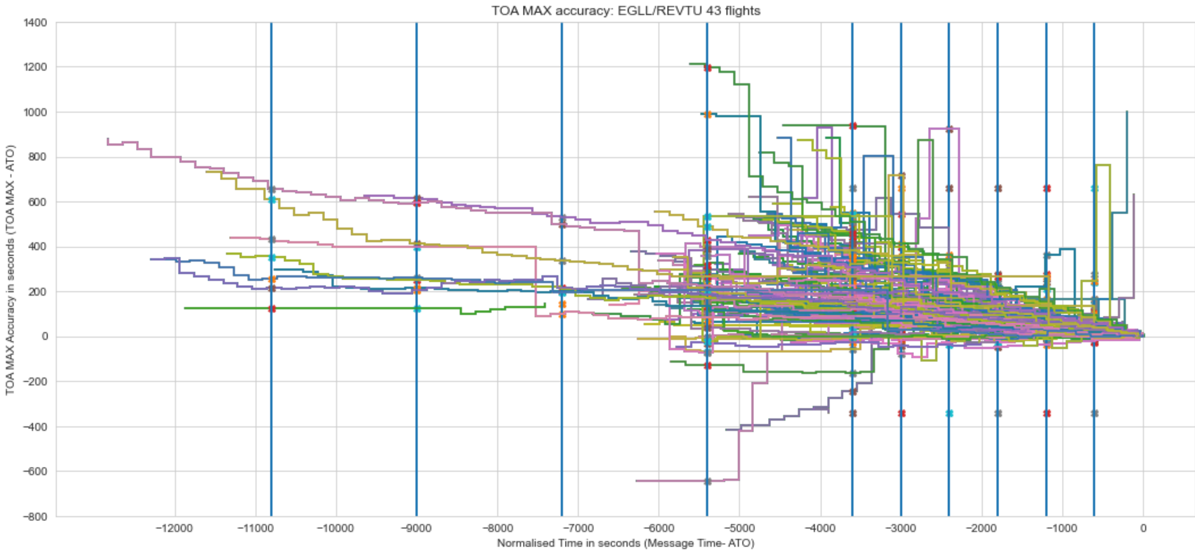
- TOA MAX accuracy

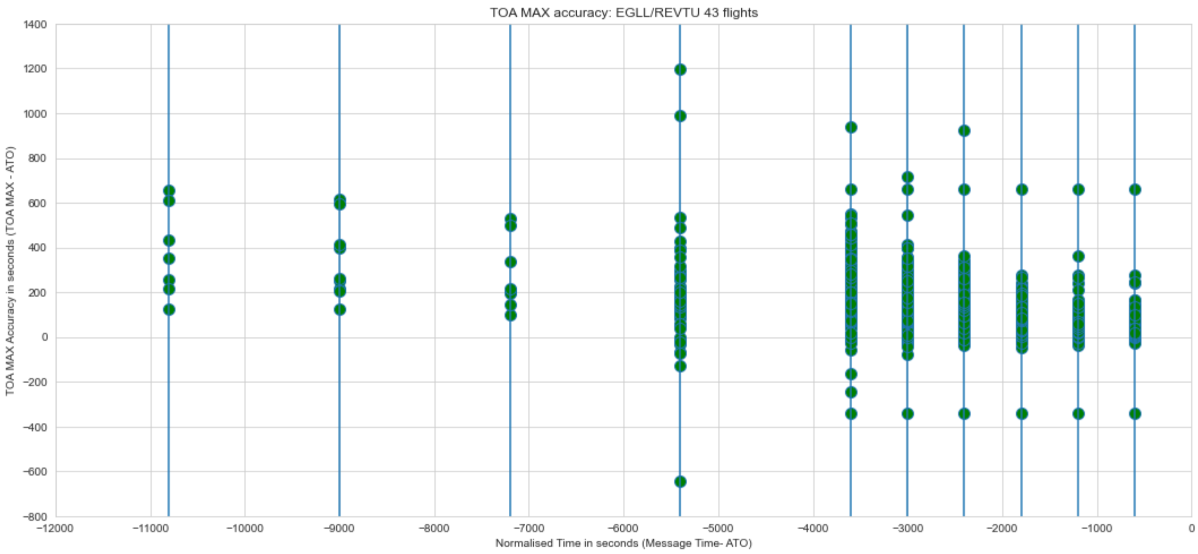
The TOA MAX time deltas for the Heathrow arrivals passing through the REVTU exhibit a consistent behaviour throughout the entire dataset with values ranging between +100s and +600s for the TOA MAX estimations provided between 180 and 90 minutes prior to reaching the waypoint.

From the 90 minutes mark, the variation in time deltas starts to show some negative values with about 10% of all data underestimating the TOA MAX when compared to the ATO while the higher end of the variation interval goes to +420s when excluding some of the outliers.

From the two plots below, it can also be observed that around the 80 minute mark the number of flights providing valid data increases, with prediction values slightly higher than before. Therefore, the time delta variation for the 60 minute timestamp has now increased to a maximum value of around +470s and going as low as -58s. However, the underestimation can only be observed for about 10% of the total values recorded at the 60 minute mark.

As the flights get closer to the waypoint, there is a much steeper convergence of the TOA MAX estimations, with the time deltas reported at the 10 minute timestamp ranging between -10s and +160s. However, it should be noted that the underestimations are also reducing in number and therefore representing a much lower percentage as time passes.



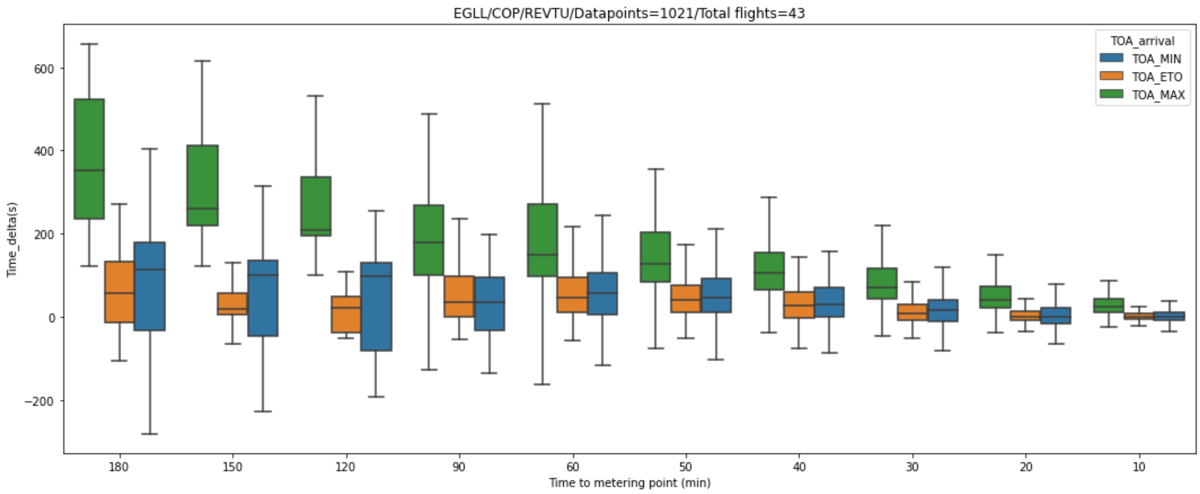


- TOA ETO/MAX/MIN overall box plot

The boxplot for the REVTU waypoint clearly shows the bigger variation in the TOA MIN data with the average value being consistently about 50s higher than the estimated TOA ETO values. However, this trend is only consistent until the 90 minutes timestamp from which the average values for these two TOA estimations start to be in synchronise.

The broader variations for the 180 to 90 minutes timestamps are explained by a much lower data pool for these groups.

One important observation is however the consistent underestimation of the TOA for both ETO and MIN values for the REVTU waypoint which requires a more in-depth analysis to establish a cause.



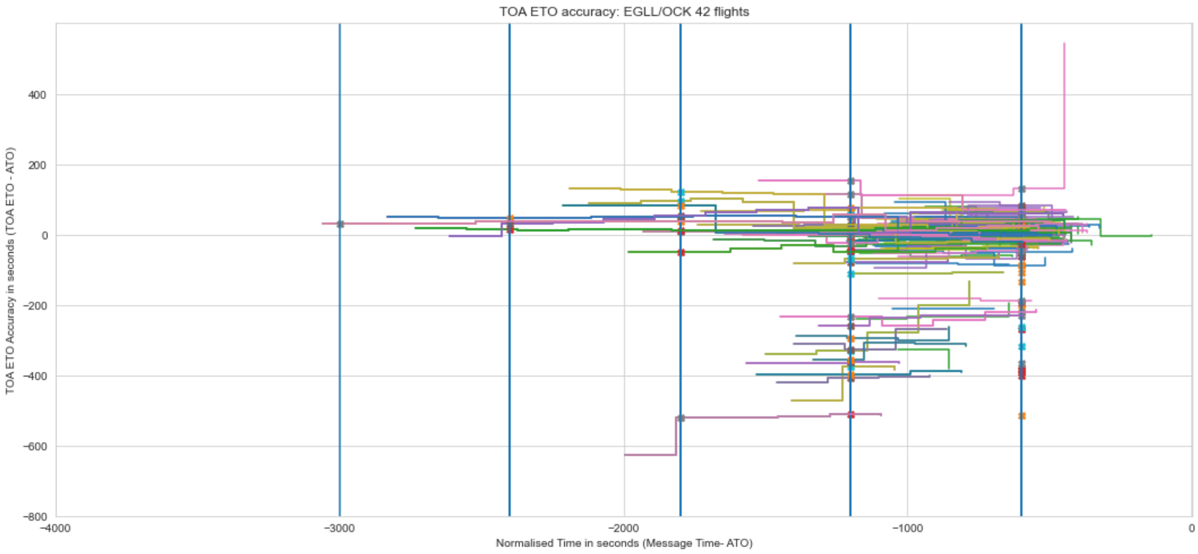
G.3.2.1.1.2.6 EGLL – OCK (IAF)

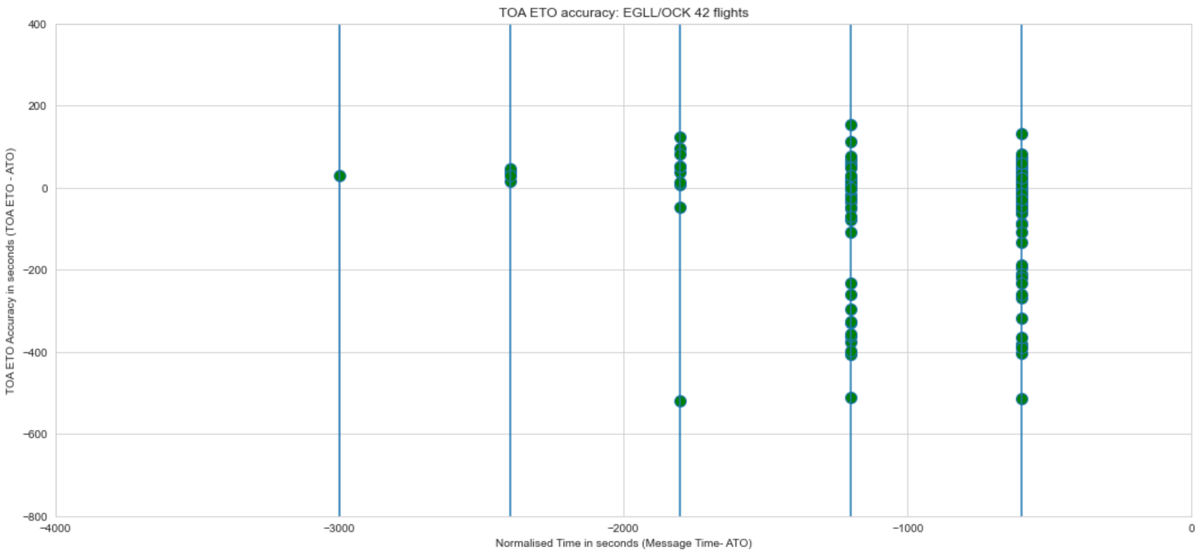
- TOA ETO accuracy

The datapoints relevant for the OCK IAF waypoint start to be shown from about 50 minutes before the flights reached this waypoint. The main reason for this is that each ADS-C Periodic contract can only be set to provide TOA Range data group for a single specified waypoint and each aircraft can only accept one Periodic contract per ATSU. Therefore, the IAF target waypoints will only be included in the periodic reports once the flights have passed their target COP or if the COP is not part of the latest received EPP report.

The values for the TOA ETO time deltas for the 50 minutes and 40 minutes timestamps are very limited with only 1 and 4 flights respectively providing data for these timestamps. Starting from the 30 minutes timestamp, there seems to be two flows of traffic: one that provides TOA estimations until closer to OCK whose time deltas vary around 0s and one that only provides TOA estimations for only about 10 minutes around the 20 minutes timestamp. Due to the inconsistency in data provision, the data provided by the latter flow of traffic is not considered in this analysis.

Looking at the flights providing data for more or less 30 minutes prior to OCK, the TOA ETO estimations vary between -48s and +123s at the 30 minutes mark. This behaviour of the time deltas is consistent for the rest of the time with the 20 minutes timestamp including values between -109s and +155s while the 10 minutes timestamp sees time deltas between -108s and 83s, when removing the outliers through the Z-calculation.



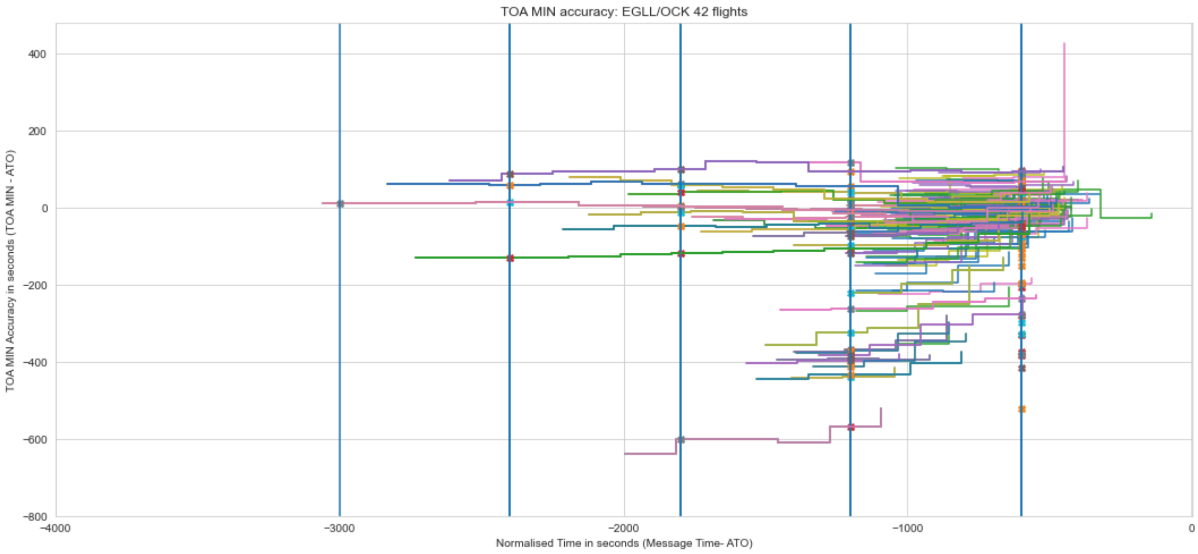


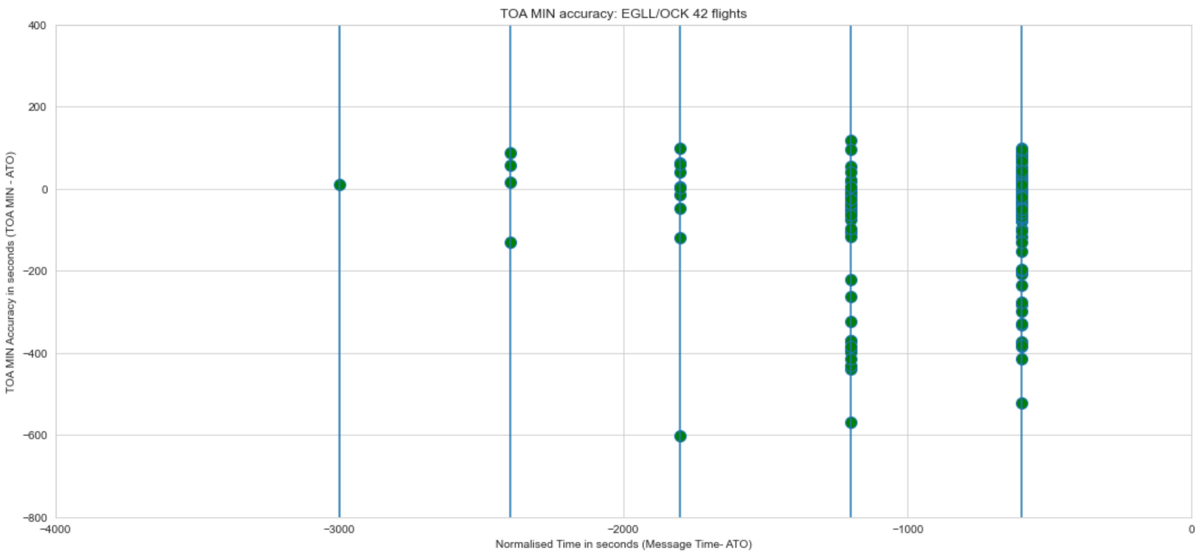
- TOA MIN accuracy

The TOA MIN time deltas provided through the flights going through the OCK IAF waypoint follow a similar pattern to the TOA ETO data provided in the sense that for the 50 minutes and 40 minutes timestamps there is only 1 and 4 datapoints respectively included in the dataset making these snapshots not statistically significant.

Similar to the TOA ETO results, the two flows of traffic can be observed for the TOA MIN time deltas, though with a much smaller gap between the two flows and a trend converging towards 0 quicker for both flows.

Looking at the 30 minute timestamps and onwards, more data is being reported. However, the TOA MIN time deltas are still widely spread covering a range between -118s and +99s for the 30 minutes mark, a range between -117s and +118s for the 20 minutes mark and a range of -77s and +98s for the 10 minutes mark. The slight increase in the variation of the TOA MIN time deltas from the 30 minute to 20 minute timestamp can be explained by the additional aircraft which have been considered for the latter timestamp.

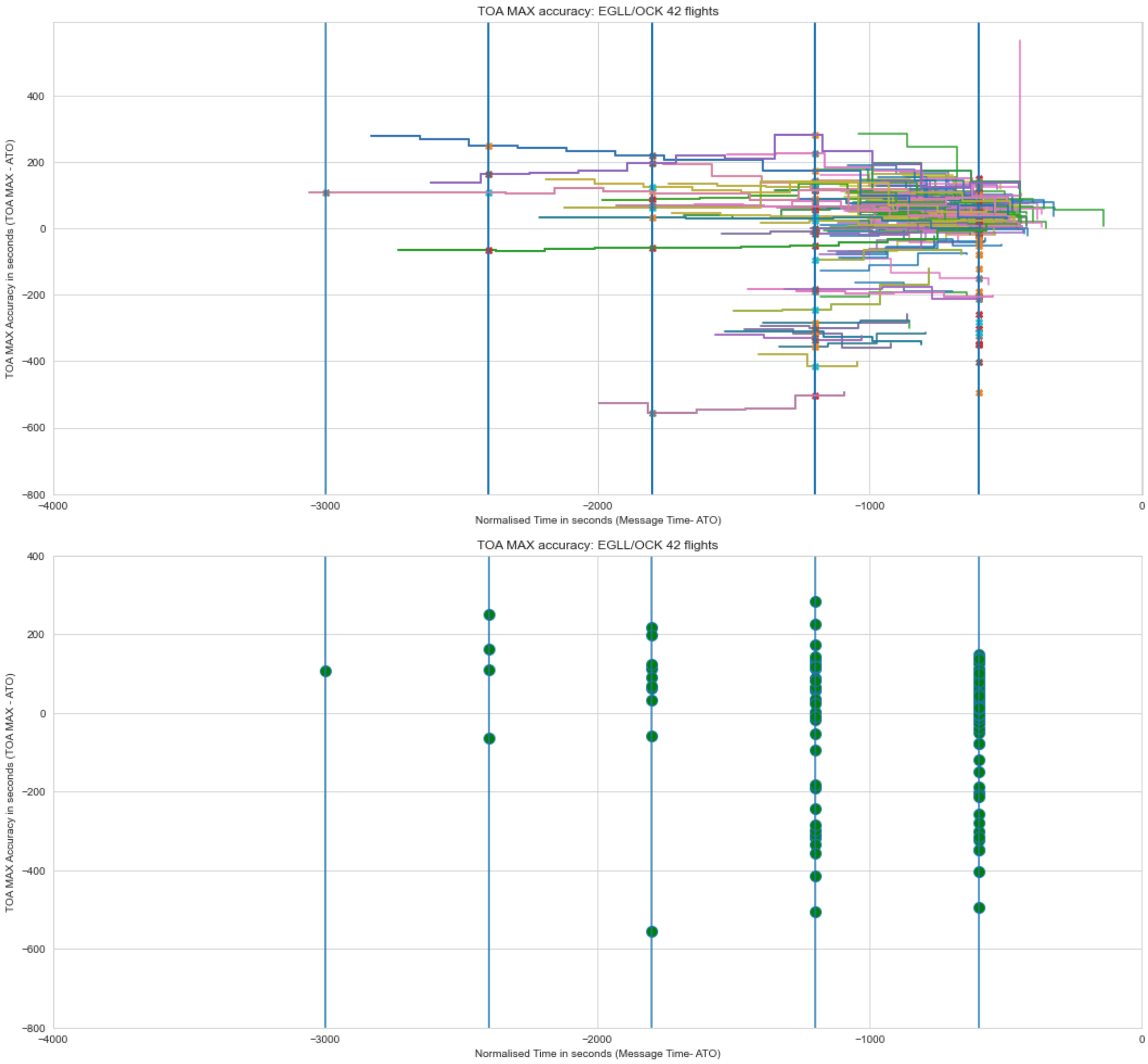




- TOA MAX accuracy

The TOA MAX estimations for the flights going through OCK waypoint again are split into the two flows of traffic we've seen in the results for the TOA ETO and MIN analysis. However, in the case of the TOA MAX time deltas, the flow of traffic with less datapoints indicates an underestimation but given the very limited information provided these are not considered as statistically significant.

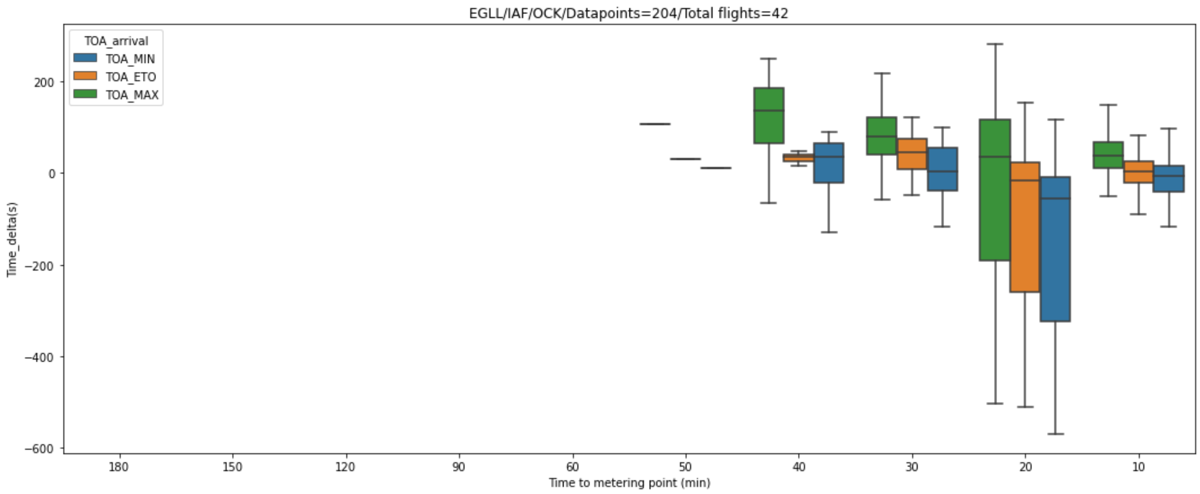
Similarly, to the previous two TOA estimations, the 30 minute timestamp is where data starts to become more relevant with the TOA MAX time deltas being between -57s and +219s with the -57s value being the only one on the negative scale. The next two timestamps at 20 and respectively 10 minutes report the similar values for the TOA MAX time deltas between -52s and +173s for the 20 minute mark and between -50s and +150s for the 10 minute mark.



- TOA ETO/MAX/MIN overall box plot

The boxplot below of the distribution of the TOA ETO, MAX and MIN time deltas when compared to the ATO, points to the conclusion that those flights going through OCK are flying close to their max speed due to the mean values for the TOA ETO time deltas being consistently closer to the TOA MIN time deltas. This trend is maintained throughout the entire dataset despite the boxplots for the 50 and 40 minute timestamp having very limited datapoints.

Also, it should be noted that the boxplot for the 20 minute timestamp shows a much wider variation due to the two flows of traffic that have been recorded in the dataset. However, as explained, there seems to be a number of flights providing data only for a very short period of time around this timestamp and despite this the mean values for the TOA ETO time deltas follow the observed trend of being closer to the TOA MIN time deltas.

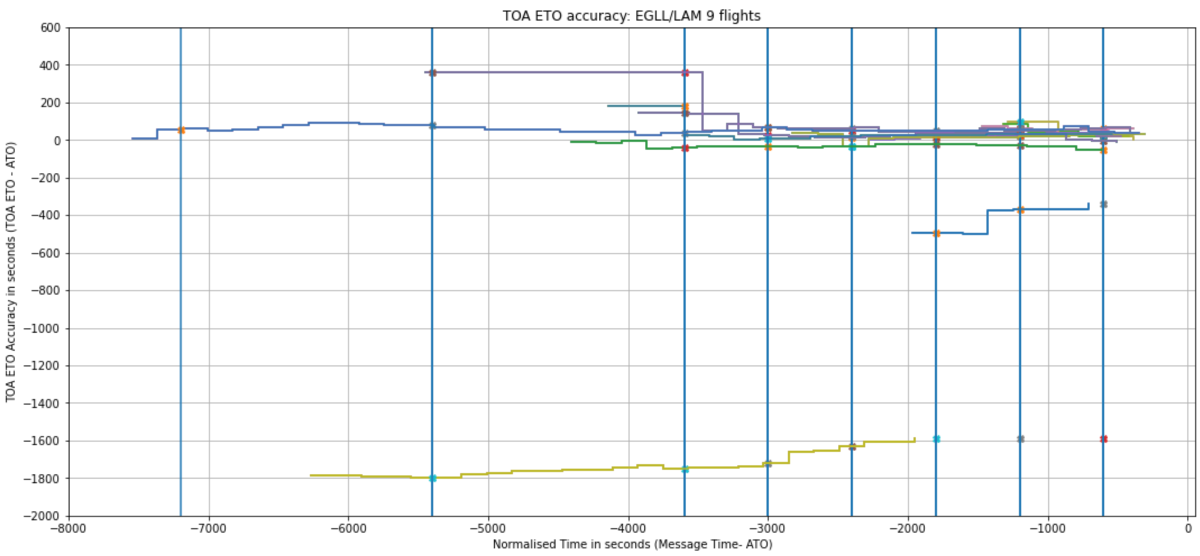


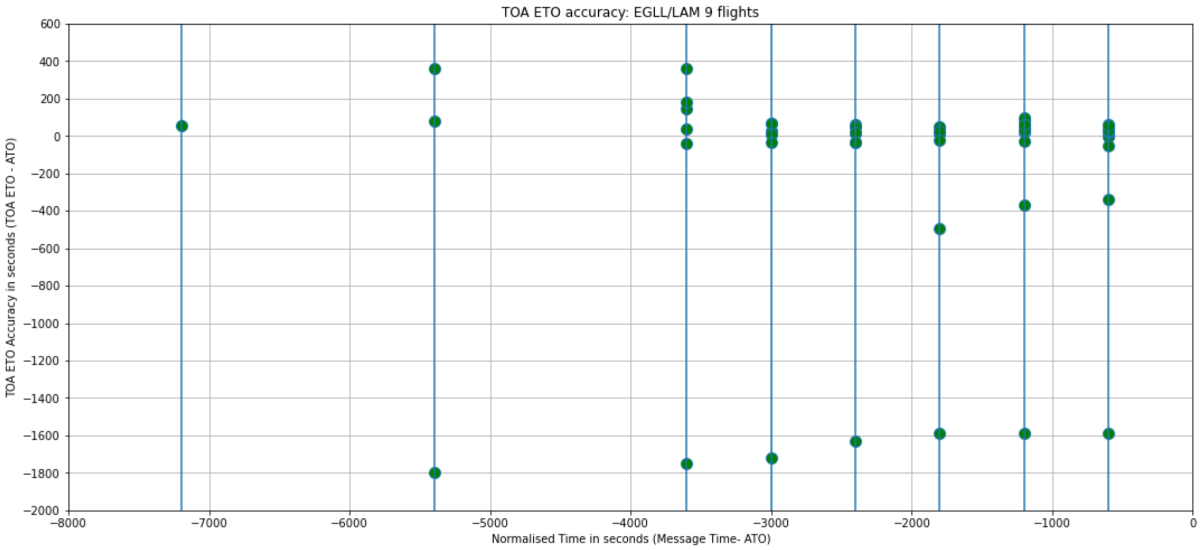
G.3.2.1.1.2.7 EGLL – LAM (IAF)

- TOA ETO accuracy

The analysis dataset comprised of a limited number of flights passing through the LAM IAF waypoint, with the timestamps in the reports limited to the 120 minute mark. Based on the 9 aircraft flying through LAM, there is a clear trend for the TOA ETOs being stable from the 50 minute timestamp with all values being between -30s and + 70s of the ATO with all the upcoming deltas being within 100s variation excluding the outliers. For the 60 minute mark there is a bit more variation in the recorded data going between -43s and +360, suggesting the ADS-C TOA overestimates the ETO compared to the ATO.

It can be observed from the two plots below, that one particular flight provided a TOA ETO which had underestimated by 30 and 26 minutes when compared to the ATO. An in-depth analysis of this flight indicates that this large discrepancy was due to a holding procedure which resulted in the aircraft getting to LAM significantly later than anticipated.

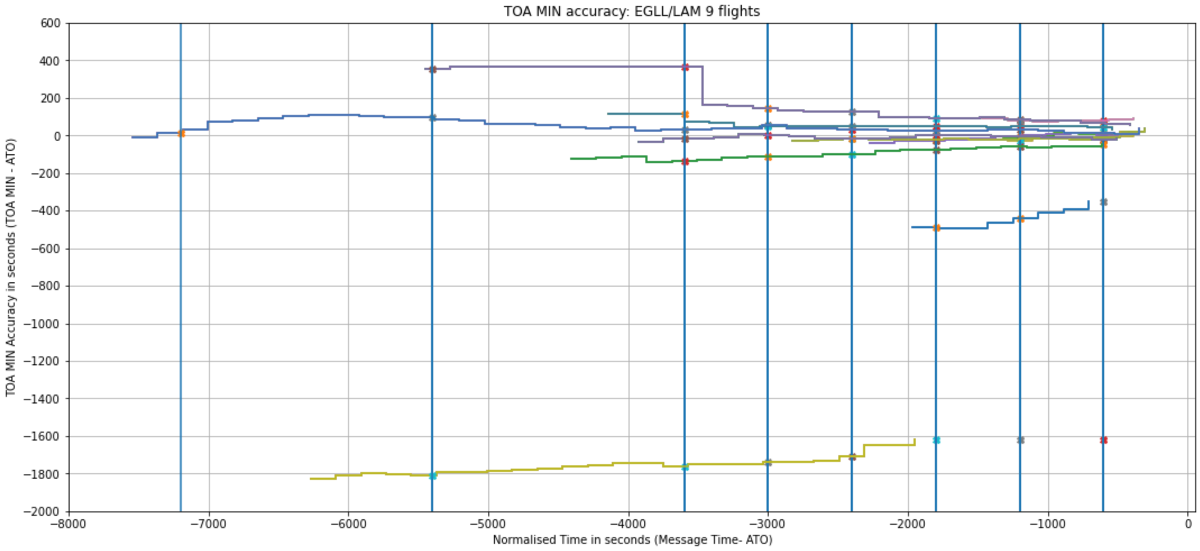


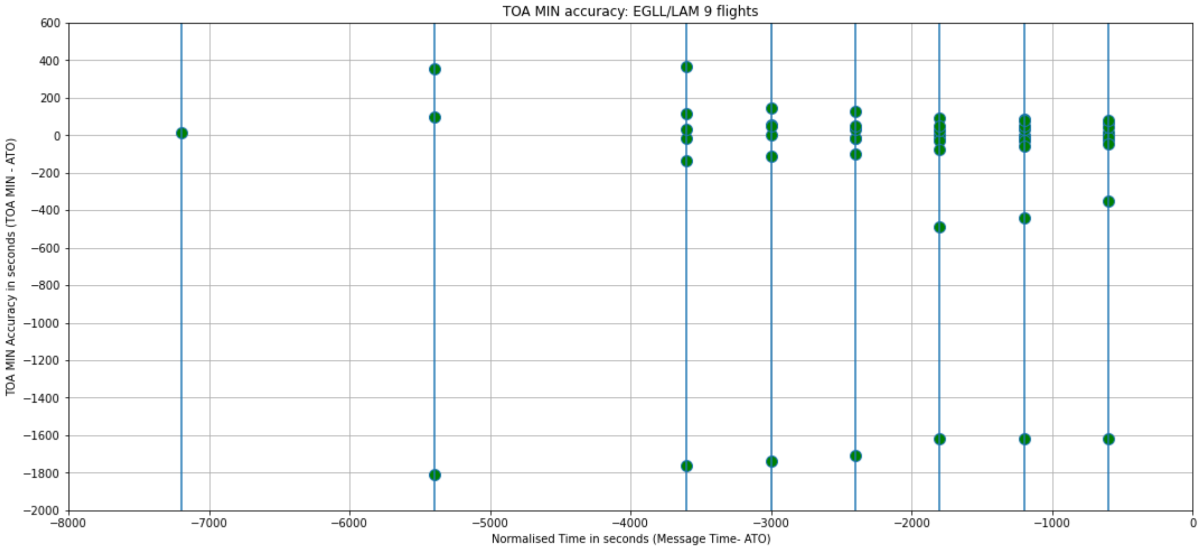


- TOA MIN accuracy

In terms of the TOA MIN values for the flights passing through LAM, a similar distribution to the TOA ETO values can be observed, however with a slightly larger variation. This is somewhat expected given the TOA MIN values provide an indication of how much the aircraft can accommodate a speed increase. At the 60 minute mark, the TOA MIN deltas varied between -137s and +365s with the two extreme values corresponding to the flights where the TOA ETA deltas were -43s and -360s respectively. As the aircraft get closer to LAM the variation interval starts to reduce, reaching values between -74s and +93s at the 30 minute timestamp, while at the 10 minute mark this has been between -48s and +77s, again excluding the outliers.

Regarding the flight mentioned in the TOA ETO assessment which encountered a large holding period, the TOA MIN values are again consistent with the ones seen in the ETO analysis, varying between 30 and 26 minutes (- 10/15 seconds more per timestamp when compared to ETO).





- TOA MAX accuracy

The TOA MAX predictions overestimate for all values, except for the outliers. It can also be observed that the TOA MAX estimations are also getting closer to the ATO as the aircraft are getting closer to LAM, with all flights showing TOA MAX deltas consistently spread over 100/150s interval starting from the 50 minute timestamp all the way through to the 10 minute timestamp.

The aircraft discussed in the previous two sections exhibit a consistent pattern, with the TOA MAX estimations between 30 and 26 minutes.

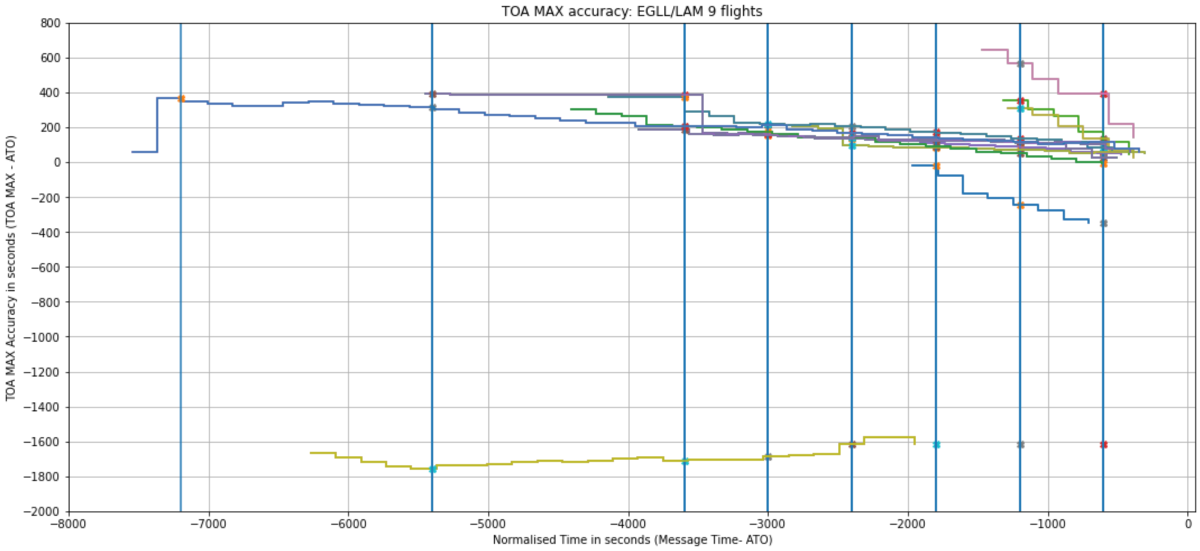


Figure 113: TOA MAX EGLL/LAM step plot

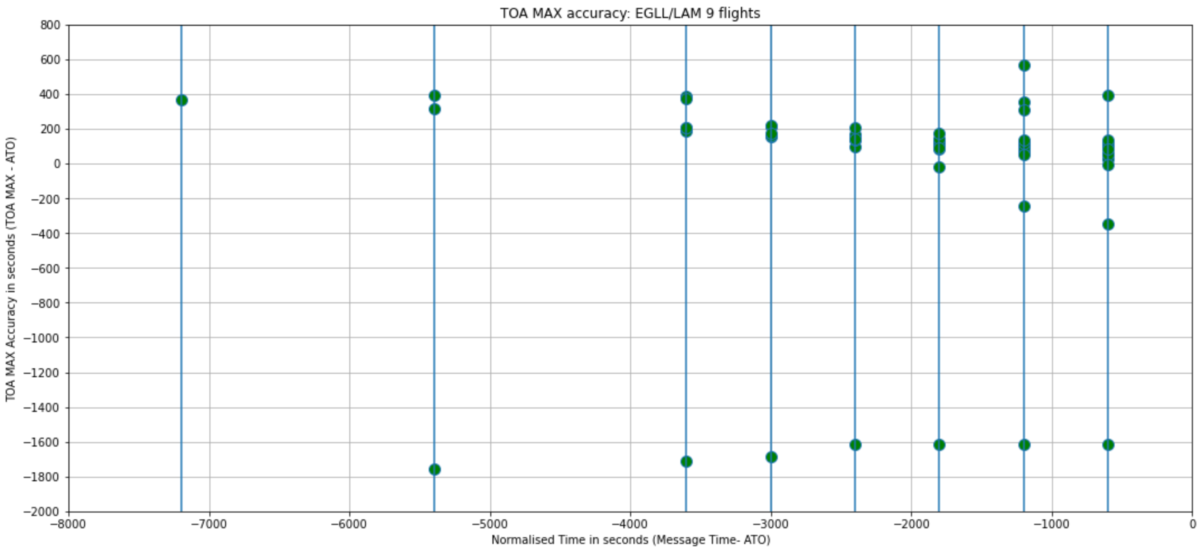


Figure 114: TOA MAX EGLL/LAM distribution plot

- ETO/MAX/MIN overall box plot

It can be observed from the timestamp distribution plots for TOA ETO, MIN and MAX that for the 120 minute timestamp there is a single value while for the 90 minute mark and only 3 values for the other times, so these results should not be considered as significant.

However, starting from the 60 minute mark, the TOA estimations for flights going through LAM are consistently converging towards the ATO of each flight. It can also be observed that the TOA ETO values are closer to the TOA MIN values, indicating the aircraft are flying closer to their high-speed and could therefore accommodate a speed reduction if needed for ATC operational purposes.

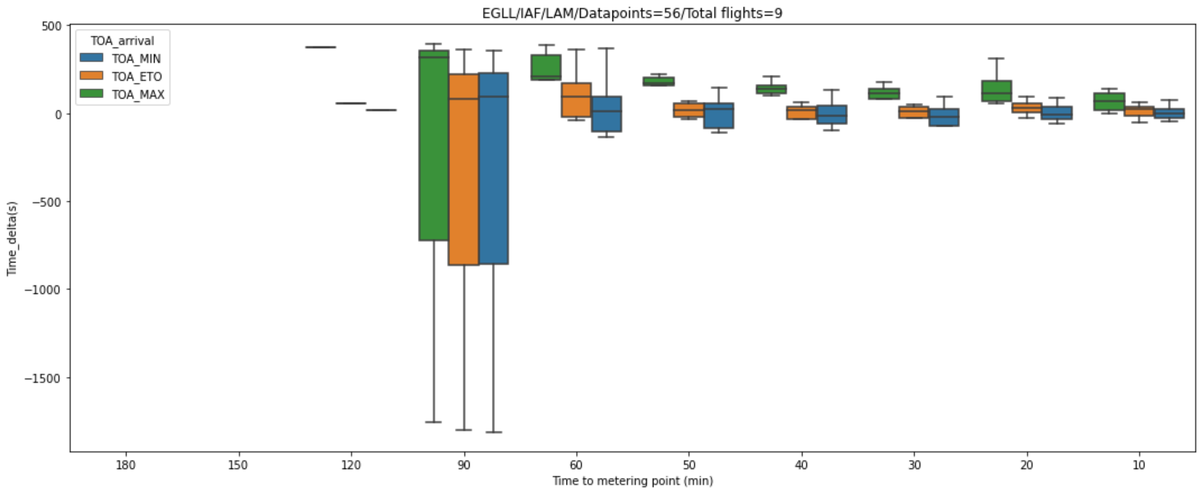


Figure 115: TOA MIN/ETO/MAX EGLL/LAM boxplot

G.3.2.1.1.3 Conclusion

Throughout the entire dataset, the expected behaviour of the TOA ETO, MIN and MAX has been consistently observed with the following conclusions for the COPs estimations:

- TOA ETO deltas vary between -100s and +200s at the 60 minute timestamp and between -100 and +100 at the 30 minute timestamp
- TOA MIN deltas vary between -180s and +200s at the 60 minute timestamp and between -150s and +150s at the 30 minute timestamp, and
- TOA MAX deltas varying between -50s and +400s at the 60 minute timestamp and between -50s and +200s at the 30 minute timestamp

Based on the very limited dataset available for this analysis, the behaviour of the TOA estimations for the IAFs appears to be a lot less predictable than for the COPs, particularly evident in the high variability in the WILLO and the OCK IAF waypoint estimates, probably due to the increased likelihood of ATC interventions in the initial descent phase. Compared to the cruise phase however, as much as it could be concluded the IAFs estimation:

- TOA ETO deltas varied on an interval of 150s around 0 at the 30 minute timestamp with values for example going between -50s to +100s for a specific waypoint
- TOA MIN deltas varied on an interval of 250s to 300s around 0 at the 30 minute timestamp with values for example going between -200s and +50s for a specific waypoint
- TOA MAX deltas varied on an interval of about 200s around 0 at the 30 minute timestamp with values for example going between -40s and +200s for a specific waypoint

G.3.2.1.2 Queue management operations enhancement using ADS-C TOA Range data

As stated in section G.2, the use of a prototype for AMAN to provide a quantitative assessment of operational benefits of ETA Min/Max within a queue management support tool was not realised, therefore the analysis instead focused on understanding the current assumptions and values used by AMAN regarding the streaming functionalities that would ingest the TOA Range information.

In current concepts for queue management, the calculation for how much an aircraft could slow down in order to reduce the amount of holding delay can be done either by using the planned min/max speeds in the cruise and/or descent phase or by using the planned ETA min/max values for the target COP which therefore has an impact on the time planned to reach the IAF.

The current operational assumption is that all aircraft can accommodate a speed reduction of 0.04 Mach in cruise, which based on the BADA nominal speed will result in approximately 60 seconds of flight time being added to an aircraft during the cruise for an AMAN with a horizon extending out 35 minutes from the COP to the flight's TOD (Top of Descent).

Figure 116 below shows the calculated time-to-lose based on the TOA Range data at the AMAN horizon of 35 minutes before the COP. This was calculated by looking at the difference between the TOA Range ETO and the TOA Range MAX value for the COP of each flight as reported in the latest ADS-C report received just before the 35 minute AMAN horizon was crossed. The histogram below has been split into 30s groups for ease of reading.

> **Note:** As mentioned previously, this analysis is indicative only as the 'actual time over' estimates could include ATC interventions made since the TOA Range was downlinked.

It can be observed that the majority of flights, based on the TOA Range data, can lose between 30s and 90s if the aircraft fly its lowest speed. While this conclusion doesn't necessarily provide the basis for an enhancement of the queue management concept (due to the lack of integration with an AMAN prototype), it does provide supplementary evidence that a 60 seconds delay during the cruise phase can be achieved by most DIGITS aircraft types (A320 Family) with some of them able to lose up to 250 seconds in real world conditions.

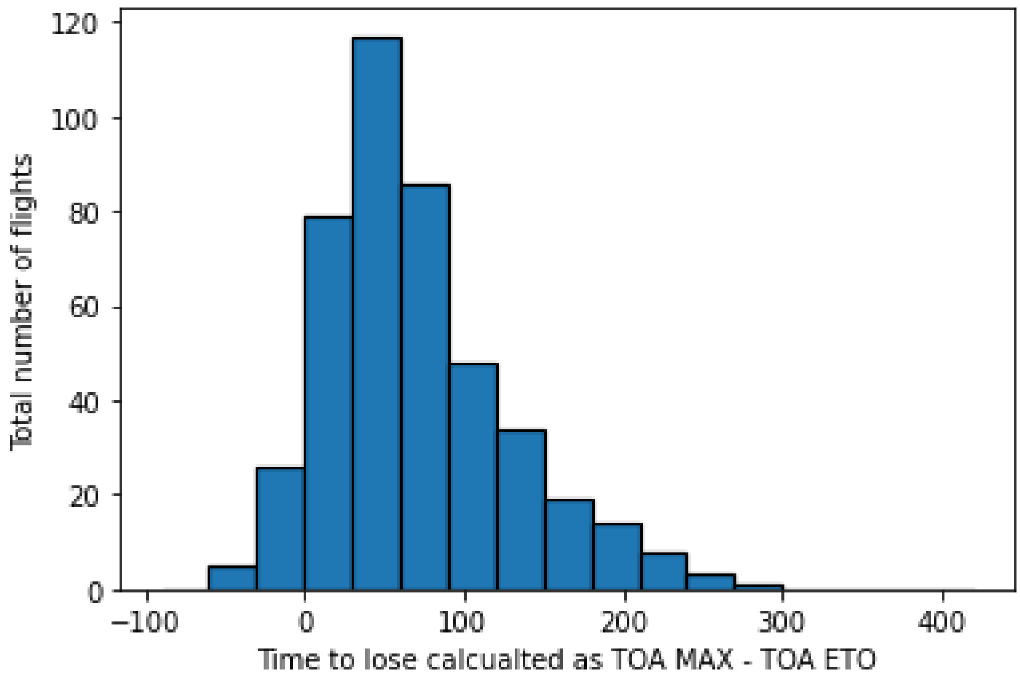


Figure 116: Breakdown of time-to-lose values based on TOA Range at the 35 min AMAN horizon prior to COP

G.3.2.2 EX7-OBJ-38-W3-DEMOP-TECH-0005 Results

The TOA Range data group provides an Estimated Time of Arrival, the earliest time (ETA min) and the latest time (ETA max) an aircraft is predicting to reach a specific target waypoint. In the 4D concept and associated certification, the FMS has to ensure that an RTA defined within reliable RTA interval (TOA Range in EPP) will be met on a 95% probability basis. This means the TOA Range is computed taking into account wind and temperature uncertainties and any altitude as well as speed restrictions inserted in the FMS flight plan. The reliable ETA min and ETA max are computed with margin for additional unpredicted Head wind. Figure 117 below provides an illustration for how the earliest and latest ETAs are computed for a specific target waypoint along the route e.g. WPT4.

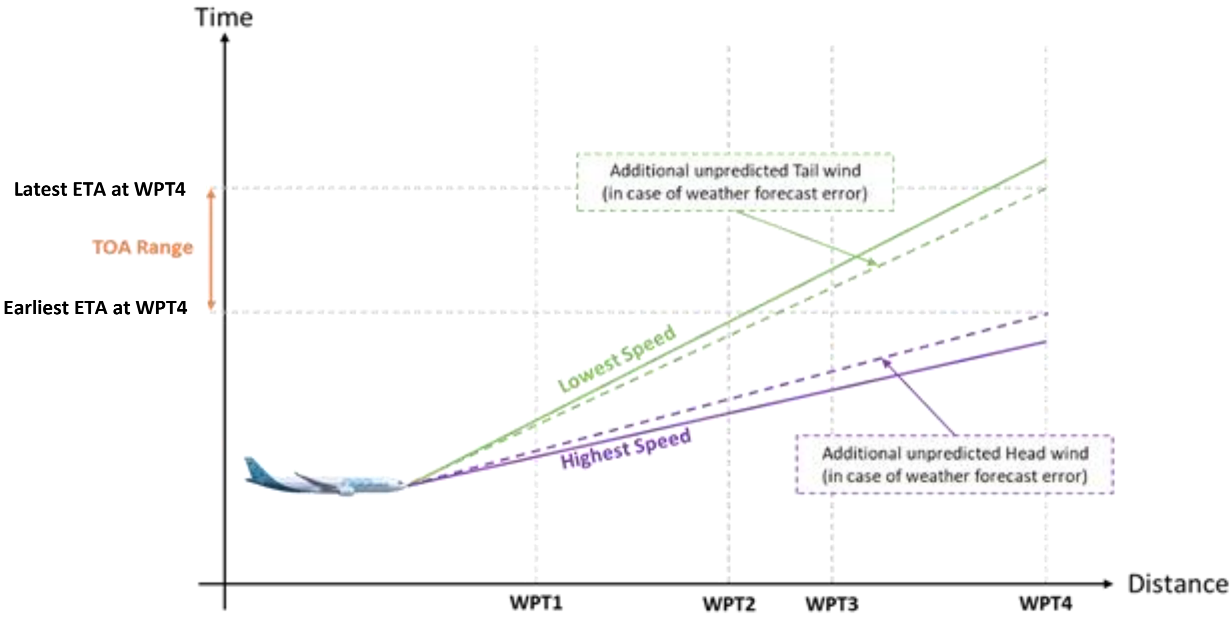


Figure 117: TOA Range interval computation for Waypoint 4 along the route

The TOA Range data group can be provided via either a Periodic contract or a Demand contract however the main requirement for both types of contracts is that the target waypoint is part of the flight plan in FMS and therefore reported in the ADS-C EPP data. When there are multiple route points targeted throughout a flight, the periodic contract can be set up to report on the 1st target waypoint and once it has been considered as overflown, then a new periodic contract is set up to start reporting on the next target waypoint.

Regarding the ADS-C demand contracts for the TOA Range data group, there is no logic to currently set demand contracts for multiple target waypoints. Therefore, a similar logic to the one for the periodic contracts would need to be put in place on the ACS client side where only one demand contract is requested at any one time.

In conclusion, if there is a need to obtain TOA Range data for multiple waypoints at the same time, the option is to set up a periodic contract targeting one of the waypoints (e.g. COP) and a demand contract targeting another waypoint (e.g. IAF). If more than 2 waypoints per flight are targeted, these demand contracts will have to be staggered.

G.3.2.2.1 Provision of ADS-C TOA Range data through periodic contracts

The analysis below looks into identifying how often the TOA Range data has been provided through the ADS-C periodic reports collected between 18th May 2022 and 8th December 2022 by ESSP on their ACS client connected to their ACS distribution server.

Erreur ! Source du renvoi introuvable. below provides an initial overview of the percentage per flight of periodic reports providing TOA Range data as requested through the contract. Initially, the entire dataset has been analysed followed by a filtering of ADS-C reports where certain conditions during the flight prevented the aircraft to send a TOA Range MIN/Max data i.e. when the aircraft is flown in fully *Selected* mode. A second filtering was done to remove all ADS-C reports where the TOA target waypoint was no longer part of the EPP. A final filtering was done to remove all those flights which didn't provide any TOA Range data during their connection.

In the full dataset, it can be observed that on average 85% of the total periodic reports for each flight are providing the requested data. It should also be noted that 21.9% of all flights provided the TOA Range data in all their downlinked periodic reports. On the flip side, the number of flights providing TOA Range data in less than 80% of their reports is around 160 flights out of the total of 745 which represents 21.5% of the entire dataset.

In the filtered dataset, it can be observed that despite only 10 flights being filtered out, the average percentage of periodic reports per flight providing the TOA Range data is just short of 90% with 204 flights providing the TOA Range in 100% of their periodic reports. Out of all 735 flights, 105 of them (14% of the filtered dataset) had a rate of providing TOA Range data in periodic reports less than 80%. Lastly, if the outliers are removed from the filtered dataset (i.e. removing the flights within the 5% percentile) takes the total number of flights to 698 with the average rate for TOA Range data provision via periodic reports going up to 92.5% with a standard deviation of 9.05.

Table 47: TOA Range data provision via periodic reports overview

	Percentage of periodic reports providing TOA Range data per flight	
	Full dataset	Filtered dataset
Total number of flights	745	735
mean	85.20	89.66374
std	19.40	15.74097
min	0	7.69
5%	41.194	54.029
10%	60.81	72.64
25%	82.05	88.89
50%	91.11	94.74
75%	98.11	100
90%	100	100
95%	100	100
max	100	100

EUROPEAN PARTNERSHIP

Co-funded by the European Union

The figure below shows a breakdown per days split by flights providing TOA Range data in more than 80% of their periodic reports vs the ones providing the same data in less than 80% of their periodic reports as observed in the filtered dataset. Based on the dataset analysed, there isn't any correlation observed between the time of the year or even the number of flights within each day. Therefore, a much deeper review of the flights providing TOA Range in less than 80% of the reports is needed to understand how these are broken down.

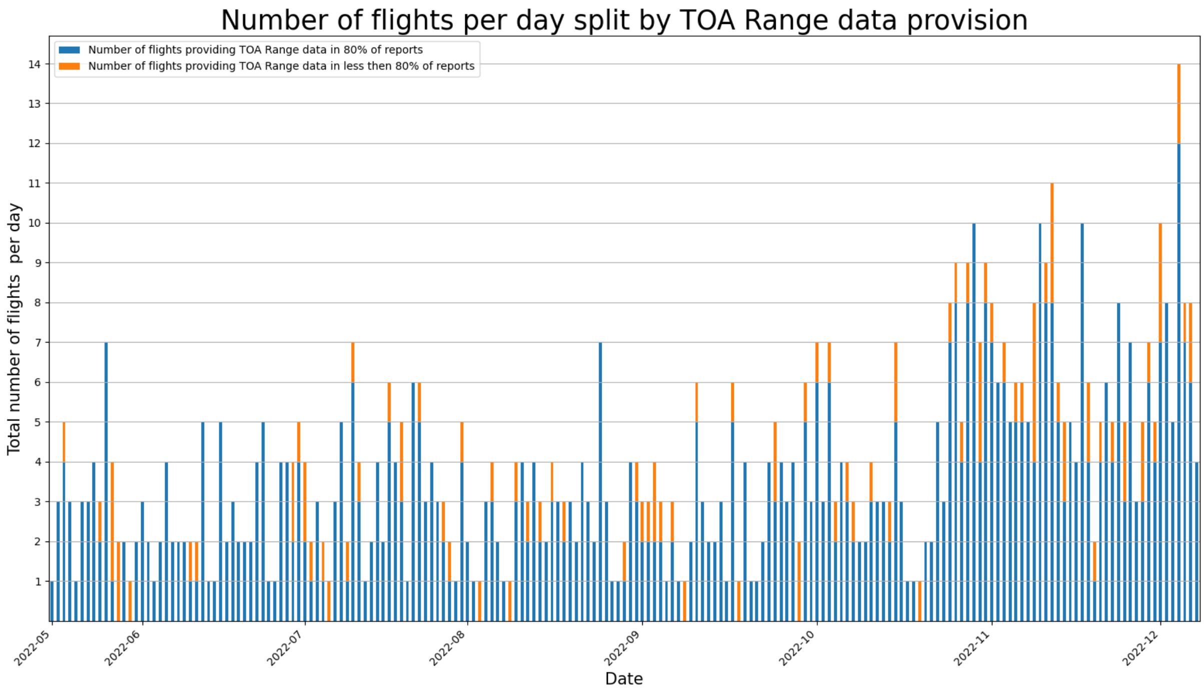


Figure 118: TOA Range data provision breakdown by flights per day

Erreur ! Source du renvoi introuvable. below presents both the full and the filtered dataset breakdown of those flights which provided the TOA Range data in less than 80% of their periodic reports.

It can be observed that the full dataset includes 160 flights with an average of TOA Range data provision around 55.5% of the periodic reports with about 59 of the 160 flights (i.e. 37% of the dataset) sitting above the 70% mark.

Regarding the filtered dataset, this only includes 104 flights with a ratio for providing TOA Range data via periodic contracts of 57.4%. The number of flights providing the TOA data in more than 70% of their periodic reports is 41 out of 104 which represents 39.4%.

For both datasets, it should be noted that the standard deviation has a value of 22 and 19.5 respectively which are both consistent with the value observed for the entire dataset shown in **Erreur ! Source du renvoi introuvable.** whereas the standard deviation for those flights providing TOA Range data in more than 80% of their periodic reports sits around the value of 6 (with an average of 93%). This points to the conclusion that the standard deviation shown in **Erreur ! Source du renvoi introuvable.** is mostly coming from the less performing flights in terms of TOA Range data provision.

Table 48: TOA Range data provision for under-performing flights via periodic reports

	Percentage of periodic reports per flight providing TOA Range data in less than 80% of the reports	
	Full dataset	**Filtered dataset**
Total number of flights	160	104
mean	55.4966875	57.41461538
std	22.2806078	19.50877024
min	0	7.69
5%	4.633	19.2705
10%	22.081	27.342
25%	41.67	44.2275
50%	62.625	63.41
75%	73.85	73.835
90%	76.47	76.754
95%	77.438	77.7545
max	79.69	79.69

Out of the 8 flights with 0% TOA Range data provided observed in the full dataset, 6 of them had only one report and therefore statistically not relevant however, the 2 remaining both had a significant number of periodic reports (13 and respectively 52) where no TOA Range data was provided. Looking purely at the ADS-C data provided, no insights could be generated to explain this behaviour. Therefore, a more in-depth analysis of each flight would be required to understand the exact reasons of the observed behaviours by looking into the airframe's logs combined with the ATC instructions issued if deemed necessary.

Erreur ! Source du renvoi introuvable. below provides a more in-depth view of the percentage of TOA Range data provision via periodic reports in the filtered dataset for those flights with a provision rate below 80%. As mentioned above, a flight-by-flight review of those flights which are considerably below the 80% target for TOA Range data provision needs to be undertaken however this could not be accommodated within the existing timescales.

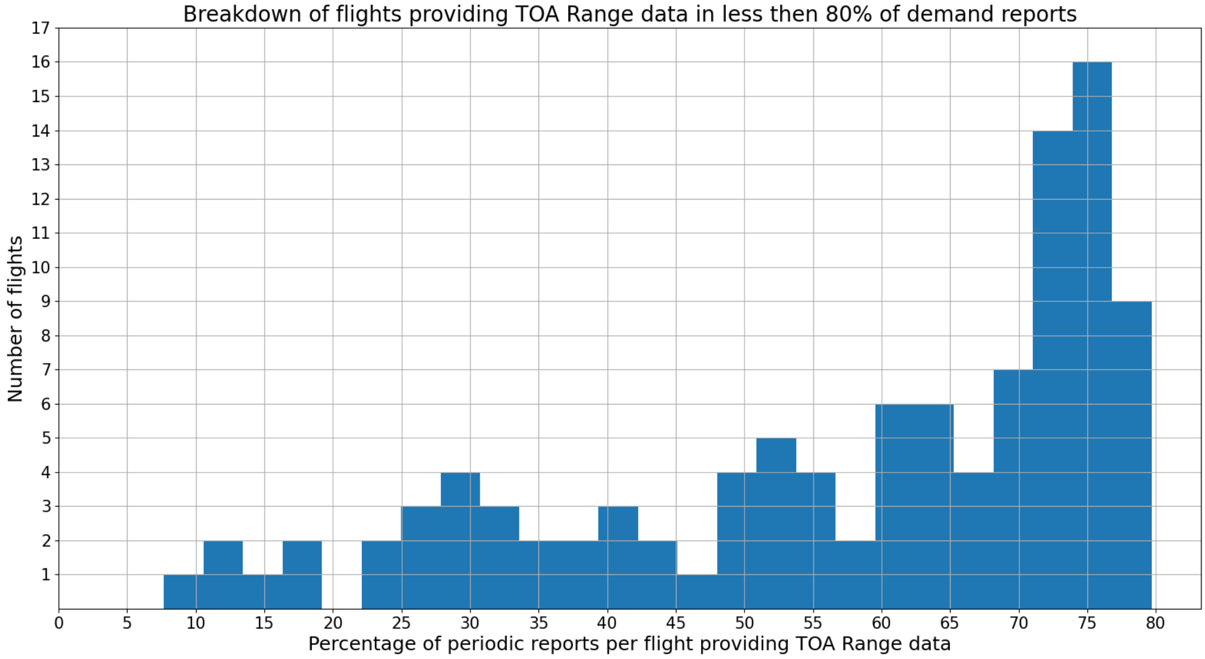


Figure 119: Breakdown of flights providing TOA Range data in less than 80% of periodic reports (based on the filtered dataset)

G.3.2.2.2 Provision of ADS-C TOA Range data through Demand contracts

Demand Contracts were established from the NATS ACS client for 15 weekdays between 30th Jan – 16th February 2023. To maximise the collection of data during a relatively short timeframe, the Client established Demand Requests when the EPP in a received ADS-C report received from the ACS default subscription indicated that an aircraft would fly over one of the Initial Approach Fixes (IAF's). This resulted in 193 flights being recorded as providing TOA Range data in 10 days over the 15 day period.

The same filtering as for the periodic contracts dataset has been applied to the TOA Range demand contracts dataset.

Erreur ! Source du renvoi introuvable. below provides an initial overview of the percentage of demand reports per flight providing TOA Range data for the two datasets.

For the full dataset, it can be observed that similarly to the data provided via periodic reports, the average of the demand reports per flight providing the requested TOA Range data is just above the 80% target. Yet again the standard deviation is around the value of 23 which means there is a big variation in the data provision among the flights within the demand contracts dataset. There are 67 out of the 193 flights (i.e. 35% of the total flights) which are providing TOA Range data in less than 80% of their demand reports. These flights are further analysed below.

After filtering, despite the number of flights going down by only 6 flights, the average rate of providing TOA Range data via demand contracts has increased to above 91%, which aligns with the value observed in the filtered dataset for the periodic contracts. The number of flights providing TOA Range data via demand contracts is 28 out of the 187 flights (i.e. 15%). These flights are being discussed further down in this report.

Furthermore, if the outliers are removed from the filtered dataset (i.e. removing the flights within the 5% percentile), this takes the total number of flights to 177 with the average rate for TOA Range data provision via periodic reports going up to 93.6% with a standard deviation of 9.14.

Table 49: TOA Range data provision via demand reports overview

	Percentage of demand reports per flight providing TOA Range data	
	Full dataset	**Filtered dataset**
Total number of flights	193	187
mean	81.20450777	91.13706
std	23.48005224	14.19141
min	0	23.91
5%	31.762	57.998
10%	50	74.092
25%	71.43	88.89%
50%	89.36	97.83%
75%	100	100%
90%	100	100%
95%	100	100%
max	100	100%

Erreur ! Source du renvoi introuvable. below shows a breakdown per days split by flights providing TOA Range data in more than 80% of their demand reports vs the ones providing the same data in less than 80% of their demand reports as observed in the filtered dataset. The 80% split has been chosen due to the success criteria set in the PJ38 DEMO Plan. Similar to the periodic reports, there doesn’t seem to be any direct corelation between the TOA Range data provision and the time of the week or the number of flights per day.

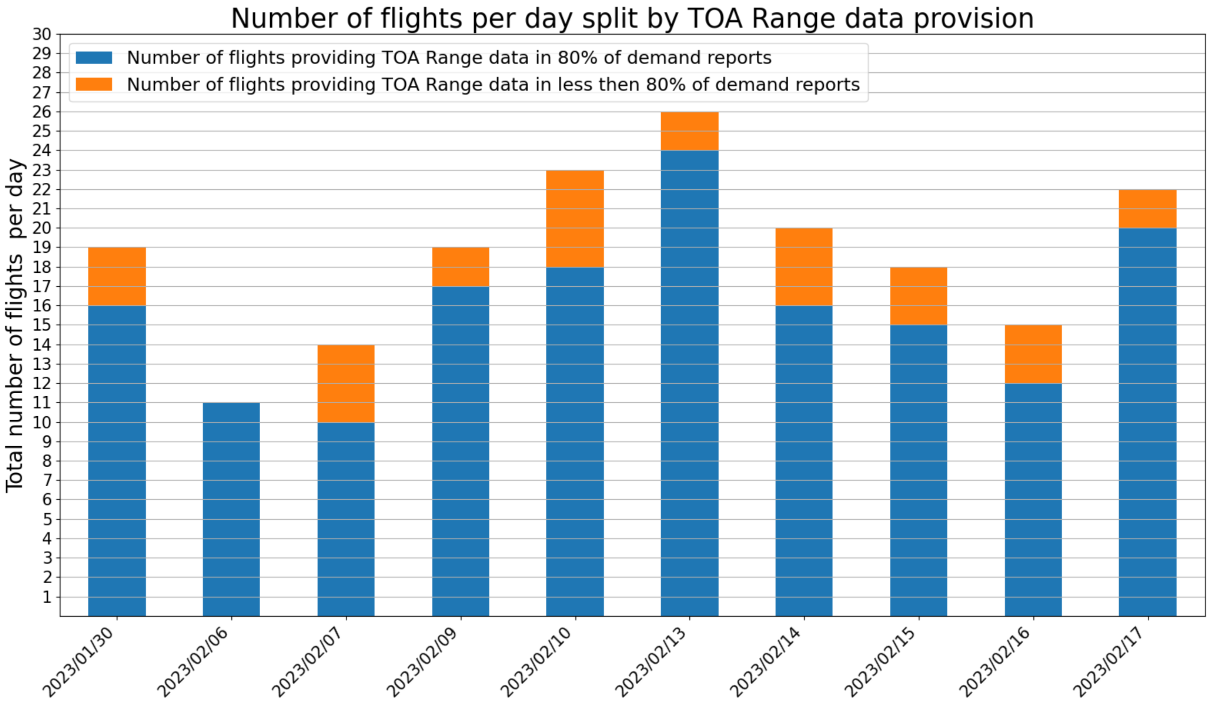


Figure 120:Number of flights per day split by TOA Range data provision

Erreur ! Source du renvoi introuvable. below breaks down those flights which provided the TOA Range data in less than 80% of their demand reports as observed in both the full and the filtered datasets.

For the full dataset, similar to the periodic reports analysis of the same flight type, the average sits around 55% of the demand reports per flight with 41 out of the total 67 flights sitting above this average (i.e. 61% of the dataset).

For the filtered dataset, the total number of flights drops to 28 with an average rate for providing TOA Range in demand contracts of 62.7%. Of these 28 flights, 12 of them (representing 42.8% of the dataset) have a rate of provision for TOA Range above 70% - again, similar to the behaviour observed in the periodic reports.

It should also be noted that the standard deviation has a value of about 22.6 for the full dataset while for the filtered dataset this sits around 15. Despite the drop in standard deviation, the two values are consistent with the values observed for the entire dataset shown **Erreur ! Source du renvoi introuvable.** (i.e. 23.5). The standard deviation for those flights providing TOA Range data in more than 80% of their demand reports sits around the value of 6 with an average of 94% for the full dataset while the filtered one shows a standard deviation of 5.5 with an average of 96%. This points to the conclusion that the standard deviation shown in **Erreur ! Source du renvoi introuvable.** is mostly coming from the less performing flights in terms of TOA Range data provision via demand reports.

Table 50: TOA Range data provision for under-performing flights via demand reports

	Percentage of demand reports per flight providing TOA Range data in less than 80% of the reports	
	Full dataset	**Filtered dataset**
Total number of flights	67	28
mean	55.60881	62.745
std	22.61773	15.08544
min	0	23.91
5%	0	31.1655
10%	24.564	44.999
25%	50	55.3075
50%	62.5	68.75%
75%	72.73	75.00%
90%	76.368	77.78%
95%	78.116	77.78%
max	79.17	77.78%

Out of the 6 flights with 0% TOA Range data provided observed in the full dataset, 5 of them had only up to 3 reports sent and therefore statistically not relevant however, the remaining one had 17 demand reports where no TOA Range data was provided. Looking purely at the ADS-C data provided, no insights could be generated to explain this behaviour. Therefore, a more in-depth analysis of each flight would be required to understand the exact reasons by looking into the airframe's logs combined with the ATC instructions issued if deemed necessary.

Erreur ! Source du renvoi introuvable. below provides an even more in-depth view of the percentage of TOA Range data provided in demand reports for the 28 flights within the filtered dataset. As mentioned above, a flight-by-flight review of those flights which are considerably below the 80% target for TOA Range data provision needs to be done however this could not be accommodated within the existing timescales.

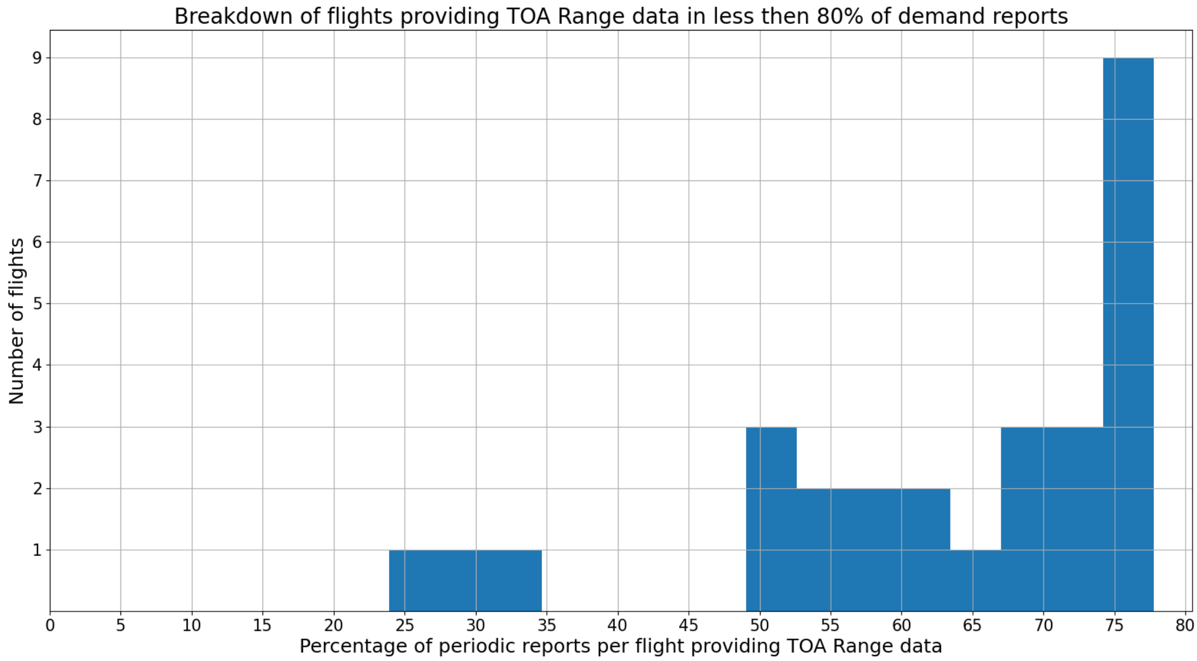


Figure 121:Breakdown of flights providing TOA Range in less than 80% of demand reports

G.3.2.3 EX7-OBJ-38-W3-DEMOP-TECH-0006 Results

Client – ACS Assessment Overview

The following analysis is intended to provide an indicative assessment of the performance of Demand contract requests facilitated by ADS-C Common Service – Client architecture to address exercise objective EX7-OBJ-38-W3-DEMOP-TECH-0006 with associated success criteria EX7-CRT-38-W3-DEMOP-031 and EX7-CRT-38-W3-DEMOP-033.

The assessment is only considered to be indicative as the times are measured by the Client prototype and did not use a high availability ATM network for the ground-ground component. The scope does not specifically include an appraisal of the quality of the received data to address EX7-CRT-38-W3-DEMOP-032, that aspect is instead partially addressed by the analysis supporting success criteria CRT-38-W3-DEMOP-028 of EX7-OBJ-38-W3-DEMOP-TECH-0005 in section G.3.2.2.

EXE-PJ38-4-7 aims to assess the potential of using ETA Min/Max data within arrival management tools. The Periodic contract requests generated by the ACS can include the request for the TOA Range ETA Min/Max data group when an aircraft EPP report includes a boundary Coordination Point (COP) or Initial Approach Fix (IAF) waypoint. However, the Periodic contract request can only provide this data group for a single specified waypoint.

For cases where two or more waypoints of interest for a particular flight may be required to support arrival management tools, then it is anticipated that Demand contracts could be used to obtain the required ETA Min/Max information for the waypoint(s) of interest not provided by the Periodic contract.

The end-to-end dataflow and interfaces between the NATS developed Prototype ACS Client and the DIGITs aircraft is shown in **Erreur ! Source du renvoi introuvable.** below.

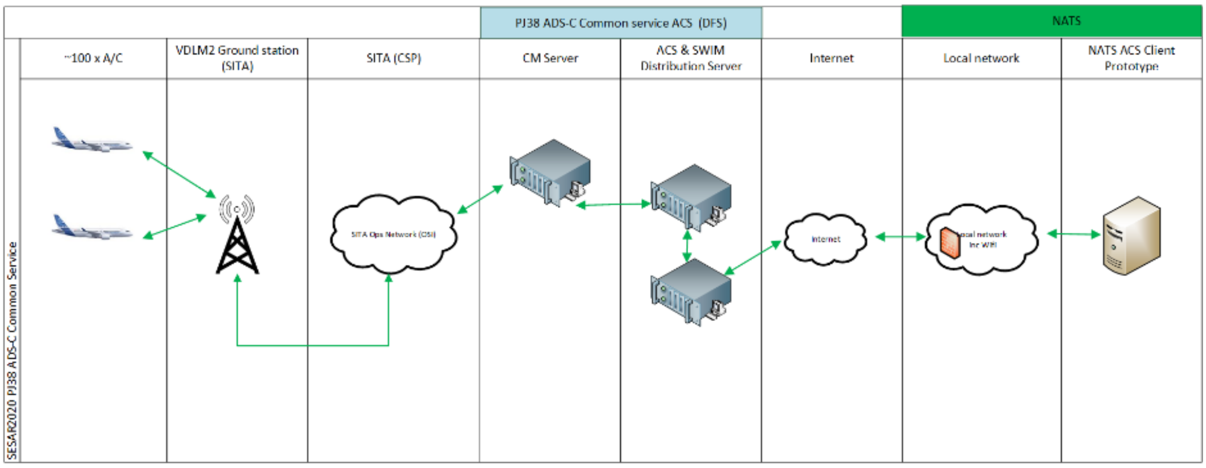


Figure 122: ACS - Client dataflow

In this analysis, London Heathrow (EGLL) and London Gatwick (EGKK) IAF's are the targets for requesting TOA Range ETA Min/Max data group in Demand contract requests:

EGLL = BIG, BNN, LAM, OCK

EGKK = TIMBA, WILLO.

Note that the Periodic contracts established by the ACS also consider TOA Range data group for aircraft with EPP's reporting the following COPs: ABNUR, AMRIV, COA, DCS, IBNOS, KESAX, RAPIX, REVTU.

Demand Contracts were established from the NATS ACS client for 15 weekdays between 30th Jan – 16th February 2023. To maximise the collection of data during a relatively short timeframe, the Client established Demand Requests when the EPP in a received ADS report received from the ACS default subscription indicated that an aircraft would fly over one of the IAF's. The logging capability of the Client was used to provide the message identification and timestamps for the analysis.

Assessment

The following table details the key time delta measurements as recorded in the Client log files for the dataset described above.

Summary Statistic / Percentile	Client Request time - ACS Demand Request Time	ACS Demand Request Time - Demand Confirmation Report Time	Demand Confirmation Report Time - Demand Report Time	ACS Demand Request Time - Demand Report Time	Client Request time - Demand Report Time
Count	7215	7143	7080	7080	7080
mean	0.469	2.323	2.377	4.660	5.128
min	0.243	0.000	0.002	0.006	1.324
95%	0.623	6.259	7.262	11.524	12.332
99%	5.775	13.021	15.591	22.557	24.143
99.90%	15.137	52.634	86.871	92.098	92.404
max	17.094	174.242	186.845	197.105	197.593

Table 51: Key Demand Contract Request Time Deltas

The first column of measurements consider the time taken between the client submitting a Demand request and the ACS providing an accept/reject response.

The total requests sent from the Client to the ACS was 8904, of which, 1689 (18.96%) were rejected by the ACS as another Demand contract was already in progress for that aircraft as established by the ACS. It should be noted that it is likely that this high rejection value could be attributed to the artificially high number of requests sent by the Client to maximise the data collection during the short timeframe of the exercise, rather than an operational concern.

Client Request Time - ACS Demand Request Time

The second column of measurements look at the time between the Client request and the ACS sending the Demand Request to the aircraft.

Of the remaining 7215 requests, the average time delta between the Client request and response from the ACS was 0.509 seconds, with 95% received within 0.623 seconds. **Erreur ! Source du renvoi introuvable.** below shows the histogram of the deltas in 0.25 second bins and indicate 5 second interval feature in a small proportion of deltas. Note the y-axis is in log scale.

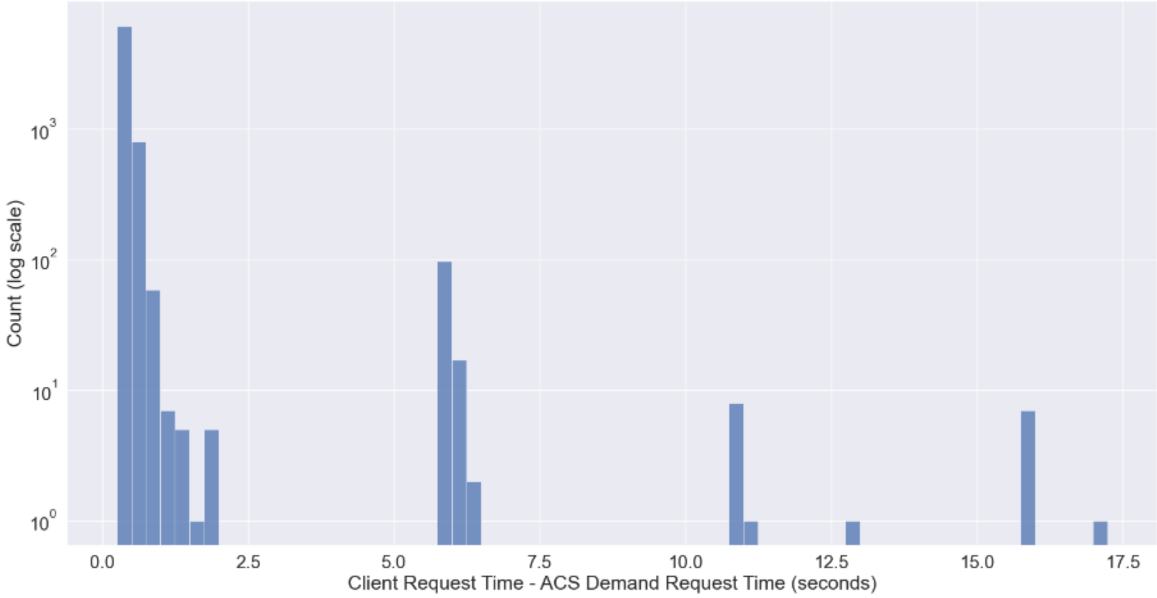


Figure 123: Client Request Time - ACS Demand Request Time

Analysis of a sample of the reports that had either a 5,10 or 15 second plus delta, suggest an internet latency issue was likely the cause, as the research prototype ACS client was not connected to the ACS via a high availability ATM network.

ACS Demand Request Time - Demand Confirmation Report Time

For the 7143 Demand requests sent by the ACS which received an associated confirmation reply, the average time delta between the ACS request to the aircraft and the demand confirmation report received by the client was 2.323 seconds, with 95% received within 6.259 seconds. As this involves the aircraft link, it was expected that the time deltas would be more spread out than the solely ground-ground (client - ACS) measurement. The reason for the loss of 72 confirmation reports is unknown but logging discrepancies within the Client cannot be discounted.

Erreur ! Source du renvoi introuvable. below shows the histogram of these deltas. Note the x-axis has been clipped at 50 seconds to show the 'core' of the distribution.

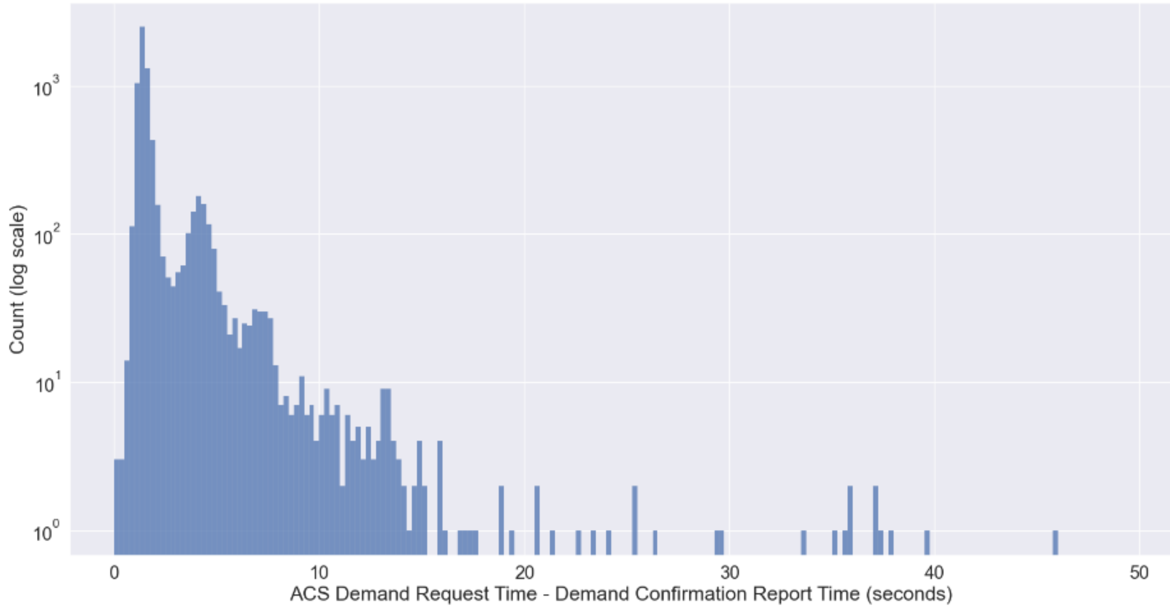


Figure 124: ACS Demand Request Time - Demand Confirmation Report Time

The core of the distribution of the time between the receipt of the Demand confirmation report and the ADS Demand Report broadly follows that of above as shown in **Erreur ! Source du renvoi introuvable.** below (also clipped at 50 seconds on the x-axis).

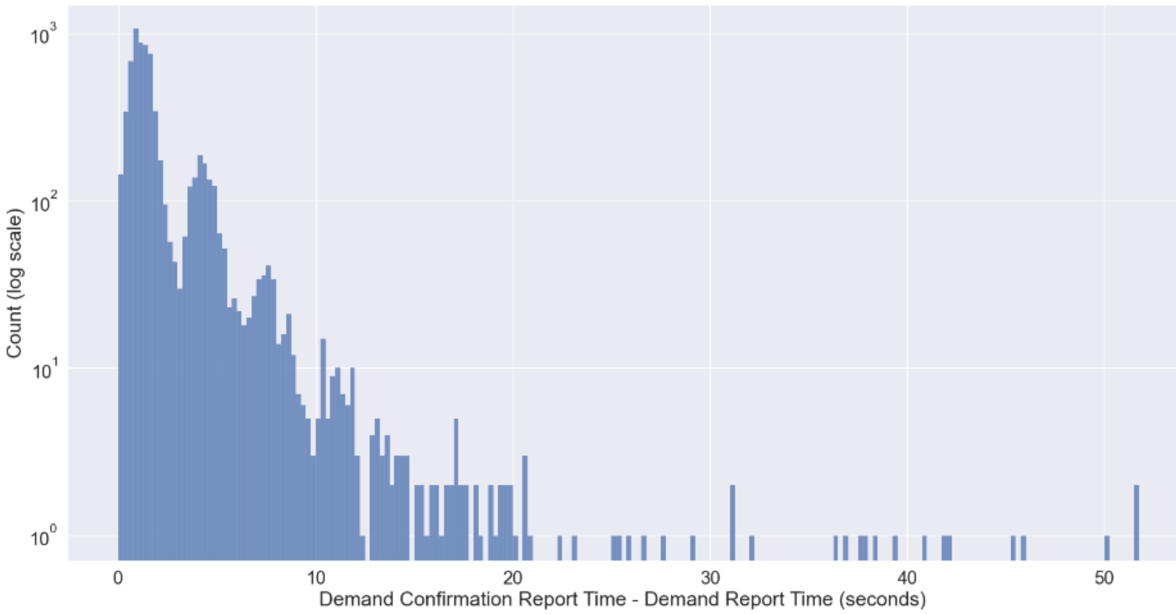


Figure 125: Demand Confirmation Report Time - Demand Report Time

Although measured at the Client, the deltas between the Demand Request sent from the ACS and the Demand Report received by the ACS can be indicative of the airborne ADS-C performance. The 7080 eligible messages resulted in a long-tail distribution with large outliers, however the average delta was measured at 4.658 seconds, with 95% of deltas measuring under 12 seconds, as expected by the ATS B2 performance specification. This distribution is shown in **Erreur ! Source du renvoi introuvable.** below:

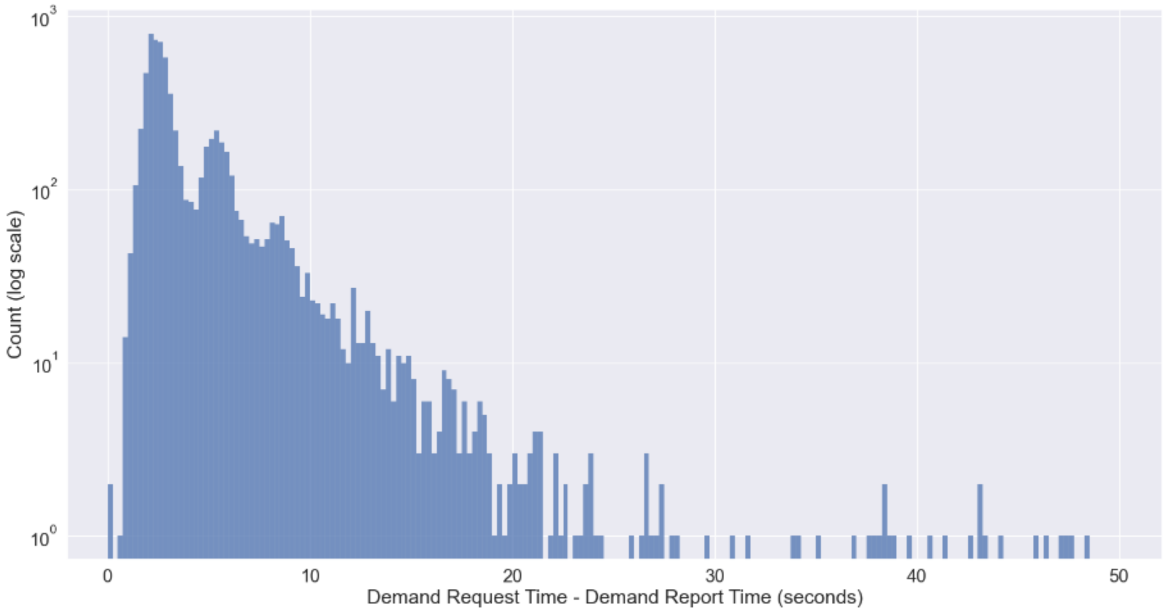


Figure 126: ACS Demand Request Time - Demand Report Time

Of the 7080 Demand Contracts that could be both fulfilled by the ACS and the aircraft, the average complete Client – ACS – Aircraft round-trip time was measured to be 5.128 seconds. The 95% of time deltas were within 12.332 seconds, partly driven by five deltas of over 120 seconds within the dataset.

The core of the distribution for the time delta between the Client request and received Demand report is shown below in **Erreur ! Source du renvoi introuvable.**.

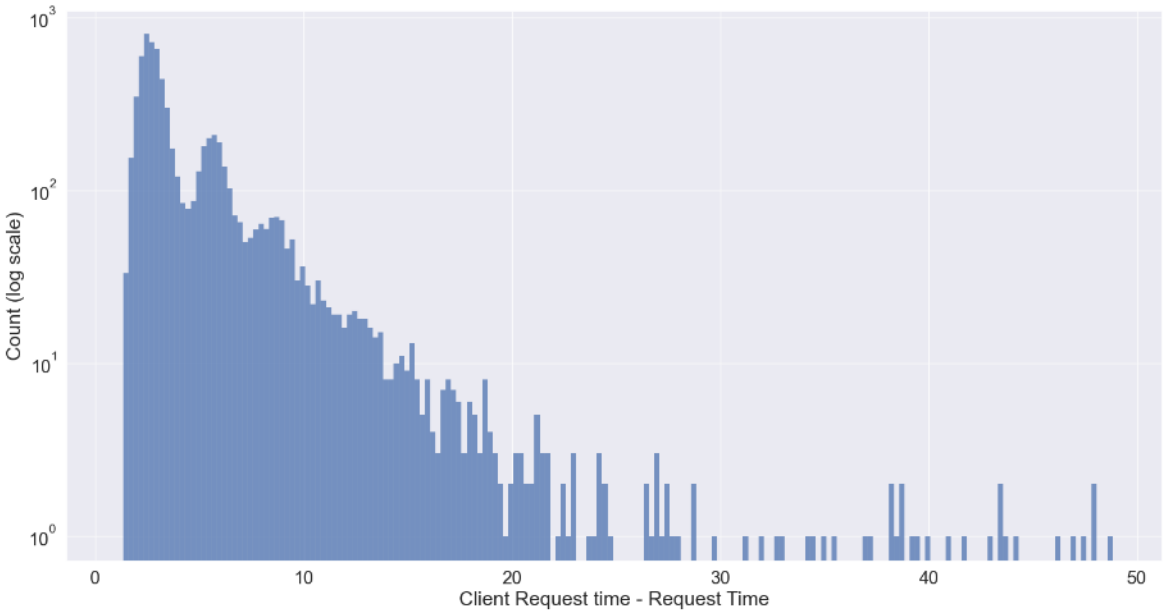


Figure 127: Client Request time - Demand Report Time

Conclusions: Demand contract requests facilitated by the Client-ACS architecture in support of assessing success criteria EX7-CRT-38-W3-DEMOP-031 and EX7-CRT-38-W3-DEMOP-033, the analysis indicates that the performance of the ACS-Client architecture should be suitable for future provision of ADS-C Demand Contract data. Further investigation of the Client-ACS architecture could be undertaken to determine if more targeted Demand Contract requests (as opposed to the large data collection method used within this analysis) results in a reduction of large deltas along with removing the EPP data group from the Demand requests could also be considered to see if this has a beneficial impact on the maximum measured deltas.

G.3.3 Unexpected Behaviours/Results

None.

G.3.4 Confidence in the Demonstration Results

G.3.4.1 Level of significance/limitations of Demonstration Exercise Results

For the EX-7-OBJ-38-W3-DEMOP-OPRF-0003 objective, the significance of the analysis done should be treated as low due the deviation from the planned activities which involved feeding the ADS-C TOA Range data into an AMAN prototype, correlation with ATC interventions was also not possible to discount variances introduced after the TOA predictions.

Regarding EX7-OBJ-38-W3-DEMOP-TECH-0006, the level of significance of the Client-ACS Demand contract assessment should be treated as low as the assessment is only considered to be indicative as due to setup limitations the times are measured at the Client prototype and did not use a high availability ATM network between the Client and the ACS prototype.

Furthermore, the provision analysis requires further in-depth analysis to determine the apparent observation of missing TOA Range reports, which are likely to be attributed to the requested waypoint no longer being in the FMS route.

G.3.4.2 Quality of Demonstration Exercise Results

As noted above with regards to the assessment in support of addressing success criteria EX7-CRT-38-W3-DEMOP-031 and EX7-CRT-38-W3-DEMOP-033, the results are indicative only due to limitations with the setup of the assessment.

G.3.4.3 Significance of Demonstration Exercises Results

For the EX-7-OBJ-38-W3-DEMOP-OPRF-0003 objective, the significance of the analysis done should be treated as low due to the evidence being produced being only at a qualitative level as well as the deviation from the planned activities which involved feeding the ADS-C TOA Range data into an AMAN prototype.

Regarding success criteria EX7-CRT-38-W3-DEMOP-031 and EX7-CRT-38-W3-DEMOP-033, the level of significance of the Client-ACS Demand contract assessment results should be treated as low as the assessment is only considered to be indicative as the times are measured at the Client prototype and did not use a high availability ATM network between the Client and the ACS prototype.

G.4 Conclusions

Regarding the ADS-C TOA Range data, the estimations provided by this data group have shown good accuracy and stability values across the various target metering points. However, depending on the ground tool targeted (i.e. whether it is a tool used in the tactical phase or one that is used in the strategic phase), a more in-depth and targeted analysis should be conducted to understand some of the sudden changes while also making sure that ATC instructions from outside the target sector can be factored in.

Regarding the provision of the ADS-C TOA Range data as requested through the ADS-C Periodic and Demand Contracts, it has been observed that this data group is provided on average in more than 90% of both periodic and demand reports of each flight. Furthermore, looking through the flights where this percentage is below the 80% target objective, it has been observed in the analysis of both types of contracts that the percentage of reports providing TOA Range data is still high sitting around 55% for the periodic reports and around 62% for the demand reports. Looking purely at the ADS-C data provided, no insights could be generated to explain the reason behind some of the reports not providing the TOA Range data as expected. Therefore, a more in-depth analysis of each flight would be required to understand the exact reasons by looking into the airframe's logs combined with the ATC instructions issued if deemed necessary. The remaining reports where this data group is not provided could be explained by changes in the initial planned route which would see either the target COP or IAF being removed and therefore the periodic and/or demand contracts being refused by the airframe. However, with the current rate of provision for the TOA Range data, a combination of periodic contracts with demand contracts can be used to fulfil the operational needs of the ATC ground systems.

Regarding the Demand contract requests facilitated by the Client-ACS architecture in support of assessing success criteria EX7-CRT-38-W3-DEMOP-031 and EX7-CRT-38-W3-DEMOP-033, the analysis indicates that the performance of the ACS-Client architecture should be suitable for future provision of ADS-C Demand Contract data. Further investigation of the Client-ACS architecture could be undertaken to determine if more targeted Demand Contract requests (as opposed to the large data collection method used within this analysis) results in a reduction of large deltas along with removing the EPP data group from the Demand requests could also be considered to see if this has a beneficial impact on the maximum measured deltas.

G.5 Recommendations

G.5.1 Recommendations for industrialization and deployment

This exercise highlights that if the ETA Min/Max is required for two waypoints on an aircraft's flight plan, then a Periodic contract in addition to a Demand contract can be used to downlink the TOA Range data group from the aircraft. However, the prototype ACS and Client used within this exercise would be unable to queue multiple Demand contracts to the same aircraft at the same time for instances where TOA Range for more than two waypoints of interest would be required.

Further investigation of the Client-ACS architecture could be undertaken to determine if more targeted Demand Contract requests (as opposed to the large data collection method used within this analysis) results in a reduction of large deltas observed, along with removing the EPP data group from the Demand contract requests.

G.5.2 Recommendations on regulation and standardisation initiatives

N/A

Appendix H Demonstration Exercise #08 (EXE-PJ38-4-8 by HUNGAROCONTROL with BULATSA and AIRBUS DEFENCE AND SPACE) Report

H.1 Summary of the Demonstration Exercise #08 Plan

H.1.1 Exercise description and scope

The exercise performed by HungaroControl, BULATSA and AIRBUS Defence and Space (hereinafter referred to as ADS) continues the work done under PJ18-W2.53B. Instead of a VLD approach originally set out in the DEMOP, the validation used a real-time simulation. This is due to the extremely low amount of ADS-C capable aircraft in the Hungarian airspace. With this small sample size most of the success criteria could not have been addressed, and also would have reduced the power of the study. Section H.2 further explains the reasons for this decision. The simulation was held between 14-17th November, 2022 at HungaroControl premises.

The scope of the HungaroControl & BULATSA & ADS exercise was to demonstrate using Enhanced Conflict Detection and resolution tools (TESLA tool) in ACC and APP operational environment:

- The benefit of using ADS-C EPP data in the Trajectory Prediction tool and in the Conflict Detection & Resolution tools,
- The benefits of improved trajectory display and management (thanks to EPP) for ATCO situation awareness, safety, flight efficiency

The following cases of EPP data usage were addressed:

- Conflict Detection & Resolution tools enhancements,
- Trajectory Information display enhancements,
- Increased level of assistance with aid automation (solutions ranking),

For the RTS, the airspace was the Budapest TMA and LHCC ACC environment within Budapest FIR.

H.1.2 Summary of Demonstration Exercise #08 Demonstration Objectives and success criteria

This exercise aimed at addressing the following objectives:

- **Safety improvement** (OBJ-38-W3-DEMOP-SAFE-0001): prove that ADS-C data contributes to improving Safety. The main objective is to validate that there is a reduction of the number of potential conflicts, or an earlier resolution due to the CD&R tool.
- **Human Performance improvement** (OBJ-38-W3-DEMOP-HPRF-0002): Demonstrate that improvements due to applying ADS-C data in a validation environment enhances the Human Performance.
- **Operational Performance improvement** (OBJ-38-W3-DEMOP-OPRF-0003): Demonstrate that improvements due to applying ADS-C data in a validation environment enhances the Operational Performance.
- **Operational feasibility** (OBJ-38-W3-DEMOP-OPSF-0004): Demonstrate that the use of ADS-C data paired with an HMI and a CD&R tool is acceptable and trustable by the ATCOs.

- **Access to ADS-C data** (OBJ-38-W3-DEMOP-TECH-0006): Demonstrate that the use of an ADS-C Common Service improves the access to data assessing that the data received via the ADS-C Common service is reliable and it is correctly received.

H.1.3 Summary of Validation Exercise #08 Demonstration scenarios

The following table shows the validation scenarios. The two main variables were the traffic occupancy and traffic complexity in order to see the impact of the enhanced CD&R tools.

Scenario ID	Traffic occupancy	Traffic complexity	Use cases - APP	Runway direction	Use cases - ACC
1	Mid	Not too complex	Arrival-Departure conflict where the SID-STAR meet	13	Budapest/Vienna/Zagreb/Belgrade departure/arrival conflict One aircraft has several conflicts within APP and also ACC.
2	Mid	Very complex	Many conflicting situations where the STARs meet, for ACC arrival traffic, including: • Budapest (LHBP)-Kecskemét (LHKE) departure conflict • Bratislava (LZIB) arrival-Budapest (LHBP) departure conflict	31	NATEX stream
3	High	Not too complex	Arrival-Departure conflict at SID-STAR merge	31	NATEX stream
4	High	Very complex	Many conflicting situations where the STARs meet, for ACC arrival traffic, including: • Budapest (LHBP)-Kecskemét (LHKE) departure conflict • Bratislava (LZIB) arrival-Budapest (LHBP) departure conflict	13	Budapest/Vienna/Zagreb/Belgrade departure/arrival conflict One aircraft has several conflicts within APP and also ACC.

Figure 128. validation scenarios for EXE 4-8

The scenarios were created in two copies- one of them served as a reference and the other as the solution scenario.

Reference scenario:

- no ADS-C capable aircraft
- no assistance function, no ranking (enhanced CD&R tools)

Solution scenario

- 40% ADS-C capable aircraft
- assistance function, ranking (enhanced CD&R tool)

Co-funded by the European Union

The idea behind this split was to let the ATCOs judge the added value of the ADS-C data and also of the new CD&R tools they do not have in their OPS room (i.e. resolution advisory). The solution scenarios still contained 60% non-ADS-C capable aircraft, thus they could evaluate how much ADS-C adds on top of the CD&R tools.

These 8 scenarios (i.e. 4 solution and 4 reference) were run over the course of 2 days with 4 ATCOs (2 APP and 2 ACC). To increase sample size, the simulation was repeated right after the two days, but with a new ATCO group and in different scenario sequence. In total, there were 8 ATCOs participating in the study.

Prior to the real-time simulation there was a “pilot” simulation in May 2022, i.e. an RTS that mainly served as a training for the ATCOs, but they could also express their system related thoughts that would be further improved for the actual validation. Little did the team know that those improvements will not be channelled into a system optimised for a live trial, yet some of those ideas could be integrated into the real-time simulation prototype. Before the final validation, ATCOs received a refresher training, both theoretical and practical.

H.1.4 Summary of Demonstration Exercise #08 Demonstration Assumptions

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
PJ38-ASS-01	ADS-C data provision		The ADS-C Common Service (ACS) is available with appropriate functionalities (including TOA Range demand contracts) and performances	Pre-requisite to be able to carry out ANSP validation exercises	High
PJ38-ASS-02	ADS-C data usability		The received ADS-C data are usable (available on time, not corrupted, etc.)	Pre-requisite to be able to use ADS-C data. The same avionics as in PJ31 will be used. The ACS must ensure that the received data are correctly conveyed to the ANSPs	High

PJ38-ASS-03	VDL2 performances		VDL2 performances support an efficient downlink of ADS-C data	Pre-requisite to be able to downlink the ADS-C data	High
PJ38-ASS-04	Future Covid situation		Future Covid situation will not affect the organisation of the exercises (e.g. travel restrictions)	It is anticipated that the future Covid situation will not be as bad as it was in 2020 and early 2021	High
PJ38-EX8-ASS-01	HMI training	Human Performance	ATCOs will receive extensive training on the TESLA tool's HMI in order to feel at ease with the functionalities and its design.	The reason is that the CD&R tool will run on a separate screen next to the main ATM system and will have a different HMI. The need for training is exacerbated by the fact that the validation is a Live trial.	High

Table 52: Exercise #08 Demonstration Assumptions overview

H.2 Deviation from the planned activities

Due to the very low number of ADS-C equipped aircraft in the Hungarian airspace, it was decided to switch the validation exercise into a simulated one. The following points led to this conclusion:

- In July 2022 1,32% of all IFR flights in the Hungarian airspace were equipped with ADS-C, resulting in 101 LHBP arrivals and 101 departures, meaning 3-3 flights per day on average. HungaroControl had no influence on and information about when those aircraft will arrive/depart, and this uncertainty would have made the ATCO rostering difficult (see point 4).

- The TESLA has its own HMI, which is considerably different from the main ATM system (i.e. MATIAS). A direct data connection could not be established between the Tesla and the MATIAS, thus the ATCO should have fed the TESLA system with the same inputs that he already made in the MATIAS to see the added value of TESLA. Consequently, ATCOs in the OPS room should have received training on the Tesla functionalities to be able to work with it in live environment (see point 4).

- The Tesla was supposed to be on a separate screen in the APP and ACC Controller Working position. As described in the previous point, the ATCO should have fed the system on top of managing the live traffic with MATIAS. This extra task hence workload could not be assigned to the Executive Controller, and for the APP the need for an additional APP position was on the table. Adding an extra position just to monitor the ~6 ADS-C capable flights somewhere during the day would not have been feasible. Especially since there was a huge uncertainty as to when those aircraft will be scheduled (see point 1), thus planning ahead the traffic and synchronizing the shifts accordingly was impossible.The idea was that only a handful of ATCOs will receive a training on the TESLA functionalities, so that they can safely operate the system in the OPS room.

- However, with this low number of ADS-C capable flights it would have been extremely difficult/impossible to ensure that the trained ATCO was rostered to the Tesla equipped position at the time those ADS-C aircraft appeared. Based on these points above the team agreed that this low sample size would give insufficient data for meaningful results, especially when considering all the rostering challenges.

This decision led to a redefinition of the platform architecture, and within this context the systems developed by ADS are structured as follows:

- TESLA: Main component implementing all the advanced ground services,
- GENETICS: Flexible and modular system able to reproduce and create air traffic situation,
- SIMUATC: CWP-prototype to demonstrate the TESLA services.

This deviation from the plan affected criterion 041, 011, 012, 030, 031, 032, 033 which could not be addressed, and are mentioned in Table 53 of H3.1.

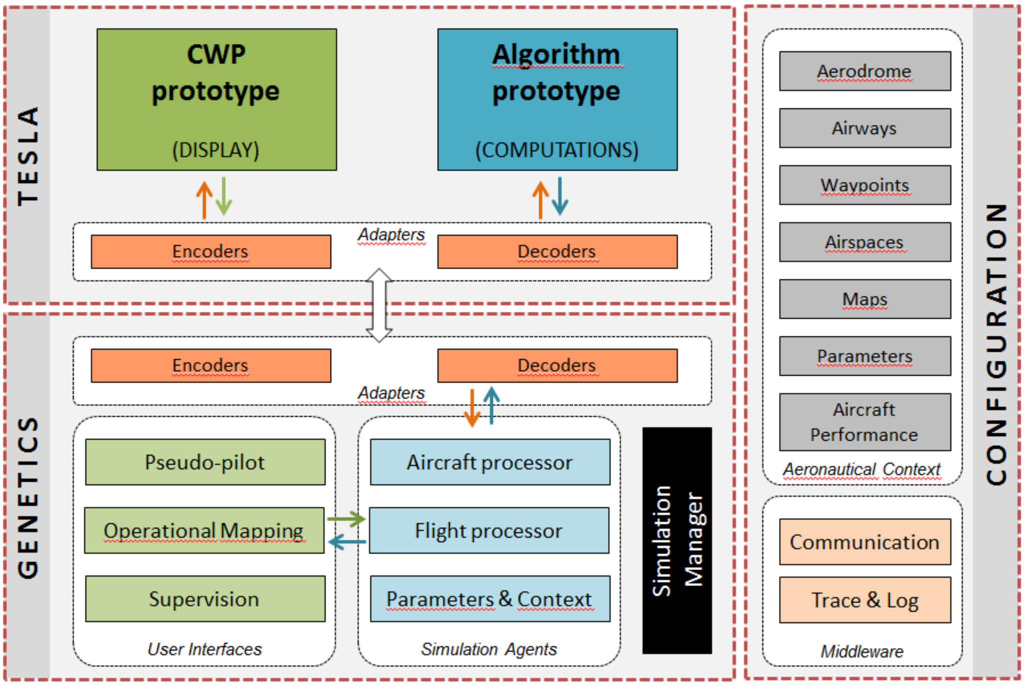


Figure 129: Architecture of the Software components

Some of the success criteria could not be addressed due to switching to simulation. From HP point of view, EX8-CRT-38-W3-DEMOP-011 and EX8-CRT-38-W3-DEMOP-012 would have only made sense in VLD. From the Tech point of view OBJ-38-W3-DEMOP-TECH-0006 could not be assessed either because of switching to a simulation, thus the ADS-C datalink wasn't analysed whatsoever.

However, from the Safety point of view there was only minor difference between CRT-38-W3-DEMOP-002 and CRT-38-W3-DEMOP-041, thus they were merged in the results.

H.3 Demonstration Exercise #08 Results

H.3.1 Summary of Demonstration Exercise #08 Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-38-W3-DEMOP-SAFE-0001	Demonstrate that the use of ADS-C data improves the Safety	CRT-38-W3-DEMOP-002	The CD&R tools enhanced by the use of additional data with more reliability is adequate for safe service provision according to the ATCOs.	ENR-TMA	The majority of controllers agreed that the tool supports safe service provision. The use of additional data definitely means a high improvement in terms of safety.	OK
OBJ-38-W3-DEMOP-SAFE-0001	Demonstrate that the use of ADS-C data improves the Safety	CRT-38-W3-DEMOP-003	There is no increase in the number of tactical conflicts taking into consideration increase in traffic.	ENR-TMA	Based on the data logs 3 conflicts passed the level of tactical conflicts during the simulation of solution scenarios. Tactical conflict management was semi-automatized and based on the debriefing sessions and observations it worked safely.	Partially OK
OBJ-38-W3-DEMOP-SAFE-0001	Demonstrate that the use of ADS-C data improves the Safety	CRT-38-W3-DEMOP-004	There is no increase in the number of imminent infringements taking into consideration increase in traffic.	ENR-TMA	Based on the data logs 3 imminent infringements happened during the simulation of solution scenarios.	Partially OK
OBJ-38-W3-DEMOP-SAFE-0001	Demonstrate that the use of ADS-C data	CRT-38-W3-DEMOP-041	The working of enhanced CD&R tools was appropriate and	ENR-TMA	This success criterion could not be addressed due to switching	Not covered

	improves the Safety		supported safe service provision		to simulation. For details see H.2.	
OBJ-38-W3-DEMOP-HPRF-0002	Demonstrate that the use of ADS-C data improves the Human Performance	CRT-38-W3-DEMOP-005	The situation awareness is considered improved by the users (e.g. ATCO).	ENR-TMA	There was no significant difference between the reference and solution scenarios. Also, only around 50% agreed that ADS-C and the assistance CD&R functions had a positive impact on situational awareness. Therefore, the success criterion is not completely confirmed- a clear improvement in situational awareness cannot be stated with full confidence based on the RTS.	Partially OK
OBJ-38-W3-DEMOP-HPRF-0002	Demonstrate that the use of ADS-C data improves the Human Performance	CRT-38-W3-DEMOP-007	The user's level of workload is within acceptable limits (e.g. ATCO).	ENR-TMA	The level of workload was within acceptable limits regardless of using ADS-C or the assistance tools. Yet there was a scenario that was very complex with high occupancy figures that resulted in unacceptable workload level.	OK
OBJ-38-W3-DEMOP-HPRF-0002	Demonstrate that the use of ADS-C data improves the Human Performance	CRT-38-W3-DEMOP-009	CD&R tool: The HMI design supports ATCOs in performing their tasks efficiently and effectively.	ENR-TMA	The majority of the ATCOs had no issues with the CD&R HMI. APP ATCOs struggled with the CD&R heading design.	OK

			(Solution SC: The HMI design supports users (e.g. ATCO) in performing their tasks efficiently and effectively.)			
OBJ-38-W3-DEMOP-HPRF-0002	Demonstrate that the use of ADS-C data improves the Human Performance	CRT-38-W3-DEMOP-010	The predictions of the CD&R tool(s) are accurate enough to support ATCO decisions on tactical level. *(Solution SC: The use of ADS-C data provides assistance for user decision in a timely and optimal manner.)*	ENR-TMA	The majority of the ATCOs agreed that the enhanced CD&R tools supported efficient decision making. The stability of the recommendations were much better than before to support traffic management. However, only 37.5 % agreed that having EPP (ADS-C) flights had a positive effect on efficient traffic management, making the success criteria POK.	Partially OK
OBJ-38-W3-DEMOP-HPRF-0002	Demonstrate that the use of ADS-C data improves the Human Performance	CRT-38-W3-DEMOP-011	Actual conflicts are detected earlier thanks to enhanced CD&R tool.	ENR-TMA	This success criterion could not be addressed due to switching to simulation. For details see H.2.	Not covered
OBJ-38-W3-DEMOP-HPRF-0002	Demonstrate that the use of ADS-C data improves the Human Performance	CRT-38-W3-DEMOP-012	The number of spurious detection of conflicts is reduced thanks to enhanced CD&R tool.	ENR-TMA	This success criterion could not be addressed due to switching to simulation. For details see H.2.	Not covered
OBJ-38-W3-DEMOP-HPRF-0002	Demonstrate that the use of ADS-C data improves the Human Performance	CRT-38-W3-DEMOP-014	CR: The ranked "what-next" recommendations provided by enhanced Conflict-	ENR-TMA	The solutions offered did not match the mental model of the ATCOs. Many unrealistic	Partially OK

 Co-funded by the European Union

			Resolution assistance tool match ATCO's expectations		solutions were offered (e.g. FL and speed values). Yet the ranking of the proposed solutions were in line with the working methods, leading to a "Partially OK" assessment of this SC.	
OBJ-38-W3-DEMOP-OPRF-0003	Demonstrate that the use of ADS-C data improves the Operational Performance	CRT-38-W3-DEMOP-016	CD&R: the number of instructions to modify flights trajectories is reduced thanks to the reduction of spurious detection of conflicts	ENR-TMA	The average number of instructions per scenario did decrease, although only slightly when comparing the solution to the reference scenarios.	OK
OBJ-38-W3-DEMOP-OPRF-0003	Demonstrate that the use of ADS-C data improves the Operational Performance	CRT-38-W3-DEMOP-017	CD&R: The overall distance flown by the whole traffic is reduced thanks to earlier and more accurate conflict detection (and advised resolution).	ENR-TMA	In the TMA the average track length was reduced by 4%, fuel consumption and CO_2 emission was reduced by 6.8 % in the analysed scenarios. In the en-route area while the average track length was reduced by 3%, fuel consumption and CO_2 emission stayed the same while comparing the solution to the reference scenarios.	OK
OBJ-38-W3-DEMOP-OPRF-0003	Demonstrate that the use of ADS-C data improves the Operational Performance	CRT-38-W3-DEMOP-018	CD&R: The reduced detection uncertainty buffers of the improved CD&R	ENR-TMA	The operational performance was defined by ATCO workload values during the scenario.	Partially OK

			tool MTCD lead to a higher operational performance due to a higher reliability of the planned trajectories.		Altogether there has been a slight increase in the workload metric by 5.4 %. This could be due to the ATCOs still being unfamiliar with the system and the HMI. Although in some selected scenarios the workload did decrease.	
OBJ-38-W3-DEMOP-OPSF-0004	Demonstrate that the use of ADS-C data is Operationally feasible beyond what has been demonstrated in PJ31	CRT-38-W3-DEMOP-023	EPP data: The HMI design supports ATCOs in performing their tasks efficiently and effectively. *Solution CRT: Display: the display of ADS-C data is considered useful by users (e.g. ATCO).*	ENR-TMA	In general, ATCOs expressed that ToD, ToC points were really useful in the system.	OK
OBJ-38-W3-DEMOP-OPSF-0004	Demonstrate that the use of ADS-C data is Operationally feasible beyond what has been demonstrated in PJ31	CRT-38-W3-DEMOP-024	The CD&R tools enhanced by ADS-C data are acceptable for the ATCOs.	ENR-TMA	ATCOs agreed that the display of the ToD, ToC was very useful additional data.	OK
OBJ-38-W3-DEMOP-OPSF-0004	Demonstrate that the use of ADS-C data is Operationally feasible beyond what has been demonstrated in PJ31	CRT-38-W3-DEMOP-025	The predictions of the CD&R tool(s) are accurate enough to establish trust in the system. *Solution CRT: The system enhancement allows to establish trust in the system*	ENR-TMA	ATCOs had a mixed feeling when it comes to trust. There were issues with the assistance and ranking function (e.g. when a conflict occurred, sometimes the offered solution was unrealistic). ATCOs agreed that EPP data	Partially OK

Co-funded by the European Union

					have to be 100% accurate all the time for it to be trusted by the ATCO and provide more situational awareness and lighten the workload. The SATI questionnaire reflects these thoughts as well, emphasis being on the reliability and robustness.	
OBJ-38-W3-DEMOP-TECH-0006	Demonstrate that the use of an ADS-C Common Server improves the access to data	CRT-38-W3-DEMOP-030	ADS-C periodic, on event contracts are successfully established and maintained by the ADS-C Common Service, and resulting data shared with the clients in due time.	ENR-TMA	This success criterion could not be addressed due to switching to simulation. For details see H.2.	Not covered
OBJ-38-W3-DEMOP-TECH-0006	Demonstrate that the use of an ADS-C Common Server improves the access to data	CRT-38-W3-DEMOP-031	ADS-C on demand contracts are correctly passed through the ADS-C Common Service established on client request, and resulting data shared in due time.	ENR-TMA	This success criterion could not be addressed due to switching to simulation. For details see H.2.	Not covered
OBJ-38-W3-DEMOP-TECH-0006	Demonstrate that the use of an ADS-C Common Server improves the access to data	CRT-38-W3-DEMOP-032	Data received via the ADS-C Common Service are reliable (i.e. they faithfully reflect the latest situation provided by the aircraft).	ENR-TMA	This success criterion could not be addressed due to switching to simulation. For details see H.2.	Not covered

OBJ-38-W3-DEMOP-TECH-0006	Demonstrate that the use of an ADS-C Common Server improves the access to data	CRT-38-W3-DEMOP-033	The ACS successfully receives, processes and distributes ADS-C data to multiple clients via SWIM in real time.	ENR-TMA	This success criterion could not be addressed due to switching to simulation. For details see H.2.	Not covered

Table 53: Exercise #08 Demonstration Results

H.3.2 Analysis of Exercises Results per Demonstration objective

H.3.2.1 EX8-OBJ-38-W3-DEMOP-SAFE-0001 Results

Demonstrate that the use of ADS-C data contributes to improve Safety. It might either be:

- a direct improvement of safety level, or
- a demonstration that the level of safety is maintained while another aspect of improvement is addressed (Operational efficiency or Human performance).

H.3.2.1.1 CRT-38-W3-DEMOP-002 CD&R tool impact on safety

Success Criteria	Evidence	Decision
The CD&R tools enhanced by the use of additional data with more reliability is adequate for safe service provision according to the ATCOs.	The majority of controllers agreed that the tool supports safe service provision. The use of additional data definitely means a high improvement in terms of safety.	OK

Exercise #08 Results on CD&R tool supports safe service provisionFigure 130 shows results from the post-simulation survey involving controllers' point of view on CD&R tool impact on safety. During the simulation controllers did not experienced any safety critical event. 7 out of 8 controllers agreed that the tool supports safe service provision. Controllers (both APP and ACC) expressed the same opinion on the debriefings, according to them the use of additional data definitely means a high improvement in terms of safety. Although it does not mean a big change on controllers' side and the benefits are difficult to see directly (in terms of the differences between routes of EPP equipped and non-equipped flights) but having more reliable data which gives a more precise trajectory is a key factor in safety. According to both ACC and APP controllers the extrapolation, the vertical profile calculation and the top of descend (TOD), top of climb (TOC) information is really helpful. The EPP data makes the calculation easier for the controllers and adds another layer of information that controllers can analyze and rely on. However, it was highlighted by the controllers that EPP data should be fully accurate in order to be trusted. During the simulation EPP had slight effect on ATCO workload and situational awareness (see Human Performance success criteria CRT-38-W3-DEMOP-005 in section H.3.2.2.1 and CRT-38-W3-DEMOP-007 in section H.3.2.2.2) so in order to build trust adequate amount of training and practice is still necessary before implementation.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

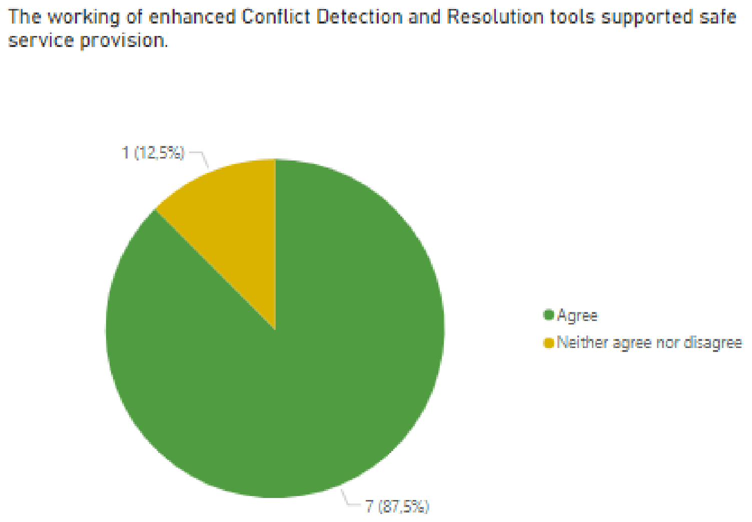


Figure 130: Exercise #08 Results on CD&R tool supports safe service provision

In terms of conflict detection, it should be emphasized that the TESLA tool is a TCT (detecting conflicts in a horizon from 5 to 10 min) and), not a MTCD (horizon time like 20 min). With the 12-minute parameter setting the main advantage could be seen in terms of mid-term conflicts. However, ATCOs mentioned that in ACC environment long-term conflict detection (in a 25-30 minute timeframe) could be automated as well in order to start conflict detection much earlier in ACC. When they only solved conflicts in a 12-minute timeframe most of the time it was just postponing the conflict (creating another conflict in a downstream sector). Sometimes the ATCO saw the conflict far more ahead of time than Tesla.

In terms of false negative cases (missing conflicts) ACC controllers did not specify any case. However, they mentioned that the conflict calibration could be set higher than 5 NM in order to detect conflicts with a separation of i.e. 5.03 miles. Although it is enough separation but it would be better to make the controllers aware of that in time.

In APP environment the mid-term conflicts were efficiently solved by the tool however ATCOs would have appreciated more if the tool detects short-term conflicts in a shorter timeframe (especially in higher traffic when controllers can use vertical separation until the base turn/point). With mid-term conflict detection big changes can be foreseen in clearances. If there is a smaller time window, and the ATCO only solves the short-term conflicts it will be a smaller change in clearances (in heading) though it might result in a bit higher ATCO load.

One APP controller mentioned that he noticed possible conflicts which were not warned by the tool. These were situations where a little change in the performances could have result in conflicts.

Neither ACC or APP controllers did not specify any false positive cases.

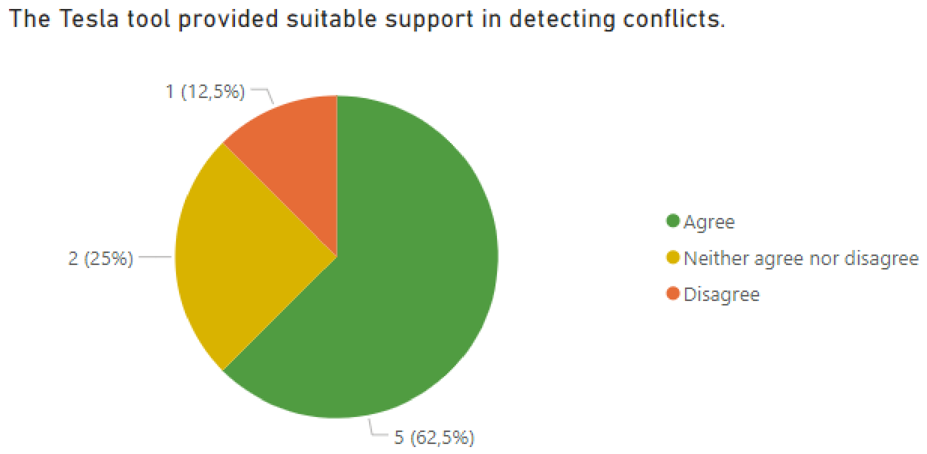


Figure 131: Exercise #08 Tesla tool support in detecting conflicts

Conflict resolution was a controller task having supported by the Tesla tool. According to APP controllers the task of conflict detection and resolution did not get easier. The suggestions were often unrealistic and the calculation in the background was hard to understand. In low and medium workload, it can give help and situational awareness, but under high load it is difficult to pay attention to which can have a negative effect on safety. The results of controller opinion on the support of conflict detection and resolution provided by the Tesla tool is more detailed in section H.3.2.2.4 CRT-38-W3-DEMOP-010 about Decision-making, traffic management and in section H.3.2.2.5 CRT-38-W3-DEMOP-014 about CD&R “What next” recommendations.

It was highlighted before that the system should be fully accurate for it to be trusted by controllers. Figure 132, Figure 133, Figure 134 show the results about the technical working of CD&R tool from controllers’ perspective. In terms of reliability 3 out of 8 controllers replied “Sometimes”. In terms of accuracy most of the controllers stated that the function worked accurately in most of the cases. Controllers also mentioned that the conflict detection was very precise. In terms of robustness 2 controllers replied “Seldom” and “Sometimes”.

The CDR tool was reliable.

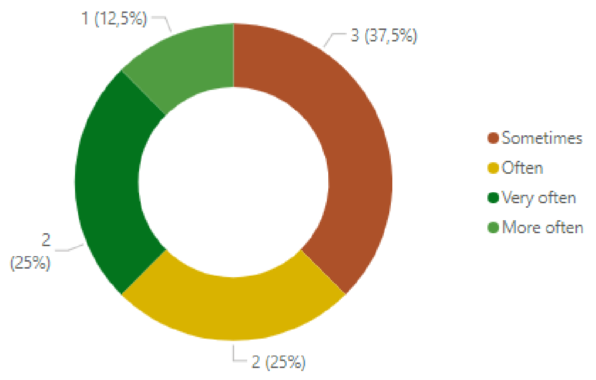


Figure 132: Exercise #08 CDR reliability

The CDR tool worked accurately.

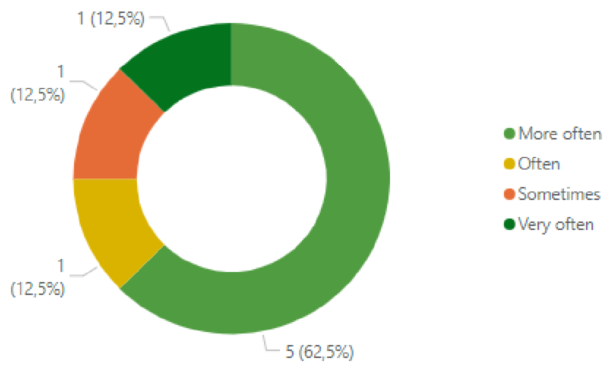


Figure 133: Exercise #08 CDR accuracy

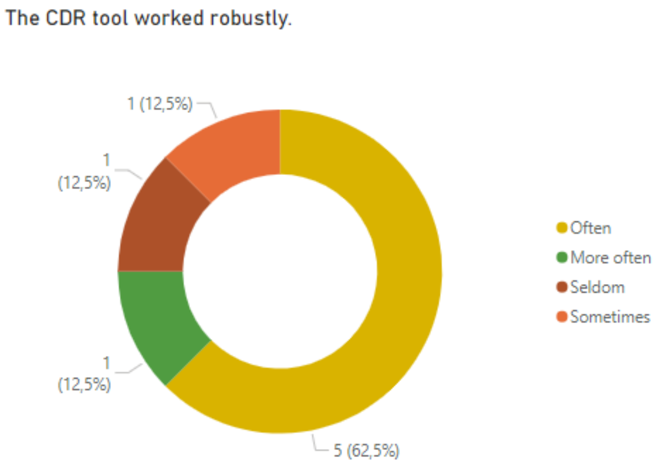


Figure 134: Exercise #08 CDR robustness

H.3.2.1.2 CRT-38-W3-DEMOP-003 Increase of tactical conflicts

Success Criteria	Evidence	Decision
There is no increase in the number of tactical conflicts taking into consideration increase in traffic.	Based on the data logs 3 conflicts passed the level of tactical conflicts during the simulation of solution scenarios. Tactical conflict management was semi-automatized and based on the debriefing sessions and observations it worked safely.	P-OK

Tactical conflict is a situation where an imminent infringement -coming from a crew/aircraft induced conflict or an ATC planned conflict- was prevented by tactical conflict management. Conflicts in 12-minute timeframe were automatically detected by the system. Controllers were always a step ahead detecting and resolving conflicts before the tool in long-term (ACC). While APP controllers was thinking about more in the short-term. However, for the sake of the simulation controllers tried to work mostly with the options proposed by the CD&R.

During the simulation separation minima infringements were logged via STCA alerts. Infringements happened when one of the flights was assumed by the FEEDER (in 15 cases) does not have to be taken into account. Considering the fact that STCAs were triggered and logged when the separation reached below 5NM STCA alerts were not valid in 16 cases when both flights were assumed by TMA (since there the separation minimum distance is 3NM). Table 54 contains a list of separation infringements with 4 relevant cases.

Run	Type	Callsign plane 1	Callsign plane 2	Minimum distance reached	Sector plane 1	Sector plane 2	Detection time
6	Solution scenario with medium traffic, medium complexity	WZZ884	LOT34	1.40	TMA	TMA	2022/11/15 09:29:10
6	Solution scenario with medium traffic, medium complexity	RYR2278	AUA865	1.80	ENR	ENR	2022/11/15 09:27:45
13	Solution scenario with medium traffic, high complexity	RYR8PK	CSA796	0.10	TMA	TMA	2022/11/17 09:27:15
15	Reference scenario with high traffic, high complexity	AIC154	EWG4FX	4.90	ENR	ENR	2022/11/17 10:58:40

Table 54: Exercise #08 Separation infringements logged in the simulation

According to the system logs 3 out of 4 infringements happened when running the solution scenario (with 40% ADS-C capable traffic and enhanced CD&R tool was functioning); 2 infringements in TMA with 1,40 and 0,10 Nm separation and 1 infringement in ENR environment with 1,80 separation.

Considering the data logs, it is worth to take a look at the hazards identified in the DEMOP Appendix A section A.2.3 safety plan. The most relevant hazards are presented in Table 55.

First of all, several controllers mentioned that the lack of training and practice in the system has a huge impact on the results (Hz#6). The fact that the tool is totally different from the operational system MATIAS made it difficult to work safely and effectively. On the other hand, the effects of Hz#04 and Hz#05 can be also seen in terms of imminent infringements presented before. Due to the fact that CD&R tool was inaccurately designed and parameterized for Hungarian characteristics (in terms of restrictions in ACC or speed control in APP) and the fact that CD&R tool does not fit the controllers' needs (detecting on mid-term level and not on long-term or short-term) imminent infringements were expected. Based on the results the simulation validated these expectations, and showed that adequate design are more than necessary for safe service provision.

Hz ID	Description of hazard	Impacted (new/modified) causes	Impacted (new/modified) effects
Hz#04	CD&R tool fails to support the ATCO in the resolution of the conflict on time	The CD&R tool **fails to provide resolution support on time due to inaccurate design** or software integrity	Increased ATCO workload **Imminent Infringement**
		CD&R tool **fails to detect conflicts on time, thus it is unable to provide resolution** support	
		The conflict data presented by the CD&R tool **is not clear for the ATCOs**	

Hz ID	Description of hazard	Impacted (new/modified) causes	Impacted (new/modified) effects
Hz#05	CD&R tool provides erroneous conflict resolution support to the ATCO	The CD&R tool **provides erroneous resolution support due to inaccurate design** or software integrity	Increased ATCO workload Decreased ATCO situational awareness **Imminent Infringement**
Hz#06	ATCOs are not familiar with the CD&R tool	Working procedures are not updated accordingly, training is not adequate	Increased ATCO workload Decreased ATCO situational awareness

Table 55: Exercise #08 Relevant hazards identified by HungaroControl in DEMOP A.2.3.

H.3.2.1.3 CRT-38-W3-DEMOP-004 Increase of imminent infringements

Success Criteria	Evidence	Decision
There is no increase in the number of imminent infringements taking into consideration increase in traffic.	Based on the data logs 3 imminent infringements happened during the simulation of solution scenarios.	P-OK

Imminent infringement is a situation where an imminent collision was prevented by ATC Collision prevention. During the simulation controller intervention -when needed- usually happened in a timely and safely manner, in low and medium workload the tool was a good support in the calculation process during conflict resolution. Based on the data logs and the observations 3 conflicts turned out to be an imminent infringement when running the solution scenarios which can be derived to the same roots and reasons than CRT-38-W3-DEMOP-003.

H.3.2.1.4 CRT-38-W3-DEMOP-041

The criteria says that "the working of enhanced CD&R tools was appropriate and supported safe service provision" which is a duplication of CRT-38-W3-DEMOP-002.

H.3.2.2 EX8-OBJ-38-W3-DEMOP-HPRF-0002 Results

H.3.2.2.1 CRT-38-W3-DEMOP-005: Situational awareness

Success Criteria	Evidence	Decision
The situation awareness is considered improved by the users (e.g. ATCO).	There was no significant difference between the reference and solution scenarios. Also, only around 50% agreed that ADS-C and the assistance CD&R functions had a positive impact on situational awareness.	Partially OK

	Therefore the success criteria is not completely confirmed- a clear improvement in situational awareness cannot be stated with full confidence based on the RTS.	

ATCOs filled out a post-run and a post-simulation survey and both of those addressed situational awareness. The post-run version used the standardized questionnaire SASHA-Q, developed by EUROCONTROL.

The scale comprises 6 items, which are not assigned to individual scales. Responses to the items are given on a seven-point Likert scale ranging from “never” to “always”.

Figure 133 shows the results separated between reference and solution runs, and also between the different scenario IDs (i.e. traffic load and complexity). The median scores are close to 4, which indicates a good level of situational awareness. It further confirms that there was no significant effect of the solution scenario (i.e. ADS-C flights, enhanced CD&R tools), although the upper quartile of the solution is higher than in the reference scenario. It is also clear that Scenario 4 (High traffic load, high complexity) had an influence on the situational awareness level. ATCOs agreed that the traffic in the scenario was overwhelming, and pseudo-pilots often had some delay responding. It was difficult to use the assistance tools in these cases.

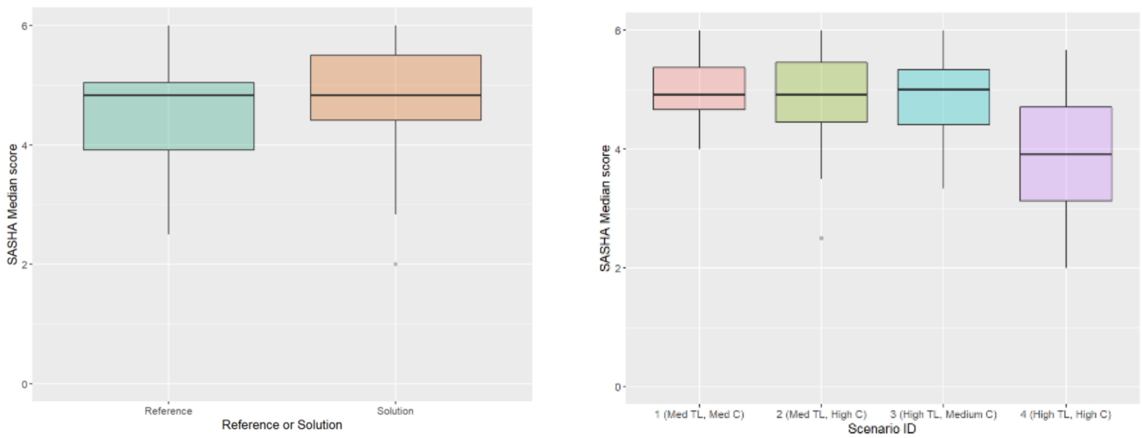


Figure 135: Exercise #08 Median scores on SASHA-Q situational awareness scale

The post-simulation questionnaire touched upon the following two questions. As Figure 136 shows, around 50% agreed that ADS-C and the assistance CD&R functions had a positive impact on situational awareness.

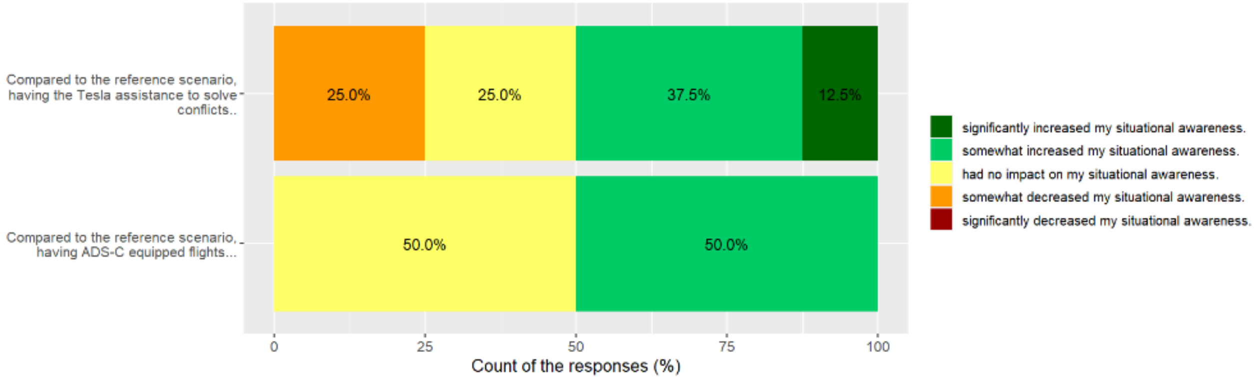


Figure 136: Exercise #08 Situational awareness post-simulation questions

Debriefing sessions touched upon the topic of EPP usefulness and its impact on workload or situational awareness. APP ATCOs thought that whilst it was nice to see what changes EPP would bring to the flight leg, TOD, TOC, it doesn't give more situational awareness.

H.3.2.2.2 CRT-38-W3-DEMOP-007: Workload

Success Criteria	Evidence	Decision
The user's level of workload is within acceptable limits (e.g. ATCO).	The level of workload was within acceptable limits regardless of using ADS-C or the assistance tools. Yet there was a scenario that was very complex with high occupancy figures that resulted in unacceptable workload level.	OK

ATCOs filled out post-run questionnaires and a post-simulation survey, both of which addressed workload. The post-run version used the standardized Bedford Workload Scale. The following table illustrates the meaning of the scale's values:

Bedford Workload Scale legend	
10	Task abandoned
9	Extremely high workload
8	Very high workload, no spare capacity
7	Very high workload, almost no spare capacity
6	Very high workload, no impact on primary ATM
5	Little spare capacity
4	Insufficient spare capacity
3	Enough spare capacity
2	Workload low
1	Workload insignificant

Table 56: Exercise #08 Bedford Workload Scale legend

According to Figure 137 there is a slight difference between solution and reference scenario- the median workload was lower in the solution scenarios (MDN=3) than in the reference versions (MDN=4), although this difference is not statistically significant. Based on the figure on the right, the most difficult scenario had a huge impact on the workload, where the value reached a critical limit (MDN=7). The reasons for the high workload were described in the questionnaire and are as follows:

- “Overwhelming traffic especially with no routine on handling the HMI. There was no chance to use the assistance tools.”
- “Working with the system (differences to MATIAS, no STARs and points on screen, grey incoming traffic)”

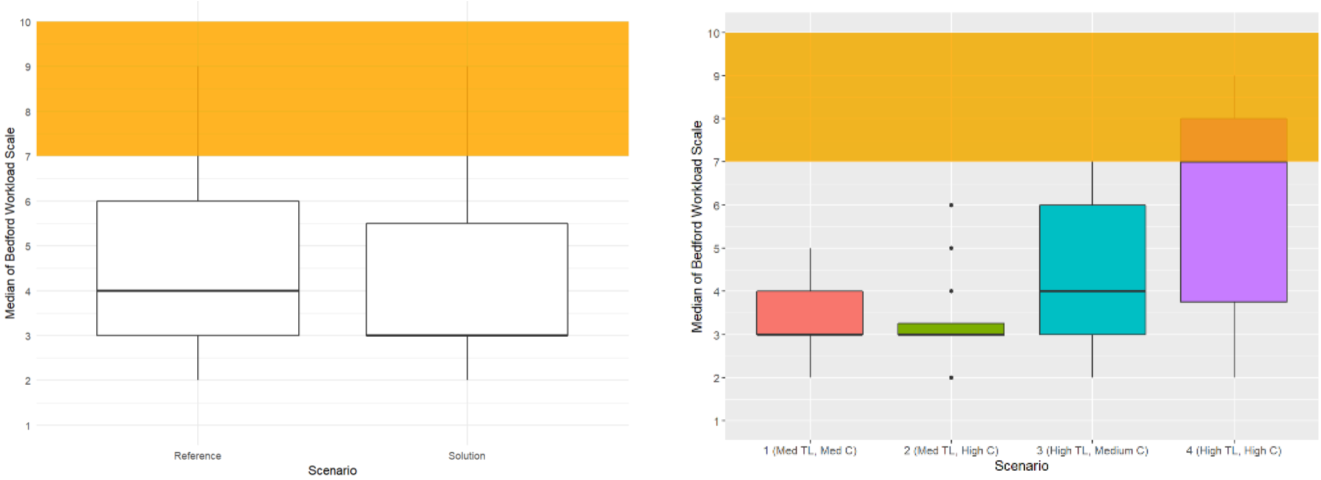


Figure 137: Exercise #08 Workload levels

H.3.2.2.3 CRT-38-W3-DEMOP-009: CD&R tool HMI design

Success Criteria	Evidence	Decision
CD&R tool: The HMI design supports ATCOs in performing their tasks efficiently and effectively. *(Solution SC: The HMI design supports users (e.g. ATCO) in performing their tasks efficiently and effectively.)*	The majority of the ATCOs had no issues with the CD&R HMI. APP ATCOs struggled with the CD&R heading design.	OK

The next eight questions on Figure 138 are part of the CD&R tools’ HMI design subsection of the post-simulation questionnaire. According to the results the majority of the ATCOs were satisfied with the tools’ HMI design in general.

Co-funded by the European Union

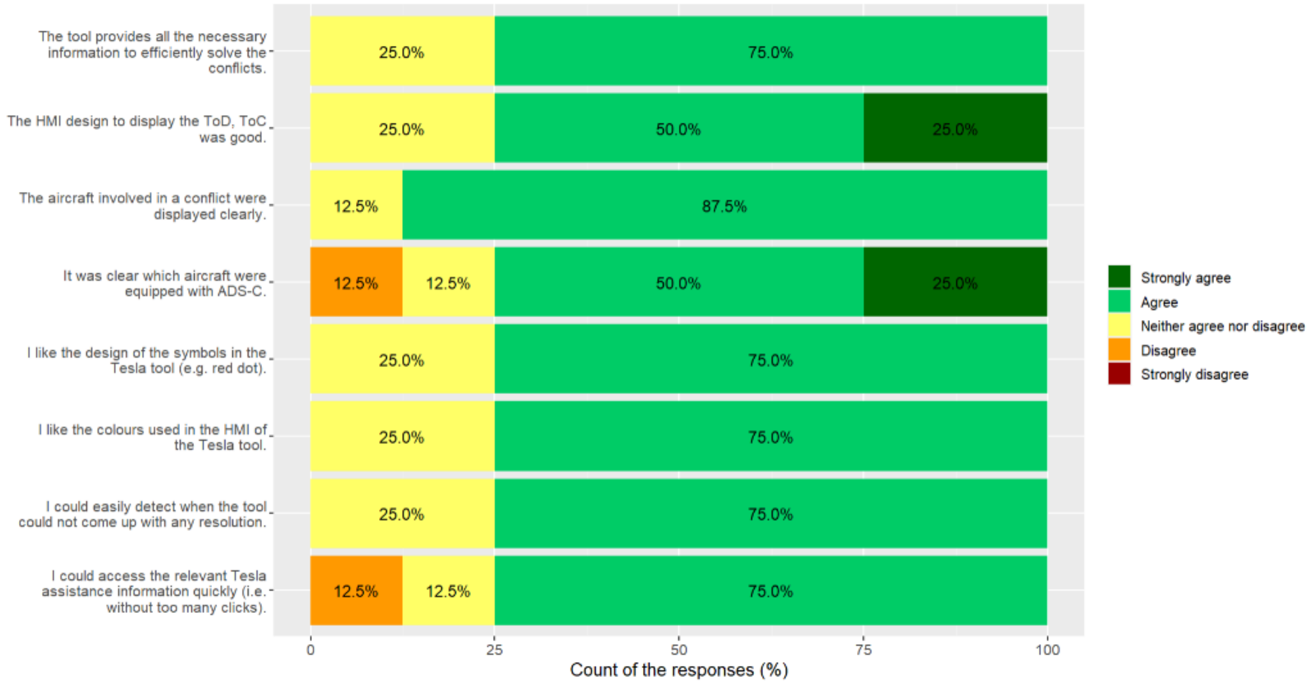


Figure 138: Exercise #08 CD&R tool HMI design results

The only issue worth to report was the CD&R's heading assistance map element, whose benefit the APP controllers struggled to understand. They couldn't see why that specific heading option wasn't good at a first glance, and the whole solution wasn't dynamic enough for an APP environment.

H.3.2.2.4 CRT-38-W3-DEMOP-010: Decision-making, traffic management

Success Criteria	Evidence	Decision
The predictions of the CD&R tool(s) are accurate enough to support ATCO decisions on tactical level. *(Solution SC: The use of ADS-C data provides assistance for user decision in a timely and optimal manner.)*	The majority of the ATCOs agreed that the enhanced CD&R tools supported efficient decision making. The stability of the recommendations was much better than before to support traffic management. However, only 37.5 % agreed that having EPP (ADS-C) flights had a positive effect on efficient traffic management, making the success criteria POK.	Partially OK

Figure 139 shows the results of the post-simulation questionnaire that address Tesla's assistance functions. According to the chart, the majority of the ATCOs were satisfied with the function's timeliness (i.e. its validity remained stable, and appeared on time) and the colours on the labels helped to make decisions efficiently. However, only 37.5% of the ATCOs agreed that EPP flights supported a more efficient traffic management.

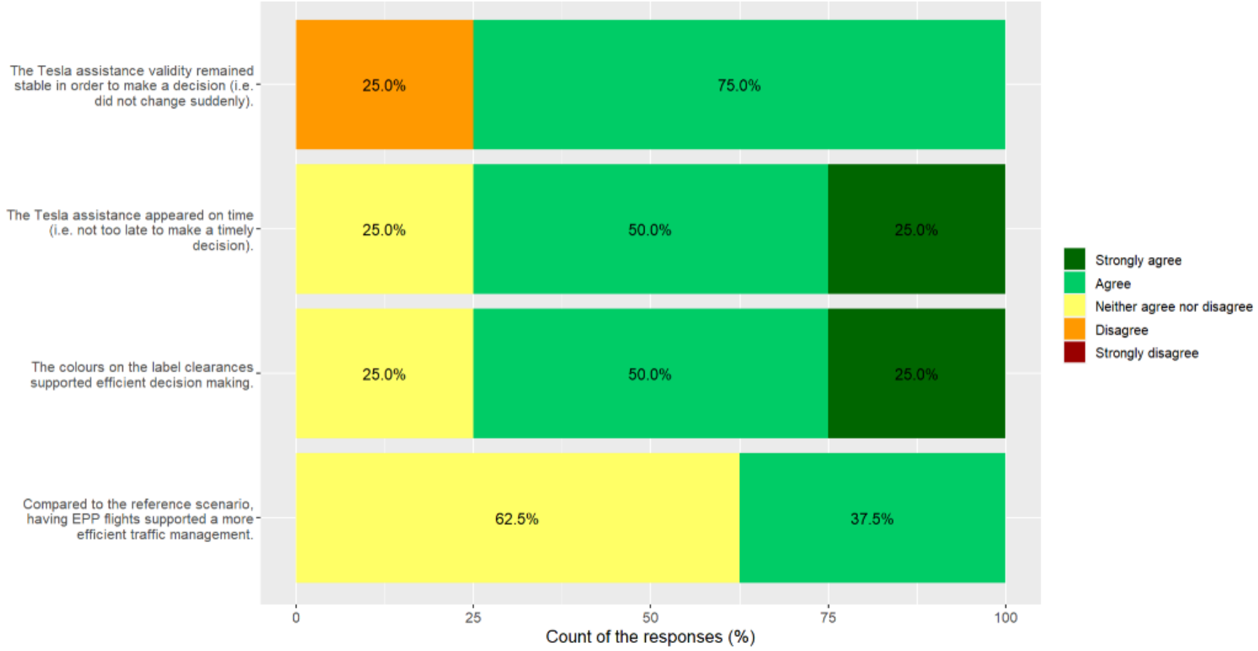


Figure 139: Exercise #08 Decision-making, traffic management results

To better understand the survey's results, ATCOs elaborated their thoughts in the questionnaire itself and also during the debriefings. Based on their experience, the system conflict calculation varied a lot, sometimes it calculated a conflict to be sufficient, next minute it indicated not enough separation. Still, it was considered as a clear improvement compared to its state in the first training simulation half a year earlier.

ATCOs found the colours of the suggested commands sometimes overwhelming, there was loads of options to choose from. There was always a value that was the most efficient, but the (APP) ATCO did not know if it was the most efficient for the controller. Yet they argued that it might be just a matter of getting used to. Occasionally, a usual command that they would use in a real-life scenario came up in red, which was confusing. In such cases, they could extrapolate and see the aircraft's trajectory and understand why there was a conflict. They voiced the need to understand the calculations behind it to establish trust (note: this is also linked to DEMOP-025).

Furthermore, an APP ATCO pointed out that he wouldn't rely on the speed advisory of the system, since by descending with a fixed indicated speed, the ground speed will change and the aircraft will get closer to each other.

To complement the last question on Figure 139, ATCOs noted that although it was nice to see what changes EPP would bring to the flight leg, it didn't make the job of separation the aircraft easier and did not improve situational awareness. They said the trust in the EPP data to be accurate 100 % of the time is the most important for the system to be helpful in the controller duties (see DEOP-025 Trust).

ATCOs also discussed the time-horizon of the Tesla CD&R tool, which is aimed to be a TCT CD&R tool with similar look-ahead time. ATCOs questioned whether this solution was ideal, as there were many occasions when ACC ATCOs realised it won't help them:

- it might create another conflict in a downstream sector;

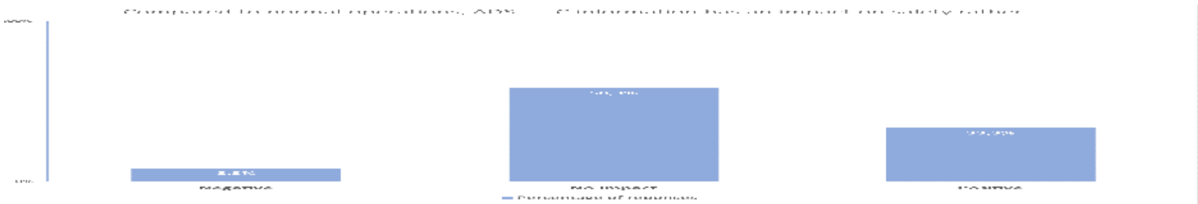
- when there were three aircraft in a conflict with each other, a solution for one conflict did not take into account how that instruction affected the third conflicting traffic.

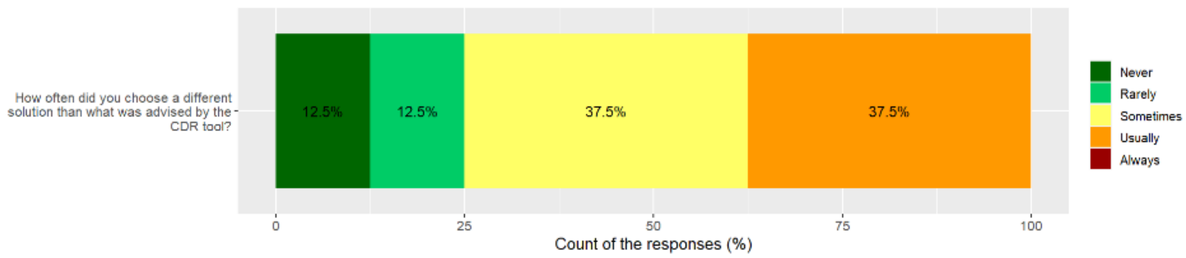
On the contrary, in APP environment the time parameter should be less than 12 minutes.

H.3.2.2.5 CRT-38-W3-DEMOP-014: CD&R "What next" recommendations

Success Criteria	Evidence	Decision
CR: The ranked "what-next" recommendations provided by enhanced Conflict-Resolution assistance tool match ATCO's expectations.	The solutions offered did not match the mental model of the ATCOs. Many unrealistic solutions were offered (e.g. FL and speed values). Yet the ranking of the proposed solutions were in line with the working methods, leading to a "Partially OK" assessment of this SC.	Partially OK

Figure 140 shows four questions that were asked in the post-simulation questionnaire. The results indicate that the ranking function did not always match the ATCOs mental model. This has been also attested by the ATCOs during the simulation as well. Most of the times they pointed to unrealistic values, be it a FL solution or speed solution (e.g. offering FL410 for an Airbus 320 which is usually not possible). ATCOs had to interpret what the system was suggesting and step in quite frequently. But the idea behind prioritising the solutions was in accordance with their working methods (i.e. directs are preferred before anything else, if possible).





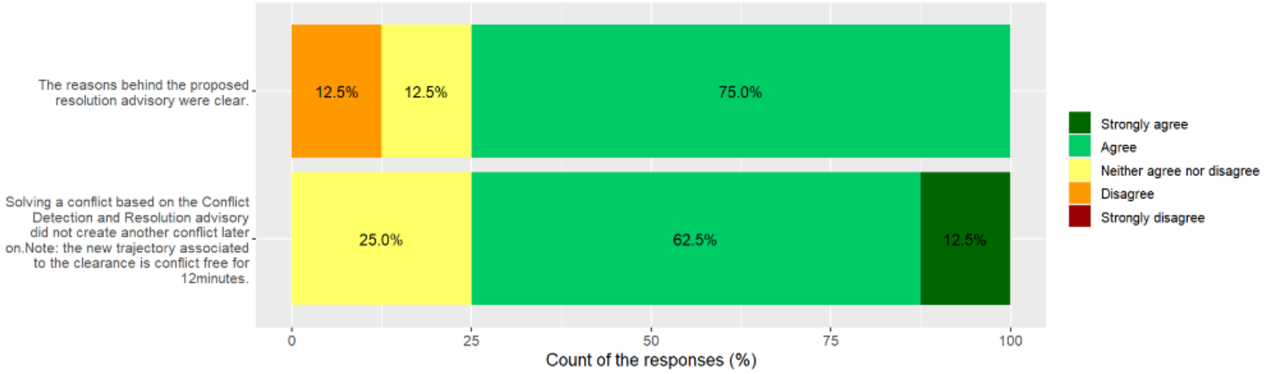


Figure 140: Exercise #08 CD&R "What next" recommendations results

H.3.2.3 EX1-OBJ-38-W3-DEMOP-OPRF-0003 Results

H.3.2.3.1 CRT-38-W3-DEMOP-016 Results

Success Criteria	Evidence	Decision
CD&R: the number of instructions to modify flights trajectories is reduced thanks to the reduction of spurious detection of conflicts	The average number of instructions per scenario did decrease, although only slightly when comparing the solution to the reference scenarios.	OK

Comparing the 8 reference scenarios to their specific solution scenarios, where the CD&R tool was enabled, on average there has been a slight decrease in the number of instructions by 0,17 %. This was calculated by dividing the instructions needed in the specific scenarios by the total amount of controlled flight hours in minutes, resulting in a metric which shows how many instructions were needed per controlled flight hours per scenario.

However, in specific scenarios there have been cases of a nominal reduction in the number of instructions, which shows that the CD&R tool is able to support the ATCOs with spurious detection of conflicts.

In the selected scenarios, in which the number of instructions needed increased, could be due to factors listed below:

- There are already well-established free-route airspace procedures in the Hungarian airspace, which minimize the number of instructions needed by the ATCOs, since the scenarios were based off real traffic. In the higher traffic and complexity scenarios the CD&R tool could support the ATCOs in decreasing the number of instructions needed, while in low traffic and complexity scenarios, due to the 12-minute look ahead time, in the ACC it might not pick up conflicts which are further ahead. In the TMA it might pick up false conflicts, which would be resolved due to procedures.
- The TESLA system and its HMI is largely different compared to HungaroControl's own ATM system, MATIAS, which without proper and long enough training could result in the ATCOs being uncomfortable with the system, thus increase the number of instructions needed.

- The attitude of the ATCOs was hugely supportive during the whole validation, they approached the system as one, which was under R&D, thus tried out various traffic solutions, which in a live environment they wouldn't have.
- Altogether out of the 8 reference and solution scenario pairs in 5 the number of instructions needed decreased. The exact values are visible in the Table 57.

MediumT-MediumC-13 (Scenario 1)		MediumT-HighC-31 (Scenario 2)	
Session 1	Session 2	Session 1	Session 2
Instructions needed	Instructions needed	Instructions needed	Instructions needed
-7,38%	-11,50%	-20,70%	31,14%
HighT-MediumC-31 (Scenario 3)		HighT-HighC-13 (Scenario 4)	
Session 1	Session 2	Session 1	Session 2
Instructions needed	Instructions needed	Instructions needed	Instructions needed
11,19%	-11,22%	-14,85%	21,31%

Table 57: Exercise #08 Instructions needed per controlled flight hours

H.3.2.3.2 CRT-38-W3-DEMOP-017 Results

Success Criteria	Evidence	Decision
CD&R: The overall distance flown by the whole traffic is reduced thanks to earlier and more accurate conflict detection (and advised resolution).	In the TMA the average track length was reduced by 4%, fuel consumption and CO_2 emission was reduced by 6,8 % in the analysed scenarios. In the en-route area while the average track length was reduced by 3%, fuel consumption and CO_2 emission stayed the same while comparing the solution to the reference scenarios.	OK

Comparing the solution scenario track length, fuel consumption and CO_2 emission values to the reference scenario ones, there is a total average decrease in all regards. Although in the TMA the average track length was reduced by 4%, fuel consumption and CO_2 emission were reduced by 6,8% in the analysed scenarios, in the ENR while the average track length was reduced by 3%, fuel consumption and CO_2 emission stayed the same while comparing the solution to the reference scenarios. The second phenomenon could be due to two identified factors:

- The flights between the reference and solution scenarios weren't exactly the same, thus the trend might have been inflected.
- ATCOs might have instructed some flights to descend to lower flight levels, while still keeping the shorter flight route, but increasing fuel consumption and CO_2 emission in the process.

The exact values for each scenario from the data logs are visible in Table 58, while the trends are visible in Figure 141. We had to leave out the values of Scenario 2 – Session 1, since the increase in track length and fuel consumption, together with CO_2 emission were outstandingly high.

ΔENR	Track length (NM)	Fuel consumption (kg)	CO2 emission (kg)
Sc. 1	5,7102	67,7516	218,4668
Sc. 2	8,0292	91,6810	295,9638
Sc. 3	-4,9727	-12,8897	-41,5813
Sc. 4	-9,2067	-60,2156	-194,0774
AVG	-0,1100	21,5818	69,6930
ΔENR	Track length (NM)	Fuel consumption (kg)	CO2 emission (kg)
Sc. 1	7,85%	6,59%	6,59%
Sc. 2	10,81%	12,93%	12,94%
Sc. 3	-4,84%	-1,60%	-1,60%
Sc. 4	-9,49%	-8,05%	-8,04%
AVG(-S2)	-3,11%	-0,21%	-0,21%
ΔTMA [%]	Track length (NM)	Fuel consumption (kg)	CO2 emission (kg)
Sc. 1	0,6668	-84,7792	-273,7443
Sc. 2	-0,2526	15,5512	50,2393
Sc. 3	-5,0361	-57,7994	-186,4610
Sc. 4	-3,4546	-15,1149	-48,4895
AVG	-2,0191	-35,5356	-114,6139
ΔTMA [%]	Track length (NM)	Fuel consumption (kg)	CO2 emission (kg)
Sc. 1	1,38%	-12,92%	-12,93%
Sc. 2	-0,55%	3,53%	3,53%
Sc. 3	-9,05%	-11,40%	-11,39%
Sc. 4	-6,72%	-3,08%	-3,06%
AVG	-4,01%	-6,78%	-6,78%

Table 58: Exercise #08 Evaluation of track length, fuel consumption and CO_2 emission

Figure 141: Exercise #08 Evaluation of track length, fuel consumption and CO_2 emission

Altogether the total average environment-impacting values could be decreased by the support of the CD&R tool in the solution scenarios. However, the improvement of values in the TMA are much better than the ENR.

H.3.2.3.3 CRT-38-W3-DEMOP-018 Results

Success Criteria	Evidence	Decision
CD&R: The reduced detection uncertainty buffers of the improved CD&R tool MTCD lead to a higher operational performance due to a higher reliability of the planned trajectories.	The operational performance was defined by ATCO workload values during the scenario. Altogether there has been a slight increase in the workload metric by 5,4 %. This could be due to the ATCOs still being unfamiliar with the system and the HMI. Although in some selected scenarios the workload did decrease.	Partially OK

In this case the operational performance was defined by ATCO workload values derived from the TESLA logs recorded during the validation event. This was calculated on an instruction needed per minute basis, weighted by the number of aircraft in that specific validation scenario.

The defined operational performance metric cannot be separated from Human Factor results either because of its workload nature. Taking this into account the slight increase in workload can be due to the ATCOs not being familiar enough with the TESLA system and HMI, which is largely different than our current ATM system, MATIAS. Further influencing Human Factor results are discussed in their regarding sections.

Table 59 shows the exact values of the workload impacts while comparing the solution scenarios to the reference scenarios.

MediumT-MediumC-13 (Scenario 1)		MediumT-HighC-31 (Scenario 2)	
Session 1	Session 2	Session 1	Session 2
Workload impact	Workload impact	Workload impact	Workload impact
1,52%	-1,84%	18,87%	22,32%
HighT-MediumC-31 (Scenario 3)		HighT-HighC-13 (Scenario 4)	
Session 1	Session 2	Session 1	Session 2
Workload impact	Workload impact	Workload impact	Workload impact
20,30%	0,46%	-15,07%	4,67%

Table 59: Exercise #08 Workload impact per scenario

Altogether we have identified 2 scenarios where the workload was decreased, 3 where it was close to the reference ones, and 3 where it increased in the solution scenarios. ATCOs had to get used to the new HMI, which resulted in additional workload, therefore solution advisory provided by the system did not reach its potential full efficiency. Improvement in situational awareness provided by the CD&R tool was negligible, while more timely conflict resolutions for ATCOs did take place, resulting in increased capacity of both TMA and ENR airspaces.

H.3.2.4 EX8-OBJ-38-W3-DEMOP-OPSF-0004 Results

H.3.2.4.1 CRT-38-W3-DEMOP-023: ADS-C data display

Success Criteria	Evidence	Decision
EPP data: The HMI design supports ATCOs in performing their tasks efficiently and effectively. *Solution CRT: Display: the display of ADS-C data is considered useful by users (e.g. ATCO).*	In general, ATCOs expressed that ToD, ToC points were really useful in the system.	OK

Figure 142 shows the post-simulation questionnaire's results on the HMI with regards to ADS-C. The display of the ToD and ToC was welcomed by the ATCOs and this has been emphasized during the debriefing sessions as well. The majority of the ATCOs (75%) could also identify easily which aircraft was equipped with ADS-C.

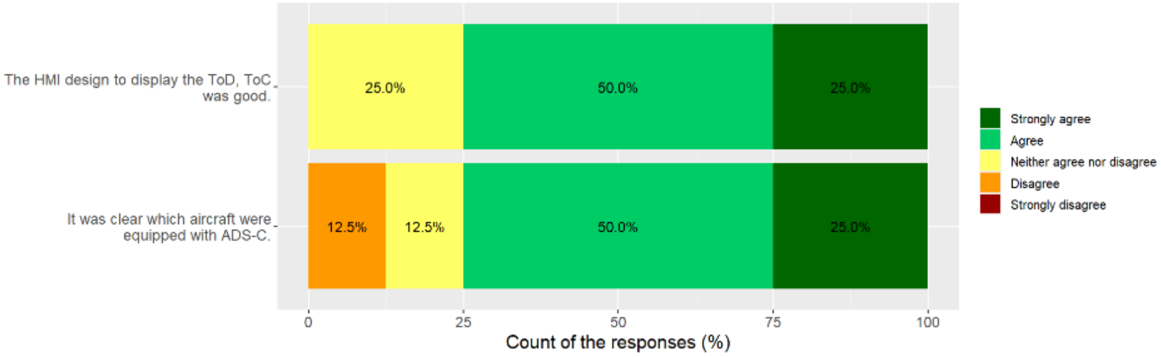


Figure 142: Exercise #08 ADS-C data display results

In general, ATCOs expressed that the most useful EPP information were the ToD, ToC points, speed and the more precise vertical profile calculation.

H.3.2.4.2 CRT-38-W3-DEMOP-024: User acceptance

Success Criteria	Evidence	Decision
The CD&R tools enhanced by ADS-C data are acceptable for the ATCOs.	ATCOs agreed that the display of the ToD, ToC was very useful additional data.	OK

ATCOs had mixed feelings with regards to EPP usefulness. They unanimously agreed that ToC and ToD are really useful information. The EPP could lead to more precise conflict detection and increased the level of safety, since it added another layer of information that they could analyse. Yet all the 4 ATCOs in the second group expressed in the debriefing that they could not identify major difference with regards to EPP.

H.3.2.4.3 CRT-38-W3-DEMOP-025: Trust

Success Criteria	Evidence	Decision
The predictions of the CD&R tool(s) are accurate enough to establish trust in the system. *Solution CRT: The system enhancement allows to establish trust in the system*	ATCOs had a mixed feeling when it comes to trust. There were issues with the assistance and ranking function (e.g. when a conflict occurred, sometimes the offered solution was unrealistic). ATCOs agreed that EPP data has to be 100% accurate all the time for it to be trusted by the ATCO and provide more situational awareness and lighten the workload. The SATI questionnaire reflects these thoughts as well, emphasis being on the reliability and robustness.	Partially OK

The Figure 143 demonstrates the post-simulation survey's SATI questionnaire, which covers several aspects of trust in an (ATM) system. Based on the results it seems that reliability and robustness were among the key factors that caused some difficulties.

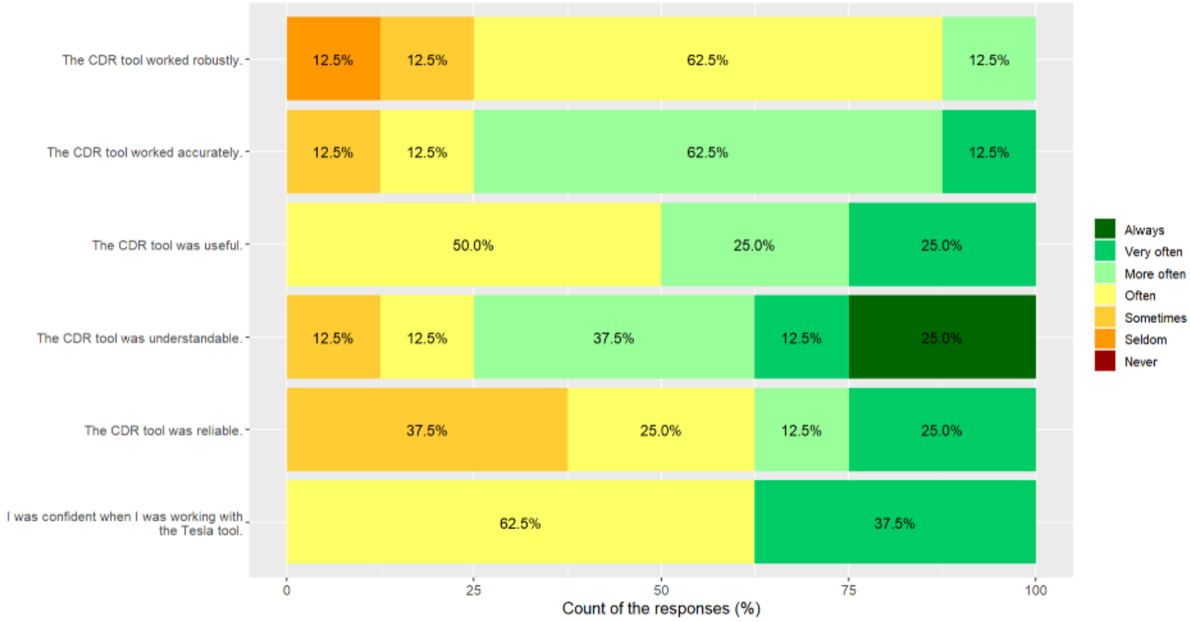


Figure 143: Exercise #08 Trust (SATI) results

In terms of the reliability of the TESLA tool, the vertical profile calculation was usually considered as good. The stability of the assistance function also improved a lot since the first& simulation.

Debriefing sessions touched upon the topic of EPP usefulness and its impact on workload, situational awareness and trust. APP ATCOs thought that whilst it was nice to see what changes EPP would bring to the flight leg, it didn't make the job of separation the aircraft easier and did not improve situational awareness. They said that the trust in the EPP data to be accurate 100% of the time is the most important for the system to be helpful in the controller duties. ACC ATCOs agreed that it has to be 100% accurate all the time for it to be trusted by the ATCO and provide more situational awareness and lighten the workload.

H.3.2.5 EX1-OBJ-38-W3-DEMOP-TECH-0006 Results

From the Tech point of view OBJ-38-W3-DEMOP-TECH-0006 could not be assessed either because of switching to a simulation from a Live VLD scenario, thus the ADS-C datalink could not be analysed whatsoever due to this.

H.3.3 Unexpected Behaviours/Results

There were no unexpected behaviours or results during the simulation.

H.3.4 Confidence in the Demonstration Results

H.3.4.1 Level of significance/limitations of Demonstration Exercise Results

The validation exercise and some parts of the test platform were built with focus on replicating the real-life environment and day to day operations. Therefore:

- Both ENR and TMA sectors were targeted during the validation exercise. In addition, the simulated manipulated the traffic occupancy and complexity in order to test how the enhanced CD&R tools help in different traffic situations.
- Proper communication channels and radio telephony phraseology were used by the ATCOs.
- Licensed and active ATCOs participated in the validation.

On the flip side, the HMI could not have been fully customized to the Hungarian main ATM system, and the sector handover constraints were not taken into account, which deducts from the level of certainty that the results would be entirely representative. Furthermore, the profile calculation was somewhat different to the real-life operation, which led to some unexpected behavior in the resolution advisory. But if the ATCO selected the red value and used extrapolation, he could see the conflict and the flight evolution and that helped understanding the logic implemented in the system.

With regards to the profile with EPP, ATCOs mentioned that they only saw minor differences between the EPP and non-EPP flights. Note, that the profile with EPP was calculated with a different mass and this was the distinguishing factor between non-EPP and EPP flights. Due to this reason the evaluations of each objective have been assessed based on this.

H.3.4.2 Quality of Demonstration Exercise Results

The exercise can report on high quality results with regards to the HMI design of the ADS-C enhanced CD&R tools, obtained via questionnaires and debriefing sessions from 8 operational air traffic controllers. The ACC ATCOs enjoyed working with some of the tools that cannot be found in their current ATM system. The participants also provided useful recommendations for future improvement.

The exercise is less certain in answering the questions of how ADS-C data affects traffic management, as the passive shadow validation could not be conducted.

H.3.4.3 Significance of Demonstration Exercises Results

According to the statistical analysis, no significant differences were observed in the workload and situational awareness values between reference and solution scenarios. The data suggests that ATCOs had acceptable workload and situational awareness levels in both cases, but the scenario with high traffic count and complexity had a major influence on these values.

In terms of operational significance, the simulated environment can be considered representative as the airspace and traffic samples adhere to the real Hungarian en-route and TMA environment (albeit with missing sector handover constraints). All ATCOs were and still are active controllers at HungaroControl. However, the HMI was not fully tailored to the Hungarian main ATM system, which made the interaction with the system more difficult, regardless of the numerous training sessions.

H.4 Conclusions

The following conclusions must be put in context in order to better understand the outcomes: Our exercise was supposed to be a VLD, the systems were developed with an emphasis on the interfaces and the ACS. At the very last moment because of the lack of equipped ADS-C flights it had to be switched to a simulation exercise. The preparation needed to set-up a proper simulation exercise had to be shortened, thus the results regarding the EPP benefits might not be that meaningful.

H.4.1 Conclusions on concept clarification

A possible positive impact of EPP usage on conflict detection was identified by the majority of the ATCOs. Furthermore, they have a positive opinion on the concept itself, but have articulated challenges in usability of the current tool.

The use of the CD&R tool benefits the ATCOs in helping to identify long-term conflicts and also provides suggested solutions, however, there have been discrepancies between the established procedures and the solution advisory of the system.

Areas for further development and fine tuning were identified by the project team and the ATCOs.

H.4.2 Conclusions on technical feasibility

The test platform is built by Airbus DS based on operational requirements provided by BULATSA and HungaroControl. The project team made considerable effort to tune the simulator environment to the Hungarian ATCO's needs, however, the TESLA HMI was still largely different from HungaroControl's main ATM system HMI (i.e. MATIAS).

ATCOs had to get used to the new HMI, which resulted in additional workload, therefore solution advisory provided by the system did not reach its potential full efficiency.

Results show that this functionality – after further development, fine tuning and testing - can be integrated into a generic ATM system. System parameters have to align with specific ATM procedures.

H.4.3 Conclusions on performance assessments

The results of the validation exercise are broken down in accordance with the expected achievements. The exercise organisation and set up allowed to address the following performance areas providing arguments for achieving benefits:

Human Performance

The ATCOs welcomed having information on ToC and ToD on the HMI and could see the positive impact of EPP on conflict detection. They emphasized that the EPP information had to be 100% accurate to establish trust. However, the metrics show no improvement in the situational awareness and workload of the ATCOs and this was further attested by them during the debriefings. ATCOs appreciated the CD&R tool's HMI design.

Operational Efficiency and Environment

Results including logs from GENETICS and TESLA show that the overall track length, fuel consumption and CO2 emission was reduced. In the TMA results are more significant, reaching 4-7% reduction, in En-route track length reduction was noticeable, while fuel consumption and CO2 emission reduction was negligible.

Thanks to the pioneering Free Route Airspace in the Hungarian airspace, the aircraft were already flying their optimal trajectories, which did not require a great number of modifications, resulting in a low number of instructions for aircraft flying in the En-route sectors. This produced a rather constant value for fuel consumption in these sectors.

Capacity

Improvement in situational awareness provided by the CD&R tool was negligible, while more timely conflict resolutions for ATCOs did take place, resulting in increased capacity of both TMA and En-route airspaces.

Safety

Based on the ATCO feedbacks gathered on the debriefings and questionnaires the level of safety can be maintained with the use of the CD&R tool. ATCOs emphasized that however the effects of EPP is difficult to describe but the additional data is definitely a safety improvement. The quantitative results -logging 3 STCAs during the solution scenarios- indicates that the lack of training and the differences to the active operational system has a huge impact on safe service provision.

H.5 Recommendations

H.5.1 Recommendations for industrialization and deployment

How ADC-C data affects traffic management or decision-making should be further assessed in live operational environment, with a sufficient sample size of ADS-C equipped aircraft, and preferably with an ATM system that already has the ADS-C capability and the enhanced CD&R tools integrated to make sure that ATCOs have the capacity to update the trajectories with their clearances.

H.5.2 Recommendations on regulation and standardisation initiatives

None

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Appendix I Demonstration Exercise #09 (EXE-PJ38-4-9 by PANSA) Report

I.1 Summary of the Demonstration Exercise #09 Plan

I.1.1 Exercise description and scope

PANSA exercise is designed to continue the work done under wave 1 project PJ10-02a. The goal is to confirm downlinked EPP ANSP benefits already shown in the PJ10-02a exercises but this time with real ADS-C EPP data (as opposed to simulated data used in previous project).

In this exercise PANSA iTEC platform was fed with pre-recorded ADS-C EPP data associated with pre-built traffic scenarios. The ADS-C EPP data was provided using DFS ADS-C Common Service prototype implementation. Feedback and preliminary evaluation of the prototype ADS-C Common Service is an auxiliary goal associated with the demonstration preparation phase. For this validation PANSA has dedicated two ATCOs.

The expected basic operational scope of this exercise is the confirmation of ADS-C EPP benefits resulting from implementation of the enhanced TP capability in MTCD tool for planner controller. The prototypes for the demonstration were developed by INDRA.

The operational environment of this exercise was carried out simultaneously in sectors from:

- UK – London ACC, Scottish ACC,
- Germany – Karlsruhe ACC.

I.1.2 Summary of Demonstration Exercise #09 Demonstration Objectives and success criteria

Safety improvement (OBJ-38-W3-DEMOP-SAFE-0001): ADS-C data does not deteriorate safety while other aspect of improvement is addressed. For this demonstration objective, the following success criteria were assigned:

- CRT-38-W3-DEMOP-001 - The number of tactical conflict is not increased.
- CRT-38-W3-DEMOP-041 - The working of enhanced CD&R tools was appropriate and supported safe service provision
- CRT-38-W3-DEMOP-043 - ADS-C allows for reduction of potential infringements or resolved earlier.

Human Performance (OBJ-38-W3-DEMOP-HPRF-0002): ADS-C data has a positive impact and improves the Human Performance. For this demonstration objective, the following success criteria were assigned:

- CRT-38-W3-DEMOP-005 - The situation awareness is considered improved by the users

- CRT-38-W3-DEMOP-006 - The use of ADS-C data leads to reduction of ATCO's workload due to reduced radio conversation asking for the aircraft intention.
- CRT-38-W3-DEMOP-010 - The use of ADS-C data provides assistance for user decision in a timely and optimal manner.
- CRT-38-W3-DEMOP-011 - Actual conflicts are detected earlier thanks to enhanced CD&R tool.

  Note: on top of improving Human Performance by giving more time to react to ATCO, this early detection gives the time to take a better decision thus improving Safety or flights efficiency (Performance).
- CRT-38-W3-DEMOP-011 - Actual conflicts are detected earlier thanks to enhanced CD&R tool.

  Note: on top of improving Human Performance by giving more time to react to ATCO, this early detection gives the time to take a better decision thus improving Safety or flights efficiency (Performance).
- CRT-38-W3-DEMOP-012 -The number of spurious detection of conflicts is reduced thanks to enhanced CD&R tool.
- CRT-38-W3-DEMOP-013 - 2D-CC: 2D Consistency check and Conformance monitoring is considered improved by ATCOs.

Operational performance (OBJ-38-W3-DEMOP-OPRF-0003): Use of ADS-C data improves the Operational performance improving reliability of the planned trajectories. For this demonstration objective, the following success criteria were assigned:

- CRT-38-W3-DEMOP-018 - CD&R: The reduced detection uncertainty buffers of the improved CD&R tool MTCD lead to a higher operational performance due to a higher reliability of the planned trajectories.

Operationally feasibility (OBJ-38-W3-DEMOP-OPSF-0004): Use of ADS-C data is Operationally feasible beyond what has been demonstrated in PJ31. For this demonstration objective, the following success criteria were assigned:

- CRT-38-W3-DEMOP-023 - Display: the display of ADS-C data is considered useful by users (e.g. ATCO).
- CRT-38-W3-DEMOP-024 - The CD&R tools enhanced by ADS-C data are acceptable for the ATCOs
- CRT-38-W3-DEMOP-025 - The system enhancement allows to establish trust in the system

Improved data access (OBJ-38-W3-DEMOP-TECH-0006): Use of an ADS-C Common Service improves the access to data

CRT-38-W3-DEMOP-030 - ADS-C periodic, on event contracts are successfully established and maintained by the ADS-C Common Service, and resulting data shared with the clients in due time.

CRT-38-W3-DEMOP-036 - The ADS-C data provision satisfies the operational needs of the clients

I.1.3 Summary of Validation Exercise #09 Demonstration scenarios

During the exercise, the live and pre-recorded data for ADS-C data was used. Over the 3 days ATCOs were observing traffic that was generated live from real traffic that used EPP data. A flight plan was created from first received EPP message, along with information taken from live traffic observation tools (Flight Radar etc.). Then a simulated track was created in the system to represent the flight, each next EPP message was considered by the system as it was sent by that aircraft, enabling the validation process. Based on that possible deviations and benefits coming from the use of the EPP were observed.

I.1.4 Summary of Demonstration Exercise #09 Demonstration Assumptions

There were no new assumptions beyond those identified on Solution level.

I.2 Deviation from the planned activities

During the validation, several deviations from the original plan were taken. First of all, the exercise took place at Indra premises in Madrid. This decision was made due to high risk of significant delay in implementing a stable ADS-C Common Service connection, due to technical issues known to INDRA, which occurred during deployment in DFS, decision was made to utilize existing stable connection. Additionally, instead of using FIR Warszawa airspace, due to not sufficient number of a/c equipped with EPP, it was more beneficial for the exercise to take place in airspace where the EPP data was more available. Therefore, the decision to use the airspace of NATS and DFS.

Due to this changes, we were not able to use ATCOs as initially planned. Instead of managing traffic, ATCOs were only observing traffic and comparing EPP data with real performance. As a result of that the following critaria couldn't be assessed:

- CRT-38-W3-DEMOP-011
- CRT-38-W3-DEMOP-012
- CRT-38-W3-DEMOP-018

I.3 Demonstration Exercise #09 Results

I.3.1 Summary of Demonstration Exercise #09 Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status

EX1-OBJ-38-W3-DEMOP-SAFE-0001	Demonstrate that the use of ADS-C data contributes to improve Safety.	EX1-CRT-38-W3-DEMOP-001	No safety event is added by the ADS-C Display		ATCOs considered that the data provided by the system was reliable and allowed them to perform their tasks without any issues.	OK
EX8-OBJ-38-W3-DEMOP-SAFE-0001	Demonstrate that the use of ADS-C data contributes to improve Safety	EX8-CRT-38-W3-DEMOP-002	The CD&R tools enhanced by the use of additional data with more reliability is adequate for safe service provision according to the ATCOs.			Not covered
EX8-OBJ-38-W3-DEMOP-SAFE-0001	Demonstrate that the use of ADS-C data contributes to improve Safety.	CRT-38-W3-DEMOP-043	Reduction of potential infringements or resolved earlier thanks to the availability of EPP information.		ATCOs agree that data EPP data could be very beneficial for possible conflict detection and resolution.	OK
EX8-OBJ-38-W3-DEMOP-SAFE-0001	Demonstrate that the use of ADS-C data contributes to improve Safety.	CRT-38-W3-DEMOP-041	The working of enhanced CD&R tools was appropriate and supported safe service provision			Not covered

EX8-OBJ-38-W3-DEMOP-HPRF-0002	Demonstrate that the use of ADS-C data improves the Human Performance	EX8-CRT-38-W3-DEMOP-005	The situation awareness is considered improved by the users (e.g. ATCO).		ATCOs considered that the trajectory of the aircraft was relevant as well as EPP information. They indicated that any data reflecting real trajectory of aircraft and thus they increase their situational awareness	OK
EX8-OBJ-38-W3-DEMOP-HPRF-0002	Demonstrate that the use of ADS-C data improves the Human Performance	EX8-CRT-38-W3-DEMOP-006	The use of ADS-C data leads to a reduced ATCO workload due to reduced radio conversation asking for the aircraft intention		ATCOs indicated during debriefing that the use of ADS-C EPP should remove lots of questions about the behavior of aircraft decreasing the amount of discussion with pilots	OK
EX8-OBJ-38-W3-DEMOP-HPRF-0002	Demonstrate that the use of ADS-C data improves the Human Performance	EX8- CRT-38-W3-DEMOP-010	The use of ADS-C data provides assistance for user decision in a timely and		ATCOs considered that ADS-C data were useful to manage the traffic even if some	OK

			optimal manner.		improvements have been discussed as the possibility to have details about the update of EPP.	
EX8-OBJ-38-W3-DEMOP-HPRF-0002	Demonstrate that the use of ADS-C data improves the Human Performance	EX8-CRT-38-W3-DEMOP-011	Actual conflicts are detected earlier thanks to enhanced CD&R tool.			Not covered
EX8-OBJ-38-W3-DEMOP-HPRF-0002	Demonstrate that the use of ADS-C data improves the Human Performance	EX8-CRT-38-W3-DEMOP-012	The number of spurious detection of conflicts is reduced thanks to enhanced CD&R tool.			Not covered
EX8-OBJ-38-W3-DEMOP-HPRF-0002	Demonstrate that the use of ADS-C data improves the Human Performance	EX8-CRT-38-W3-DEMOP-013	D-CC: 2D Consistency check and Conformance monitoring is considered improved by ATCOs.		Further studies where ATCOs would be in charge of the traffic in different situations seem necessary to deeply investigate this point	POK
EX8-OBJ-38-W3-DEMOP-OPRF-0003	Demonstrate that the use of ADS-C data improves the Operational performance	EX8-CRT-38-W3-DEMOP-018	CD&R: The reduced detection uncertainty buffers of the improved CD&R tool			Not covered

			MTCD lead to a higher operational performance due to a higher reliability of the planned trajectories.			
EX8-OBJ-38-W3-DEMOP-OPSF-0004	Demonstrate that the use of ADS-C data is Operationally feasible beyond what has been demonstrated in PJ31 (i.e. highlight 2D consistency check discrepancies)	EX8- CRT-38-W3-DEMOP-023 EPP data: The HMI design supports ATCOs in performing their tasks efficiently and effectively.	Display: the display of ADS-C data is considered useful by users (e.g. ATCO).		ADS-C data allowed ACTOs to perform all of the tasks successfull y	OK
EX8-OBJ-38-W3-DEMOP-OPSF-0004	Demonstrate that the use of ADS-C data is Operationally feasible beyond what has been demonstrated in PJ31 (i.e. highlight 2D consistency check discrepancies)	EX8-CRT-38-W3-DEMOP-024	The CD&R tools enhanced by ADS-C data are acceptable for the ATCOs.		No conflicts were observed during the validation, however, possible gains can be obtained when combining the tool with CD&R	POK
EX8-OBJ-38-W3-DEMOP-OPSF-0004	Demonstrate that the use of ADS-C data is Operationally feasible beyond what has been demonstrated in PJ31 (i.e. highlight 2D consistency check discrepancies)	EX8- CRT-38-W3-DEMOP-025	The system enhancemen t allows to establish trust in the system		The tool has a positive impact on the trust of the system.	OK

EX8-OBJ-38-W3-DEMOP-TECH-0006	Demonstrate that the use of an ADS-C Common Service improves the access to data	EX8-CRT-38-W3-DEMOP-030	ADS-C periodic, on event contracts are successfully established and maintained by the ADS-C Common Service, and resulting data shared with the clients in due time.		Data provided by the system was reliable.	OK

Table 60: Exercise #09 Demonstration Results

I.3.2 Analysis of Exercises Results per Demonstration objective

This exercise has been performed in "real time, It must be noted that the aim for ATCOs was not to manage the traffic, they were only asked to give their feelings about the relevance of aircraft's trajectories and EPP information.

Different means have been used to assess objectives:

- Questionnaire

We have proposed some questions where they had to consider they used the system in real situations to answer.

Questionnaire consists of open questions and statements that participants had to agree/ disagree with on a 5-point Likert scale (1 being "Strongly disagree", 2 – "Disagree", 3 – "Neither disagree or agree", 4 – "Agree", 5 – "Strongly agree").

- Debriefing

At the end of each day, a debriefing with ATCOs and observers was performed to address topics and events which occurred during the sessions.

- ISA (workload) and SASHA (situational awareness)

Given that **ATCOs were not in charge of the traffic**, the workload and the situational awareness were not assessed by specific means like ISA or SASHA. ATCOs were only asked some questions during debriefings to collect some tendencies about their workload and situational awareness as well.

For each Success Criterion identified within the Validation Plan a status has been proposed considering results of the different questionnaires and data collected during debriefing.

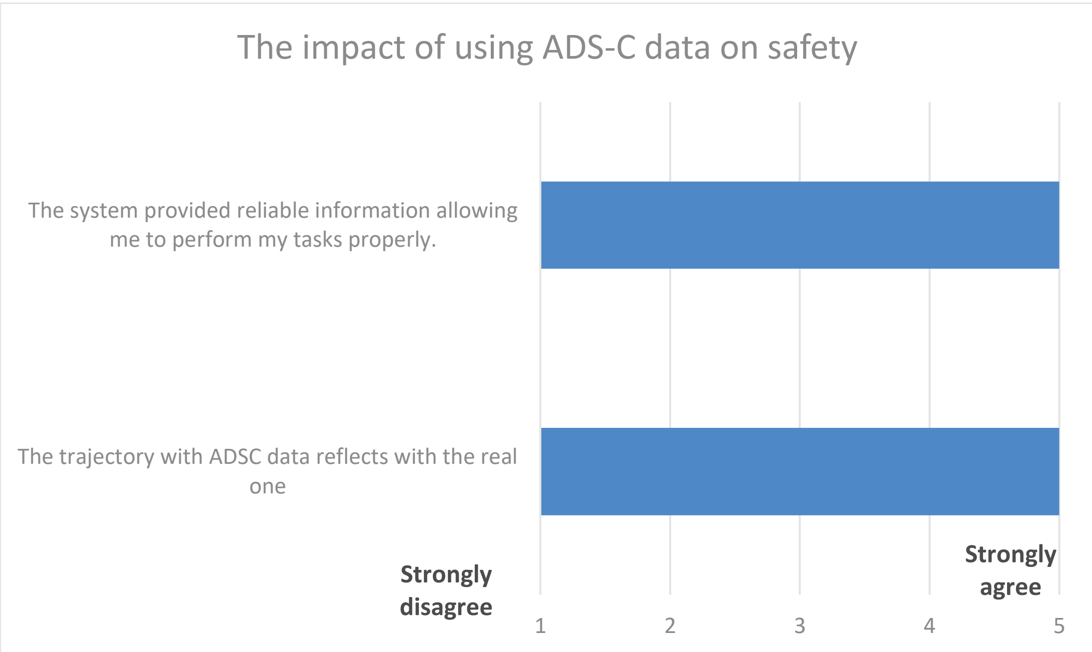
I.3.2.1 EX8-OBJ-38-W3-DEMOP-SAFE-0001 Results

Demonstrate that the use of ADS-C data does not degrade safety.

Questionnaire and debriefing have been used to assess OBJ-38-W3-DEMOP-HPRF-0002

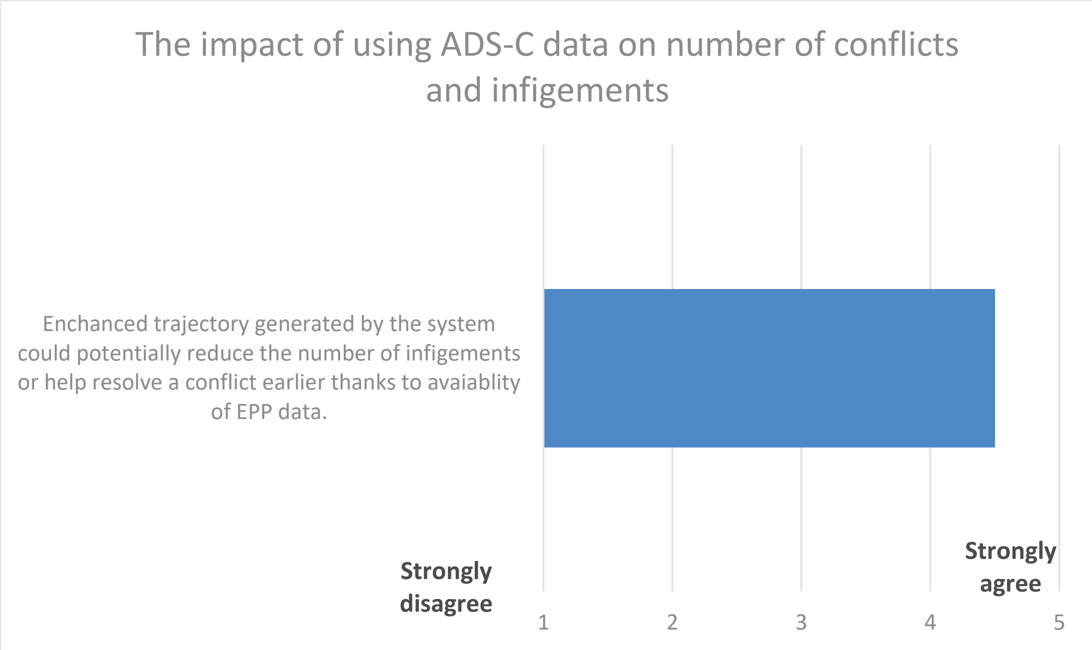
Validation Objective ID	Success Criterion ID	Title of the criterion	Questions	Success Criterion Status
OBJ-38-W3-DEMOP-SAFE-0001	CRT-38-W3-DEMOP-001	No safety event is added by the ADS-C Display	• The system provided reliable information allowing me to perform my tasks properly. • The trajectory with ADSC data reflects with the real one"	OK
OBJ-38-W3-DEMOP-SAFE-0001	CRT-38-W3-DEMOP-043	Reduction of potential infringements or resolved earlier thanks to the availability of EPP information.	• Enchanced trajectory generated by the system could potentially reduce the number of infrigements or help resolve a conflict earlier thanks to availablity of EPP data.	OK

➢ **CRT-38-W3-DEMOP-001**



ATCOs considered that the data provided by the system was reliable and allowed them to perform their tasks without any issues. Strong support in this part reflects possible gains to be achieved from the tool. Especially, mentioned during the debriefing that declared Top od Climb (ToC) was only a few seconds off the real one. Little differences between the tool's data and real performance make the system even more reliable for future operational use.

- **CRT-38-W3-DEMOP-043**



ATCOs agree that data EPP data could be very beneficial for possible conflict detection and resolution. Once combined with a long and medium-term conflict detection tool should provide with many benefits for the end users (ATCOs).

Conclusion of objective “Demonstrate that the use of ADS-C data contributes to improve Safety”:

For all verified criteria, ATCOs identified possible benefits for usage of ADS-C data in the future especially by CD&R tools. During debriefing they pointed to the accurate data from EPP available without requesting any information from the a/c, being available at their disposal in the system. Additional gains can come from further implementing the tool with already available MTCD and LTCD tools.

I.3.2.2 EX8-OBJ-38-W3-DEMOP-HPRF-0002 Results

Demonstrate that the use of ADS-C data improves the Human Performance

Questionnaire and debriefing have been used to assess OBJ-38-W3-DEMOP-HPRF-0002.

- **Questions asked according success Criterion**

Validation Objective ID	Success Criterion ID	Title of the criterion	Questions	Success Criterion Status

OBJ-38-W3-DEMOP-HPRF-0002	CRT-38-W3-DEMOP-005	The situation awareness is considered improved by the users (e.g. ATCO).	• You do not identify elements that could have decreased ATCOs' situational awareness in an unacceptable way • The use of ADS-C data's information by the system could increase ATCOs' situational awareness	OK
OBJ-38-W3-DEMOP-HPRF-0002	CRT-38-W3-DEMOP-006	The use of ADS-C data leads to a reduced ATCO workload due to reduced radio conversation asking for the aircraft intention .	• The use of ADS-C data's information by the system could lead to a decrease of your workload by reducing radio conversation asking for the aircraft intention	OK
OBJ-38-W3-DEMOP-HPRF-0002	CRT-38-W3-DEMOP-010	The use of ADS-C data provides assistance for user decision in a timely and optimal manner.	• The use of ADS-C data's information by the system could have provided assistance to take your decision in a timely and optimal manner. • You do not identify situations that could led to a loss of confidence to the system's functionalities • The use of ADS-C data's information by the system in solution scenario would not decrease your job's satisfaction	OK
OBJ-38-W3-DEMOP-HPRF-0002	CRT-38-W3-DEMOP-013	2D-CC: 2D Consistency check and Conformance monitoring is considered improved by ATCOs.	• The use of ADS-C data's information by the system could allowed you to better anticipate the behaviour of the aircraft in solution scenario	POK

Table 61: OBJ-38-W3-DEMOP-HPRF-0002 "Demonstrate that the use of ADS-C data improves the Human Performance"

➢ **CRT-38-W3-DEMOP-005 and CRT-38-W3-DEMOP-013**

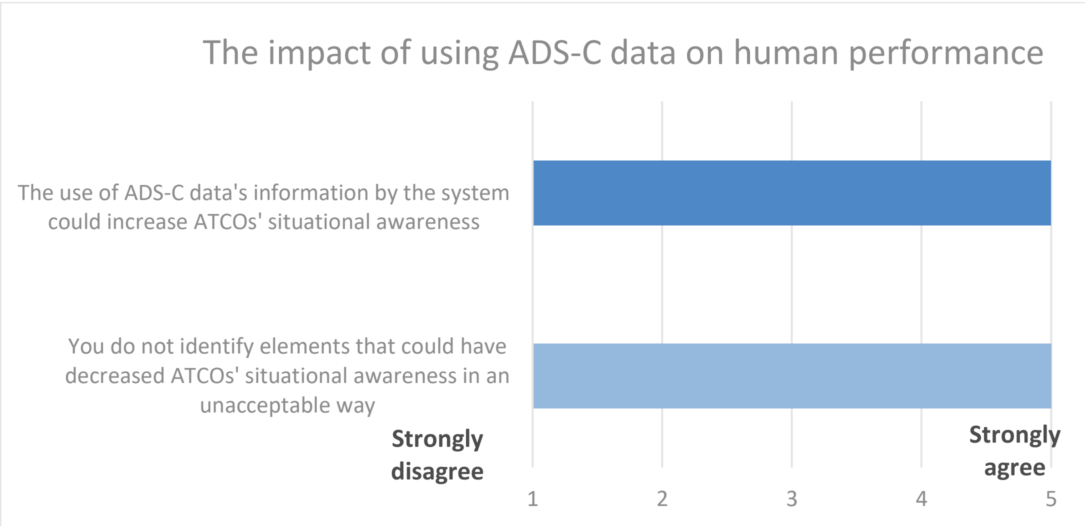


Figure 144: The impact of using ADS-C data on human performance

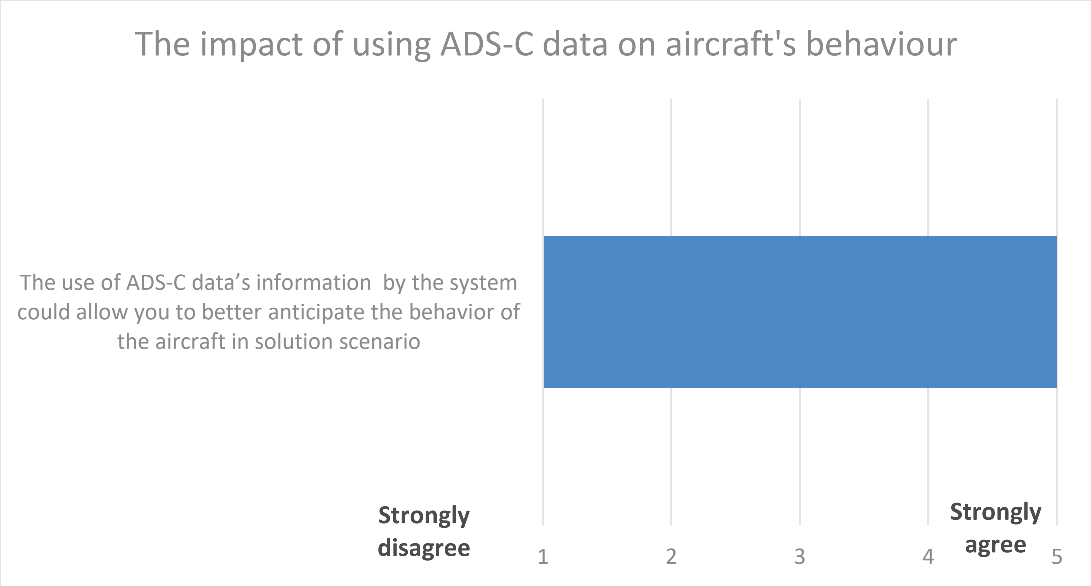


Figure 145: The impact of using ADS-C data on aircraft's behaviour

ATCOs considered that the trajectories of the aircraft with EPP information had a positive impact on situation awareness. They indicated that any data reflected real trajectories of aircraft and thus they increased their situational awareness. Moreover, ATCOs said that information about aircraft trajectories could also decrease their workload as they could plan conflict resolution earlier. Nevertheless, during debriefing ATCOs reported that it would be interesting to have details about the update of the TP. Indeed, in some cases, knowing whether the TP had just been updated or a few minutes before could impact the way to analyze the situation. Similarly, ATCOs indicated that having the possibility to get the accuracy of the TP would be very useful.

Regarding particularly the 2D Consistency check, if ATCOs considered that it could be helpful, we had no cases during the experimentation to validate its added value. Further studies where ATCOs would be in charge of the traffic in different situations seem necessary to deeply investigate this point.

- **CRT-38-W3-DEMOP-006**

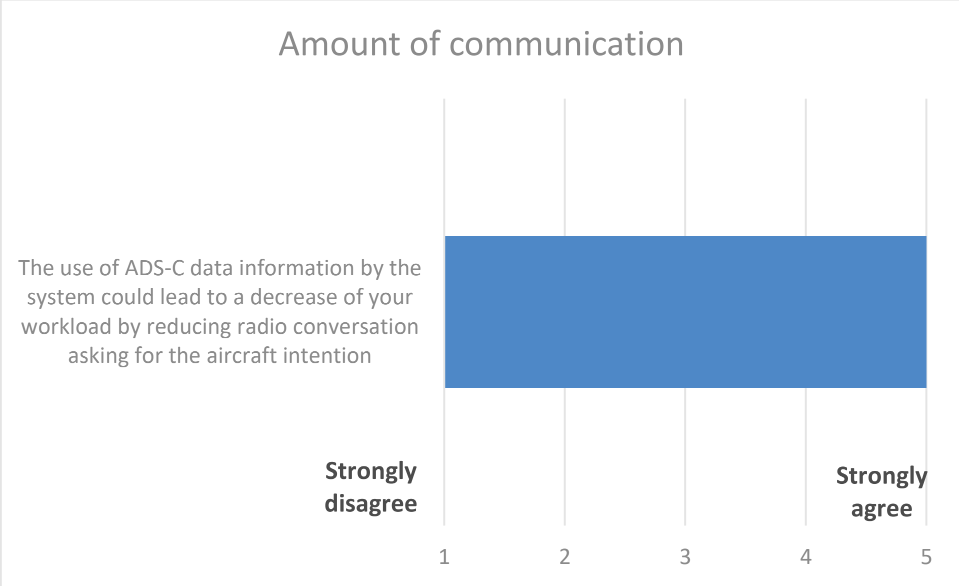


Figure 146: Amount of communication

ATCOs confirmed that having EPP information and aircraft trajectories should decrease the amount of communication with pilots. ATCOs indicated during debriefings that it would be quicker to check TOD or intended speed by looking in the EPP table rather than asking the pilot. More generally, knowing the aircraft speed during specific phases (cruise, climb or descent phases) could lead to a decrease in communication with pilots and thus a decrease of workload. The use of ADS-C EPP should remove lots of questions about aircraft distance to TOD.

On the contrary, it has been discussed during debriefing whether the availability of new information like EPP could not increase the workload. ATCOs concluded that they will only look for EPP when necessary and that consequently it was not an issue.

- **CRT-38-W3-DEMOP-010**

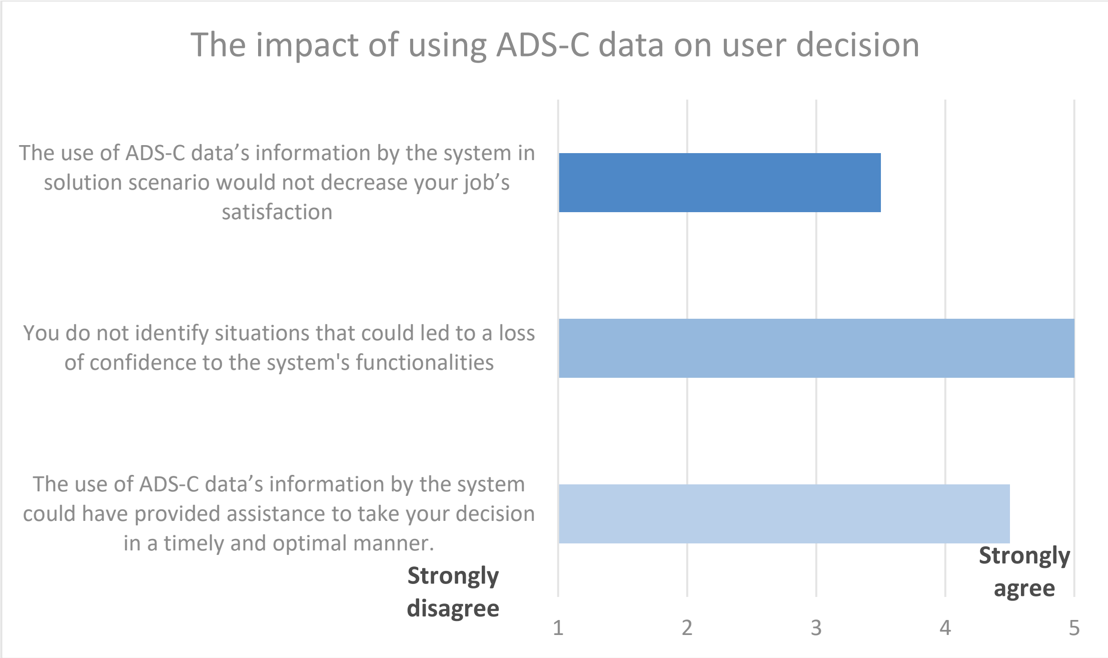


Figure 147: The impact of using ADS-C data on user decision

ATCOs considered that ADS-C data were useful to manage the traffic even if one reported some missing data. For instance, during the climb phase of flight, ATCO reported that having information only about crossover altitude and top of climb were not sufficient enough. Indeed, there is no possibility to check estimated altitude before the Top Of Climb because there is no navigational point between the current position of the aircraft and TOC. ATCO added that having the possibility to check estimated FL at any moment could be very useful as well.

Regarding the job's satisfaction, one ATCO considered that having ADS-C data improved it whereas the other one considered that ADS-C data decreased his satisfaction. Indeed, he indicated during debriefing that the use of data could reduce the role of ATCOs in conflict detection and resolution and could therefore leads ATCOs to a feeling of being more passive.

- **CRT-38-W3-DEMOP-011 and CRT-38-W3-DEMOP-012**

During experimentation, only few aircraft were assessed and displayed on the radar screen and thus no conflict could occur. For these reasons, these two criteria have been removed from the analyses.

Conclusion of objective “Demonstrate that the use of ADS-C data improves the Human Performance”:

ATCOs considered that the trajectories of the aircraft were relevant as well as EPP information, even if some improvements, like the possibility to have details about the update of EPP, have been discussed. ATCOs indicated during debriefing that the use of ADS-C EPP should remove lots of questions about the behavior of aircraft thus decreasing the amount of discussion with pilots. Globally, they thought that information could increase their situational awareness and decrease their workload. Regarding the job's satisfaction, results were mixed with one ATCO who considered that having ADS-C data improved his satisfaction whereas the other one considered that it could lead to a feeling of being more passive. To conclude, the behavior of conflict detection tools could not be assessed because of the set-up of the experimentation.

I.3.2.3 EX8-OBJ-38-W3-DEMOP-OPRF-0003 Results

Validation Objective ID	Success Criterion ID	Title of the criterion	Questions	Success Criterion Status
OBJ-38-W3-DEMOP-OPRF-0003	CRT-38-W3-DEMOP-018	CD&R: The reduced detection uncertainty buffers of the improved CD&R tool MTCD lead to a higher operational performance due to a higher reliability of the planned trajectories.	• N/A (no conflicts during validation)	N/A

I.3.2.4 EX1-OBJ-38-W3-DEMOP-OPSF-0004 Results

Validation Objective ID	Success Criterion ID	Title of the criterion	Questions	Success Criterion Status
OBJ-38-W3-DEMOP-OPSF-0004	CRT-38-W3-DEMOP-023	Display: the display of ADS-C data is considered useful by users (e.g. ATCO).	The data displayed by the system could allow me to perform my tasks properly.	OK
OBJ-38-W3-DEMOP-OPSF-0004	CRT-38-W3-DEMOP-024	The CD&R tools enhanced by ADS-C data are acceptable for the ATCOs.	• Use of CD&R tools enhanced by ADS-C is acceptable by the end users (ATCO)	POK
OBJ-38-W3-DEMOP-OPSF-0004	CRT-38-W3-DEMOP-025	The system enhancement allows to establish trust in the system	• The data displayed inspires confidence in the system	OK

CRT-38-W3-DEMOP-023,

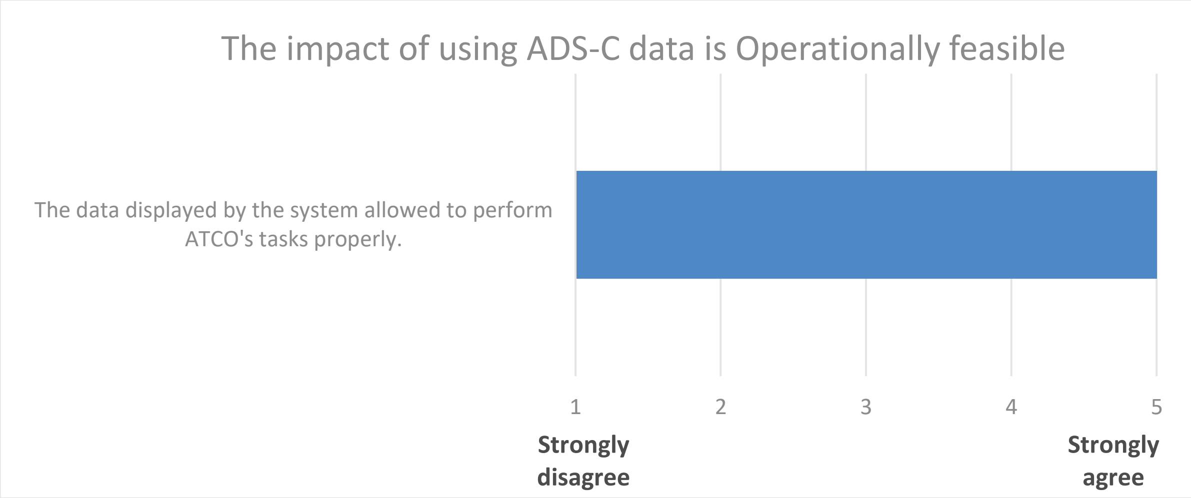


Figure 148 The impact of using ADS-C data is Operationally feasible

ATCOs strongly agreed that ADS-C data allowed them to perform all of the tasks successfully. They confirmed that the data was easy to access and performing theirs tasks.

- **CRT-38-W3-DEMOP-024**

Similar to CRT-38-W3-DEMOP-011 and CRT-38-W3-DEMOP-012 because during exercise, only few aircraft were displayed on the radar screen no conflict could occur. For these reasons, this criteria have been removed from the analyses.

- **CRT-38-W3-DEMOP-025**

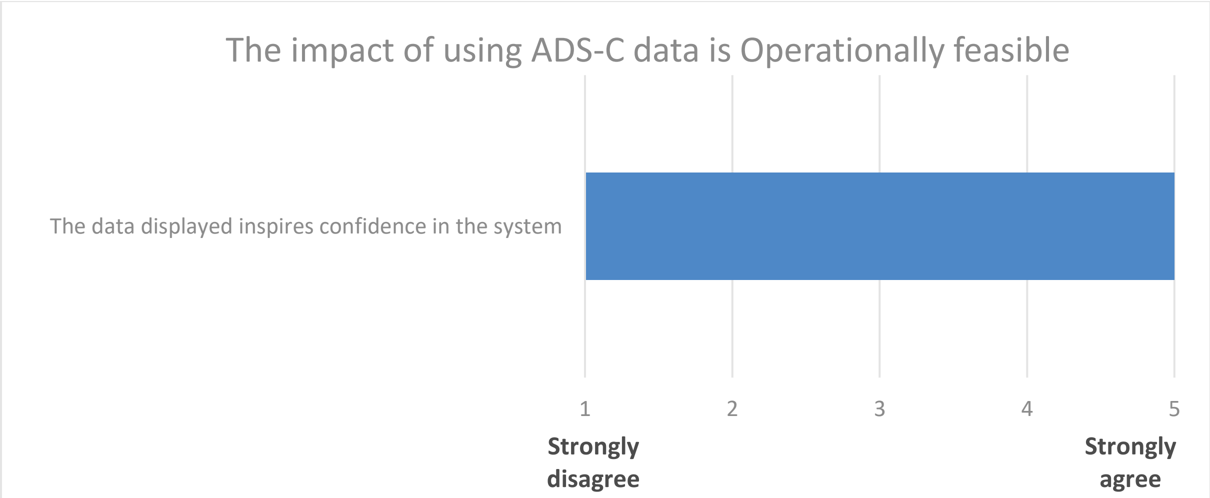


Figure 149 The impact of using ADS-C data is Operationally feasible

ATCOs strongly agreed with the positive impact of the tool. Data display is acceptable and very high precision is appreciated. They have also mentioned that some additional changes may be needed to optimize the tool on the HMI for more comfortable use.

Conclusion of objective "Demonstrate that the use of ADS-C data is Operationally feasible beyond what has been demonstrated in PJ31 (i.e. highlight 2D consistency check discrepancies)":

ATCOs considered that the trajectories and the data displayed would allow them to perform their responsibilities with some benefits when the tool gets more mature and optimized. During debriefing, ATCOs stated that as some additional work may be needed the general outcome is positive.

I.3.2.5 EX8-OBJ-38-W3-DEMOP-TECH-0006 Results

Validation Objective ID	Success Criterion ID	Title of the criterion	Questions	Success Criterion Status
OBJ-38-W3-DEMOP-TECH-0006	CRT-38-W3-DEMOP-030	ADS-C periodic, on event contracts are successfully established and maintained by the ADS-C Common Service, and resulting data shared with the clients in due time.	Data provided by the ADS-C is reliable	OK

➢ **CRT-38-W3-DEMOP-030**

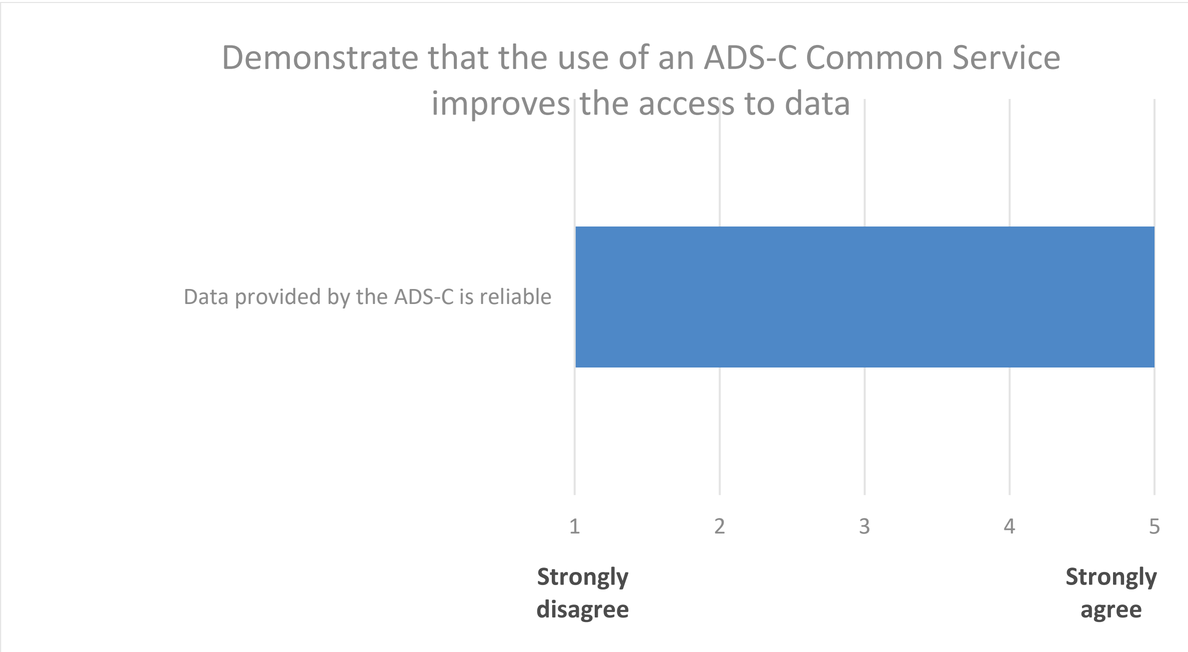


Figure 150 Demonstrate that the use of an ADS-C Common Service improves the access to data

ATCOs have stated that the data provided by the system is reliable as it was observed during the exercise on the display screen of the simulation and confirmed using another platform. In these few samples that were in line with the simulator and in real life, they were able to confirm that the displayed data and prediction were in line with the real performance.

Conclusion of objective “Demonstrate that the use of an ADS-C Common Service improves the access to data”:

Despite the fact that validation was performed in a different way than initially planned, during the exercise ATCOs were able to confirm that for several of the a/c data provided by the system were similar to real-life performance. Taking this into consideration, the tool was met with positive feedback for ATCOs in this aspect.

I.3.3 Unexpected Behaviours/Results

None were observed.

I.3.4 Confidence in the Demonstration Results

I.3.4.1 Level of significance/limitations of Demonstration Exercise Results

Some limitations that reduced the level of significance of validation results were observed. The most crucial was the above-mentioned low level of traffic valid for these exercises - a/c used for validation were a copy of a real a/c to a simulation environment with all the data it broadcasts. Once copied to the simulation ACTOs couldn’t make any changes to the a/c, therefore if in real life, ATCO has issued a different clearance than in the FPL, that a/c would not be used for validation process. This issue significantly decreased the amount of a/c available for validation.

Additionally, no emergency or abnormal situations were addressed in the validation.

Nevertheless, the traffic used was a copy of real-time traffic from NATS and DFS airspaces of responsibility giving a highly realistic view of the use of EPP by a/c.

Taking all of the mentioned above into account, as the tool was not fully tested (especially the lack of possible emergency situations), some of its results can be extrapolated to the operational environment nevertheless additional testing shall be arranged to address the missing part.

I.3.4.2 Quality of Demonstration Exercise Results

The quality of the validation results is determined as medium due to the following:

- Experienced controllers with appropriate ratings participated in the validation exercise.
- It wasn’t possible to actively control the traffic and observe changes (ATCOs during validation were not aware of any clearance changes given by ATCOs from NATS or DFS).

I.3.4.3 Significance of Demonstration Exercises Results

As described above, some limitations that reduced the level of significance of validation exercise results were observed. The limited number of a/c sending the necessary information as well as the fact that ATCOs couldn't actively manage the traffic limited the operational significance of the analyzed results.

Nevertheless, for a/c that can be counted as valid for the exercise, ATCOs identified several positive aspects of the tool that when mature could bring significant benefits.

I.4 Conclusions

Following the assessment of success criteria linked to each exercise-level objective they were either satisfied or not verified during the validation.

First of all – data provided by the system was in the eyes of the ATCOs valid, true to life, and possibly bringing benefits in the future. As observed during the validation, especially values like ToC will bring beneficial information to ATCOs without the need to use voice communication. Tools like medium and long-term conflict detection might greatly benefit from incorporating data from EPP.

The second aspect is that the impact on the HP is either neutral or positive showing a slightly positive impact overall. The ATCOs were using the tool for the first time however the tool seemed intuitive they felt expressed a possible interest of using it in the future.

In the aspects of operational feasibility, it was determined that the information provided can be helpful in building the situation awareness of ATCOs and reducing radio communication.

I.5 Recommendations

I.5.1 Recommendations for industrialization and deployment

Before deployment, the tool has to be tested on real traffic, for example in a shadow mode environment to determine its operational use in real-life scenario especially in:

- Emergency situation
- Airspace with high density traffic

I.5.2 Recommendations on regulation and standardisation initiatives

Appendix J Demonstration Exercise #10 (EXE-PJ38-6-1 by Honeywell) Report

J.1 Summary of the Demonstration Exercise #10 Plan

J.1.1 Exercise description and scope

The exercise was planned to validate interoperability and performance of the following features implemented in the Honeywell's avionics hosted on the Embraer E170 test aircraft with the existing European B2 ADS-C infrastructure using the Inmarsat's SB-S ATN/OSI service:

- B2 ADS-C v1 (including EPP downlink)
- ATN/OSI dual link using Iris SATCOM and VDL2

The validation campaign was planned to consist of roughly 2 weeks of the test aircraft's operations in European airspace. It aimed to validate performance during standard En-Route operations but also during other phases of flight. The campaign was planned to include flights in busy core Europe areas, but also in areas near the edge of the GEO SATCOM coverage.

J.1.2 Summary of Demonstration Exercise #10 Demonstration Objectives and success criteria

EXE#10 Demonstration Objective	EXE#10 Demonstration Success criteria ID	Success criterion	Coverage
OBJ-38-W3-DEMOP-TECH-0007	CRT-38-W3-DEMOP-038	End-to-End performance measures match with published SPR.	Fully covered
OBJ-38-W3-DEMOP-TECH-0007	CRT-38-W3-DEMOP-039	Demonstrate ATN/OSI dual link (Iris SATCOM and VDL2) performance with test aircraft avionics	Fully covered
OBJ-38-W3-DEMOP-TECH-0007	CRT-38-W3-DEMOP-040	Demonstrate B2 ADS-C v1 interoperability with test aircraft avionics.	Fully covered

Table 62: Demonstration Objectives applicable to EXE-PJ38-6-1 per Demonstration Plan

J.1.3 Summary of Validation Exercise #10 Demonstration scenarios

Per the demonstration plan the exercise scenario infrastructure consists of the following key elements:

- Honeywell's test aircraft (Embraer E170, tail number N170EH):
    - B2 ADS-C v1 (with retained CPDLC v1 capability) implemented in the Honeywell's NGFMS
    - Honeywell's Aspire 400 SATCOM terminal (AES) featuring the Inmarsat SB-Safety services including ATN/OSI.
    - ATN/OSI dual link capability implemented in Honeywell's CMF. (Initial version with downlink preferences configurable in the aircraft.)

- Inmarsat's BGAN network with overlaid SB-Safety services:
  - I4 satellites (nominally the Alphasat satellite when flying in Europe)
  - Ground infrastructure including Ground Earth Station (GES) and the "AeroRack" containing SB-Safety gateways and the ATN/OSI Air-Ground Router (AGR)
- SITA's VDL2 infrastructure:
  - VHF Ground Stations (VGS)
  - Air Ground Router (AGR)
- SITA's ATN operational ground infrastructure.
- ATN ground end systems:
  - Test end systems enabling validation of B2 ADS-C and CPDLC as well as B1 CPDLC
  - Operational end systems using B1 CPDLC.

The exercise setup is illustrated in Figure 151.

The Collins' VDL2 infrastructure also shown in the figure was not used in the exercise execution.

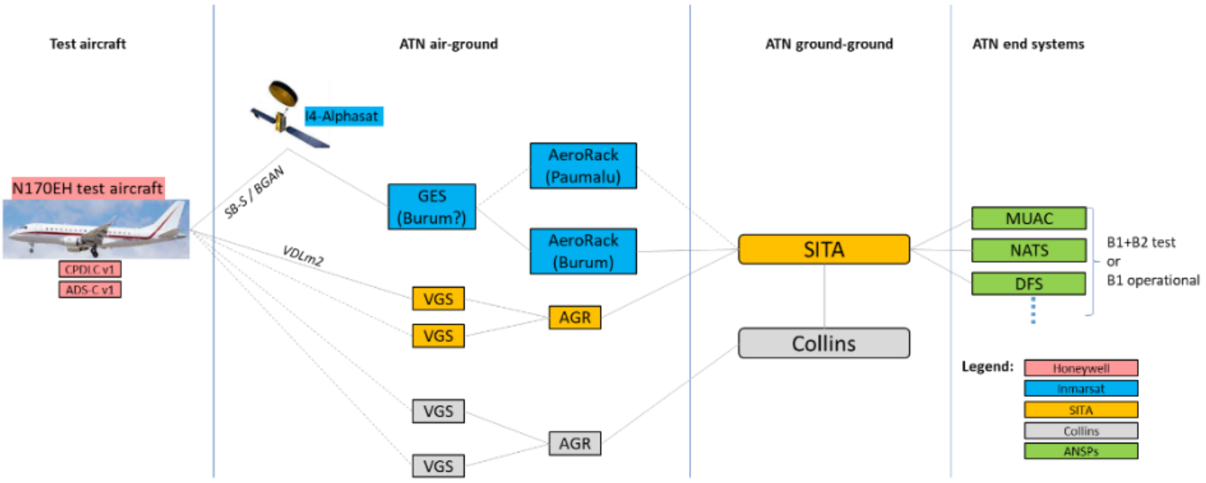


Figure 151: EXE-PJ38-6-1 scenario (EPP over ATN/OSI dual link with Honeywell's test aircraft)

J.1.4 Summary of Demonstration Exercise #10 Demonstration Assumptions

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
PJ38-ASS-05				See common assumptions in the main body of this report.	
PJ38-ASS-06				See common assumptions in the main body of this report.	
PJ38-EX10-ASS-01	SATCOM primary		Flight tests will be executed with SATCOM set as the preferred link. (I.e. SATCOM is used for all ATN uplinks and downlinks, whenever the connection over SATCOM is available.)	Validation of SATCOM performance is one of the main objectives of this campaign. In longer term, having SATCOM as primary is also the only way to alleviate the VHF congestion. Furthermore, loss of VDL when VDL is set as primary will result in Provider Abort within the current network.	No significant impact
PJ38-EX10-ASS-02	SITA's direct involvement		SITA's direct involvement will not be necessary to support troubleshooting or analysis of a CSP-specific issues.	The ATN/OSI dual link via SITA operational ATN infrastructure is in place and has been validated under ESA Iris. Therefore, absence of SITA in the PJ38 consortium should not cause any issues.	No impact if the assumption holds.

Table 63: Exercise #10 Demonstration Assumptions overview

J.2 Deviation from the planned activities

The plan for this campaign was to fly Honeywell's test aircraft from US to Europe and spend roughly 55 flight hours in European airspace, covering primarily busy core Europe (Germany, UK, Netherlands, France…) and northern Europe (Iceland, Scandinavia).

Unfortunately, due to major aircraft failures unrelated to this project (broken windshield and malfunctioned landing gear) the aircraft had to stay grounded most of the time after arrival to Oslo

(Norway). As a result, the aircraft spent only slightly over 16 flight hours between Iceland and Scandinavia with no flights in core Europe. Even with this limited scope, the campaign still provided lots of useful data and the results are presented in the following subsections of this appendix.

J.3 Demonstration Exercise #10 Results

J.3.1 Summary of Demonstration Exercise #10 Demonstration Results

This exercise was linked to single demonstration objective and three success criteria. The overall results per criterion are summarized in the table below and detailed in the following sections. Because the scope of this exercise was limited to Honeywell's avionics and because the flight test campaign was limited due to the aircraft problems, **the exercise by itself does not fully demonstrate fulfilment of the applicable success criteria but rather contributes to their fulfilment**.

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-38-W3-DEMOP-TECH-0007	Availability of multilink via SATCOM	CRT-38-W3-DEMOP-038	End-to-End performance measures match with published SPR.		Measured 1-way latencies over SATCOM comply with applicable RSP-160 targets.	OK
		CRT-38-W3-DEMOP-039	Demonstrate ATN/OSI dual link (Iris SATCOM and VDL2) performance with test aircraft avionics		Failover from SATCOM (preferred) to VDL2 (backup) and recovery back to SATCOM was tested in flight and on the ground.	OK
		CRT-38-W3-DEMOP-040	Demonstrate B2 ADS-C v1 interoperability with test aircraft avionics.		All types of contracts (periodic, demand, event) and different types of report (icl. EPP) were tested in flight.	OK

Table 64: Exercise #10 Demonstration Results

Co-funded by the European Union

J.3.2 Analysis of Exercises Results per Demonstration objective

J.3.2.1 EX10-OBJ-38-W3-DEMOP-TECH-0007 Results

J.3.2.1.1 CRT-38-W3-DEMOP-038 – SATCOM link performance

With respect to the performance criterion CRT-38-W3-DEMOP-038, the main objective of the exercise was to demonstrate that the Inmarsat SB-S ATN/OSI service can meet the apportioned 1-way RSTP latency targets, i.e. $RSTP_{SSP}$ from the Figure 152.

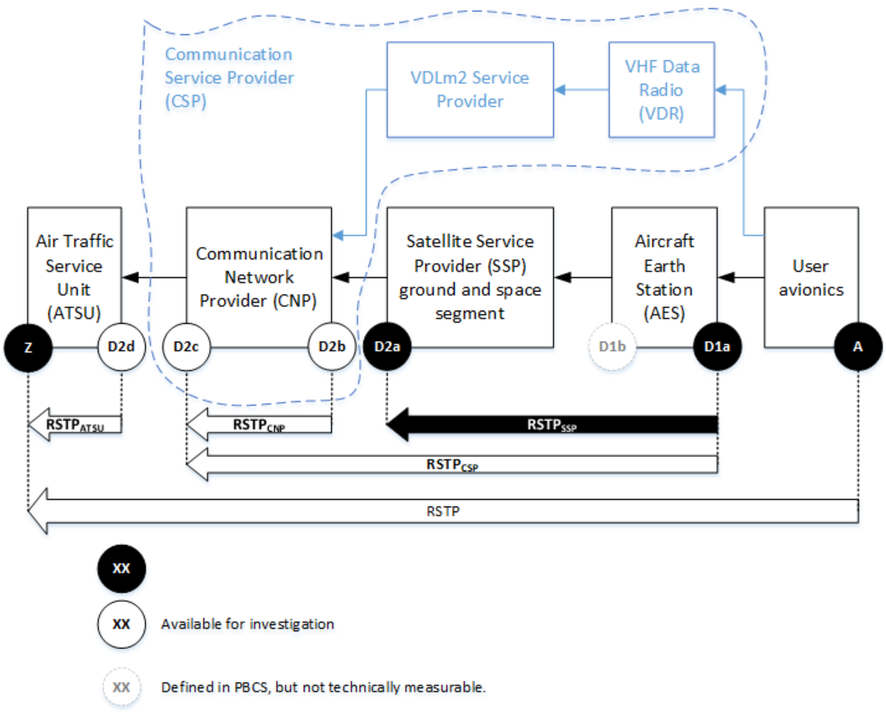


Figure 152: RSP apportionments and measurement points

Within the delineated $RSTP_{SSP}$ segment, the ADS-C reports are carried by AAP, i.e. the bespoke SB-S transport protocol used for tunnelling of ATN/OSI CLNP packets across the Inmarsat IPv4 BGAN network. Majority of the AAP data used for the analysis was collected during the following test flights when periodic EPP reports were activated:

- Oslo – (loop up to 69.8deg north) – Helsinki [12-Nov-2021 8:12-11:59 UTC]
- Helsinki – Oslo [12-Nov-2021 12:14-13:54 UTC]
- Oslo – (loop up to 67deg north) – Oslo [12-Nov-2021 15:19-18:00 UTC]
- Oslo – Copenhagen [13-Nov-2021 10:11-11:20 UTC]

Additional data were collected during transatlantic flights between Goose Bay (Canada), Keflavik (Iceland) and Oslo (Norway), where periodic EPP reports were active during portions of some flights and where FANS 1/A+ was used for operational purposes using the same SATCOM link.

The collected AAP traffic logs contained 4,886 downlink messages out of which 2,456 were delivered on the ground in between flights and 2,430 in flight. The AAP messages can carry B2 ADS-C reports, FANS 1/A+ messages or ACARS and ATN/OSI signalling. From AAP perspective all these types of data

 Co-funded by the European Union

are treated the same way, therefore all the captured messages can be used for the SATCOM link performance analysis.

The results of the analysis are presented in the table below, where the measured 95% and 99.9% AAP downlink latencies are compared to the applicable $RSTP_{CSP}$ limits. (Because apportionment between CSP and SSP has not been formally agreed, only the CSP limit is shown.)

$RSTP_{CSP}$ limits	95% <5sec	99.9% <12sec	Notes
Including all messages	PASS 95% < 2.3 sec	FAIL 99.2% at 12 sec	Out of the 4,886 logged messages 38 (i.e. 0.8%) exceeded the 12 sec latency limit. Nevertheless, all these messages were associated to one of the following non-nominal conditions: • Satellite switch-over above Greenland • Taxiing in Keflavik (Iceland) • Departure from Keflavik (Iceland) Because these are all expectable events at very low satellite elevations it is considered legitimate to exclude them from the statistics.
Excluding messages delayed due to known non-nominal conditions	PASS 95% < 2 sec	PASS 99.9% < 9.4 sec	

Table 65: EXE-PJ38-6-1 SATCOM performance results summary (CRT-38-W3-DEMOP-038)

As explained in the table above, all the excessively delayed AAP downlink messages can be attributed to well understood non-nominal conditions and therefore SATCOM performance is considered as compliant with the RSP-160 latency requirements and the criteria is assessed as PASSED.

To complement the $RSTP_{SSP}$ analysis, the ground-ground latency from the Inmarsat's ground gateway to the ANSP end system was analysed (i.e. approx. from D2a to Z in Figure 152). This observed latency was consistently below 0.2 seconds and thereby practically negligible compared to the end-to-end latency. This can be seen in Figure 153, where the SSP latency (D1a to D2a) is shown together with the combined SSP + CNP + ATSU latency (D1a to Z). The figure is based on a sample of 300 periodic EPP reports delivered during to the Eurocontrol's ATC test system (LFPYADSC) during one of the northwards flights from Oslo on 12th of November 2021.

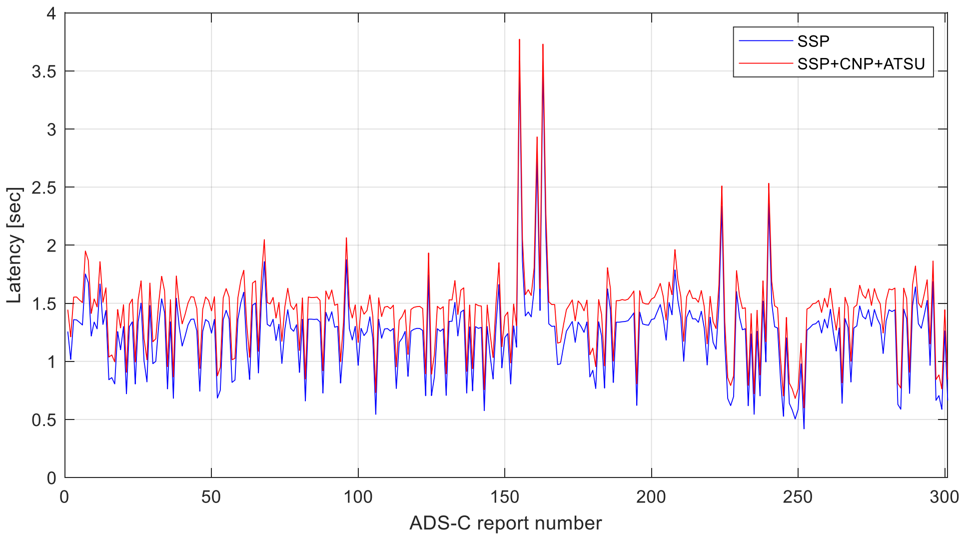


Figure 153: Contribution of ground-ground infrastructure to the end-to-end latency

J.3.2.1.2 CRT-38-W3-DEMOP-039 – ATN/OSI dual link

The ATN/OSI dual link testing was planned to be executed later in the campaign during operations in core Europe. Nevertheless, as already explained, the campaign had to be terminated early due to aircraft problems unrelated to this project. Only one informal but successful test was thus performed while the aircraft was on the ground in Oslo:

- Periodic EPP contract was established with SATCOM and VDL2 links available. Because SATCOM was set as preferred during the whole campaign, the reports were being delivered over SATCOM.
- After several reports were delivered over SATCOM, the AES was manually logged off.
- CMF detected loss of SATCOM and immediately redirected all ATN/OSI downlink traffic to VDL2.
- After few ADS-C reports were delivered over VDL2, the AES logon was enabled again.
- When the SATCOM link recovered, the CMF redirected ATN/OSI traffic back to SATCOM and ADS-C reports continued to be delivered over SATCOM.
- No ADS-C report loss or excessive delay was detected.

Because this test was not meant to be formal, no logs were captured. For reference, results of similar test performed during earlier flight test campaign in Seattle/US on 4th of August 2021 are shown below.

<table>
<tr><th>Periodic report received at LFPYEDTA</th><th>AAP downlink messages logged by SATCOM ground datalink gateway</th></tr>
<tr><td>08:39:14.355</td><td>8:39:14.253</td></tr>
<tr><td>08:39:45.165</td><td>8:39:45.064</td></tr>
<tr><td>08:40:16.811</td><td>8:40:16.710</td></tr>
<tr><td>08:40:45.064</td><td>8:40:44.964</td></tr>
<tr><td>08:41:15.076</td><td>8:41:14.976</td></tr>
<tr><td>08:41:44.835</td><td rowspan="8">Logoff request from aircraft received at 8:41:26.0

NO SATCOM LINK → reports received by LFPYEDTA delivered over VDL2

Logoff request from aircraft received at 8:45:16.1</td></tr>
<tr><td>08:42:14.598</td></tr>
<tr><td>08:42:44.486</td></tr>
<tr><td>08:43:14.616</td></tr>
<tr><td>08:43:44.568</td></tr>
<tr><td>08:44:14.569</td></tr>
<tr><td>08:44:44.570</td></tr>
<tr><td>08:45:14.600</td></tr>
<tr><td>08:45:45.280</td><td>8:45:45.178</td></tr>
<tr><td>08:46:15.162</td><td>8:46:15.061</td></tr>
<tr><td>08:46:45.144</td><td>8:46:45.043</td></tr>
</table>

08:47:14.349	8:47:14.244

Table 66: SATCOM-VDL failover during Honeywell's US flight test campaign

J.3.2.1.3 CRT-38-W3-DEMOP-040 – B2 ADS-C interoperability

The B2 ADS-C application implemented in the Honeywell's NGFMS avionics and used during the flight campaign is an initial prototype with known limitations. This prototype was rather an enabler for SATCOM performance testing than a subject of the test, nevertheless, extensive functional tests were performed during and before the flight campaign to demonstrate the interoperability. This included:

- Successful establishment and termination of all types of contracts (demand, event, periodic).
- Successful establishment of different types of reports (EPP, ground speed, air speed etc.).
- Successful testing of different types of events for the event contracts.
- Successful testing with different ATC test systems (MUAC, Eurocontrol, DFS, SITA)

J.3.3 Unexpected Behaviours/Results

No unexpected behaviours or results related to the SATCOM link or the ATN/OSI dual link were observed during the campaign. Several link interruptions and excessive downlink message delays were identified in the logs, nevertheless all of them were related to one of the following:

- Non-nominal scenarios at very low satellite elevations, such as departure from Iceland or satellite switchover near Greenland.
- Test engineer's intervention, such as manual SDU reset or logoff.
- Known SDU software bug.

Some unexpected behaviours related to the B2 ADS-C application prototype were observed, including "impolite" termination of the ADS-C contract at the end of the flight (terminated without notifying ground) or unreliable manually triggered user abort from the air side. The issues are well understood and will be fixed by Honeywell in the future prototype and product developments.

J.3.4 Confidence in the Demonstration Results

J.3.4.1 Level of significance/limitations of Demonstration Exercise Results

#1 – Reduced campaign duration due to aircraft failures: The plan for this campaign was to fly Honeywell's test aircraft from US to Europe and spend roughly 55 flight hours in European airspace, covering primarily busy core Europe (Germany, UK, Netherlands, France…) and northern Europe (Iceland, Scandinavia). Unfortunately, due to major aircraft failures unrelated to this project (broken windshield and malfunctioned landing gear) the aircraft had to stay grounded most of the time after arrival to Oslo (Norway). As a result, the aircraft spent only slightly over 16 flight hours between Iceland and Scandinavia with no flights in core Europe.

#2 – Amount of RSTP performance data: The collected amount of downlink messages (4,886 with roughly half collected in-flight) and the limited geographical flight test coverage in Europe (only Scandinavia) imply that the performance assessment presented under detailed results for CRT-38-W3-DEMOP-038 do not allow to draw unambiguous conclusion on SATCOM compliance with the applicable RSTP 99.9% latency targets. Nevertheless, the positive outcomes are consistent with the similarly positive outcomes of the additional flight and lab test campaigns performed by Honeywell under ESA Iris and SESAR PJ.14-W2-107 projects.

#3 – B2 ADS-C prototype maturity: The B2 ADS-C prototype implemented in the Honeywell's NGFMS and used during the flight trials was an early prototype (~TRL4/5) with known limitations, including contracts with only one ATC at a time and some unsupported report parameters. Additional unexpected behaviours were identified during the campaign (see previous section). Despite these limitations the prototype helped demonstrate good level of interoperability of independently developed avionics with the existing B2 ADS-C ground end systems. The prototype limitations will be addressed in future developments by Honeywell.

J.3.4.2 Quality of Demonstration Exercise Results

The SATCOM performance results were obtained using production SATCOM avionics (Honeywell's Aspire 400 AES) and operational Inmarsat's BGAN network. Within the constraints given by the limitations #1 and 2 described in the previous section, the results are thus of adequate quality and credibility to be considered as one of the preliminary inputs for assessment of the acceptability of the Inmarsat SB-S service as enabler for B2 ADS-C.

J.3.4.3 Significance of Demonstration Exercises Results

The results of this exercise significantly increase the confidence that the Inmarsat SB-S service can be used as enabler for the B2 ADS-C. Nevertheless, the results are not meant to be used as the sole proof of compliance with the success criteria linked to this exercise. Also due to the limitations presented in the previous sections the results are meant to contribute to the criteria assessment and they should be considered in combination with the results of the other exercises performed under this project, the ESA Iris program and SESAR 2020 PJ.14-W2-107.

J.4 Conclusions

Even though the scope of this exercise was significantly reduced due to the test aircraft's technical problems unrelated to this project, the results significantly strengthen the confidence, that SATCOM can be used as a complementary enabler for B2 ADS-C in the European airspace.

- The EPP and other B2 ADS-C contracts were successfully established and operated inflight using the Inmarsat's SB-S service.
- The applicable RSTP latency targets were met with good margins, even though for proper assessment of the 99.9th percentile more data would be needed.
- No performance degradation was observed even during the flights in the north of Norway (up to 69.8 deg north).
- Failover from SATCOM to VDL and back to SATCOM was successfully demonstrated with no impact on the ongoing periodic ADS-C reports delivery.

The exercise also demonstrated that independently implemented B2 ADS-C airborne application can interoperate with the existing B2 ADS-C ground end systems.

J.5 Recommendations

J.5.1 Recommendations for industrialization and deployment

Based on the results of this exercise, Honeywell recommends the following:

- SATCOM should keep being considered and promoted as an adequate complementary enabler for B2 ADS-C and the CP1 mandate.

J.5.2 Recommendations on regulation and standardisation initiatives

Based on the results of this exercise, Honeywell recommends the following:

- SATCOM should be explicitly recognized in applicable regulations (EASA CS-ACNS or equivalent) as an acceptable enabler for B2 ADS-C and the CP1 mandate.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Appendix K Demonstration Exercise #11 (EXE-PJ38-6-2 by Airbus) Report

K.1 Summary of the Demonstration Exercise #11 Plan

K.1.1 Exercise description and scope

Airbus has developed new avionic systems enabling ATN over SATCOM capability, namely the ATSU standard CSB10 and the Light Cockpit SATCOM (LCS) Inmarsat standard L4.

Airbus solution uses the IRIS system via the Inmarsat Swift Broadband-Safety (or SB-S) constellation to connect to the ATN network.

IRIS is a Data Link Service satellite system funded and promoted by the European Space Agency (ESA). It is based on Inmarsat Swift Broadband-Safety technology that is already approved for Air Traffic Service (ATS) oceanic use (FANS 1/A Technology over ACARS network), and is soon to be extended for use in continental airspace for the provision of Data Link ATS services over ATN network (referred to as ATN B1 and ATS B2).

A dedicated flight test campaign supported by MSN 6101 (F-WNEO), A320-271 Neo has occurred at the end of March 2022 and beginning of April 2022, followed by a second one in the first half of May 2022.

Several European Air Navigation System Providers (NATS, DFS, MUAC, skyguide) capable of ATN B1 CPDLC or B2 CPDLC and B2 ADS-C have supported a flight test trial enabling operational exchanges via both SATCOM and VDL2.

Airbus is making use of test flights in preparation of certification of FANS C over SATCOM to feed Demonstration objectives with additional data for further analysis.

K.1.2 Summary of Demonstration Exercise #11 Demonstration Objectives and success criteria

Demonstration Objective	Demonstration Success criteria	Coverage and comments on the coverage of Demonstration objectives	Demonstration Exercise 11 Objectives	Demonstration Exercise 11 Success criteria
OBJ-38-W3-DEMOP-TECH-0007	CRT-38-W3-DEMOP-038	Fully covered	EX11- OBJ-38-W3-DEMOP-TECH-0007 Same description as OBJ-38-W3-DEMOP-TECH-0007	EX11- CRT-38-W3-DEMOP-038 Demonstrate ATN/OSI dual link (Iris SATCOM and VDL2) performance with Airbus flight test avionics

OBJ-38-W3-DEMOP-TECH-0007	CRT-38-W3-DEMOP-039	Fully covered	EX11- OBJ-38-W3-DEMOP-TECH-0007 Same description as OBJ-38-W3-DEMOP-TECH-0007	EX11- CRT-38-W3-DEMOP-039 Demonstrate ATN/OSI dual link (Iris SATCOM and VDL2) performance with Airbus flight test avionics
OBJ-38-W3-DEMOP-TECH-0007	CRT-38-W3-DEMOP-040	Fully covered	EX11- OBJ-38-W3-DEMOP-TECH-0007 Same description as OBJ-38-W3-DEMOP-TECH-0007	EX11- CRT-38-W3-DEMOP-040 Demonstrate B2 ADS-C v1 interoperability with Airbus flight test avionics

K.1.3 Summary of Validation Exercise #11 Demonstration scenarios

Purpose of the flight test campaign was to validate Air Traffic services operations using the newly developed avionic suite and over the new SATCOM link, namely IRIS, and check the absence of regression on the legacy services and legacy medias (ATN Over VDL2 and FANS 1/A over VDL and SATCOM).

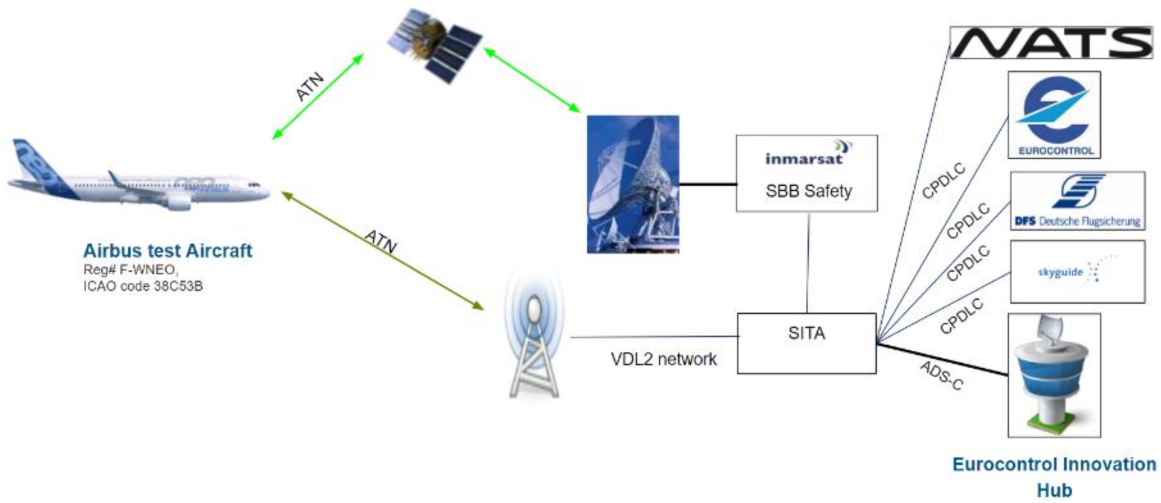
A specific development flight has supported and demonstrated the overall good behaviour as per Airbus certification test plan. This specific flight was performed with a software configuration enabling SATCOM as first subnetwork for ATN exchanges and VDL2 as second subnetwork.

The first leg from Toulouse to Edinburgh enabled development and certification testing with connections to Airbus ATC Simulated centre (capable of simulating FANS 1/A centres, ATN B1 centres and B2 centres)

The second leg from Edinburgh to Toulouse supported the demonstration of operational CPDLC exchanges with ATN B1 centres, namely EGTT (NATS UK), EDYY (MUAC), EDUU (DFS), LSAZ and LSAG (Skyguide).

A specific flight in a VHF/SATCOM transition area, precisely over the Gascogne Gulf in the Atlantic Ocean, has supported performance demonstrations and assessed functioning during loss of VHF coverage and reversion to SATCOM link as well as correct return to VHF sub-network once back in coverage zone. A configuration enabling VDL2 as first subnetwork and SATCOM as second was installed.

Exposure flights supporting performance testing (PBCS measurements) were performed in a shadow mode while Test Aircraft was flying for other test purposes.



The flight test also benefited from SESAR PJ31/PJ38 infrastructure to exchange B2 ADS-C reports with DFS and Eurocontrol Innovation Hub.

The test program for Airbus Flight Test Campaign has covered the following items:

- Assessment of the overall good behaviour of the FANS C product with ATN over SATCOM capability (media routing, HMI, crew workload...), within a representative high-density traffic, operational environment.
- Demonstration of the good functioning of the overall datalink system over the various networks and media available:
    - The new ATN over SATCOM capacity
    - Its complementary with the pre-existing ATN over VDL2 link
    - Non-regression tests for ACARS (incl. FANS A+) over VDL mode A/2 & SATCOM.

  Note: Compliance demonstrations to RCP/RSP performance requirements allocated to the aircraft system are achieved by an analytical demonstration. It is however complemented by end-to-end time transmission flight test data (gathered during the development of the intermediate standards) for FANS product maturity purpose.

The test program has covered the following services:

- ATS623 services
- Notification and Transfer of authority
    - Evaluation of the manual notification process both during preflight and in-flight.
    - Performance of representative procedures of transfer of authority among and between FANS A, ATN B1 & B2 ATC centres to demonstrate their complete transparency to the flight crew.
    - Observation of the DCDU display of the Active (and Next) ATC Centre during and after transfer procedures.
- CPDLC

- Exchange of a sampling of representative messages for each type of FANS connection (FANS A, ATN B1, B2).
- For uplinks, a sample of messages including:
  - Standard Clearances
  - Loadable Clearances
  - Deferred Clearances
  - Information Messages ("EXPECT...")
  - Report Requests
  - Confirm Messages
  - (Open) Negotiation Messages
  - Messages without answer
  - And Multi-Elements uplinks containing combinations of the above

- ADS-C
  - Establishment of ADS-C contracts with both FANS A (ACARS) and FANS C (ATS B2) centres. In particular to obtain higher than usual loads on the communication media in use (connecting both the ACARS & ATN networks).

In terms of communications means, the test program has included:

- ATN over SATCOM and over VDL2.
- ACARS over SATCOM and over VHF for non-regression purposes
- Change of the CSP in flight (ARINC or SITA)
- ATN downlink routing preferences set as 'SATCOM then VHF' and as 'VHF then SATCOM' for Performance flights.

Failure case scenario have been positively assessed, including loss of VDL2 and recovery via SATCOM, loss of SATCOM.

K.1.4 Summary of Demonstration Exercise #11 Demonstration Assumptions

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
PJ38-ASS-05			See section		
PJ38-ASS-06			See section		
PJ38-EX11-ASS-01	Test of VDL2 loss		It is assumed that when available on the aircraft, the SATCOM system will be configured to be the	For the sake of exercise's objective demonstration, the Airbus flight test	Low

			primary means of datalink communication, which basically does not allow to test the way SATCOM link can recover datalink in case of VDL 2 loss.	system will also be tested in a specific configuration allowing to have VDL2 as a primary means to connect in datalink.	

Table 67: Exercise #11 Demonstration Assumptions overview

K.2 Deviation from the planned activities

None.

The tests performed have allowed demonstrating the good behaviour of the ATN Over SATCOM function but also non regression of legacy communication means (e.g. VDL2) in representative datalink environment conditions, also including high-density Multi-Frequency VDL2 airspace. The cockpit HMI in the case of various failure cases has been positively assessed.

K.3 Demonstration Exercise #11 Results

K.3.1 Summary of Demonstration Exercise #11 Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-38-W3-DEMOP-TECH-0007	Demonstrate that a SATCOM/VDL2 dual link is suitable for managing an ADS-C connection	CRT-38-W3-DEMOP-038	End-to-End performance measures match with published SPR.	En-Route	Flight tests have gathered measurements to support Airbus analytical demonstration of ED228A RCP/RSP allocations	OK
OBJ-38-W3-DEMOP-TECH-0007	Demonstrate that a SATCOM/VDL2 dual link is suitable for managing an ADS-C connection	CRT-38-W3-DEMOP-039	Demonstrate ATN/OSI dual link (Iris SATCOM and VDL2) performance with test aircraft avionics	En-Route	A specific development flight has supported and demonstrated the overall good behaviour as per Airbus certification test plan. This specific flight was performed with a software configuration	OK

					enabling SATCOM as first subnetwork for ATN exchanges and VDL2 as second subnetwork.	
OBJ-38-W3-DEMOP-TECH-0007	Demonstrate that a SATCOM/VDL2 dual link is suitable for managing an ADS-C connection	CRT-38-W3-DEMOP-040	Demonstrate B2 ADS-C v1 interoperability with test aircraft avionics.	En-Route	Passed, during Tests with EDYY systems and Airbus simulated platforms.	OK

Table 68: Exercise #11 Demonstration Results

Flight tests have gathered measurements to support Airbus analytical demonstration of ED228A RCP/RSP allocations.

Below tables present a summary of the results per centre type and services using SATCOM media

		ED228A - RCP 130 / A1	
		RCTP Required Communication Technical Performance	
ATC center type	Count of CPDLC	95% (<20sec)	99,9% (<32sec)
ATS ATN B1	299	**99,33%**	**100%**
ATS B2	467	**100%**	**100%**

		ED228A - RSP 160 / A1	
		RSMP Required Surveillance Monitored Performance	
ATC center type	Count of ADS-C with EPP	95% (<90 sec)	99,9% (<160 sec)
ATS B2	674	**98,96%**	**99,11%**

Note: The ADS-C reports that did not meet the performance requirement were observed due to the T5 timer issue described in K.3.3 below.

K.3.2 Analysis of Exercises Results per Demonstration objective

K.3.2.1 EX11-OBJ-38-W3-DEMOP-TECH-0007 Results

The demonstration objectives have been fulfilled and the test program was fully performed.

The behaviour of the FANS C function "with ATN over SATCOM" and of its contributing systems has been positively assessed by the flight crew during the development and the certification flight tests. Nonetheless, it shall be underlined that some unexpected behaviours were observed and are detailed below in section K.3.3.

K.3.3 Unexpected Behaviours/Results

The main ATN- related technical items to be reported on the flight are:

- Loss of ATN link over SATCOM with no recovery after satellite transition from MEAS to EMEA (Ground test at LFBO).
    - Note: For the purpose of this test, VHF3 was set to voice mode preventing VDL2 reversion.
    - **Analysis**: Issue (absence of self-recovery of ATN link via SATCOM) has been linked to one of the timer (T5 timer) being setup to a wrong value. Inmarsat has then modified the timer to the correct value.
    - **The correction has been validated at Airbus Laboratory and with Test Aircraft on the 20th of May.**
- Loss of ATN link over SATCOM with no recovery (In-flight over MUAC Airspace)
    - Note: As VHF3 was set to DATA mode a seamless reversion to VDL2 occurred with no cockpit impact and no operational impact
    - **Analysis**:
        - Absence of self-recovery of ATN link via SATCOM has the same root cause as the previous item (T5 timer).
        - The loss of ATN satcom service was initially caused by signal degradation due to intermittent external RF interference during period 11:10-11:20 UTC. The satcom link recovered once the signal to noise ratio was back to required levels, but the incorrect setting of T5 timer meant that the ATN connection was not correctly re-established and all traffic was routed via VDL as the alternate link. Investigations are on-going with RF regulatory authorities to identify source of interference.
        - The correction has been validated at Airbus Laboratory and with Test Aircraft on the 20th of May.

Several SATVoice calls were unduly dropped.

- A number of unexpected SATCOM logoffs have been seen when trying to perform voice calls between 11:14 and 11:19 UTC. These observations were due to a significant decrease in the carrier-to-noise ratio (C/No) off the North Sea coast, near Amsterdam.
- The root cause of this signal degradation issue is not fully identified yet but is not linked to the aircraft and out of Inmarsat control (outside interference). Investigations are on-going to identify source of interference.

The main interoperability-related observations are the following:

- Despite log-on to TESTEDGG, Eurocontrol Innovation Hub (EIH with address LFPYADSC) could not establish ADS-C contracts.
    - **Analysis**: A first flight filed as AIB101 was scheduled for the 30th of March where Ground testing was performed but flight eventually cancelled. At this occasion, log-on to TESTEDGG occurred along with LFPYADSC contracts' establishment. As AIB101 remained active in Eurocontrol NM (Network Manager) servers until the 5th of April, the flight status in EIH ground systems remained unchanged, and the new CM contacts could not trigger any ADS-C contract establishment.
- Airbus crew expected B2 CPDLC and ADS-C over MUAC Airspace whereas only B1 CPDLC was established.
    - **Analysis**: F-WNEO was not present in the MUAC B2 white list established in the frame of DIGITS and ADSCENSIO projects, hence only authorised for B1 operations.
    - B2 exchanges were performed via SATCOM during second flight.
- During transition from EGTT to EDYY, the Next Data Authority was not presented to the crew. The CPDLC was then established after EGTT disconnection. This sequence of event was not expected by Airbus.
    - **Analysis**: Thanks to NATS UK logs and MUAC logs, the observed sequence was analysed as follows:
        - At 10:59:48, UM160 NEXT DATA AUTHORITY EDYY is sent by EGTT
        - At 10:59:48, CPC Start Request is sent by EDYY
        - At 10:59:49, CPC Start Request is received on board and rejected by DL107 NOT AUTHORIZED NEXT DATA AUTHORITY
        - At 10:59:50, UM160 is received on-board.
        - At 10:59: 53, Logical acknowledgment is received by EGTT
    - The airborne side behaved as expected.
    - Root-cause is linked to NATS system. The Flight Data Processing system responsible for the CM (called NAS) is a different system than the one which handles the CPDLC (called SFS). In some cases, this can cause a 'race condition' where NAN (Next Authority Notified) is transmitted to the next centre before the aircraft has received and responded with a Logical Acknowledgment to the UM160 uplink. This is tracked by NATS as known Problem Trouble Report (PTR) #65835
    - Sequence is as follows:
        - LOF (Logon Forward) is sent to Maastricht by the "NAS" module
        - "NAS" module informs "SFS" module to notify NDA (NEXT DATA AUTHORITY)
        - "SFS" module uplinks UM160 to the A/C and then informs "NAS" module **instead of waiting for the Lack from the aircraft (NATS PTR #65835)**
        - "NAS" module receives "SFS" information and sends a NAN (Next Authority Notified) to MUAC
        - Upon NAN reception, MUAC system sends CPC Start Request
        - A/C rejects CPC start request as UM160 is not yet received.

- After UM74 uplink by MUAC, a DL 62/98 Error// Uplink delayed in network and rejected, resend or contact by voice is received by MUAC.
  - **Analysis**:
    - Uplink message has exceeded the max uplink delay set to 40 seconds in ATN B1 environment. Event occurred during perturbation of Inmarsat network.
    - The root cause of this signal degradation issue is not fully identified yet but is not linked to the aircraft and out of Inmarsat control (outside interference).
- At 11:37z, during transition from EDYY to EDUU, the Next Data Authority was not presented to the crew. The CPDLC was then established after EDYY disconnection. This sequence of event was not expected by Airbus.
  - **Analysis**: Thanks to MUAC logs and DFS logs, the observed sequence was analysed as follows:
    - At 11:26:38, UL160 NEXT DATA AUTHORITY EDUU is sent by EDYY
    - Right after, still at 11:26:38, Logical acknowledgment is received.
    - At 11:31:37, CM contact request is uplinked by EDYY
    - At 11:31:54, CM contact confirm is positive
    - At 11:38:04, CPDLC session with EDYY is ended following the WILCO to UM117 concatenated with CPC End Request.
    - At 11:38:43, CPDLC start request is sent by EDUU
  - The airborne side behaved as expected.
  - Root-cause is linked to DFS system. DFS have indicated that OLDI parameters (Online Data Interchange) of type LOF (Logon Forward) and NAN (Next Authority Notified) are well received from EDYY but no LAM (logical acknowledgement message) was sent by EDUU. The Maastricht system reacted correctly and triggered the CMContact procedure. Currently the implementation in DFS system provides that the CPDLC start request for flights using the CM Contact procedure is only triggered with the first MAS (Manual Assumption), hence when radio communication is established (initial call).
  - DFS has defined a new system requirement that will trigger the CPDLC start request after the successful CM Contact Response in the future (parameter to be defined – most probably on the basis of the ACT entry time). There is currently no implementation date for this.
  - **Expected transfer sequence was observed during second flight on the 20th of May.**
- MUAC has observed 4 ADS-C reports for which the Extended Projected Profile Computation Time stamp is more than 40 seconds in the past compared to ground reception Time Stamp.
  - **Analysis**: Airbus analysis has confirmed normal behaviour of the ATSU product. The root-cause is linked to FMS frames exchanged with ATSU, that are used to build EPP and ADS-C. There is no confirmed issue as it is considered that even if computation time is earlier in the past, predictions may still be up-to-date. Deeper analysis with FMS supplier has been launched.

- skyguide has observed that on the VDL2 side, there is an XID_CMD_LE procedure which was done on ZRHT at 12:40:08 UTC and reported an unexpected Link Establishment (instead of HO).
    - **Analysis**: Airbus analysis has confirmed a DM frame from the current VGS which explains the reconnection via CMD_LE. Reason for the sending of the DM by the VGS is unknown.

K.3.4 Confidence in the Demonstration Results

K.3.4.1 Level of significance/limitations of Demonstration Exercise Results

CM and CPDLC ATN B1 exchanges and CPDLC B2 and ADS-C B2 were performed with real ATC Centres (EGTT, LSAG, LSAZ, EDUU, EDYY, LFMM and ADSCEDGG), in addition to the Airbus-simulated (Toulouse Technique) ATC Centre in an operational ATC environment.

K.3.4.2 Quality of Demonstration Exercise Results

The demonstration here described is the one that has been used for Airbus certification purposes demonstrating compliance to JAR25 1301 (a)(b)(d) and 1309(a) as amended by CRI SE-65.

JAR25 Requirements summary

- Each item of installed equipment must:

  (a) Be of a kind and design appropriate to its intended function;

  (b) Be labelled as to its identification, function or operating limitations;

  (d) Function properly when installed.

- The equipment, systems, and installations

  (a) whose functioning is required by the JAR and national operating regulations must be designed to ensure that they perform their intended functions under any foreseeable conditions (...).

K.3.4.3 Significance of Demonstration Exercises Results

ATN B1 exchanges have been performed in an operational context with real ATC centres.

B2 exchanges with MUAC have been performed in an operational context.

The results are considered significant from an operational perspective.

K.4 Conclusions

The demonstration objectives have been fulfilled.

The behaviour of the FANS C function “with ATN over SATCOM” and of its contributing systems has been positively assessed by the flight crew during the development and the certification flight tests.

In particular, the flight tests demonstrated the good behaviour of the airborne systems operating the capacity to perform air/ground ATN exchanges using the SATCOM media/sub network for ATN B1/FANS B and B2/FANS C datalink operations.

Flight tests have also demonstrated the good behaviour of the airborne systems operating in a high-density VDL2 environment, with exposition to Multi-Frequency implementations. Non-regression testing on ACARS network via both SATCOM and VDL were satisfactorily demonstrated. Simultaneous ACARS/ATN transfers using SATCOM were also satisfactorily demonstrated.

No significant issue have been encountered but outside interferences, localised, are being investigated with state authorities.

K.5 Recommendations

K.5.1 Recommendations for industrialization and deployment

Considering the different stakeholders involved (SSP, DSP, ANSP) and associated owned infrastructure, a deployment will require particular care and attention on the routers settings to ensure uplink and downlink routes are well set.

K.5.2 Recommendations on regulation and standardisation initiatives

None

Appendix L Demonstration Exercise #12 (EXE-PJ38-6-3 by NATS) Report

L.1 Summary of the Demonstration Exercise #12 Plan

L.1.1 Exercise description and scope

The original intention of EXE-PJ38-6-3 led by NATS was to collect ATS B2 link performance metrics from Iris SATCOM equipped aircraft conducting revenue services (referred to as Iris pre-commercial flights). Due to significant delays in the European Space Agency funded Iris IOC project that the exercise was dependent on, EXE-PJ38-6-3 initiated the PJ38-RISK-02 mitigation action of utilising a ground-based avionics platform combined with a live operational Iris SATCOM link instead – referred to as the Iris Test Facility (ITF). This externally developed test platform includes the capability to simulate; the A/G link, antenna steering and position reporting via the Satellite Data Unit (SDU) and connectivity for a variety of stakeholders.

The tests to be undertaken with the Iris Test Facility were agreed amongst the WP6 partners in a series of small workshops to provide additional complementary evidence of Iris SATCOM performance beyond that collected for system verification. The focus of the tests would be on demonstrating seamless ATN connection throughout transition / switch-over between VDL and SATCOM utilising both ADS-C (NATS) and CPDLC (ENAIRE).

During the detailed planning of the testing which occurred during the later months of the project, INMARSAT recommended that the testing should specifically exercise the routing behaviour during Iris VDL-SATCOM switch-over with NATS' unusual dual connection to both ATN Communication Service Provider (CSP) networks of Collins (ARINC) and SITA. Furthermore, it was realised that to facilitate this specific testing the Airbus Test laboratory would be better suited for representing the aircraft end system rather than the ITF.

Unfortunately, Collins prohibit non-operational end-systems on their production network and establishing the required connectivity to the development (test) networks between the Airbus Test laboratory and NATS end-system was not possible within the remaining timeframe of PJ38. As such exercise EXE-PJ38-6-3 was not conducted.

It should be noted that prior to initiation of the PJ38-RISK-02 mitigation action, the work package partners maintained close coordination with the Iris IOC project, undertaking preparatory activities to facilitate the Iris pre-commercial flights.

L.1.2 Summary of Demonstration Exercise #12 Demonstration Objectives and success criteria

EXE-PJ38-6-3 was associated with only addressing one objective which is to demonstrate that a SATCOM/VDLm2 dual link is suitable for managing an ADS-C connection. This objective is technical in nature and has three success criteria, of which EXE-PJ38-6-3 will contribute to addressing EX12-CRT-38-W3-DEMOP-038 which demonstrates that 'the measured end-to-end performance matches the published SPR'.

L.1.3 Summary of Validation Exercise #12 Demonstration scenarios

For EXE-PJ38-6-3 the 'reference scenario' was considered to be aircraft or avionics providing ATS Baseline 2 ADS-C communications, but over the VHF Datalink Mode 2 medium rather than over Iris SATCOM.

L.1.4 Summary of Demonstration Exercise #12 Demonstration Assumptions

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
PJ38-ASS-05			See section 3.3.4		PJ38-ASS-05
PJ38-ASS-06			See section 3.3.4		PJ38-ASS-06
PJ38-EX12-ASS-01	Flight procedures agreed	Revenue flight constraints	It is assumed that adequate flight crew procedures are agreed and applied.	Flight procedures agreed	High

Table 69: Exercise #12 Demonstration Assumptions overview

It should be noted that PJ38-EX12-ASS-01 was no longer applicable to EXE-PJ38-6-3 as the demonstration activity involving the Iris pre-commercial flights was cancelled.

L.2 Deviation from the planned activities

PJ38 had a dependency on the European Space Agency funded Iris IOC project to provide Space-Ground infrastructure and equip several aircraft with a certified 'Iris' avionics capability. Although the Space-Ground infrastructure was deployed in-time to facilitate the Airbus and Honeywell dedicated flight tests in EXE-PJ38-6-2 and EXE-PJ38-6-1 respectively (see Appendix J and Appendix K), the certification of the revenue flight aircraft and Iris Service Provider was significantly delayed.

The original intention of EXE-PJ38-6-3 was to collect link performance metrics from the Iris equipped aircraft conducting revenue services (referred to as Iris pre-commercial flights). Due to the significant delay of the pre-commercial flights ultimately occurring outside of the PJ38 timeframe, as noted in the DEMOP Release 2, WP6 triggered the initiation of the mitigation action associated with risk PJ38-RISK-02. This mitigation initiated a deviation to the exercise to utilise the Iris Test Facility (ITF) to complement the flight test exercises with ground-based avionics tests that make use of a live SATCOM link.

The tests to be undertaken with the Iris Test Facility were agreed amongst the WP6 partners in a series of small workshops to provide additional complementary evidence of Iris SATCOM performance beyond that collected for system verification. The focus of the tests would be on demonstrating seamless ATN connection throughout transition / switch-over between VDL and SATCOM utilising both ADS-C (NATS) and CPDLC (ENAIRE).

During the detailed planning of the testing which occurred during the later months of the project, INMARSAT recommended that the testing should specifically exercise the routing behaviour during Iris VDL-SATCOM switch-over with NATS' unusual dual connection to both ATN Communication Service Provider (CSP) networks of Collins (ARINC) and SITA. Furthermore, it was realised that to facilitate this specific testing the Airbus Test laboratory would be better suited for representing the aircraft end system rather than the ITF.

Unfortunately, Collins prohibit non-operational end-systems on their production network and establishing the required connectivity to the development (test) networks between the Airbus Test laboratory and NATS end-system was not possible within the remaining timeframe of PJ38. As such exercise EXE-PJ38-6-3 was not conducted.

L.3 Demonstration Exercise #12 Results

L.3.1 Summary of Demonstration Exercise #12 Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-38-W3-DEMOP-TECH-0007	Availability of multilink via SATCOM	CRT-38-W3-DEMOP-038				Not covered

Table 70: Exercise #12 Demonstration Results

L.3.2 Analysis of Exercises Results per Demonstration objective

L.3.2.1 EX1-OBJ-38-W3-DEMOP-SAFE-0001 Results

Not applicable to EXE-PJ38-6-3.

L.3.2.2 EX1-OBJ-38-W3-DEMOP-HPRF-0002 Results

Not applicable to EXE-PJ38-6-3.

L.3.2.3 EX1-OBJ-38-W3-DEMOP-OPRF-0003 Results

Not applicable to EXE-PJ38-6-3.

L.3.2.4 EX1-OBJ-38-W3-DEMOP-OPSF-0004 Results

Not applicable to EXE-PJ38-6-3.

L.3.2.5 EX1-OBJ-38-W3-DEMOP-TECH-0006 Results

N/A – exercise cancelled.

L.3.3 Unexpected Behaviours/Results

N/A – exercise cancelled.

L.3.4 Confidence in the Demonstration Results

N/A – exercise cancelled.

L.3.4.1 Level of significance/limitations of Demonstration Exercise Results

N/A – exercise cancelled.

L.3.4.2 Quality of Demonstration Exercise Results

N/A – exercise cancelled.

L.3.4.3 Significance of Demonstration Exercises Results

N/A – exercise cancelled.

L.4 Conclusions

Conclusions are unable to be drawn from this exercise as it and the planned mitigation activity were cancelled due to external factors outside of the control of the project.

L.5 Recommendations

L.5.1 Recommendations for industrialization and deployment

It is recommended that the monitoring of the link performance of the Iris Pre-Commercial Flights is conducted by the European Space Agency funded Iris IOC project. This activity should utilise the ADS-C Common Service (ACS) Prototype developed by PJ38 WP5 as the data source for ADS-C reports, with migration to the industrialised ACS in the Digital Sky Demonstration project 'HERON' if necessary. Furthermore, the link performance metrics to be assessed for the Pre-Commercial Flights should broadly follow those metrics developed under WP2, with a focus on transmission time latency.

L.5.2 Recommendations on regulation and standardisation initiatives

N/A

Appendix M Data analysis performed by WP3

The ADSCENSIO project includes the preparation of D3.1 deliverable, describing the way Data analysis activities contribute to the results displayed in Demonstration Reports.

Three tasks were performed in the framework of the ADSCENSIO project (PJ38):

1. Task 3.1, ***Technical data analysis***, to analyse the performances of ADS-C data exchange from a technical perspective;
2. Task 3.2, ***Operational data analysis***, to analyse characteristics and the behaviour of ADS-C data contents from an operational perspective;
3. Task 3.3, ***Common analysis platform***, to support the common data analysis developing a common platform.

The Technical Data Analysis – Task 3.1 reports on the "technical performance metrics" and details the results of the data analyses that have been performed by the ADSCENSIO partners. These analyses have gone beyond the one strictly necessary to achieve the demonstration objectives but are considered important by the partners to:

- Provide additional insight in PJ38 significance
- Allow the monitoring of PJ38 operations

The rest of Technical Data Analysis reports the data analysis results along 'PJ38 significance' axis. It doesn't directly report the result of the monitoring actions that took place during the VLD expect, if they affected the demonstration significance or had an impact on further deployment.
MUAC and EIH data collection approaches haven't significantly changed in PJ38 ADSCENSIO compared to PJ31 DIGITS. This reflects in the technical metrics reported in the D3.1, which are quite similar to the one reported with the ones reported in PJ31.

Compared to PJ31 DFS system, ESSP/DFS together in PJ38 changed to an ACS approach and maintained ADS-C connection throughout the flight as long as ATN coverage existed. This significantly increased the amount of data collected and also makes some numbers difficult to compare (e.g. higher number of flights in arrival/departure, less overflights, triggering different event types). A notable difference is, for the test domain, the much lower airline participation rate.

The Operational Data Analysis – Task 3.2 is comprised of eight sets of analysis that aim to assess the operational usability of various data groups provided by ATS-B2 ADS-C. The PJ38 partners that undertook these tasks were: AIRBUS, DSNA, EUROCONTROL, NATS and SKYGUIDE.

- **EPP Variability (EUROCONTROL)**
  EPP 'variability' which is essentially a statistical measure predictability is a valuable metric, as comparing EPP's against the actual flown profile could suggest poor EPP prediction performance where ATC intervention was necessary for the safe handling of the flights and therefore diverged from the optimal profile.
  The variability analysis concludes that flights in "fully managed" mode have reduced variability for TOD and named waypoint estimates. Due to STAR changes or shortcuts just before or after the TOD; the operational usability of the descent waypoint time estimates is impacted, as changes in the descent lateral path increase variability, however the level variability for these waypoints is low likely due to level constraints in the descent profile. Furthermore, the

analysis also found that the TOD distance offset variability has reduced over time to just 1.89 NM.

- **Accuracy of EPP in Climb and Descent (AIRBUS)**
  This analysis considered the representative of the descent profile from the last EPP provided in cruise (before the top of descent), which should correspond to the theoretical descent profile from the FMS and therefore be considered as the referent descent profile in terms of energy management of the aircraft. Although ATC interventions in the descent make it challenging to draw definitive conclusions from the analysis, identifying the energy state of the based on the EPP derived theoretical descent profile could provide benefits for ground-based trajectory prediction.

- **Comparison of EPP against Ground Trajectory predictions using alternative baseline BADA model (NATS)**
  Undertaking a comprehensive evaluation of trajectory prediction (TP) covering lateral, vertical and temporal error metrics, this analysis concludes that ground-based TP enhanced with ADS-C mass produces the most accurate representation of the aircraft planned trajectory when compared against the actual flight profile, when considering predictions based on BADA only, ADS-C mass, ADS-C speed and ADS-C mass & speed.

- **EPP use in Trajectory Prediction during Climb and Descent Phases (AIRBUS)**
  This continuation study from PJ31 aims at evaluating how the ADS-C and mainly the EPP can improve the representativeness of the Ground TP for Climb and Descent. For climb, the analysis concludes that although consideration of the speed has a limited impact on the improvement of the vertical accuracy, it does contribute to reduce the distance error.

- **Comparison of Conflict detection tools using Trajectory Prediction enhanced with EPP (skyguide)**
  This study details a comparative evaluation of Conflict Detection & Resolution (CD&R) tool performance when the input Trajectory Prediction is enhanced with EPP. The evaluation found that the CD&R tool was greatly improved thanks to reduced detection envelopes that consider the ‘real’ performance of the aircraft as denoted by the EPP and speed schedule data. Furthermore, the New Trajectory Prediction used was based on calibrated performance data calculated taking into account EPP and speed schedule data which was also found to improve the computation of the TP, therefore providing even greater precision/accuracy.

- **EPP Trajectory Intent Status and Top of Descent Analysis (DSNA)**
  This analysis evaluates the accuracy of the EPP provided TOD and ETA at selected Metering Fixes within French airspace against ETFMS Flight Data, considering the selected or managed mode that the aircraft is in as indicated by the Trajectory Intent Status. For ETA at Metering Fixes, the analysis concludes that the accuracy provided by the EPP when the aircraft is in Fully managed or Speed selected mode is consistently better than EFD.

- **EPP derived Final Approach Speed analysis (NATS)**
  The aim of this study was to determine the accuracy and stability of the Final Approach Speed prediction provided by EPP. The study found that the planned EPP speed at runway threshold stabilizes within about an hour before the aircraft reaches this point with only 12% of the flights showing a deviation of more than 5 kts between the reports received in the final 20 minutes of the flight.

The accuracy of the planned EPP speed was found to be between +/- 5kts when compared to the mean measured IAS for ~ 80% flights reaching +/- 10kts for most of the remaining flights.

- **Exploration of Ground Vector, Air Vector and Met-info groups (NATS)**

This study characterised and assessed the data quality of the ADS-C Ground Vector, Air Vector and Met Info data groups for their potential benefit as supplementary inputs into ATC ground tools and meteorological forecasts. Together these groups provide the components of the 'wind triangle' which represents the relationship between motion of the aircraft and wind, as well as the local air temperature at the time and location the ADS-C report was downlinked.

Task 3.3 "Common analysis platform" has proposed a methodology for the development of a common analysis platform based on the most relevant ADS-C (Automatic Dependent Surveillance – Contract) metrics to be managed and monitored; in addition the task introduced an approach to help converting flight improvements due to ADS-C into fuel /CO2 values.
Furthermore, a high-level architecture of this ADS-C common analysis platform called ACS PMS (Performance Management System) has been proposed; it could be built based on two main components:

- a "static" component developed with a client-server architecture focused on ADS-C/EPP technical performance and their compliance with applicable standards and SLA.
- a "dynamic" component, based on a distributed architecture, which could allow, in the future, to improve other ATM functionalities using ADS-C/EPP data, including sharing of more information among stakeholders and including what-if scenarios to optimise the overall flight performance.

A final recommendation from the task is to further investigate a dynamic ACS PMS as being operationally driven, using the available elements (metrics) to build a comprehensive system to act in specific cases as fully integrated into the operations, contributing to increase the flight control and performance.

Appendix N Inputs to standardization and industrialization of the ADS-C Common Service

DEMOR R2 includes the final version of the ACS Requirements and the SWIM ICD developed by PJ38 WP5. It supersedes the Appendix N included in DEMOR R1.

N.1 ADS-C Common Service CONOPS

The purpose of this section is to present the high-level view of the usage of the service, the impact on operations and the necessary topics to be addressed in order to deploy the Wave 3 ADS-C demonstrator.

N.1.1 Service Responsibility and Flight Assignment

The ADS-C common service assumes responsibility for collecting ADS-C data from airborne users and distributes this data to entitled ground users. The responsibility of the service and the set of flights it collects and distributes data for in a given moment may be defined by one of the following principles:

- geographically (by Area of Service), taking into account the aircraft position, or
- by assignment of a defined subset of aircraft (based on icao24bit address).

N.1.1.1 Flight Assignment by Airspace / Area of Service

The ADS-C common service is intended to collect and distribute ADS-C data while aircraft traverse a defined Airspace or Area of Service (AoS). Ideally there will be one connected/cohesive AoS with no holes (i.e. no blind spots or missing areas). This area is where ADS-C connections will be established. Alternatively there could be a small number of Areas of Service which may be served by different service instances or service providers.

The aggregation of all AoSs will cover the entire region with ATN coverage and have no holes so that ADS-C data is available wherever ATN coverage exists. In order to realize the goal of saving VDL2 bandwidth, the AoSs should not overlap more than necessary (i.e. to establish the new contract before the previous one is cancelled). (The geographical definition of the AoSs is of out of scope for this document).

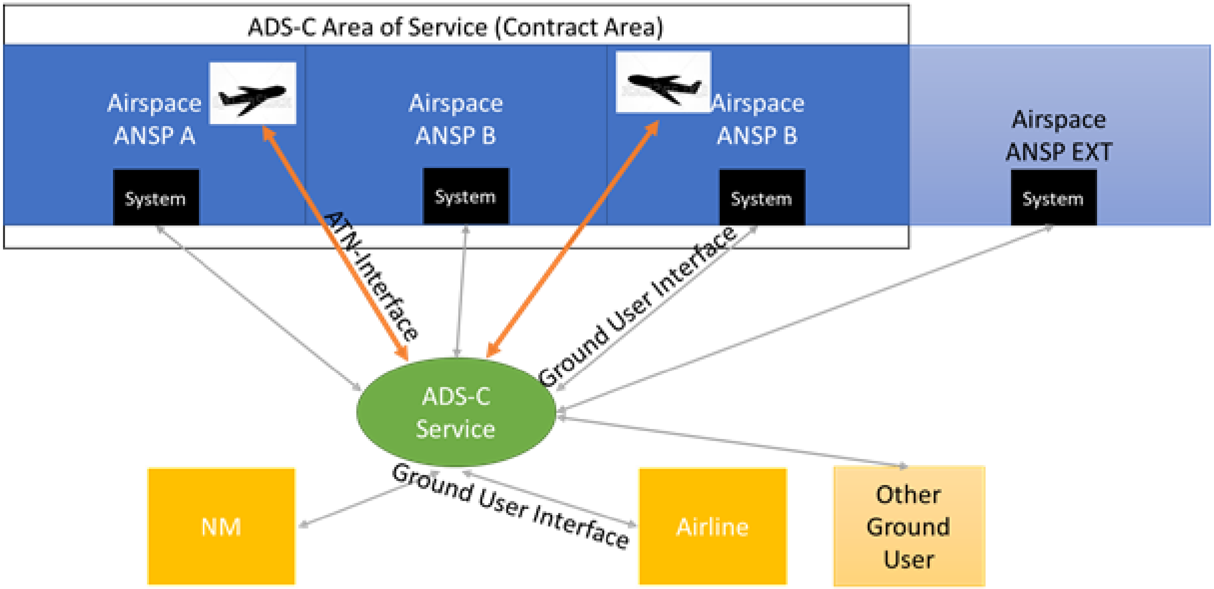


Figure 154: ADS-C Area of Service and Service Interfaces to Airspace Users and Ground User

N.1.1.2 Assignment by subset of aircraft (based on icao24bit address)

Under this principle, an aircraft (and thus a flight) is assigned to a responsible ADS-C service instance / service provider based on its icao24bit address for the entire length of the flight.

The service is responsible for a subset of flights (defined by a list of icao24bit addresses) in the entire region of ATN coverage. Effectively this can be treated as the case of one unlimited AoS.

N.1.1.3 Fallback solutions

Under both assignment principles (by geographic AoS or by icao24bit address), requirements may be defined to guarantee a handover of flights from one service instance to another in case one instance becomes unavailable. This is assumed to be a topic for further evolution and outside the scope of this document version.

N.1.2 Data Providers and Data Consumers

N.1.2.1 Airspace Users

The Airspace Users (AUs) are part of Data Providers and are key enablers to the service. In order to feed data to the service, the aircraft have to be ATS B2 equipped and at least ADS-C v1 capable.

ATS B2 equipped aircraft are technically capable of supporting ADS-C contracts with at least 4 Ground facilities in parallel (5 for current Airbus implementation). A key goal of this service however is to avoid abusing this capability for distribution several times the same (or similar) information, with view to the scarce capacity of VDL2 A/G link.

From the perspective of the flight it is possible that its departure (ADEP) and/or arrival (ADES) lie outside or inside the service Area of Service.

In the long-term/large-scale deployment scenario with several service areas, a single flight may traverse several service areas.

N.1.2.2 Ground Users

The Ground Users (GUs) who are the end users of the service act as Data Consumers because they receive data from the service and derive value by using the data in their diverse applications.

The group of ground users is expected to include ANSPs and NM initially, but additional user groups may eventually benefit from the service as well (e.g. Airlines for their fleet, Airports for traffic to their Destination, Meteo Service for Wind data) etc. In addition to that, on a system level, several systems could have a need for ADS-C data per organization, (e.g. several ATSUs FDPs per ANSP, Arrival Manager). These users could establish separate connections to the ACS.

A key assumption and motivation for building an ADS-C Common Server is that more than one ground user will be interested in and should have access to the ADS-C data for a flight at any given time. (This is in contrast to the application of CPDLC which is tied to a single control authority – the CDA - at any time). From the assumption of multiple ground users being interested in the same data comes the goal of avoiding redundant downloads of the same information via a channel (VDL2) with limited bandwidth.

Note that ground users may reside geographically outside the AoS of the ADS-C Service or have an interest in data that go beyond a single AoS. In particular ANSPs which are downstream to the service instance's AoS for a given flight may have a legitimate interest in the data. [4]

N.1.3 Handling of CM Logon Information

In order for the ADS-C service to establish contracts with the aircraft, the initial requirement is to obtain CM Logon information for the flight.

It is currently assumed that the ACS will receive CM Logon Information through direct CM Logon notification from the aircraft, either as a result of a pilot manual action or through the CM Contact mechanism (through an external CM Service). Other ways to receive the logon information are possible (like SYSCO LOF message) and will have to be explored as service evolutions.

The ADS-C service will need one registered Ground Facility Designator (GFD) and ATN CM application address in order to receive the aircraft logons.

The CM Logon will be notified to the ADS-C service:

- for any flight planned to cross the ADS-C Area of Service
- as soon as ATN coverage is available and the flightcrew has resources to do so. (Ideally, this will be before entering the Area of Service from outside or before take-off within the Area of Service)

Note: This logon procedure for flightcrews is expected to be essentially the same as the one for CM Service / TESTEDGG in PJ31 wave#1.

---

[4] In the scope of the complementary ICD [2] ground users will also be referenced to as "clients" and ground user applications as "client applications" of the service.

- No ADS-C contracts will be established before a valid logon is received.
- For the duration of Wave 3 demo it is assumed the ADS-C service will use a "Logon List" to provide the service only to known aircraft. For the final deployment scenario this restriction is likely to be removed. Technically, the logon list should be statically/dynamically configurable.
- Based on the assumption that there may be more than one ADS-C service instance, an external CM service is necessary having the capability of sharing CM information with a configurable list of other facilities (Similar to TESTEDGG in PJ31 wave#1). This can be achieved through Ground to Ground forwarding of CM Logon data or basically via the use of CM Contact.
- As part of the Wave 3 demonstration, the TESTEDGG Ground Facility Designator is planned to be re-used for the CM Service.
- In the mid-term, an appropriate new Ground Facility Designator and ATN CM application address needs to be registered (->Action to determine which).
- The CM logon to the CM service implies one additional manual Logon for the flight crew, on top of the one currently needed for CPDLC Operations
- For future evolutions (beyond Wave 3) solutions could be investigated to allow establishment of ADS-C contracts without a dedicated/extra logon to the ADS-C Service (SYSCO LOF or other ground-based solutions).

N.1.4 CM Logon Information vs. FPL Verification

The ADS-C service will be connected to a source of FPL data (e.g. NM B2B – Flight Data service).

The ADS-C service will offer functionality to verify logon data against available FPL data with possible outcomes verification success, verification failure, or no FPL data available.

The service will establish ADS-C contracts with aircraft regardless of the outcome of the verification process. If verification is not successful despite FPL data being available, the ADS-C service will mark any distributed data as "verification failed". If no FPL data is available (in degraded mode) the ACS will mark data as "verification unable". It remains in the responsibility of the Ground User to decide whether such data will be used. This may depend on the use case and safety case. The service will provide means to filter data based on the verification outcome and also, the ground user may have additional verification means (e.g. CM Logon information against FPL data in its own system, or other kind of checking of the ADS-C data received) to perform a client-side verification.

The general principle here is to use NM B2B data in a positive way to enhance connection behaviour. It should be avoided that the service loses ADS-C data which would otherwise be obtained (e.g. if the Flight is not on NM B2B yet).

N.1.5 Use of Aircraft Position Information

The ADS-C service will be connected to a source of a/c position information (e.g. NM B2B Flight Data Service)

The a/c position information will be used to determine triggers needed for the management of ADS-C contracts:

- Entry and exit to the area of service. (This information is not contained in the Logon information, and the logon may be significant time before entering the AoS. Thus, external position information will be used to determine AoS entry and exit. Periodic and Event ADS-C contracts with an a/c will only be established while the a/c is within the AoS.

- Modification of ADS-C contract: in future evolutions the ADS-C service may also implement different sub-regions of the service, where different ADS-C contract parameters may be applied (e.g. upper and lower airspace, regions with different ATN network capacity). Position information may also be used to associate the aircraft to different sub-regions of the service.

As presented in previous section, the service should still be available in degraded mode when no position data is available[5].

N.1.6 ADS-C Contract Management

The Wave 3 version of the ADS-C service will implement at least periodic and event contracts. In a later stage, it will also support on-demand contracts.

N.1.6.1 Periodic and Event Contracts

The ADS-C service will seek to establish one periodic and one event contract for each a/c which successfully logged on and is currently located within the AoS (Area of Service). The contracts will be established as soon as the aircraft is within the AoS and it could begin on the ground before departure if the aircraft departs from an ADEP within the AoS.

(Handling of failure cases and non-nominal cases such as Provider Aborts and User Aborts are treated in detailed requirements).

A key principle for the management of periodic and event contracts will be the independence and decoupling of ADS-C Contract Management from Ground User/Client-Side Interface for periodic and event contracts. It is assumed that periodic and event contract definitions and parameters will be agreed in advance by appropriate governance representing the service users, with the goal of maximizing benefit to the user community while respecting performance limits of the network. The agreed parameters for periodic and event contracts can then be implemented by adaptation data /configuration. They will not depend on the state and parameters of ground user subscriptions.

As a first implementation step a pair of one event and one periodic contract definition may be agreed, which will be applied to the entire area of service.

In subsequent evolutions, the ADS-C service is expected to:

- Distinguish different sub-volumes of airspace for which different contract-parameters will be applied (e.g. upper vs. lower airspace).
- Chose contract parameters depending other variables such as flight phase or ADES
- Be able to establish event tolerance contracts on unnamed waypoints such as ToC and ToD to be notified about time or position shifts of these points according to the aircrafts FMS planning.

---

[5] The absence of position data (such as radar tracks, ADS-B…) shall be non-blocking. If no other track data is available for a given flight, the ADS-C Service may obtain an initial a/c position by an ADS-C on demand contract. If this position is inside the Area of Service Definition (AoS), ADS-C contracts may be initiated and further logic (end of contract, switch of contract if needed) may be based on ADS-C position data as well.

N.1.6.2 On-Demand Contracts

In addition to periodic and event contracts the ADS-C service will support on-demand contract requests from ground users.

In contrast to pre-defined periodic and event contracts, demand contracts can be parametrized by ground user requests. AU Interface and ATN Messaging is in this case directly triggered by Ground User actions. The demand contract will be issued one time, and the result (in general ADS Report data) will be returned to the respective ground.

Results of demand contracts by one will also be distributed to other users provided they maintain a corresponding subscription for ADS-C data from this flight.

When a user requests a demand contract while another demand contract for this aircraft is being processed, the service will reject the request with return code “busy”. The reason is that on the airspace-users interface (ATN interface) only one request can be executed at a time for one aircraft. The client should wait until seeing a demand contract report passing by and then (if still necessary) try again.

The frequency of requests of one ground-user per aircraft will be limited (e.g. to 1 request per minute, configurable).

The application scenario is a ground user requesting data that is not covered by the standard contracts or at a time where standard contracts don’t provide up to date information.

N.1.7 Data Distribution / Service Interface to Ground Users

The service will offer a distribution interface (based on publish/subscribe principle) to Ground Users. The interface will be compliant with the SWIM yellow profile requirements.

Subscribers may register for specific messages at runtime e.g.

- only ADS-Reports, or
- all ADS Messages including contract requests, or
- ADS-Reports only when FPL-verified, or d) messages only for specific flights)

The ADS-C Service will therefore act as a dynamic gateway.

The Data Distribution Module of the ADS-C Common Service has to provide authentication and authorization mechanisms. It is assumed that ground users will be known before requesting service (legitimation process in advance, no totally unknown ground users, at least for Wave 3 scope).

It is assumed that ground users may have different and limited access rights. E.g. some users may only be entitled to see subsets of flights (e.g. Airlines for their own fleet). The access to on-demand contracts will also be limited with certain privileges. It is assumed that users and privileges will need to be managed. Between the subscription and publishing of data a process will need to ensure that the user is entitled to this data (potentially not in the initial service but in the evolution)

As proposed in N.1.4 the Data Distribution will clearly indicate whether the CM and ADS-C data received could be successfully verified against FPL data or not.

The following table intends to cover and contrast the information needs of different stakeholder groups and how this may translate into requirements for the Publish/Subscribe I/F.

User Group	ANSP	NM	Airline
Flights of Interest	All flights planned to cross ANSP Area of Interest	All flights	Airline fleet, based on ICAO 24-bit address
Selection criteria for flights	Per flight, based on Callsign, ADEP, ADES, EOBT and EOBD Alternatively: All flights and Filtering on client-side icao24bit address	All flights	Permanent subscription for fleet? E.g. based on list of icao24bits? Alternatively, based on Airline Code in Callsign? Combination of "ICAO Airline Identifier" (Three characters) and icao24bit address. (logical AND)
Data of Interest	All Messages (including CM) Individual ADS-C Message types to be analysed (make configurable) Only logon and ADS-C Reports? Or also other status information, Contract Requests, Aborts….	All Messages (including CM)	ADS-C Reports?
ADS-C clusters of interest? Subscription to certain data elements?	All in step 1 (No filtering of data elements in Wave 3)	All in step 1 (No filtering of data elements in Wave 3)	All in step 1 (No filtering of data elements in Wave 3)
Check of User Privileges and data access rights / vs subscription	None, entitled to all data	None, entitled to all data	Airline fleet? (by icao24bits and/or "ICAO Airline Identifier"
Need for FPL vs. Logon Verification	Yes, on client-side and potentially server-side as well	Yes	No?
Data Format	XER	XER	XER
Expected use of on-demand contracts	Yes	Yes / Potentially	No (t.b.c)

Table 71: Ground Users, Information Needs and Subscription Profiles

Note: The ADS-C Common Service SWIM Interface is specified in the separate ICD (section N.3).

N.2 ADS-C Common Service Requirements

This section contains an initial list of requirements to be satisfied by the server and the service itself

The content of this section is work in progress, subject to corrections and refinements.

N.2.1 Requirements Template

Template used for the following Requirements

ID	Feature	Partner
Title		
Text		
Rationale		

ID: Requirement ID REQ-38-XX-YYY.ZZZ

Feature: e.g. Trajectory Visualization or Discrepancy Monitoring

Title: Requirement Title

Text: Requirement Text

Rationale: Requirement rationale and background

Partner: If requirement is applicable to a specific Partner

N.2.2 Functional Requirements for ADS-C Common Service

The ADS-C Common Service shall be developed in accordance with [18] and [19].

N.2.2.1 Context Management (CM)

N.2.2.1.1 CM Logon Processing

Figure 155 describes the overall flow of CM Logon Processing.

REQ-38-CM-001.001	Context Management	Partner
B2 Logon Acceptance		
Upon receipt of CM Logon Request message, the ADS-C Common Service shall return a positive CM Logon Response to the aircraft when the following requirements are fulfilled: • The CM Logon Request includes at least ADS-C application information (i.e. aeQualifier: 0, apVersion:1), and • The aircraft address is included in the Logon List Otherwise a negative Cm Logon Response shall be returned to the aircraft		

Note: A positive CM Logon Response contains ADS-C as single application (aeQualifier: 0, apVersion: 1).
Rationale

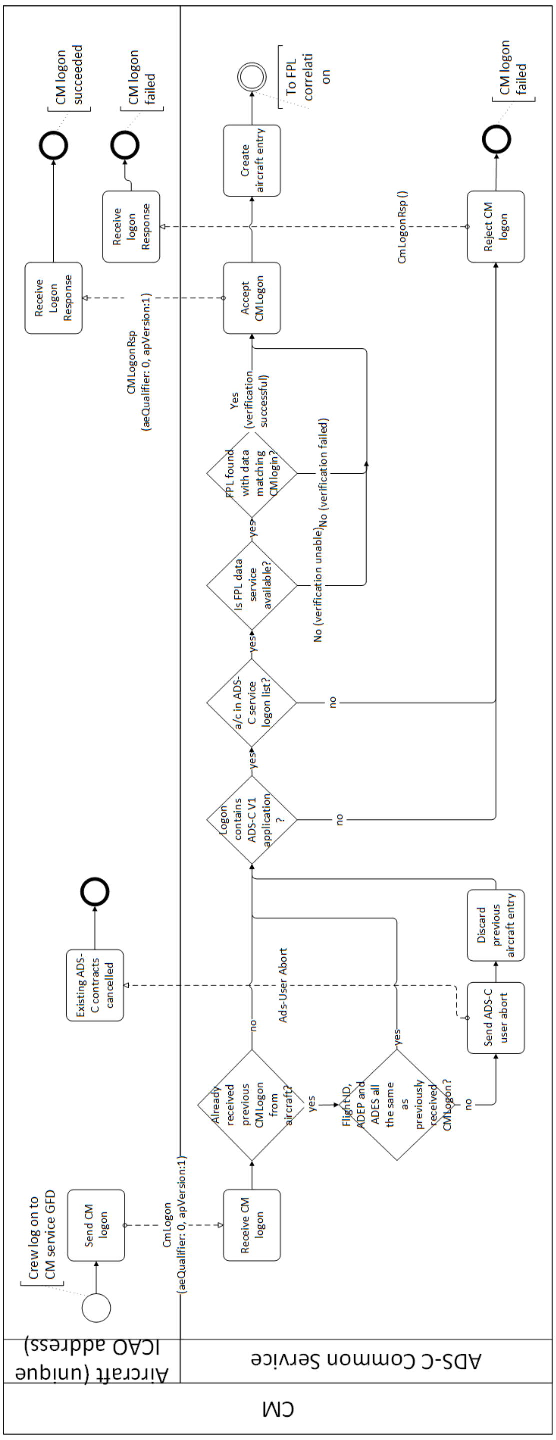


Figure 155: ADS-C Area of Service and Service Interfaces to Airspace Users and Ground User

REQ-38-CM-001.002	Context Management	Partner
Subsequent CM Logon for same aircraft and FlightID		
Any subsequent CM Logon from the same ATS B2 aircraft (with same flightID, same icao24bit address and same ADEP ADES) shall be logged and answered according to REQ-38-CM-001.001. The additional Logon shall not affect active ADS-C contracts, if any.		
Rationale		

REQ-38-CM-001.003	Context Management	Partner
New Logon with different FlightID, ADEP or ADES (non-nominal scenario)		
New Logons from the same aircraft (same icao24-bit address) with either different callsign, ADEP or ADES shall • Trigger the abortion (Ads-User Abort reason=undefined) of open contracts for aircraft with that icao24bit • Lead to removal of the previous aircraft/flight information in the system • then lead to proceed according to REQ-38-CM-001.001		
Rationale		

N.2.2.2 Logon Verification against FPL Data

REQ-38-FP-001.001	FPL data source	Partner
B2 Logon Verification against FPL and ground data		

When receiving an ATS B2 Logon (i.e. a Logon including ADS-C application information i.e. aeQualifier: 0, apVersion: 1) from an aircraft included in the Logon List, the ACS shall correlate the logon with Flight Plan data (analogue to ED228A “CM-OR 230” and “CM-OR 231” for ATSU systems).
 	
The verification result that is returned shall be
• “successful” only if all the correlation with the FPL data stored on the server is successful. This is if a valid FPL can be found where the following information are equal to the ones in the CM Logon:
  ○ Flight ID,
  ○ icao24bit address
  ○ ADEP, ADES
• “failed”, if FPL data service is available, but no matching FPL is found which satisfies all conditions stated for “successful” result above.
• “verification unable”, if no valid FPL data service is available (due to degraded mode)		

The verification result (successful, failed, unable) will be clearly flagged on any data published to ground users
The FPL correlation is introduced due to the following safety requirements:

ED228A	ADSC	SR-GD-ADSC-20B	SO-ADSC-3d, SO-ADSC-3u, SO-ADSC-4, SO-ADSC-5d, SO-ADSC-5u, SO-ADSC-6	When flight plan correlation is performed, either as part of CM or a given application (e.g., ADS-C), the ATSU system shall only establish and maintain data link services when as a minimum the flight identification and aircraft identification (either the Registration Marking or the 24-bit Aircraft Address) correlates with the ground system's corresponding identifiers in the current flight plan.

N.2.2.3 Aircraft Position and Track Source

REQ-38-TS-001.001	Position/Track Source	Partner
Use of aircraft position data		
The system shall be able to consume the following data sources to determine the current aircraft position: • NM B2B Flight Data service • (optional) NM EFD data • (optional) ADS-B service • (optional) track data		
Having access to the aircraft position allows to improve the service: i.e. knowing when to establish and maintain the ADS-C contract with the aircraft		

REQ-38-TS-001.002	Position/Track Source	Partner
Determine aircraft position from ADS-C data when no other track data available		
If none of the data sources listed in REQ-38-TS-001.001 are available, the system shall determine the last known a/c position from the latest received ADS-C position report. Before periodic and event contracts are established, an initial ADS-C on-demand contract request shall be issued to get an initial position.		
This requirement is only applicable if several geographical service areas are established (see section N.1.1). As this is not intended for PJ38 demo, it is N/A in this context. This requirement is only needed if the service is required to handle ADS-C contracts for flights where no position data is available from the standard source. In this case, an initial position could be obtained from an ADS-C on-demand report.		

N.2.2.4 Automatic Dependent Surveillance – Contract (ADS-C)

REQ-38-AD-001.001	ADS-C	Partner
Necessary conditions to establish periodic and event ADS-C contracts		
The following conditions shall be necessary for the establishment of periodic and event contracts: • The flight has made a successful ATS B2 logon according to REQ-38-CM-001.001 • The position of the flight is within the area of service (AoS) In case no source of position data is available, no periodic and no on-event contracts shall be established.		
In case of several limited geographical Areas of Service (AoS) Periodic and event contracts shall only be established for flights within the AoS. In case of one unlimited AoS as intended for PJ38 demo, the second condition is per se fulfilled.		

REQ-38-AD-001.002	ADS-C	Partner
Necessary conditions to establish on-demand ADS-C contracts		
The following conditions shall be necessary for the establishment of on-demand contracts: The flight has made a successful ATS B2 logon (REQ-38-CM-001.001), AND • An on-demand contract is requested by a consumer (see SWIM ICD in section N.3), OR • The ACS triggers an internal request to determine aircraft position when no track data from other services are available (REQ-38-TS-001.002)		
On-demand contracts may be established for flights with unknown position (e.g. to get initial position) and also for flights outside AoS.		

REQ-38-AD-001.003	ADS-C	Partner
Title Automatic establishment of periodic and event contracts		
If the conditions for periodic and event contracts are met (REQ-38-AD-001.001) pre-defined periodic and event contracts shall be automatically established one after each other and maintained until the ACS Area of Service exit (as far as not facing any communication issues)		
Note that future service evolution may include “switching” of contract settings as a function of flight-phase or AoS sub-volumes (see REQ-38-CS-001.001 REQ-38-CS-001.001), which is realized by cancellation and re-establishment with new settings.		

REQ-38-AD-001.004	ADS-C	Partner
Provider Abort Handling		
In case of a provider abort (adsPAbortInd) received, the system shall try to re-establish every n minutes, before giving up after m failed attempts. (n and m shall be configurable)		
Current assumptions are n=6 minutes and m=3 failed attempts.		

REQ-38-AD-001.005	ADS-C	Partner
User Abort (reason undefined) Handling – Nominal behaviour		
In case of receiving a User abort (adsUAbortInd) with reason undefined, the system shall cancel all contracts (the ADS-C connection is gone) except in the case covered by REQ-38-AD-001.010		
In absence of additional information about the flight state (from external source such as NM B2B) or if it can be confirmed that the User Abort happened after off-block, User abort reason undefined should be interpreted as end of flight		

REQ-38-AD-001.010	ADS-C	Partner
User Aborts (undefined) - Doors Open issue Handling		
The system shall re-establish ADS-C contracts in case of reception of User Aborts with undefined reason while the aircraft is still on the ground at the beginning of the flight. The ADS-C contracts shall be reattempted at aircraft take off (or as soon as it can be detected the aircraft is moving so the doors are closed). The aircraft position shall be determined with information from the Flight Plan and tracking module.		
Unexpected early User Aborts (undefined) events may occur because aircraft doors are still open when the aircraft performs CM Logon and the ADS-C contracts are established at the beginning of the flight. This is an ATSU design feature that must be taken into account even though a fix is supposed to be implemented in future release of the ATSU avionics. This functionality assumes correlation with NM flight plan and thus needs an external data source.		

REQ-38-AD-001.007	ADS-C	Partner
User Abort Handling (Other reasons)		
In case of receiving/generating a User Abort with reason different from undefined (i.e.: unknown- integrity-check, validation failure, unable-to-decode-message) the system shall		

cancel all contracts in its internal database (the ADS-C connection is gone). ADS-C contracts for that aircraft shall not be re-tried.
Such User Aborts events may reveal some End to End system misbehaviour; it makes sense not to re-attempt the contracts

N.2.2.5 Variable Periodic- and Event Contract Management

REQ-38-VC-001.001	Variable Contracts	Partner
The system shall support the following user categories and dynamic user roles:		

Static User Category	Accepted Dynamic Self-Claimed Roles
ANSP	ANSP, C-ATSU, N-ATSU, None
AMAN	AMAN, None
Airline	Airline (or Operator?), None
MET	MET, None
NM	NM, None
Other	None

These roles will be used for the purpose authorizing and prioritizing requests for variable ADS-C periodic and Event Contract Management

REQ-38-VC-001.002	Variable Contracts	Partner
Self-claiming of dynamic user role		
The system shall enable a user to make and update claims on its role with regards to an individual flight which will be identified in the request.		

REQ-38-VC-001.003	Variable Contracts	Partner
Verification of self-claimed roles		
Upon receiving a role claim of a user, the system shall perform verification of dynamic role claims against static user category data, according to the rules & table of REQ-38-VC-001.001		

The system is expected to check a role claim against static user category, but has no means to check e.g. if an ANSP claiming C-ATSU actually controls the flight at a particular moment

REQ-38-VC-001.004	Variable Contracts	Partner
Role information		
The system shall enable the user: • to request his current role status with regards to one or more flights • to request the role status of all users with regards to all flights		

N.2.2.5.1 TOA Range Periodic Contract Management

REQ-38-VC-002.001	Variable Contracts	Partner
Modes of TOA Range data collection in ADS-C periodic contracts		
The system shall support two modes of managing TOA Range in periodic ADS-C Contracts: • TOA Mode 1: Standard TOA Range data collection according to server-side configuration (if available) • TOA Mode 2: Customized TOA Range data collection according to user request		

REQ-38-VC-002.002	Variable Contracts	Partner
Authorization for customized TOA Range Requests in periodic contracts		
The system shall allow only a user with the dynamic role AMAN for a particular flight to make a custom request for TOA Range data collection (TOA Mode 2) or switch between the standard and custom mode (TOA Mode 1 and 2) for this flight		
Other users (in particular ATSUs) can obtain specific TOA range data by demand contract requests if needed		

REQ-38-VC-002.003	Variable Contracts	Partner
TOA Mode 1: Standard server-side logic		
The system shall support standard TOA Range data collection in periodic contracts according to the following procedure:		

• Step 1: ACS data collection after a/c CM Logon begins with a default ADS-C Contract (without TOA request). • Step 2: Whenever receiving an ADS-C report, ACS checks the EPP against configured list of [ADES, TOA Fix] pairs • Step 3: If the flight is planned for ADES x and passes TOA Fix y, ACS switches to specific TOA range contract for this Fix according to the list (if several TOA Fixes included in the route, the closest Fix is chosen, when this is overflown the next one)
This Logic is already implemented/demonstrated in PJ38 prototypes (although by a workaround, and not yet detailed in specification) Solution concentrates on basic requirements (keep it simple). More sophisticated logic - if needed - is delegated to the client-side (user requests) Configuration is assumed to be managed offline via the ACS governance (respective “AMAN owner“ is expected to determine list of [ADES, TOA] fix pairs for ADES).

REQ-38-VC-002.004	Variable Contracts	Partner
TOA Mode 2: Set custom TOA Fix		
The system shall enable the user with dynamic role “AMAN” to request TOA range data for a Fix of his choice (this Fix will be included in the ADS-C contract and has priority over TOA Mode 1 configuration)		

REQ-38-VC-002.005	Variable Contracts	Partner
TOA Mode 2: Custom Fix not in route		
When a TOA Fix requested by AMAN is not in the route and the contract is rejected by the a/c, the system shall revert to TOA Mode 1 (Standard logic)		

REQ-38-VC-002.006	Variable Contracts	Partner
TOA Mode 2: Cancel custom TOA Fix		
The system shall enable the user with dynamic role “AMAN” to cancel a previous request for TOA range data for a Fix of his choice, which will revert the system to TOA Mode 1.		

REQ-38-VC-002.007	Variable Contracts	Partner
TOA Mode 2: End of AMAN role		
When a user performs a dynamic role change from AMAN to none, the system shall cancel previous requests of this user for TOA range data for a Fix of his choice, which will revert the system to TOA Mode 1.		

REQ-38-VC-002.008	Variable Contracts	Partner
TOA Mode 2: Transfer of AMAN role		
When the AMAN role is transferred, because another user successfully claims this role, TOA range data requests of the previous AMAN role owner shall be cancelled, and the system will revert to TOA Mode 1.		

N.2.2.5.2 Periodic Contract Frequency Management

REQ-38-VC-003.001	Variable Contracts	Partner
Modes of frequency management in ADS-C periodic contracts		
The system shall support the management of periodic contract frequency by the following two modes: • Freq. Mode 1: Periodic frequency based on server-side adaptation, adjusted per flight phase • Freq. Mode 2: Periodic frequency requested by user Given a user requested for Freq. Mode 2, the frequency actually applied in ADS- contracts shall be the maximum of the server-side configuration and the user requested value (server-side value will change with flight phase over time)		

REQ-38-VC-003.002	Variable Contracts	Partner
Authorization to request periodic contract frequency		
The system shall allow only a user with the role C-ATSU for a particular flight to make a request for periodic contract frequency (Freq Mode 2)		

REQ-38-VC-003.003	Variable Contracts	Partner
Cancellation of user request for periodic contract frequency		
The system shall enable a user to cancel his previous request for periodic contract frequency		

REQ-38-VC-003.004	Variable Contracts	Partner
Freq. Mode 1: Periodic frequency		
The ACS shall identify the flight phase based on a received EPP as follows: • If EPP contains ToC, flight phase is climb • If EPP contains ToD but not ToC, flight phase is cruise • If EPP contains neither ToD nor ToC, flight phase is descent Based on this computation, the system applies the adapted periodicity for this flight phase to the periodic contract, issuing a new contract request if needed.		
Likely periodicity values could be 5 min for cruise and 3 min for climb&descent. In case of mismatch between airborne and ground view of the phases, C-ATSU can use custom I/F Full EPP is assumed i.e. ADS-C contract parameters with maximum of 128 waypoints.		

REQ-38-VC-003.005	Variable Contracts	Partner
Freq Mode 2: End of C-ATSU role		
When a user performs a dynamic role change from C-ATSU to none, the system shall cancel previous requests of this user for periodicity of his choice, which will revert the system to Freq Mode 1.		

REQ-38-VC-003.006	Variable Contracts	Partner
Freq Mode 2: Transfer of C-ATSU role		

When the C-ATSU role is transferred, because a new user successfully claims this role, periodicity requests of the previous C-ATSU user shall be cancelled and the system will revert to Freq Mode 1.

N.2.2.5.3 EPP Event Tolerance Contract Mangement

REQ-38-VC-004.001	Variable Contracts	Partner
Support of EPP Event Tolerance Monitoring		
The system shall support user requests for EPP Event Tolerance Monitoring based on contract parameters submitted by the user in line with ED - 228/229		

REQ-38-VC-004.002	Variable Contracts	Partner
Support for EPP Tolerance Event Monitoring acc. to Rev A and Rev B		
The system shall support via the same interface • Tolerance Event Monitoring acc. to Rev A, for only one waypoint • Tolerance Event Monitoring acc. to Rev B, for one or more waypoints		
Rev B is still in drafting phase, double-check this requirement when Rev B has been finalized.		

REQ-38-VC-004.003	Variable Contracts	Partner
Authorization and priority order for requests on EPP Event Tolerance Monitoring		
User requests for EPP Event Tolerance Monitoring shall be possible for all dynamic user roles and shall be prioritized according to the following order (from high to low) 1. C-ATSU 2. N-ATSU 3. ANSP 4. Any other role		

REQ-38-VC-004.004	Variable Contracts	Partner
EPP Tolerance Event request with higher priority		
The request of a higher priority user shall overwrite/replace a previous EPP tolerance event request of a lower priority user (only the epp event tolerance information, not other event types), leading to a modification of the ADS-C contract.		

REQ-38-VC-004.005	Variable Contracts	Partner
Request EPP Tolerance Event request with equal or lower priority		
The request of a user shall be rejected when another user already has an EPP Tolerance Event Contract in place, and the new request is from a user of lower or equal priority role.		

REQ-38-VC-004.006	Variable Contracts	Partner
Cancellation of EPP Tolerance Event requests		
The system shall enable the user to cancel his previous requests for EPP Event Tolerance monitoring (e.g. when transferring a flight)		

REQ-38-VC-004.007	Variable Contracts	Partner
EPP Tolerance Event requests maintained with role changes		
When a user A changes his role, or his role is changed through successful claim of another user, EPP Tolerance Event contracts of user A shall be kept.		
EPP Tolerance Event contract are not automatically terminated through role changes and potential role downgrading.		

N.2.2.6 Timers

REQ-38-TI-001.001	Timers	Partner
Inactivity timer at Datalink Service level		

Flights and ATN addressing information related to aircraft shall be deleted from the database after a configurable period of inactivity (no ATN transmissions of CM or ADS application). The configurable period of inactivity must be greater than the maximum expected time between a CM Logon and the entry to the AoS of the service instance (otherwise the flight will be deleted before any ADS-C contract request). This can be several hours.
Purpose of the requirement is to delete flights from the system after a configurable period of inactivity, to make sure they are not kept in system memory forever

REQ-38-TI-001.002	Timers	Partner
ADS-C Timers		
The ADS-C Common Service shall be able to support the operational timer values as described in Doc 9880 Part 1 [22] in order to detect the absence of activity or the absence of an expected operational response within an acceptable period of time. It shall act according Figure 156: ADS-C Timer Values		
Rationale		

ADS-demand-contract	t-DC-1	6 minutes	ADS-demand-contract request	ADS-demand-contract confirmation
	t-DC-2	3 minutes 30 seconds	ADS-demand-contract confirmation (pos-ack, ncn)	ADS-report indication
ADS-event-contract	t-EC-1	6 minutes	ADS-event-contract request	ADS-event-contract confirmation
	t-EC-2	6 minutes	ADS-cancel request	ADS-cancel-contract confirmation
ADS-periodic-contract	t-PC-1	6 minutes	ADS-periodic-contract request	ADS-periodic-contract confirmation
	t-PC-2	123 minutes (longest reporting rate + 3 minutes)	ADS-report indication or ADS-periodic-contract confirmation	ADS-report indication
	t-PC-3	6 minutes	ADS-cancel request	ADS-cancel-contract confirmation

Figure 156: ADS-C Timer Values

REQ-38-TI-001.006	Timers	Partner
ADS-C Periodic Contract Timer - No ADS-periodic-report received within the requested periodicity		
The ADS-C Common Service shall monitor the absence of a periodic report in a time equal to the requested periodic rate plus a configurable number of minutes (default 6 minutes) from the previous ADS-periodic-report received or from the ADS-periodic-contract confirmation. When this timer expires without receiving a periodic report, the connection shall be aborted by uplinking a UserAbort with reason "undefined".		
Rationale		

REQ-38-TI-001.007	Timers	Partner
ADS-C Periodic and Event Contract re-establishment – After UserAbort because no ADS-periodic-report received within the requested periodicity.		
The ADS-C Common Service shall try to re-establish the ADS-C contracts a configurable time (default x min) after aborting the connection (adsUAbortReq reason undefined) because of the absence of a periodic report received. If the contracts are not successfully established, the system will wait the configurable time and re-attempt to establish the contracts. This process will be repeated by the system until to the contracts are successfully established, or otherwise up to the maximum number of attempts defined (configurable parameter, default value = y).		
The absence of periodic reports may be the result of bad coverage in certain areas, because of a problem in a specific base station or because of an issue in the a/c equipment. In case the problem lies on the data link network, it is worth to reattempt to establish the contracts in order not to lose the ADS-C data for the rest of the flight, as the issue could be only happening in a certain area. However, if the issue is on the a/c equipment this will most probably not be solved along the flight and that's why a maximum number of re-attempts is defined.		

N.2.2.7 Common Service SWIM I/F

The ADS-C Common Service SWIM Interface is specified in the separate ICD (section N.3).

N.2.2.8 Infrastructure

REQ-38-IS-001.001	Infrastructure	Partner
Authentication		

Text The identity of the Client shall be authenticated.
Rationale

REQ-38-IS-001.002	Infrastructure	Partner
Authorization		
A set of authorized accesses and actions shall be attached to each authenticated client. Only these accesses and actions shall be possible for the client.		
Examples for actions which need authorization are subscriptions to certain sets of flights by ICAO, sets of message types, request for on-demand contracts		

REQ-38-IS-001.006	Infrastructure	Partner
Authorization to subset of flights by ICAO		
The system shall be configurable to limit the access of an authenticated client to a subset of aircraft which will be identified by their icao24bit address.		
Rationale Examples for actions which need authorization are subscriptions to certain sets of flights by ICAO, sets of message types, request for on-demand contracts		

REQ-38-IS-001.003	Infrastructure	Partner
Privacy		
The client connection shall be a secure connection, so that clients can be sure they receive data from the right service, the data is not corrupted, the data cannot be read by non-authorized parties		
Rationale		

REQ-38-IS-001.004	Infrastructure	Partner
Connection Profile / SWIM		
The client connection shall be based on SWIM yellow profile compatible technologies		
Rationale		

REQ-38-IS-001.005	Infrastructure	Partner
Message Format XER		
The service shall support the distribution of ATN messages XER encoded format		
Rationale		

N.2.2.9 Logging

REQ-38-LG-001.001	Logging	Partner
Local Logging		
All messages exchanged on the ATN interface and on the Client Interfaces (Publish I/F, Request I/F) and NM B2B I/F shall be logged locally		
Rationale This log data will also be exploited to put it in a database for analysis		

REQ-38-LG-001.004	Logging	Partner
Logging mechanism (2)		

All the events, commands and log files shall be logged and stored on the system in text files.
 	
When logging any event/message, the CS shall follow the rules below:
 	
• The (text) log shall be easily exportable into a DB (e.g. CSV or similar format).
• As a configurable option, all application messages shall be exported in XML format (decoded from asn.1 to XML)
• The messages shall be logged in raw and human-readable format
• Each entry in the log messages shall be timestamped in (at least) milliseconds.
• The log mechanism shall apply log rotate
    ○ Log files shall be daily
    ○ Maximum log file shall be 10 MB uncompressed
    ○ Log files shall not be overwritten
• The format of each entry shall be coherent among all the log files
• Log files shall be kept for at least 90 days		

Rationale		

REQ-38-LG-001.005	Logging	Partner
Database Logging – Overwriting of Logs		

Database logs shall be kept and not overwritten for a configurable period of time

N.2.2.10 Adaptation Data

REQ-38-AP-001.001	Adaptation	Partner
ADS-C Service Logon List Adaptation		
The adaptation interface shall provide an ADS-C Service Logon List of A/C accepted for the service, identified by their icao24bit address. This ADS-C Service Logon List shall be dynamically configurable, so that new aircraft can be added without the need to restart the service.		
Rationale		

REQ-38-AP-001.002	Adaptation	Partner
Periodic and Event ADS-C Contract Adaptation		
The adaptation interface shall provide for periodic and event contract definitions		
For a minimal service implementation, one set of default contracts to be applied everywhere/for all aircraft may be acceptable (compare REQ-38-AD-001.001). See REQ-38-CS-001.001 for more advanced logic.		

REQ-38-AP-001.003	Adaptation	Partner
Service Clients/Customers Adaptation / User Privileges		
The adaptation interface shall provide a list of known ground users which are allowed to subscribe to the service, together with user privileges which will determine which data the ground user is entitled to.		
It is assumed that the list of clients will be fairly stable i.e. not change very dynamically. It could therefore be maintained in local adaptation initially.		

REQ-38-AP-001.004	Adaptation	Partner
Online adaptation changes		
The common service shall be able to re-read / change adaptation data online, without a need to re-start the service according to Table 72: List of adaptation data supporting online changes		
Rationale		

Adaptation Data	Explanation	Static / Dynamic Configuration	Remark and Reference
ADS-C Service Logon List	Lists icao24bit addresses of a/c permitted for the service	Dynamic, to add new aircraft to the logon list without system restart.	REQ-38-AP-001.001 ADS Module
Periodic and Event ADS-C Contract Definitions	Set of periodic and event ADS-C contract definitions	Dynamic (Updates to be applied for new contract establishments only without system restart)	REQ-38-AP-001.002 REQ-38-AP-001.004 ADS Module

Table 72: List of adaptation data supporting online changes

REQ-38-AP-001.005	Adaptation	Partner
List of configurable parameters		
In addition to the previous requirements, A number of parameters shall be configurable on the ACS. At least the following ones shall be statically configurable. The system shall be designed so that the most important ones can be reloaded with the smallest possible impacting on the global service: • ATN and IP Addressing information to all local and external services • All technical Timers		
Rationale		

REQ-38-AP-001.006	Adaptation	Partner
Adaptation Data for ADS-C periodic and event Contracts		
The adaptation interface shall provide pre-configured ADS-C periodic and ADS-C event contract definitions to be applied to a flight depending on its situation. This shall take into account the following factors: • Aircraft position in relation to adapted airspace volumes • Aircraft flight phase • ADES (and ADEP?) • Aircraft (by ICAO) • Airline (by FlightID?) • Connection Type (VDL2 or SATCOM)		
Service Evolution		

REQ-38-AP-001.007	Adaptation	Partner
Adaptation Data for TOA Range Monitoring		
ACS adaptation shall include a list of pairs [ADES, TOA Fix] for the purpose of TOA range monitoring		
When a flight on the way to ADES passes TOA Fix according to its EPP, a TOA Range contract on this fix will be established, see further details in section on “variable periodic and event contract monitoring”		

N.2.2.11 Individual Flight ADS-C Connection Status

REQ-38-CST-001.010	ADS-C Connection Status	Partner
Individual Flight ADS-C Connection Status Cluster (IFACS cluster)		
The system shall compute and provide to the client a cluster of information elements describing the ADS-C Connection status of individual flights or aircraft (Individual Flight ADS-C Connection Status Cluster (IFACS cluster))		

REQ-38-CST-001.020	ADS-C Connection Status	Partner
IFACS cluster computation eligibility		
The system shall compute/maintain the iFACS cluster • for all known flights from the moment of the CM Logon is received to the time the flight is deleted from the system memory • Also for unknown flights upon client request (see REQ-38-CST-001.030 case 1)		
Describes for which flights and for which duration IFACS information cluster will be computed for.		

REQ-38-CST-001.030	ADS-C Connection Status	Partner
IFACS cluster provision to clients		
The system shall make iFACS cluster information for flights available • On client request, via a request & reply API • As part ADS-C message publication (which is a publish and subscribe mechanism), adding it as metadata to the ADS-C messages itself		

REQ-38-CST-001.031	ADS-C Connection Status	Partner
IFACS cluster on client request		
The system shall provide the IFACS cluster on client request, where the client specifies its request for a certain flight by the following parameters • Callsign (at least one of callsign or icao24bit address are mandatory) • Icao24bit address (at least one of callsign or icao24bit address are mandatory) • ADEP (Optional) • ADES (Optional) The parameters will be used in a logical AND condition, meaning all have to match to answer the request with a known flight.		

REQ-38-CST-001.050	ADS-C Connection Status	Partner
IFACS cluster information content overview		
The IFACS cluster shall contain the following information elements, of which the structure and semantics will be detailed further in referenced requirements:		

Information Element	**Mandatory (M) / Optional (O)**	**Detailed Requirement reference**
Logon Status	M	REQ-38-CST-001.060
Periodic Contract Status	M	REQ-38-CST-001.061
Event Contracts Status	M	REQ-38-CST-001.062
Demand Contract Status	M	REQ-38-CST-001.063
Abort Information	M	REQ-38-CST-001.064
Planned Retries	M	REQ-38-CST-001.065
a/c in Area of Service	M	REQ-38-CST-001.066
Last a/c contact	M	REQ-38-CST-001.067
Last ADS-C Report		REQ-38-CST-001.070
Current ADS-C Contract Setting		REQ-38-CST-001.080

REQ-38-CST-001.060	ADS-C Connection Status	Partner
Logon Status - IFACS Information Element		
This information element shall contain the following data: • Logon status: Either “NotLoggedOn” or “LoggedOn” • Verification Status: One of “NotLoggedOn”, “Pending”,”Successful”, “Failed”,”Unable”		

REQ-38-CST-001.061	ADS-C Connection Status	Partner
Periodic Contract Status - IFACS Information Element		
This information element shall qualify the status of the periodic contract as • Not Established • Established		

REQ-38-CST-001.062	ADS-C Connection Status	Partner
Event Contract Status - IFACS Information Element		
This information element shall qualify the status of the event contract as • Not Established • Established		

REQ-38-CST-001.063	ADS-C Connection Status	Partner
Demand Contract Status - IFACS Information Element		
This information element shall qualify the status of the demand contract as • Not Established • requested		

REQ-38-CST-001.064	ADS-C Connection Status	Partner
Abort Information - IFACS Information Element		
This information element shall provide data regarding • Type and time of last provider abort received (if any) • Type and time of last user abort received (if any) After successful re-establishment of an ADS-C contract this abort information shall be cleared.		

REQ-38-CST-001.065	ADS-C Connection Status	Partner
Planned retries - IFACS Information Element		
This information element indicates whether the system has pending retries and will try to re-establish the connection. Possible states are: 1. true 2. false		
REQ-38-AD-001.004 currently retries in case of PA, this will inform the client how many are left and if he can expect that the system will trigger further contract establishment attempts. REQ-38-AD-001.010 foresees that ADS-C contracts shall be attempted again after a UA which has been qualified as a doors close event, as soon as the a/c is rolling or after take-off. REQ-38-TI-001.006 and REQ-38-TI-001.007 foresee that upon expiration of a periodic event contract timer, UA undefined shall be uplinked and system shall then attempt to re-establish contracts a configurable number of times in a configurable interval.		

REQ-38-CST-001.066	ADS-C Connection Status	Partner
a/c in area of service - IFACS Information Element		
This information element shall state whether the a/c is in the AoS (Area of Service) the ACS system instance is responsible for • False: The system has a defined/limited area of service and the a/c is not inside this area • True: The a/c is known to be inside the defined AoS, or the AoS is unlimited (AoS is the full region with ATN coverage) • Unknown: No eligible aircraft position data available		

This requirement refers to the situation that there may be more than one ACS, and the different ACS instances are responsible for different Areas of Service Note: Aircraft position with regards to Area of Service may be known to some clients (e.g. ANSPs) from other sources, but for some users it may be relevant, and it adds minimal data volume.

REQ-38-CST-001.067	ADS-C Connection Status	Partner
Last a/c contact - IFACS Information Element		
This information element shall contain the time of the last ATN message successfully exchanged with the a/c		
This may be useful for technical monitoring		

REQ-38-CST-001.070	ADS-C Connection Status	Partner
Request Last ADS-C report content		
The system shall make information on the last ADS-C Report of a flight available via a Request-Reply Interface. This information element shall contain the full payload of the last ADS-C report received for this flight (if any) together with the time of the report The report can be a periodic-report, event-report, or demand-report		

REQ-38-CST-001.080	ADS-C Connection Status	Partner
Request Current ADS-C report contract settings		
The system shall provide a Request/Reply interface to request the current periodic and event contract settings applied to a flight. The information element returned shall contain the full contract settings of the periodic and event reports currently applied for a specific aircraft. If a contract is “NotEstablished”, no settings shall be provided.		

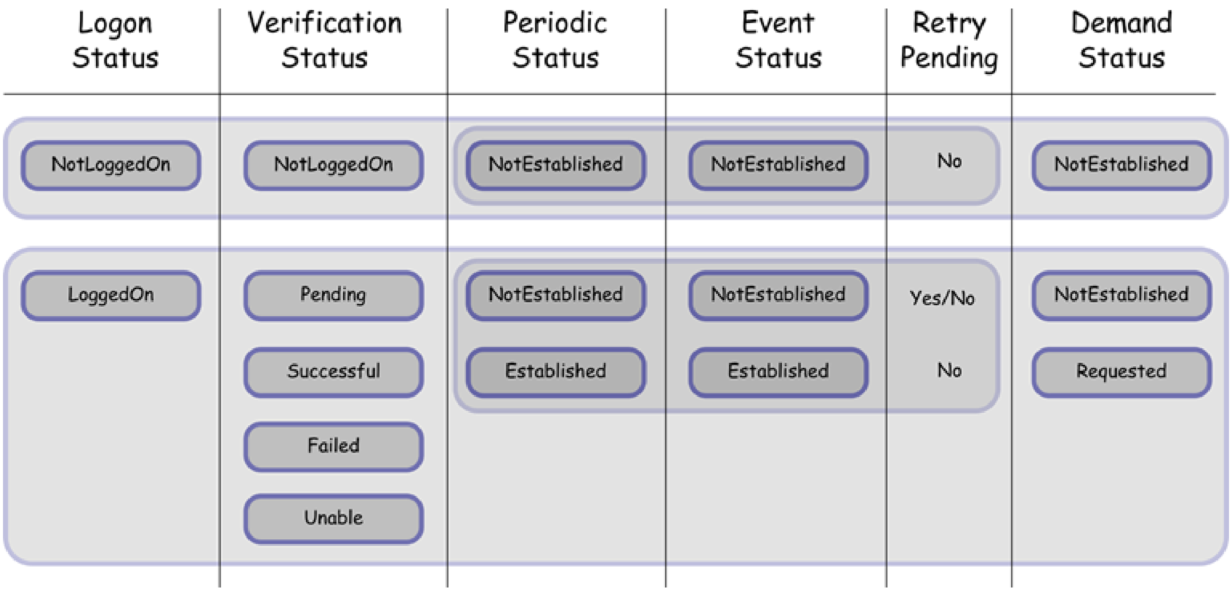


Figure 157 Main ADS-C Connection States

N.2.3 Capacity, Performance and Availability Requirements

N.2.3.1 Capacity Requirements

The current section describes what a maximal load scenario is.

REQ-38-PF-001.001	Performance	Partner
Capacity Requirements		
The system shall be able to support the following capacity		

	Wave #3	Deployment Expectation
simultaneous ADS-C aircrafts (each aircraft up to 3 ADS-C contracts)	200	1400
Connected aircraft per day	2.500	
Received ADS-C reports per day	200.000	

40% of today's flights in the air (CP1 target) would be ~1400.

2500 connected aircrafts per day, with an average of 40 reports per aircrafts = 100.000 reports. An additional margin of 100% to be at 200.000.

Message rate 40 per flight hour is an average/nominal value not peak value.

REQ-38- PF-001.002	Performance	Partner
Capacity Requirements		

The system shall be able to support the following number of ground connections:		
	Wave #3	Deployment Expectation
ANSP type user connections (one ANSP may establish several connections)	20	
"NM kind" of user	1	
Other ground users (e.g. Airlines, other R&D systems)	20	
Capacity Requirements		

N.2.3.2 Performance Requirements

REQ-38- PF-001.003	Performance	Partner
Performance requirements		
Under maximal load conditions, the system shall be able to process		

	Wave #3	Deployment Expectation
Number of messages per minute	1200	
with a maximum transit (processing) delay in milliseconds	50	

Performance Requirements

REQ-38- PF-001.004	Performance	Partner
Number of simultaneous flights and ATN message rate		
The service shall be able to support		

	Wave #3	Deployment Expectation
Number of simultaneous flights	200	1400
At messages rate per hour per flight	40	

200 Flights is assumed to be sufficient for Wave 3

Deployment Scenario is expected to have higher requirements, e.g. 40% of today's flights in the air (CP1 target) would be ~1400.

Co-funded by the European Union

N.2.3.3 Availability Requirements

REQ-38- AV-001.001	Other	Partner
Availability of the ADS-C Common Service (or the application)		
The application shall be designed to have an availability of NNN %. e.g. In case of failure of one of the software processes, the detection and recovery time shall be less than 10 seconds		
Ensure availability of the service and recovery within 10 seconds		

REQ-38- AV-001.002	Other	Partner
ADS-C contracts re-establishment after failure		
In case of system failure, the application shall automatically re-establish all ADS-C contracts. Not all contracts will be re-established at the same time to avoid any overload. An optimal order for the re-establishment of the contracts shall be proposed.		
ADS-C Contracts to be re-established after failure Evolution Requirement, Applicable for deployment, N/A for initial PJ38 development		

N.2.4 Other system Requirements

N.2.4.1 Time Synchronization

The current section contains additional system requirements

REQ-38-OT-001.001	Other	Partner
Time Synchronization Requirements		
The system shall be synchronized through NTP protocol.		
To ensure time synchronization, the ACS will have access to reliable time source through NTP (either by connecting to Internet NTP servers or by using a local GPS source). SR-9 of ED-228A requires time reference of UTC +/- 1 second, which this NTP synchronization will be able to ensure		

N.2.4.2 Monitoring and Control

REQ-38-OT-001.002	Other	Partner
Remote Monitoring and Control		

The system shall provide a remote monitoring and control function supporting SNMP or REST-based API allowing the management system to access the following commands and information:
 	
• Commands
  ○ System Reboot
  ○ Application Start/Stop/Restart (all data processing)
  ○ Enable/Disable external connections (to the ATN G/G router)
  ○ Enable/Disable connection to a specific consumer
 	
• Status
  ○ System technical and functional status
  ○ Status of each single connection (internal and external)
  ○ Application relevant information (load, number of connected A/C...)
  ○ Logical connection status
  ○ Internal processing status
  ○ Resource usage
  ○ Firewall status
 	
• Alarm
  ○ alarm to be raised in case of abnormal technical situation, service degradation, including an abnormal increase of resource, application reporting wrong behaviour, firewall alert
  ○ alarm to be raised on each internal

Remote Monitoring and Control Requirements

REQ-38-OT-001.003	Other	Partner
Local Monitoring and Control		

The system shall provide a local Monitoring and Control function with a graphical HMI, providing access to main commands for operating the ACS. The following status and controls shall be made available
 	
The full list of Status, Commands and alarms provided to the “Remote Monitoring and Control”, as well as the following additional elements:
 	
• Status
  ○ Aircraft list and their ADS-C status
  ○ Message Logging (raw) and decoding
  ○ Any relevant technical information,
  ○ External connections status (partners)
 	
• Commands for Maintenance and Application management:		

○ Software or configuration update / review ○ Access to technical and application logs, including history of commands
Local Monitoring and Control Requirements

N.2.4.3 Security Requirements

REQ-38-OT-001.004	Other	Partner
Firewall		
The system shall be protected from external intended or not system intrusion by a properly configured firewall service (iptables, firewalld). In case of unexpected event (configurable), the firewall shall raise an alarm to the central and local monitoring function		
Firewall		

REQ-38-OT-001.005	Other	Partner
Firewall – Start/Stop		
The firewall shall run permanently on the system and cannot be stopped by the remote Monitoring and Control function. Only the system administrator can stop it through local intervention.		
Firewall		

REQ-38-OT-001.006	Other	Partner
Firewall - Configuration		
• The firewall shall deny network communications traffic by default and allow network communications traffic by exception (i.e., deny all, permit by exception). • The firewall shall be configured to block unauthorized inbound traffic and block unexpected outbound traffic. • The firewall shall be configured to use filters that use packet headers and packet attributes, including source and destination IP addresses and ports • The firewall shall generate traffic log entries containing information to establish the outcome of the events, such as, at a minimum, the success or failure of the application of the firewall rule. • The firewall shall generate traffic log entries containing information such the source and destination IP address, ports, the date and time of the events. • The firewall shall generate traffic log records when traffic is denied, restricted, or discarded. • The firewall shall fail to a secure state if the firewall filtering functions fail unexpectedly.		

• The firewall shall disable or remove unnecessary network services and functions that are not used as part of its role in the architecture.
Firewall – discuss requirement split

N.2.4.4 Operating system Requirements

REQ-38-OT-001.007	Other	Partner
OS requirements		
The system shall be deployed on a recent and supported version of RedHat / CentOS.		
Operating system requirements		

REQ-38-OT-001.008	Other	Partner
Title Hardening Operating System requirements		
The Operating System shall be configured in a hardened way: • Only necessary services shall be installed and activated at boot time • Application shall get the minimal access rights (no root access). Where additional access is required, the sudo command shall be used. • Unused or unnecessary listening ports shall be closed • Non secured communication protocols (rshell, rlogin, telnet, ftp) shall be deactivated • The application shall be installed on a separate disk partition from the OS • Enable rotation for Operating System log files		
Hardening Operating system		

N.2.5 Non-functional Requirements

N.2.5.1 Introduction

This section describes "quality attributes" that the ACS shall fulfil. These are essentially non-functional requirements that affect the performance of the realized system and the delivery of the service.

Many of these attributes are expected to have a measurable effect on the ACS architecture.

The ACS architecture is "the structure or structures of the [ACS], which comprise software elements, the externally visible properties of those elements, and the relations among them." [22]

It is proposed to follow the "System and Software quality models" defined in the ISO 25010:2011 standard [24]. This standard defines a product quality model which groups the quality attributes in eight main characteristics composed in related sub-characteristics (see Figure 158).

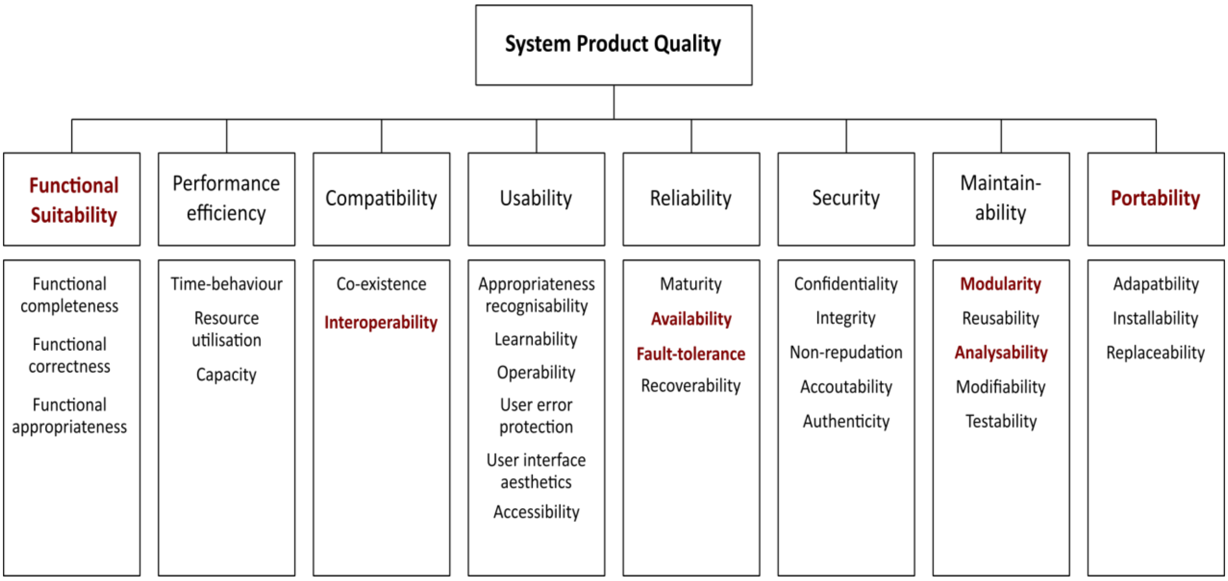


Figure 158: ISO 25010 Product Quality Model

N.2.5.2 ACS Quality Attributes

The figure highlights (bold, dark red) the characteristics and sub-characteristics considered important for the ACS.

REQ-38-AR-001.001	Architecture	Partner
Functional suitability		
The functions provided by the ACS shall meet all (completeness) the stated and implied functional requirements in order to provide correct results at the required degree of precision (correctness).		
See section N.2.6		

N.2.5.3 Functional suitability

N.2.5.4 Performance efficiency

REQ-38-AR-001.002	Architecture	Partner
Performance efficiency		
The architecture of the ACS shall allow to meet the response and processing times requirements (time behaviour).		
See section N.2.6		

N.2.5.5 Interoperability

REQ-38-AR-001.003	Architecture	Partner
Interoperability		
The ACS implementation shall exchange information using documented (and standard) protocols and formats. This shall also apply between the possible components of the ACS (see Modularity)		
See section N.2.6		

N.2.5.6 Reliability

REQ-38-AR-001.004	Architecture	Partner
Reliability		
The ACS architecture shall support a high degree of availability while being resilient to (hardware or software) faults. In case of failure, the ACS architecture shall permit to re-establish the desired state of the system (recoverability).		
See section N.2.6		

N.2.5.7 Security

REQ-38-AR-001.005	Architecture	Partner
Security		
ACS architecture shall ensure that are accessible only to the authenticated subjects/systems (authenticity) authorized to have access (confidentially).		
See section N.2.6		

N.2.5.8 Modularity

REQ-38-AR-001.006	Architecture	Partner
Modularity		
The ACS architecture shall be composed of discrete components. The (static and dynamic) dependencies amongst these components shall be identified and documented. These components shall interoperate (see interoperability) using documented and standardized formats and protocols. See also portability.		

See section N.2.6

N.2.5.9 Analysability

REQ-38-AR-001.007	Architecture	Partner
Analysability		
The ACS architecture shall enable the diagnosis of deficiencies and the detection of failure.		
See section N.2.6		

N.2.5.10 Portability

REQ-38-AR-001.008	Architecture	Partner
Portability		
The ACS shall be adaptable to the evolutions of its (technical and operational) environment and of its usage (scalability). The architecture shall permit the independent evolution of its different components (replaceability).		
See section N.2.6		

N.2.6 Rationale and possible ACS realizations

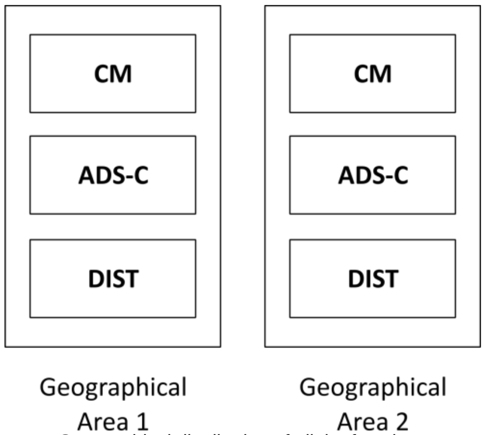
The main rationale behind the required quality attributes of the ACS architecture is to allow flexible replication and/or distribution of the functions to maximize geographical coverage and service provision by more than one service providers.

Three main functions (plus additional "peripheral" functions) are anticipated for the ACS:

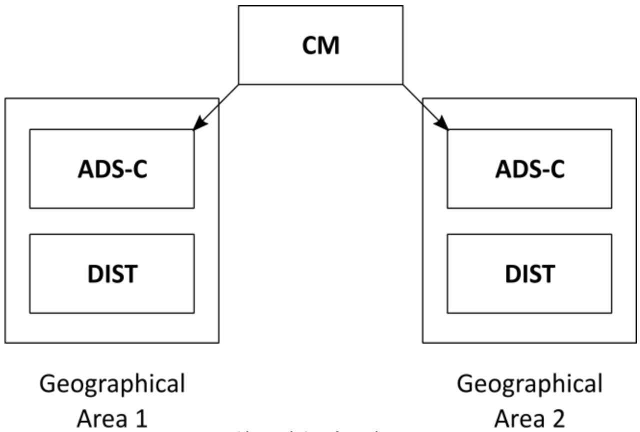
- The CM Logon/management function (CM)
- The ADS-C connection management function (ADS-C)
- The Data distribution (DIST)

The ACS architecture should allow these different functions to be replicated and potentially distributed amongst different service provider.

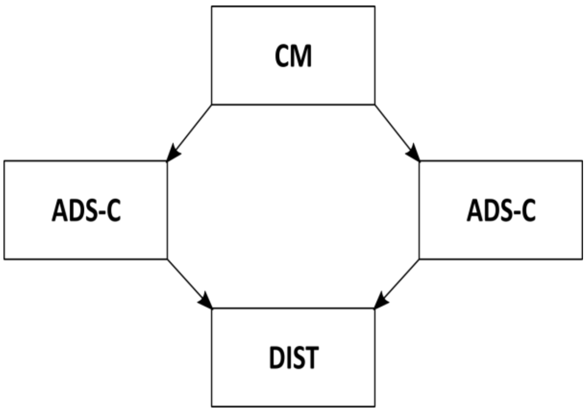
The following figures show possible realizations of the ACS:



Geographical distribution of all the functions



Shared CM functions



Shared CM and DIST functions

N.3 ADS-C Common Service SWIM ICD

N.3.1 Operational view

N.3.1.1 Supported Use Cases

The ADS-C Common Service Interface currently supports the following primary use cases from an operational perspective.

N.3.1.1.1 Use Case 1 - Subscribe by ICAO

In this use case, a client subscribes to listen to all datalink messages exchanges between a specific aircraft or set of aircraft and the ADS-C common service. The set of aircraft is identified by a list of ICAO 24-bit address. For the duration of the subscription, the client will receive live “copies” of datalink messages exchanged between ADS-C Common Service and these aircraft. The datalink message exchanges will include CM messages (Context Management) and ADS-C messages (Automatic Dependent Surveillance Contract messages).

The service supports the realization of the use case in two technical variants where either

- the client connects to a preconfigured endpoint for a bigger set of aircraft (see use case 2 or use case 5 and selects the specific aircraft by an AMQP filter, or
- the client actively sends a subscription request for a specific ICAO addresses

This is indicated by the optional box in Figure 159.

Note that the subscription itself will NOT trigger any CM or ADS-C message exchanges on the ATN side of the service. As a general rule, ADS-C periodic and event contracts are established by the ACS autonomously, independent of any client requests, according to ACS configuration. With this subscription the client starts listening.

It is possible that the aircraft logon happens before or after the client subscription. While the following Figure assumes the first case, there is an alternative flow in Section N.3.5.1which illustrates the second case.

The typical operational motivation for this use case is that a client is interested to receive information from periodic and event ADS-C contracts for a specific aircraft or a user-defined aircraft set.

As the subscription listens to all ADS-C messages for particular aircraft, it will also receive demand contracts triggered via use case 3 (for this aircraft and by this or any other client).

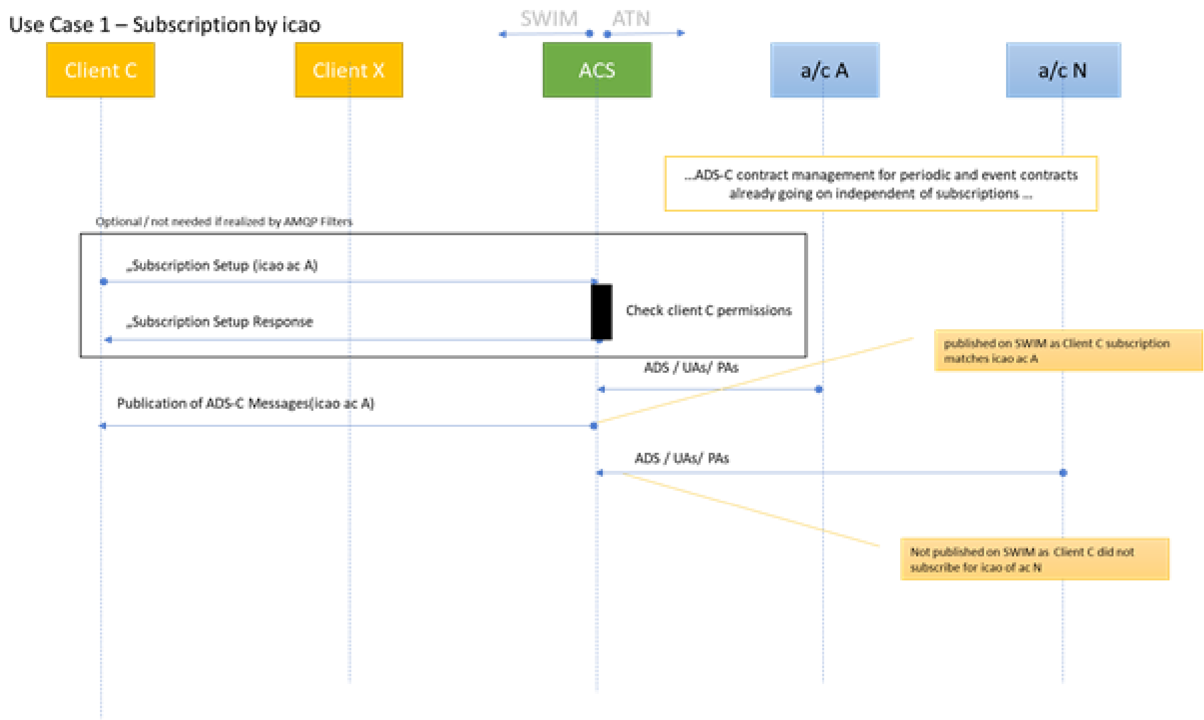


Figure 159: Use Case 1 "Subscribe by ICAO" – Sequence Diagram

N.3.1.1.2 Use Case 2 - Subscribe to all aircraft

In this use case, a client subscribes to listen to all datalink messages exchanges between all aircraft and the ADS-C common service. The service will offer a pre-configured endpoint for clients interested in "all aircraft", so an individual subscription management is not needed. Apart from this, the use case is similar to use case 1.

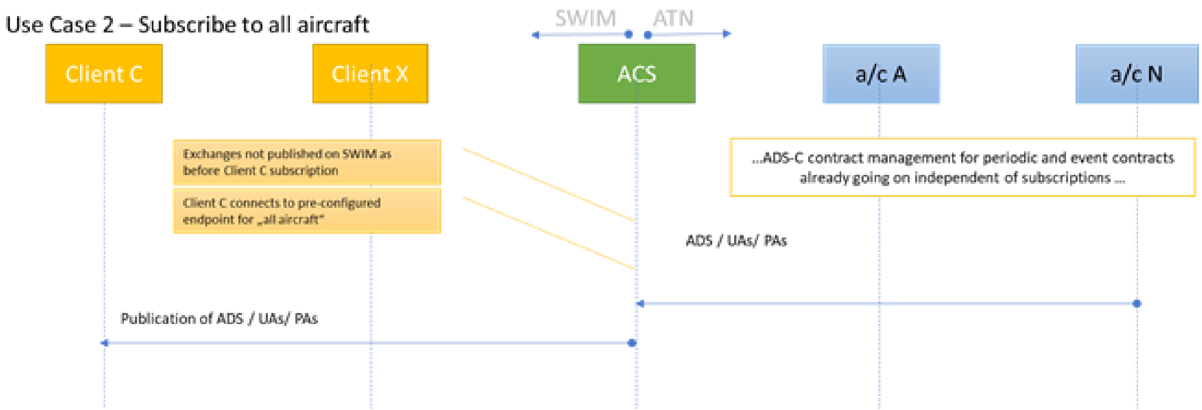


Figure 160: Use Case 2 "Subscribe to all aircraft" – Sequence Diagram

N.3.1.1.3 Use Case 3 - Demand Contract Request

This use case allows clients to request an ADS-C demand contract with individual (client-specified) contract parameters. Contrary to use case 1 and 2, use case 3 does trigger actions on the ATN side of the service. The resulting datalink exchange messages will be copied both to the requesting client itself and also to all other clients which have subscribed to messages from this aircraft e.g. via use case 1 or 2.

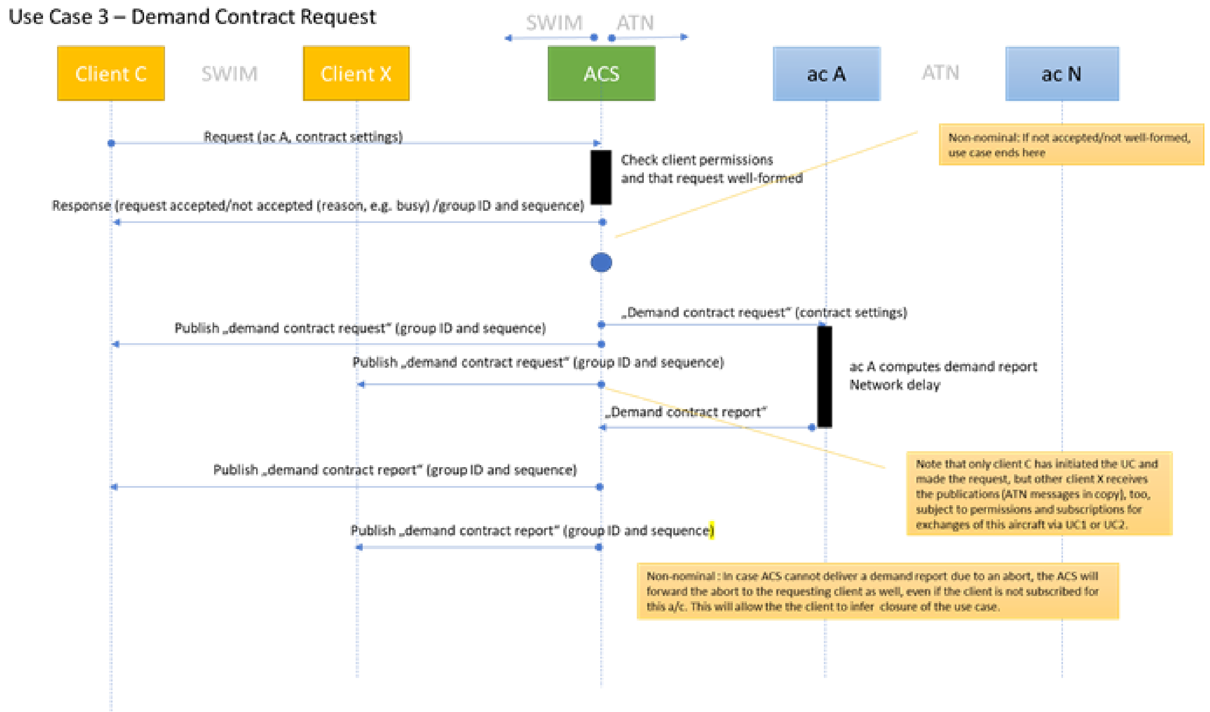


Figure 161: Use Case 3 "Demand Contract Request" – Sequence Diagram

N.3.1.1.4 Use Case 4 - Service Status Monitoring

In this use case the client subscribes to receive technical information about the service status and service health. (Status information is not configurable at this stage, so no individual subscription management is needed)

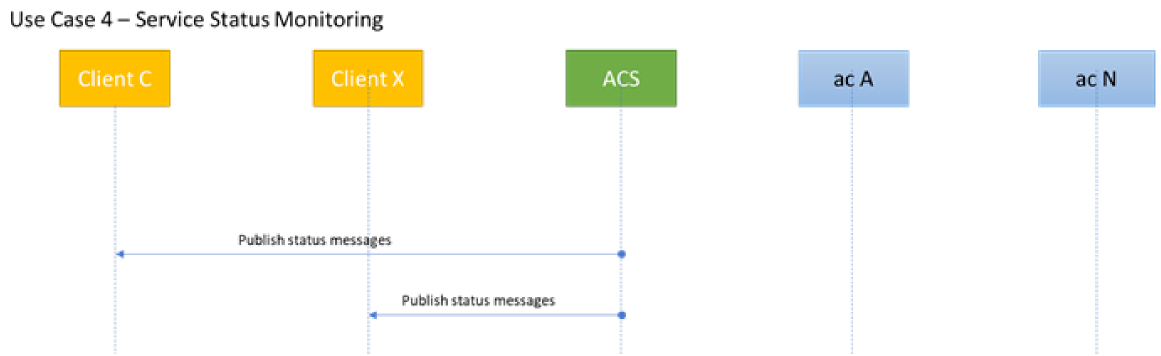


Figure 162: Use Case 4 "Service Status Monitoring" - Sequence Diagram

N.3.1.1.5 Use Case 5 - Subscribe to aircraft fleet

In this use case, a client subscribes to listen to all datalink message exchanges between the ADS-C common service and a specific aircraft fleet (a set of aircraft pre-defined by means of a list of icao24bit addresses on the server-side). This use case is mainly intended for airline users to receive data for their

Co-funded by the European Union

respective fleets. As in use case 2, no individual subscription management will be needed for this use case, as the service will offer a pre-configured endpoint.

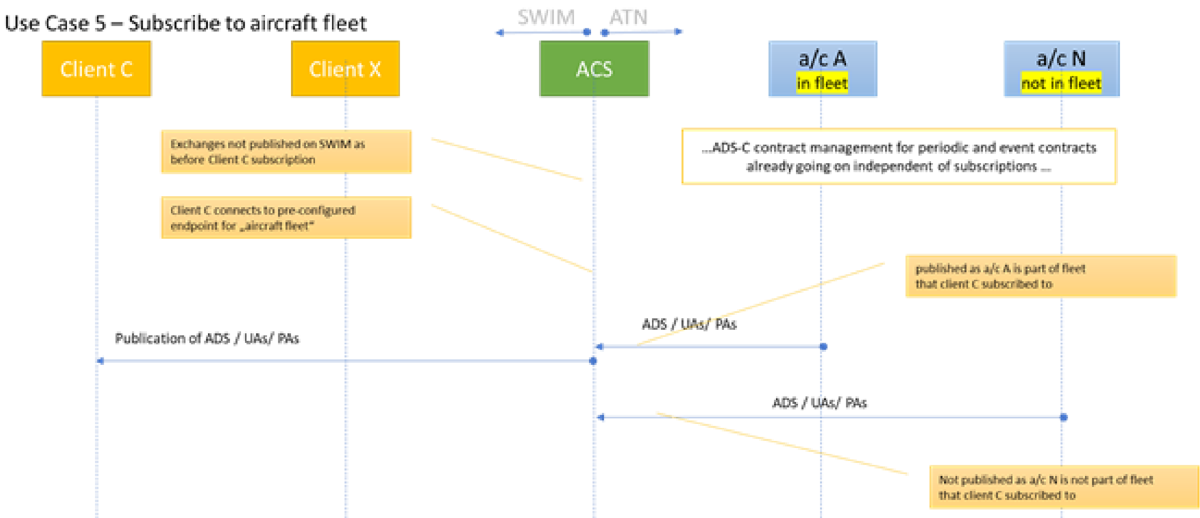


Figure 163: Use Case 5 "Subscribe to aircraft fleet" - Sequence Diagram

N.3.1.1.6 Use Case 6 - Flight Status (IFACS)

In this use case, the ACS client is able to query the status of a specific flight. The flight connection status, contract settings and last report received can be retrieved through this interface.

Connection state is also made available along the published datalink exchanges.

N.3.1.1.7 Use Case 7 – Variable Periodic and Event Contract Management

In this use case, the ACS client is able to request certain changes to periodic and event contract management. In order to authorize and prioritize such requests, users can claim certain dynamic roles (within the limits of their static user category). See appendix F.

N.3.1.2 General support for filtered subscriptions

Beyond the specific application stated in use case 1 “subscribe by ICAO”, the ICD technically supports a wider range of filtered subscriptions which allow the client to specify the set of messages it requests to receive from the service.

At the current stage filtering is supported based on the following properties. These can be combined using Apache selector syntax (compare section N.3.7.3.2) which should support a wide range of operational needs:

Property name	Value
aircraftAddress	The 24bit ICAO address of the AC.
flightID	The flight callsign.
departureAirport	ICAO Id of the departure airport
destinationAirport	ICAO Id of the arrival airport

eobd	The flight Estimated Off-Block Date. It must be an empty string when the information is not available at the time the message is published. When provided, the date is represented using YYYY/MM/DD format.
eobt	The flight Estimated Off-Block Time. It must be an empty string when the information is not available at the time the message is published. When provided, the time is UTC and it is represented using HH:MM:SS format without time zone
messageType	Unique identifier of the message types. Possible values are in Table 42.

flightPlanVerificationResult	It represents the flight plan verification result. Possible values are:
	• “successful” only if all the correlation with the FPL data stored on the server is successful. This is if a valid FPL can be found where the following information are equal to the ones in the CM Logon:
	  ○ Flight ID,
	  ○ icao24bit address
	  ○ ADEP, ADES
	• “failed”, if FPL data service is available, but no matching FPL is found which satisfies all conditions stated for “successful” result above.
	• “unable”, if no valid FPL data service is available (due to degraded mode)

As for use case 1, the ACS supports the realization in two technical variants either

- By using the Subscription API (See Section N.3.3.3) or,
- By having the client setting up an AMQP filter on its connection to the ACS (See Section N.3.7).

N.3.2 Conceptual Operation of the ACS

N.3.2.1 Overview

The ADS-C Common Services distribution (ACS) provides data services to downstream clients such as ANSPs, network managers, airlines or other users interested in the ADS-C data via a ‘SWIM Yellow Profile’ compliant interface. For the PJ.38 project, this compliance is achieved via the selection of AMQP v1.0 [25] and HTTPS for the underlying transports.

The data services provided by ACS to downstream clients consists of:

- Subscription based datalink messages from aircraft (including ADS-C and CM)
- Service status messages

Downstream clients will be required to implement AMQP v1.0 and HTTPS[6] (Web Services Light) client side software to engage with a distribution server.

In the AMQP v1.0 model, **nodes** make use of **links** to exchange **messages**. A message has **a header, properties (message properties and application properties) and a payload.**

In the HTTPS model, a client issues a **request** and receives a **reply**.

An ACS client connects to a distribution server using TLS encrypted channels (amqps:// and https://) and authenticates using appropriate credentials. Following successful authentication, the client may make subscription requests using HTTPS in order to receive ACS aircraft data published via AMQP where authorised. A client may receive service status messages from the ACS.

The remainder of this section provides further high-level detail on each of these exchanges between the downstream client and the ACS. Full detail and message formats are to be found in section N.3.3.

N.3.2.2 Consuming Datalink Messages

Datalink messages represent the core data feed of the service. They include ADS and CM messages as defined by ED-228A and ED-229A enriched with metadata for the flight. The metadata will be made available as properties of the message.

The consumption of datalink messages is implemented by the pattern "Data Distribution over AMQP", defined in section N.3.4.1.

An ACS client starts consuming datalink messages by connecting to an AMQP link exposed by the server.

The ACS offers two ways to select the mix of messages the client application receives:

- By using the Subscription API (See Section N.3.3.3) or,
- By having the client setting up an AMQP filter on its connection to the ACS (See Section N.3.7).

In the present ICD, subscriptions and filters are specified using the same language (APACHE.ORG:SELECTOR) and, so, provide the same functionality. However future ACS versions will offer more advanced ways to select/filter datalink messages that will only be possible using the Subscription API.

Access to links is subject to authentication and authorisation. The client can disconnect from the link at any time. Links will be persistent.

Data definitions applicable for the consumption of datalink messages are defined in section N.3.3.2.

[6] The need for HTTPS implementation on client-side is function of the use case. It is mandatory for use case 3 (Demand Contract Request) and to make use of the subscription API (see section N.3.3.3)

N.3.2.3 Consuming Service Status Messages

An ACS client starts consuming service status messages via a connection to the status message distribution link exposed by the server. This link is pre-defined and fixed and is implemented by the 'Data Distribution over AMQP' pattern defined in section N.3.4.1.The format of the status messages is defined in section N.3.3.5.

N.3.2.4 Managing Subscriptions

Subscription management provides a client with the means of customising the set of datalink messages that it receives via the publication mechanism.

The mechanism used to submit subscription management requests follows the request and reply pattern and is therefore implemented via the HTTPS transport.

Section N.3.3.3 provides detailed definition of this facility.

N.3.2.5 Issuing demand contract requests

Demand contracts are requests submitted to a specific aircraft which (if successful) result in a datalink report being issued in response.

The initial request for a demand contract is done using request and reply over HTTPS. Any resulting report is delivered via publish/subscribe over AMQP.

Section N.3.3.4 provides detailed definition of this facility.

N.3.2.6 Get Flight Status

Clients can request via this R/R Interface information on the flight status of individual flights, including current contract setting for a flight and last periodic and event reports.

N.3.2.7 Manage Variable Contracts

The ACS enables clients to manage/influence via an R/R mechanism certain parameters of periodic & event contracts, such as the periodicity of contracts, TOA range data collected with periodic contracts, and EPP tolerance event monitoring for user requested WPs and parameters.

Authorization and priority of such user requests is subject to the dynamic user role, which is also managed via this interface.

N.3.2.8 Assumptions on Users and Clients

Users, Clients, Digital Identity

- A user is an "administrative" notion used for authentication and authorization (it may refer to an organization, a unit or a human user of an organisation,)
- An ACS client refers to a client application (a running program) that needs to present a valid digital identity to connect to the ACS.
- For R & D we assume one digital identity per user, and allow several client applications to use this identity (without takin provision to manage interferences)

Authentication, client certificate, User&Password

- We will start in PJ38 with username and password
- Migration to client certificate can be considered later, but to demonstrate ACS general functionality has priority

Additional Assumptions:

- It is assumed that ground users will be known before requesting service (offline legitimation process in advance, no totally unknown ground users, at least for wave#3 scope).
- It is assumed that users and privileges will need to be managed.
- Additional means will be set up to limit service access to known peers

N.3.3 Data Definition

N.3.3.1 Introduction and principles

This section provides the formal definition of all the information elements exchanged between the ACS and its clients.

Four classes of information elements are distinguished for the following purposes:

- Subscription Management
- Demand Contract Management
- ADS-C and CM Datalink Exchanges
- Service Status Monitoring[7]

The reference XML schemas are available the project OST.

Data definition when applicable keeps compliance with the ATS B2 Standards (ED-228-A and ED-229-A) formal definitions when using the XER encoding ([26]). These definitions are not repeated here, and the reader is referred to these documents and, in particular, the ASN.1 syntax for the formal definitions of the elements mentioned below as belonging to these standards.

N.3.3.2 ADS-C and CM Datalink Exchanges

The format of CM and ADS-C messages published by the ACS conforms to an XER encoding of the formal definitions of these messages and their elements as provided in the ATS B2 standards (ED-228A and ED-229A). These messages are encapsulated in envelopes providing additional information about the messages notably e.g. the flight identification and the ICAO address. The envelopes conform to the XER encoding of the “de facto” standard currently in use for exchanges between front-end processors and ATC systems.

The ACS also attaches metadata to the datalink messages in the form of AMQP application properties. These metadata help to correlate the message without requiring decoding the message body. They

[7] Additional data definitions for the „Individual Flight ADS-C Connection Status“ (IFACS) and for variable periodic and event contract management are introduced in the respective appendices E and F.

include the ICAO address, the flight identifier, the airports of departure and arrival. These application properties are described in section N.3.4.1.4.

The formal definition of the payload is made of two (nested) schemas:

- ACS-Level1.xsd: the main schema providing the envelopes definitions
- ADSMessagesSetVersion1_ACS.xsd: included in ACS-Level1.xsd provides the XER encoded definitions of the elements part of the ATS B2 Standards.

The ACS publishes all datalink exchanges between the ground and the Aircraft and so both downlinked and uplinked messages are published. They correspond to the following two different root elements:

- Downlinked messages: FEP2ATCMessages
- Uplinked messages: ATC2FEPMessages

The following schema extracts provide details on the definition of these payloads.

N.3.3.2.1 FEP2ATCMessages

ACS-Level1.xsd (extract)

```
<!-- … -->

 <xsd:element name="FEP2ATCMessages" type="FEP2ATCMessagesType"/>
 <xsd:complexType name="FEP2ATCMessagesType">
    <xsd:choice>
       <xsd:element name="cmDownlinkMessages" type="CmDownlinkMessages"/>
       <xsd:element name="adsDownlinkMessages" type="AdsDownlinkMessages"/>
    </xsd:choice>
 </xsd:complexType>

 <!-- … -->

 <xsd:complexType name="CmDownlinkMessages">
    <xsd:choice>
       <xsd:element name="cmLogonInd" type="CmLogonInd"/>
       <xsd:element name="cmUAbortInd" type="CmUAbortInd"/>
       <xsd:element name="cmPAbortInd" type="CmPAbortInd"/>
       <xsd:element name="cmCancelFlightInd" type="CmCancelFlightInd"/>
    </xsd:choice>
 </xsd:complexType>

<!-- … -->

 <xsd:complexType name="AdsDownlinkMessages">
    <xsd:choice>
       <xsd:element name="adsDemandCnf" type="AdsDemandCnf"/>
       <xsd:element name="adsEventCnf" type="AdsEventCnf"/>
       <xsd:element name="adsPeriodicCnf" type="AdsPeriodicCnf"/>
       <xsd:element name="adsCancelCnf" type="AdsCancelCnf"/>
       <xsd:element name="adsCancelAllCnf" type="AdsCancelAllCnf"/>
       <xsd:element name="adsReportInd" type="AdsReportInd"/>
       <xsd:element name="adsUAbortInd" type="AdsUAbortReq"/>
       <xsd:element name="adsPAbortInd" type="AdsPAbortInd"/>
    </xsd:choice>
 </xsd:complexType>

<!-- … -->
```

Notes:

- The cmCancelFlightInd is an internal message (between the AGDLS and the FDPS). It does not correspond to a datalink exchange with the Aircraft. It appears in the schema to keep it aligned with the reference FEP2ATC ASN.1 syntax.
- adsUAbortInd has type AdsUAbortReq as the user abort indication and the user abort request share the same structure.

N.3.3.2.2 ATC2FEPMessages

ACS-Level1.xsd (extract)

```
  <!-- ... -->

  <xsd:element name="ATC2FEPMessages" type="ATC2FEPMessagesType"/>
   <xsd:complexType name="ATC2FEPMessagesType">
      <xsd:choice>
         <xsd:element name="cmUplinkMessages" type="CmUplinkMessages"/>
         <xsd:element name="adsUplinkMessages" type="AdsUplinkMessages"/>
      </xsd:choice>
   </xsd:complexType>

   <!-- ... -->

   <xsd:complexType name="CmUplinkMessages">
      <xsd:choice>
         <xsd:element name="cmLogonRsp" type="CmLogonRsp"/>
         <xsd:element name="cmUAbortReq" type="CmUAbortReq"/>
         <xsd:element name="cmCancelFlightReq" type="CmCancelFlightReq"/>
      </xsd:choice>
   </xsd:complexType>

   <!-- ... -->

   <xsd:complexType name="AdsUplinkMessages">
      <xsd:choice>
         <xsd:element name="adsDemandReq" type="AdsDemandReq"/>
         <xsd:element name="adsEventReq" type="AdsEventReq"/>
         <xsd:element name="adsPeriodicReq" type="AdsPeriodicReq"/>
         <xsd:element name="adsCancelReq" type="AdsCancelReq"/>
         <xsd:element name="adsCancelAllReq" type="AdsCancelAllReq"/>
         <xsd:element name="adsUAbortReq" type="AdsUAbortReq"/>
      </xsd:choice>
   </xsd:complexType>

   <!-- ... -->
```

Note:

- The cmCancelFlightReq is an internal message (between the AGDLS and the FDPS). It does not correspond to a datalink exchange with the Aircraft. It appears in the schema to keep it aligned with the reference ATC2FEP ASN.1 syntax.

N.3.3.2.3 General structure of the envelope

The envelope encapsulates the original CM or ADS message and adds the flight identification.

The flight identification provides the ICAO 24-bit address (aircraftAddress) and the flight identification (flightID) and has the following structure:

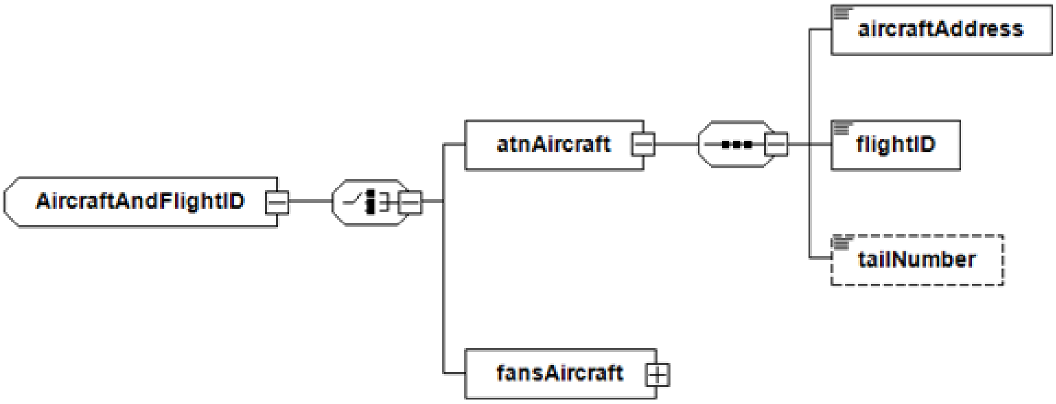


Figure 164: Schema/structure of the AircraftAndFlightID

The optional tailNumber or the fansAircraft identification are kept for compatibility with the original FEP2ATCMessages ASN.1 definitions but do not appear in the payload published by the ACS.

N.3.3.2.4 Downlinked messages (FEP2ATCMessages)

N.3.3.2.4.1 CM Messages (CmDownlinkMessages)

Envelope element	Encapsulated CM PDU	Remarks
cmLogonInd	CMLogonRequest	See N.3.7.3.1
cmUAbortInd	None	Only A/C identification
cmPAbortInd	None	A/C identification and reason
cmCancelFlightInd	None	Only A/C identification

N.3.3.2.4.2 ADS Messages (AdsDownlinkMessages)

Envelope element	Encapsulated ADS PDU	Remark
adsDemandCnf	AdsReport, ADSPositiveAcknowledgement, ADSReject or ADSNonCompliance	Report, positive acknowledgement, reject or non-compliance
adsEventCnf	idem	idem
adsPeriodicCnf	idem	idem
adsCancelCnf	None	Identification and contract type
adsCancelAllCnf	None	Identification
adsReportInd	ADSReport	See N.3.7.3.4
adsUAbortInd	None	Identification and reason, See N.3.7.3.5
adsPAbortInd	None	Identification and reason

N.3.3.2.5 Uplinked messages (ATC2FEPMessages)

N.3.3.2.5.1 CM Messages (CmUplinkMessages)

Envelope element	Encapsulated CM PDU	Remark
cmLogonRsp	CMLogonResponse	See N.3.6.3.2
cmUAbortReq	None	A/C identification
cmCancelFlightReq	None	A/C identification

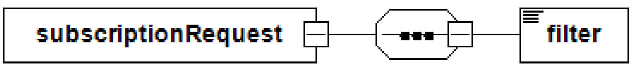
N.3.3.2.5.2 ADS Messages (AdsUplinkMessages)

Envelope element	Encapsulated CM PDU	Remark
adsDemandReq	ADSRequestContract	
adsEventReq	ADSRequestContract	
adsPeriodicReq	ADSRequestContract	See N.3.6.3.3
adsCancelReq	None	Identification and contract type
adsCancelAllReq	None	A/C identification
adsUAbortReq	None	Identification and reason

N.3.3.3 Subscription Management

N.3.3.3.1 "Subscribe" request body

A subscription is specified by the filter applied to the stream of datalink messages.



Element	Type	Description
filter	xsd:string	A filter following AMQP's APACHE.ORG:SELECTOR syntax. See section N.3.4.1.4 for the applicable properties and section N.3.7 for additional information and examples.

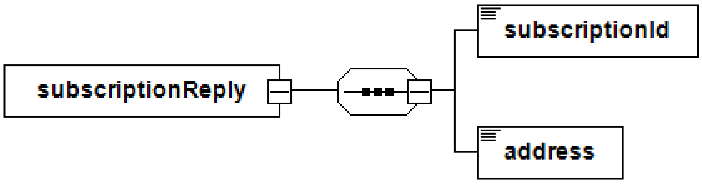
ACS-RR-Subscription_Request.xsd

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            elementFormDefault="unqualified">

  <xsd:element name="subscriptionRequest" type="subscriptionRequestType"/>

  <xsd:complexType name="subscriptionRequestType">
    <xsd:sequence>
      <xsd:element name="filter" type="xsd:string"/>
    </xsd:sequence>
  </xsd:complexType>
```

```
</xsd:schema>
```

N.3.3.3.2 “Subscribe” reply body

When a subscription is successfully created the ACS returns a subscription identifier used for subscription management and the address of an AMQP node on which the client can start a receiver to collect the datalink messages published on the subscription. Both are opaque strings.



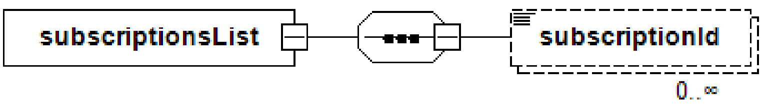
Element	Type	Description
subscriptionId	xsd:NCName	An opaque string generated by the ACS which follows XSD NCName definition and uniquely identifies the subscription on the ACS.
address	xsd:anyURI	An opaque string providing the address of the AMQP node on which the client creates a receiver to collect the datalink messages published on the subscription.

ACS-RR-Subscription_Reply.xsd

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            elementFormDefault="unqualified">

  <xsd:element name="subscriptionReply" type="subscriptionReplyType"/>

  <xsd:complexType name="subscriptionReplyType">
    <xsd:sequence>
      <xsd:element name="subscriptionId" type="xsd:NCName"/>
      <xsd:element name="address" type="xsd:anyURI"/>
    </xsd:sequence>
  </xsd:complexType>

</xsd:schema>
```

N.3.3.3.3 “List subscriptions” reply body

The reply body of the “List subscriptions” is the (possibly empty) list of subscription currently available for the user that issued the request:



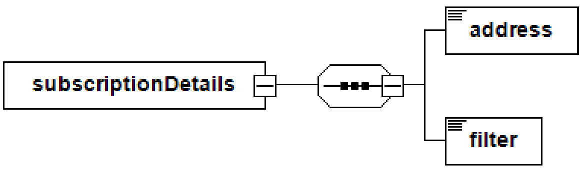
Element	Type	Description
subscriptionId	xsd:NCName	The opaque string generated by the ACS which follows XSD NCName definition and uniquely identifies the subscription on the ACS.

ACS-RR-Subscription_List-Reply.xsd

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            elementFormDefault="unqualified">

  <xsd:element name="subscriptionsList" type="subscriptionsListType"/>

  <xsd:complexType name="subscriptionsListType">
    <xsd:sequence>
      <xsd:element name="subscriptionId" type="xsd:NCName"
                   minOccurs="0" maxOccurs="unbounded" />
    </xsd:sequence>
  </xsd:complexType>

</xsd:schema>
```

N.3.3.3.4 “Subscription details” reply body

The reply body of the “Subscription details” operation provides the node address and the filter specification of the subscription:



Element	Type	Description
address	xsd:anyURI	The opaque string providing the address of the AMQP node on which the client creates a receiver to collect the datalink messages published on the subscription.
filter	xsd:string	The filter specification attached to the subscription. It follows AMQP’s APACHE.ORG:SELECTOR syntax. See section N.3.4.1.4 for the applicable properties and section N.3.7 for additional information and examples.

ACS-RR-Subscription_Details.xsd

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            elementFormDefault="unqualified">

  <xsd:element name="subscriptionDetails" type="subscriptionDetailsType"/>

  <xsd:complexType name="subscriptionDetailsType">
    <xsd:sequence>
      <xsd:element name="address" type="xsd:anyURI"/>
```


 Co-funded by the European Union

```
      <xsd:element name="filter" type="xsd:string"/>
      <!-- Additional elements to align with the ACS ICD -->
    </xsd:sequence>
  </xsd:complexType>

</xsd:schema>
```

N.3.3.4 Demand Contract Management

N.3.3.4.1 Demand Contract Request

ADS-C Demand Contract Requests are sent by the ACS Client to the ACS Server. Their main content encompasses the identification of the flight, which is the subject of the request and the ADS-C Demand Contract request itself. The request may provide an optional address (distributionAddress) to which the Datalink messages related to the ADS-C Demand Contract Request (ADS Request, ADS Response, ADS Reject, ADS Report, ADS User Abort and/or ADS Provider Abort) will be published.

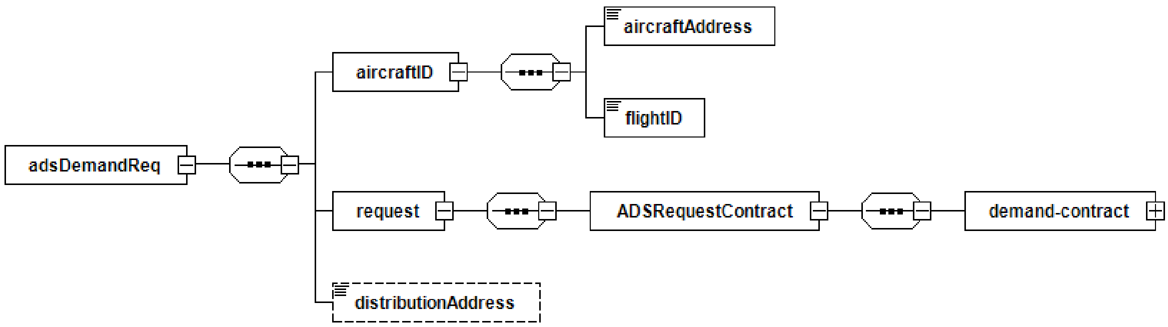


Figure 165: Schema/structure of the Demand Contract Request

The following table provides details about the different elements of the schema:

Element	Type	Description
aircraftID	ATNAircraftAndFlightID	Borrowed from FEP to ATC schema (see above)
request	ADSRequestContractType	Conforms to the schema derived from the ATS B2 standards. However only demand-contract are valid.
distributionAddress	xsd:anyURI	The (opaque) name of the address to use to publish the Datalink messages related to this request.

The “ACS-DemandContract-Req.xsd” XML Schema provides the formal definition of the “Demand Contract Request” which is the payload of a request in Demand Contract Request operation.

The following extract illustrates the structure of Demand Contract Requests:

ACS-DemandContract-Req.xsd (extract)

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
 xmlns:asn1="http://www.obj-sys.com/v1.0/XMLSchema"
```


 Co-funded by the European Union

```
 elementFormDefault="unqualified">
  <xsd:import namespace="http://www.obj-sys.com/v1.0/XMLSchema"
              schemaLocation="http://www.obj-sys.com/v1.0/XMLSchema/asn1.xsd"/>

  <xsd:element name="adsDemandReq" type="AdsDemandReq"/>

  <xsd:complexType name="ATNAircraftAndFlightID">
    <xsd:sequence>
      <xsd:element name="aircraftAddress" type="AircraftAddress"/>
      <xsd:element name="flightID" type="AircraftFlightIdentification"/>
    </xsd:sequence>
  </xsd:complexType>

  <xsd:complexType name="AdsDemandReq">
    <xsd:sequence>
      <xsd:element name="aircraftID" type="ATNAircraftAndFlightID"/>
      <xsd:element name="request">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element name="ADSRequestContract"
                         type="ADSRequestContractType"/>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
      <xsd:element name="distributionAddress" type="xsd:anyURI" minOccurs="0"/>
    </xsd:sequence>
  </xsd:complexType>

  <xsd:complexType name="ADSRequestContractType">
    <xsd:sequence>
      <xsd:element name="demand-contract" type="DemandContractRequest"/>
    </xsd:sequence>
  </xsd:complexType>

  <xsd:complexType name="DemandContractRequest">
    <xsd:sequence>
      <xsd:element name="contract-number" type="ContractNumber"/>
      <xsd:element name="projected-profile" minOccurs="0" type="asn1:NULL"/>
      <xsd:element name="ground-vector" minOccurs="0" type="asn1:NULL"/>
      <xsd:element name="air-vector" minOccurs="0" type="asn1:NULL"/>
      <xsd:element name="met-info" minOccurs="0" type="MetInfoRequest"/>
      <xsd:element name="extended-projected-profile" minOccurs="0"
type="EPPWindow"/>
      <xsd:element name="toa-range" minOccurs="0" type="TOARangeRequest"/>
      <xsd:element name="speed-schedule-profile" minOccurs="0" type="asn1:NULL"/>
      <xsd:any namespace="##other" processContents="lax" minOccurs="0"/>
    </xsd:sequence>
  </xsd:complexType>

  <!-- ... ADS-C subtypes ... conform to ED229 encoded in XER -->
</xsd:schema>
```

The Demand Contract Request payload is an XER encoded ADS-C Demand Contract Request (an ADSRequestContractType limited to “demand-contract”) encapsulated in an envelope identifying the subject Aircraft (aircraftID) and optionally providing an address (distributionAddress) where the ADS messages related to the request will be published.

By the ATS B2 standards, the 'contract-number' is mandatory and has to be provided in the request. However, due to the way the ACS operates, it will be ignored by the ACS. Given this, no assumption can be made on the contract number provided in the ADS Messages resulting from the request.

N.3.3.4.2 Demand Contract Reply

As per UC3, the ACS provides an immediate reply to the client that issued the request providing authorization, validity, and feasibility of the request (authentication is handled at connection time).

This information is conveyed through the HTTP Status code in the WS Light binding (see N.3.4.2.2.2).

N.3.3.5 Service Status Monitoring

The payloads published on the service status monitoring address have the following definition:

ACS-Status-payload.xsd (full)

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            elementFormDefault="unqualified">
  <xsd:element name="acsStatus" type="ACSStatus"/>

  <xsd:complexType name="ACSStatus">
    <xsd:sequence>
      <xsd:element name="timestamp" type="xsd:dateTime"/>
      <xsd:element name="internalStatus" type="xsd:string"
                   minOccurs="0"/>
      <xsd:element name="status" type="AcsStatusEnumeration"/>
      <xsd:element name="statusDetail" type="xsd:string"
                   minOccurs="0"/>
    </xsd:sequence>
  </xsd:complexType>

  <xsd:complexType name="EnumerationValue" final="#all" />

  <xsd:complexType name="AcsStatusEnumeration">
    <xsd:choice>
      <xsd:element name="operational" type="EnumerationValue"/>
      <xsd:element name="warning" type="EnumerationValue"/>
      <xsd:element name="degraded_minor" type="EnumerationValue" />
      <xsd:element name="degraded_major" type="EnumerationValue" />
      <xsd:element name="non_operational" type="EnumerationValue" />
      <!-- more possibilities ?? -->
    </xsd:choice>
  </xsd:complexType>

</xsd:schema>
```

N.3.4 Implementation of Data Distribution and Request/Reply

For data distribution, the ACS represents an AMQP container holding a series of AMQP Nodes. ACS client applications, representing AMQP peer, establish AMQP connection and session using physical address in the amqps form (e.g. amqps://acshost:port). In order to enable the use cases described in section N.3.1.1, and related message exchange patterns, the ACS holds AMQP nodes for storing and forwarding messages. These AMQP nodes are exposed via addresses at link level. From the AMQP node peer (ACS client application) perspective, these addresses are opaque string that the AMQP container (ACS) is able to resolve at link attach (following AMQP connection and session).

Subscription management and demand contract requests follow a request/reply MEP. The corresponding WS Light bindings are provided in section N.3.4.2.

In the following table a summary of the identified links is provided. For further reference, the links are identified via logical identifiers and names.

Link Identifier	Link name	Brief description	Technical MEP	Reference ACS use case
PS-LINKC	Publication Messages distribution	This link allows ACS client to receive publication messages (ADS and CM information)	Message distribution over AMQP 1.0 (this is the realization of the publication message distribution function of the logical Publish/Subscribe MEP. Furthermore, this link is also used to send to the client ADS and CM messages following demand contract request/reply)	Use Case 1 - Subscribe by AC ICAO address, Use Case 2 - Subscribe to all ACs Use Case 5 - Subscribe to aircraft fleet Use Case 3 - Demand Contract Request
FF-LINKD	ACS status messages distribution	This link allows ACS client to receive ACS status messages	Message distribution over AMQP 1.0	Use Case 4 - Service Status Monitoring

Table 73: ACS links summary

Further details are provided in the sections below grouping links per related technical MEP:

- PS-LINKC and FF-LINKD are described in §N.3.4.1.

N.3.4.1 Data Distribution over AMQP

N.3.4.1.1 AMQP Links

In the following table the links used for data distribution pattern are provided. ACS client application establishes an AMQP 1.0 link with the ACS provided AMQP node entity with "target" link type (link type on the ACS side is "source") to receive data / publication messages (e.g. PS-LINKC).

Link Identifier	Link name	Link source	Link Target	AMQP Node Authorization
PS-LINKC	Publication Messages distribution	ACS	ACS Client	Pre-defined subscriptions per authorization group: - authorization at link level is enforced based on authorization group. Only authenticated client application belonging to the specific authentication group are authorized to create AMQP receivers. Dynamic subscriptions per user:

				- the concerned AMQP node is for exclusive use of a given authenticated user. Only authenticated client applications presenting that specific user's credentials are authorized to create AMQP receiver for user's exclusive node.
FF-LINKD	ACS status messages distribution	ACS	ACS Client	At link level: - Only authenticated client applications are authorized to create AMQP receivers.

Table 74: ACS data distribution link

Within the limits of what a user is authorized to, authenticated client application may further filter the set of data available over link PS-LINKC:

- For pre-defined subscriptions, this is supported via AMQP filters (AMQP V1.0 §3.5.3).
- For dynamic subscriptions, this is supported by combining AMQP filters and filters provided in the subscription request (if any).

See section N.3.7 for more information on AMQP filtering options.

N.3.4.1.2 AMQP Nodes addresses

AMQP node opaque address for FF-LINKD is pre-defined and published, e.g., in services registry.

Management of AMQP node opaque addresses for PS-LINKC is different for pre-defined and dynamic subscriptions:

- Pre-defined subscriptions: pre-defined opaque addresses are defined per authorization group. These addresses are published, e.g., in services registry.
- Dynamic subscriptions: the opaque addresses are towards exclusive AMQP Nodes (per-user opaque addresses). The related opaque address is the "Consumer address reference" included in the subscription reply message (§N.3.3.3.2). In order to guarantee authorization needs for this opaque address (i.e. exclusive AMQP node) specific opaque address naming rules should be specified. As part of ACS user registration, in addition to digital identities, naming and authorization policies enforced on the ACS side have to be shared/agreed.

N.3.4.1.3 AMQP subject property and messages types

AMQP subject property shall be filled in with the right value assigned to message types identified for the ACS (refer to §N.3.3.2.1, §N.3.3.2.2 and §N.3.3.4). This property will allow to characterize the message type of the published data.

Message Type	AMQP 1.0 subject properties field values
CmLogonInd	FEP2ATCMessages/CmDownlinkMessages/CmLogonInd
CmUAbortInd	FEP2ATCMessages/CmDownlinkMessages/CmUAbortInd
CmPAbortInd	FEP2ATCMessages/CmDownlinkMessages/CmPAbortInd
CmCancelFlightInd	FEP2ATCMessages/CmDownlinkMessages/CmCancelFlightInd
AdsDemandCnf	FEP2ATCMessages/AdsDownlinkMessages/AdsDemandCnf

AdsEventCnf	FEP2ATCMessages/AdsDownlinkMessages/AdsEventCnf
AdsPeriodicCnf	FEP2ATCMessages/AdsDownlinkMessages/AdsPeriodicCnf
AdsCancelCnf	FEP2ATCMessages/AdsDownlinkMessages/AdsCancelCnf
AdsCancelAllCnf	FEP2ATCMessages/AdsDownlinkMessages/AdsCancelAllCnf
AdsReportInd	FEP2ATCMessages/AdsDownlinkMessages/AdsReportInd
AdsUAbortReq	FEP2ATCMessages/AdsDownlinkMessages/AdsUAbortReq
AdsPAbortInd	FEP2ATCMessages/AdsDownlinkMessages/AdsPAbortInd
CmLogonRsp	ATC2FEPMessages/CmUplinkMessages/CmLogonRsp
CmUAbortReq	ATC2FEPMessages/CmUplinkMessages/CmUAbortReq
CmCancelFlightReq	ATC2FEPMessages/CmUplinkMessages/CmCancelFlightReq
AdsDemandReq	ATC2FEPMessages/AdsUplinkMessages/AdsDemandReq
AdsEventReq	ATC2FEPMessages/AdsUplinkMessages/AdsEventReq
AdsPeriodicReq	ATC2FEPMessages/AdsUplinkMessages/AdsPeriodicReq
AdsCancelReq	ATC2FEPMessages/AdsUplinkMessages/AdsCancelReq
AdsCancelAllReq	ATC2FEPMessages/AdsUplinkMessages/AdsCancelAllReq
AdsUAbortReq	ATC2FEPMessages/AdsUplinkMessages/AdsUAbortReq

Table 75: AMQP 1.0 subject properties field values for ADS-C and CM messages

Message Type	AMQP 1.0 subject properties field values
ACSStatus	ACS/ACSStatus

Table 76: AMQP 1.0 subject properties field values service status monitoring messages

N.3.4.1.4 AMQP Annotated messages

In this section identified constraints for applicable and used AMQP annotated message sections are provided. For all the AMQP annotated message sections and/or fields not included in the tables not constraints have been identified: unused sections/fields shall not be used.

Following table is applicable to ADS and CM messages irrespective of the link.

AMQP Message Section	Zero or one?	AMQP Message Section field	Constraint
Header	One	durable	Used and non-durable.
		priority	Default priority.
		ttl	Used and mandatory.
(Bare Message) Properties)	One	message-id	Used and mandatory (UUID variant 2 version 4 (random) as defined in the IETF RFC 4122.).
		to	Used and mandatory. It is the opaque address of the concerned AMQP node.
		subject	Used and mandatory (Table 3).

		content-type	Used and mandatory. For all the request messages it must be "application/xml".
		absolute-expiry-time	Used and mandatory.
		creation-time	Used and mandatory.
(Bare Message) Application Properties	One	Map	ACS specific key-value pairs described in Table 6.
These properties are used to enable AMQP filters.	One	N/A	AmqpValue holding a String.

Table 77: AMQP Message Sections for ADS and CM messages

Property name/key	Type	Value
aircraftAddress	AMQP string	The 24bit ICAO address of the AC.
flightID	AMQP string	The flight callsign.
departureAirport	AMQP string	ICAO Id of the departure airport
destinationAirport	AMQP string	ICAO Id of the arrival airport
eobd	AMQP string	The flight Estimated Off-Block Date. It must be an empty string when the information is not available at the time the message is published. When provided, the date is represented using YYYY/MM/DD format.
eobt	AMQP string	The flight Estimated Off-Block Time. It must be an empty string when the information is not available at the time the message is published. When provided, the time is UTC and it is represented using HH:MM:SS format without time zone
messageType	AMQP string	Unique identifier of the message types. Possible values are in Table 41
flightPlanVerificationResult	AMQP string	It represents the flight plan verification result. Possible values are: • "successful" only if all the correlation with the FPL data stored on the server is successful. This is if a valid FPL can be found where the following information are equal to the ones in the CM Logon: ○ Flight ID, ○ icao24bit address ○ ADEP, ADES • "failed", if FPL data service is available, but no matching FPL is found which satisfies all conditions stated for "successful" result above. • "unable", if no valid FPL data service is available (due to degraded mode)

Table 78: Application properties

Following table is applicable to service status messages.

AMQP Message Section	Zero or one?	AMQP Message Section field	Constraint
Header	One	durable	Non-durable
		priority	Default priority
		ttl	Used and mandatory (set values after prototype activities)
(Bare Message) Properties)	One	message-id	Used and mandatory (time-based UUDI).
		to	Used and mandatory. It is the opaque address of the concerned AMQP node.
		subject	Used and mandatory (Table 42)
		content-type	Used and mandatory. For all the messages it must be “application/xml”.
		absolute-expiry-time	Used and mandatory (set values after prototype activities)
		creation-time	Used and mandatory.
(Bare Message) Application Data	One	N/A	AmqpValue holding a String.
Footer	Zero	N/A	Not used.

Table 79: AMQP Message Sections for service status messages

N.3.4.2 Request Reply APIs

This section provides the specification of the ACS R/R APIs over WS Light binding: it covers subscriptions management (N.3.4.2.1) and demand contract requests (N.3.4.2.2).

This specification is compliant with "EUROCONTROL Specification for SWIM Technical Infrastructure (TI) Yellow Profile" and follows the "Publish/Subscribe Push MEP: Implementation Guidance" from the SWIM Reference.

Code examples are provided in Appendix N.3.8.

N.3.4.2.1 Subscription management

N.3.4.2.1.1 API Overview

Operation	Resource endpoint	HTTP Method
subscribe	/subscriptions/	POST
unsubscribe	/subscriptions/<subscripiton_id>	DELETE
list subscriptions	/subscriptions/	GET
subscription details	/subscriptions/<subscription_id>	GET

N.3.4.2.1.2 Common error conditions

All operations may return one of the following status codes:

Code	Reason Phrase	Description
400	Bad Request	Malformed request.
401	Unauthorized	Bad credentials or attempt to access a non-authorized resource.
405	Method Not Allowed	Method not provided on that specific endpoint
406	Not Acceptable	No matching 'Accept' content
415	Unsupported Media Type	Not compatible media type (application/xml)
500	Internal Server Error	Major application error.

In case of error, the response payload may contain additional (textual) information with Content-Type text/plain.

N.3.4.2.1.3 Subscribe operation

Request	Endpoint	/subscriptions/
	Method	POST
	Headers	• Content-Type: application/xml • Accept: application/xml
	Body	See N.3.3.3.1
Reply	Success headers	• Status-Code: 201 • Reason-Phrase: Created • Content-Type: application/xml
	Success body	See N.3.3.3.2
	Specific error conditions	• 403 (Forbidden) when too many subscriptions

N.3.4.2.1.4 Unsubscribe operation

Request	Endpoint	/subscriptions/<subscription_id>
	Method	DELETE
	Headers	• Accept: application/xml
	Body	<NONE>
Reply	Success headers	• Status-Code: 204 • Reason-Phrase: No Content
	Success body	<NONE>
	Specific error conditions	• 404 (Not Found) if the subscription identifier is unknown to the ACS

N.3.4.2.1.5 List subscriptions operation

Request	Endpoint	/subscriptions
	Method	GET
	Headers	• Accept: application/xml
	Body	<NONE>
Reply	Success headers	• Status-Code: 200 • Reason-Phrase: OK • Content-Type: application/xml
	Success body	See N.3.3.3.3
	Specific error conditions	<NONE>

N.3.4.2.1.6 Subscription details operation

Request	Endpoint	/subscriptions/<subscription_id>
	Method	GET
	Headers	• Accept: application/xml
	Body	<NONE>
Reply	Success headers	• Status-Code: 200 • Reason-Phrase: OK • Content-Type: application/xml
	Success body	See N.3.3.3.4
	Specific error conditions	• 404 (Not Found) if the subscription identifier is unknown to the ACS

N.3.4.2.2 Demand contract request

N.3.4.2.2.1 API Overview

Operation	Resource endpoint	HTTP Method
demand contract request	/demandContractRequest/	POST

N.3.4.2.2.2 Operation Details

Request	Endpoint	/demandContractRequest/
	Method	POST
	Headers	• Accept: application/xml • Accept: application/xml
	Body	See N.3.3.4.1
Reply	Success headers	• Status-Code: 202 • Reason-Phrase: Accepted • Content-Type: application/xml

	Success body	See N.3.3.4.2
	Specific error conditions	• 403 (Forbidden) when the ACS cannot fulfill the request (while valid) e.g. because the client exceeded a quota (payload may provide additional information) • 404 (Not Found) if subject AC or the subscription identifier are unknown to the ACS. (details in the payload). • 409 (Conflict) if there is a pending demand contract request

N.3.4.3 Authentication and Authorisation

N.3.4.3.1 Data Distribution over AMQP

The Ground Distribution uses PLAIN Simple Authentication and Security Layer (SASL) to authenticate the user (refer to AMQP v1.0 §5.3) and TLS for server authentication (amqps form as described in AMQP v1.0 §5.2.1).

Authenticated identity is used to enforce authorization policies described in §N.3.4.1.1 and §N.3.4.1.2.

N.3.4.3.2 Request Reply APIs

The Ground Distribution uses HTTP Basic Authentication to authenticate the user and TLS for server authentication.

N.3.5 Appendix: Use Case Sequence Diagrams

In this section, use cases and sequence diagrams for alternative or non-nominal cases may be added if needed.

N.3.5.1 CM Logon after SWIM client subscription

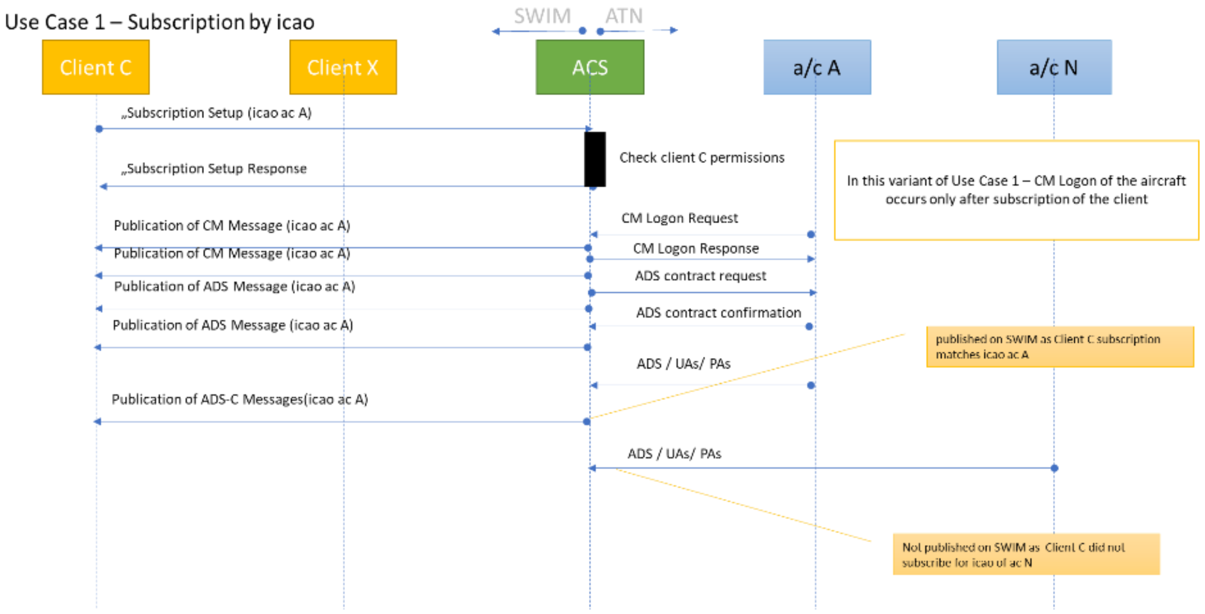


Figure 166: Use Case 1 "Subscribe by ICAO" – Sequence Diagram - Alternative Flow with Logon after Subscription

N.3.6 Appendix: Payload examples

This appendix provides payload examples corresponding to the data definitions described in section 4.

N.3.6.1 Subscription management

See section N.3.8.

N.3.6.2 Demand Contract management

N.3.6.2.1 Demand Contract Request

Demand Contract Request (full)

```
<?xml version="1.0"?>
<adsDemandReq>
  <aircraftID>
    <aircraftAddress>001110011001000111100111</aircraftAddress>
    <flightID>AFR76LF</flightID>
  </aircraftID>
  <request>
    <ADSRequestContract>
      <demand-contract>
        <contract-number>1</contract-number>
        <ground-vector/>
        <air-vector/>
        <met-info>
          <observation-window>15</observation-window>
        </met-info>
        <extended-projected-profile>
          <number-of-way-points>95</number-of-way-points>
        </extended-projected-profile>
```

```
      <speed-schedule-profile/>
    </demand-contract>
  </ADSRequestContract>
  </request>
  <distributionAddress>topic://ACS.cpy.a43f895b</distributionAddress>
</adsDemandReq>
```

N.3.6.2.2 Demand Contract Reply

Demand Contract Reply (full)


```
<?xml version="1.0"?>
<adsDemandReply>
  <acsReply>
    <acsReplyCode><requestSent/></acsReplyCode>
    <acsReplyDetails>
      Demand Contract Request successfully sent to Aircraft.
    </acsReplyDetails>
  </acsReply>
</adsDemandReply>
```


N.3.6.3 ADS-C and CM Datalink exchanges

N.3.6.3.1 CM Logon Indication (downlink)

CM Logon Indication example (extracts)


```
<?xml version="1.0"?>
<FEP2ATCMessages>
  <cmDownlinkMessages>
    <cmLogonInd>
      <aircraftID>
        <atnAircraft>
          <aircraftAddress>001110011001000111100111</aircraftAddress>
          <flightID>AFR76LF</flightID>
        </atnAircraft>
      </aircraftID>
      <version>0</version>
      <cmLogonRequest>
        <CMLogonRequest>
          <aircraftFlightIdentification>AFR76LF</aircraftFlightIdentification>
          <cMLongTSAP>
            <rDP>4141465200</rDP>
            <shortTsap>
              <aRS>3991E7</aRS>
              <locSysNselTsel>00005341414200000101</locSysNselTsel>
            </shortTsap>
          </cMLongTSAP>
          <groundInitiatedApplications>
            <!-- ...  -->
            <AEQualifierVersionAddress>
              <aeQualifier>22</aeQualifier>
              <apVersion>1</apVersion>
              <apAddress>
                <longTsap>
                  <rDP>4141465200</rDP>
                  <shortTsap>
                    <aRS>3991E7</aRS>
                    <locSysNselTsel>00005341414200000116</locSysNselTsel>
                  </shortTsap>
                </longTsap>
```

```
            </apAddress>
          </AEQualifierVersionAddress>
          <!-- ...  -->
        </groundInitiatedApplications>
        <airportDeparture>LFML</airportDeparture>
        <airportDestination>LFPG</airportDestination>
      </CMLogonRequest>
    </cmLogonRequest>
  </cmLogonInd>
 </cmDownlinkMessages>
</FEP2ATCMessages>
```


N.3.6.3.2 CM Logon Response (uplink)

CM Logon Response example (full)


```
<?xml version="1.0"?>
<ATC2FEPMessages>
  <cmUplinkMessages>
    <cmLogonRsp>
      <aircraftID>
        <atnAircraft>
          <aircraftAddress>001110011001000111100111</aircraftAddress>
          <flightID>AFR76LF</flightID>
        </atnAircraft>
      </aircraftID>
      <cmLogonResponse>
        <CMLogonResponse>
          <groundOnlyInitiatedApplications>
            <AEQualifierVersion>
              <aeQualifier>0</aeQualifier>
              <apVersion>1</apVersion>
            </AEQualifierVersion>
          </groundOnlyInitiatedApplications>
        </CMLogonResponse>
      </cmLogonResponse>
      <maintain>
        <doNotMaintain/>
      </maintain>
    </cmLogonRsp>
  </cmUplinkMessages>
</ATC2FEPMessages>
```


N.3.6.3.3 Periodic Contract Request (uplink)

Periodic Contract request example (full)


```
<?xml version="1.0"?>
<ATC2FEPMessages>
  <adsUplinkMessages>
    <adsPeriodicReq>
      <aircraftID>
        <atnAircraft>
          <aircraftAddress>001110011001000111100111</aircraftAddress>
          <flightID>AFR76LF</flightID>
        </atnAircraft>
      </aircraftID>
      <version>1</version>
      <request>
        <ADSRequestContract>
          <periodic-contract>
```

```
            <contract-number>1</contract-number>
            <reporting-rate>
              <reporting-time-minutes-scale>5</reporting-time-minutes-scale>
            </reporting-rate>
            <ground-vector-modulus>1</ground-vector-modulus>
            <air-vector-modulus>1</air-vector-modulus>
            <met-info-modulus>
              <modulus>1</modulus>
              <observation-window>15</observation-window>
            </met-info-modulus>
            <extended-projected-profile-modulus>
              <modulus>1</modulus>
              <epp-window>
                <number-of-way-points>95</number-of-way-points>
              </epp-window>
            </extended-projected-profile-modulus>
            <speed-schedule-profile-modulus>1</speed-schedule-profile-modulus>
          </periodic-contract>
        </ADSRequestContract>
      </request>
      <class>A</class>
      <checksum>
        <algorithmID>1.3.27.9.0</algorithmID>
        <checksum>11011101010111010100100011110011</checksum>
      </checksum>
    </adsPeriodicReq>
  </adsUplinkMessages>
</ATC2FEPMessages>
```


N.3.6.3.4 ADS Report indication (downlink)

ADS Report indication (extracts)


```
<?xml version="1.0"?>
<FEP2ATCMessages>
  <adsDownlinkMessages>
    <adsReportInd>
      <aircraftID>
        <atnAircraft>
          <aircraftAddress>001110011001000111100111</aircraftAddress>
          <flightID>AFR76LF</flightID>
        </atnAircraft>
      </aircraftID>
      <contractType>
        <periodic-contract/>
      </contractType>
      <report>
        <ADSReport>
          <periodic-report>
            <report>
              <position>
                <latitude>
                  <direction>
                    <north/>
                  </direction>
                  <degrees>43</degrees>
                  <minutes>25</minutes>
                  <seconds>553</seconds>
                </latitude>
                <longitude>
                  <direction>
```

```
        <east/>
      </direction>
      <degrees>5</degrees>
      <minutes>13</minutes>
      <seconds>295</seconds>
    </longitude>
    <level>21</level>
  </position>
  <time>
    <date>
      <year>2020</year>
      <month>12</month>
      <day>9</day>
    </date>
    <time>
      <hours>17</hours>
      <minutes>23</minutes>
      <seconds>4</seconds>
    </time>
  </time>
  <fom>
    <estimated-position-uncertainty>8</estimated-position-uncertainty>
    <multiple-navigational-units-operating>
      <true/>
    </multiple-navigational-units-operating>
    <aais-availability>
      <true/>
    </aais-availability>
  </fom>
  <contract-number>1</contract-number>
  <ground-vector>
    <ground-track>2674</ground-track>
    <ground-speed>24</ground-speed>
    <vertical-rate>0</vertical-rate>
  </ground-vector>
  <air-vector>
    <heading>2674</heading>
    <airspeed>
      <mach-and-ias>
        <mach>500</mach>
        <ias>0</ias>
      </mach-and-ias>
    </airspeed>
    <vertical-rate>0</vertical-rate>
  </air-vector>
  <extended-projected-profile>
    <computation-time>
      <date>
        <year>2020</year>
        <month>12</month>
        <day>9</day>
      </date>
      <time>
        <hours>17</hours>
        <minutes>23</minutes>
        <seconds>3</seconds>
      </time>
    </computation-time>
    <way-point-sequence>
      <SEQUENCE>
        <latitude>
```

```
                <direction>
                  <north/>
                </direction>
                <degrees>43</degrees>
                <minutes>28</minutes>
                <seconds>217</seconds>
              </latitude>
              <longitude>
                <direction>
                  <east/>
                </direction>
                <degrees>5</degrees>
                <minutes>9</minutes>
                <seconds>495</seconds>
              </longitude>
              <level>
                <qNEAltitude>273</qNEAltitude>
              </level>
              <name>ML316</name>
              <estimated-time>
                <hours>0</hours>
                <minutes>1</minutes>
                <seconds>39</seconds>
              </estimated-time>
              <estimated-speed>
                <ias>155</ias>
              </estimated-speed>
              <lateral-type>
                <flyby>
                  <turnRadiusNotAvailable/>
                </flyby>
                <flightPlanWayPoint/>
              </lateral-type>
            </SEQUENCE>
            <!-- ... -->
          </way-point-sequence>
          <!-- ... -->
          <trajectory-intent-status>
            <lateralFlightManaged>
              <false/>
            </lateralFlightManaged>
            <verticalFlightManaged>
              <false/>
            </verticalFlightManaged>
            <speedManaged>
              <false/>
            </speedManaged>
            <timeManaged>
              <false/>
            </timeManaged>
          </trajectory-intent-status>
        </extended-projected-profile>
      </report>
    </periodic-report>
  </ADSReport>
</report>
<checksum>
  <algorithmID>1.3.27.9.0</algorithmID>
  <checksum>11110010001010111011001100100000</checksum>
</checksum>
</adsReportInd>
```

```
  </adsDownlinkMessages>
</FEP2ATCMessages>
```

N.3.6.3.5 User Abort (downlink)

User abort example (full)


```
<?xml version="1.0"?>
<FEP2ATCMessages>
  <adsDownlinkMessages>
    <adsUAbortInd>
      <aircraftID>
        <atnAircraft>
          <aircraftAddress>001110011001000111100111</aircraftAddress>
          <flightID>AFR76LF</flightID>
        </atnAircraft>
      </aircraftID>
      <reason>
        <undefined/>
      </reason>
    </adsUAbortInd>
  </adsDownlinkMessages>
</FEP2ATCMessages>
```


N.3.6.4 Status payloads

Status payload (full)


```
<?xml version="1.0" encoding="UTF-8"?>
<acsStatus>
  <timestamp>2021-03-15T13:07:20.913787211+00:00</timestamp>
  <status><operational/></status>
  <statusDetail>Everything OK!</statusDetail>
</acsStatus>
```


N.3.7 Appendix: AMQP Filters

N.3.7.1 Introduction

This appendix details what the AMQP filters are and examples of their use with the ACS.

N.3.7.2 AMQP Filters

Section 3.5.1 of the AMQP Standard describes filters that can be attached to a source. A filter can be thought as a function taking the message as input and returning a Boolean value. If the value is true, the message is accepted by the source and sent over the link. It is otherwise ignored.

The filter types are specified outside of the AMQP standard. Today's de facto standards are the filters defined by Apache. These filters are:

- "Legacy AMQP Exchange Binding Service Support" filters whose objective is to keep some compatibility with the pre-standard versions of AMQP.
- "Java Message Service Support" filters which mimic JMS selectors and allows:
    - To filter messages locally produced (the No Local Filter), or

- ○ To select messages (**Selector Filter**) based on conditional expressions on message header fields and application properties. The syntax of these expressions follows the SQL 92 syntax for conditional expressions.

- An XQuery based filter that allows the filtering of message carrying an XML encoded body using XQuery expressions.

In this appendix, only **Selector Filters** are considered.

N.3.7.3 Examples

The following examples are based on the application properties attached to the data distribution messages by the ACS as defined in Section N.3.4.1.4. They show representative uses of AMQP message selectors.

N.3.7.3.1 Application properties

The ACS attaches the following application properties to the data distribution messages it publishes:

Property name	Value
aircraftAddress	The 24bit ICAO address of the AC.
flightID	The flight callsign.
departureAirport	ICAO Id of the departure airport
destinationAirport	ICAO Id of the arrival airport
eobd	The flight Estimated Off-Block Date. It must be an empty string when the information is not available at the time the message is published. When provided, the date is represented using YYYY/MM/DD format.
eobt	The flight Estimated Off-Block Time. It must be an empty string when the information is not available at the time the message is published. When provided, the time is UTC and it is represented using HH:MM:SS format without time zone
messageType	Unique identifier of the message types. Possible values are in Table 41: AMQP 1.0 subject properties field values for ADS-C and CM messages
flightPlanVerificationResult	It represents the flight plan verification result. Possible values are: • "successful" only if all the correlation with the FPL data stored on the server is successful. This is if a valid FPL can be found where the following information are equal to the ones in the CM Logon: ○ Flight ID, ○ icao24bit address ○ ADEP, ADES • "failed", if FPL data service is available, but no matching FPL is found which satisfies all conditions stated for "successful" result above. • "unable", if no valid FPL data service is available (due to degraded mode)

N.3.7.3.2 Selector expression examples

Selector expression for the messages from a single aircraft based on its ICAO address:

- aircraftAddress = '40772E'

Selector expression for messages from a list of aircrafts (based on their ICAO addresses):

- aircraftAddress in ('40772E', '407751', '40762B')

Selector expression for messages following a given callsign pattern:

- flightID like 'EZY%'

The simple selector expressions can be combined. The following expression selects reports for all flights originating from or going to an airport in France:

- departureAirport like 'LF%' or destinationAirport like 'LF%'

Similar expressions and examples can be formulated on eobd, eobt, messageType or flightPlanVerificationResult properties.

N.3.7.4 Use with the ACS

The AMQP filters can be combined with preconfigured subscriptions to all (authorised) aircrafts to implement UC1, UC2 and UC5.

They can be used as an alternative or in complement to the subscription management described in the current/future version of the ICD.

N.3.8 Appendix: Subscription API Examples

The following examples are run over TLS against a server on the local machine (localhost) at port 3443. Authentication uses HTTP Basic Authentication.

N.3.8.1 Java

N.3.8.1.1 Create subscription

ACSSubscribe.java (imports omitted)

```
package eu.adscensio;

import ...;

public class ACSSubscribe {
    @Root
    public static class subscriptionRequest {
        @Element
        public String filter;

        public subscriptionRequest(String filter) {
            this.filter = filter;
        }
    }

    @Root
```

```
    public static class subscriptionReply {
        @Element
        public String subscriptionId;
        @Element
        public String address;
    }

    public static void main(String[] args) {
        try {
            Serializer serializer = new Persister();
            subscriptionRequest req = new subscriptionRequest("Address = 'ABCDEF'");
            StringWriter reqXML = new StringWriter();
            serializer.write(req, reqXML);

            String auth = "Basic " +
                          Base64.getEncoder().encodeToString("user1:pass1".getBytes());

            HttpRequest request = HttpRequest.newBuilder()

.uri(URI.create("https://localhost:3443/subscriptions/"))
                                    .header("Authorization", auth)
                                    .header("Content-Type", "application/xml")
                                    .POST(BodyPublishers.ofString(reqXML.toString()))
                                    .build();

            HttpClient client = HttpClient.newBuilder().build();
            HttpResponse<String> reply = client.send(request, BodyHandlers.ofString());

            System.out.println("Status code: " + reply.statusCode());
            if (reply.statusCode() == 201) {
                subscriptionReply replyDecoded =
                         serializer.read(subscriptionReply.class, reply.body());
                System.out.println("subscriptionId: " + replyDecoded.subscriptionId +
                                   " address: " + replyDecoded.address);
            }
        } catch (Exception e) {
            System.err.println(e);
        }
    }
}
```

N.3.8.1.2 Delete subscription

ACSDelete.java (imports omitted)

```
package eu.adscensio;

import ...;

public class ACSDelete {
    public static void main(String[] args) {
        try {
            String auth = "Basic " +
                          Base64.getEncoder().encodeToString("user1:pass1".getBytes());

            HttpRequest request = HttpRequest.newBuilder()
                    .uri(URI.create("https://localhost:3443/subscriptions/" + args[0]))
                    .header("Authorization", auth)
                    .DELETE()
                    .build();
```

```
            HttpClient client = HttpClient.newBuilder().build();
            HttpResponse<Void> reply = client.send(request, BodyHandlers.discarding());

            System.out.println("Status code: " + reply.statusCode());
        } catch (Exception e) {
            System.err.println(e);
        }
    }
}
```

N.3.8.2 Python

N.3.8.2.1 Create subscription

ACSCreateSubscription.py (full)

```
import requests
import xml.etree.ElementTree as ET

subCreation = '''<?xml version="1.0" encoding="UTF-8"?>
<subscriptionRequest>
 <filter>Address = 'ABCDEF'</filter>
</subscriptionRequest>'''

r = requests.post('https://localhost:3443/subscriptions/',
                  data=subCreation.encode('utf-8'),
                  headers={'Content-Type': 'application/xml'},
                  auth=('user1', 'pass1'),
                  verify='../pki/localhost_cert.pem')

if r.status_code == 201:
    reply = ET.fromstring(r.content.decode('utf-8'))
    subscriptionId = reply.find('.//subscriptionId').text
    address = reply.find('.//address').text
```

N.3.8.2.2 Delete subscription

ACSDeleteSubscription.py (full)

```
import requests

subId = 'ca6dfefdfc243ad291a6'

r = requests.delete('https://localhost:3443/subscriptions/' + subId,
                    auth=('user1', 'pass1'),
                    verify='../pki/localhost_cert.pem')

if r.status_code == 204:
    print('Subscription deleted.')
```

N.3.8.2.3 List subscription

ACSListSubscriptions.py (full)

```
import requests
import xml.etree.ElementTree as ET

r = requests.get('https://localhost:3443/subscriptions/',
                 auth=('user1', 'pass1'),
                 verify='../pki/localhost_cert.pem')
```

```
if r.status_code == 200:
    reply = ET.fromstring(r.content.decode('utf-8'))
    subIds = [e.text for e in reply.findall('.//subscriptionId')]
```

N.3.8.2.4 Subscription details

ACSSubscriptionDetails.py (full)

```
import requests
import xml.etree.ElementTree as ET

subId = 'ca6dfefdfc243ad291a6'

r = requests.get('https://localhost:3443/subscriptions/' + subId,
                 auth=('user1', 'pass1'),
                 verify='../pki/localhost_cert.pem')

if r.status_code == 200:
    reply = ET.fromstring(r.content.decode('utf-8'))
    address = reply.find('.//address').text
    filter = reply.find('.//filter').text
```

N.3.8.3 Command line

N.3.8.3.1 Create subscription

Subscription creation using curl (with verbose output: -v)

```
echo "<subscriptionRequest>
  <filter>Address = '3946EC'</filter>
</subscriptionRequest>" | \
curl -v --user user1:pass1 --cacert ../pki/localhost_cert.pem \
     -H 'Content-Type: application/xml' -d @- \
     https://localhost:3443/subscriptions/
```

```
> POST /subscriptions/ HTTP/1.1
> Host: localhost:3443
> Authorization: Basic dXNlcjE6cGFzczE=
> User-Agent: curl/7.74.0
> Accept: */*
> Content-Type: application/xml
> Content-Length: 80
>
< HTTP/1.1 201 Created
< Content-Type: application/xml
< Date: Tue, 16 Mar 2021 10:18:19 GMT
< Content-Length: 196
<
<?xml version="1.0" encoding="UTF-8"?>
<subscriptionReply>
  <subscriptionId>bc6924875e67637fb2ce</subscriptionId>
  <address>topic://ACS.user1.bc6924875e67637fb2ce</address>
</subscriptionReply>
```

N.3.8.3.2 Delete subscription

Subscription deletion using curl (with verbose output: -v)

```
curl -v --user user1:pass1 --cacert ../pki/localhost_cert.pem -X DELETE \
     https://localhost:3443/subscriptions/bc6924875e67637fb2ce
```

```
> DELETE /subscriptions/bc6924875e67637fb2ce HTTP/1.1
> Host: localhost:3443
> Authorization: Basic dXNlcjE6cGFzczE=
> User-Agent: curl/7.74.0
> Accept: */*
>
< HTTP/1.1 204 No Content
< Date: Tue, 16 Mar 2021 10:31:56 GMT
<
```

N.3.8.3.3 List subscriptions

List subscriptions using curl (with verbose output: -v)

```
curl -v --user user1:pass1 --cacert ../pki/localhost_cert.pem
https://localhost:3443/subscriptions/
```

```
> GET /subscriptions/ HTTP/1.1
> Host: localhost:3443
> Authorization: Basic dXNlcjE6cGFzczE=
> User-Agent: curl/7.74.0
> Accept: */*
>
< HTTP/1.1 200 OK
< Content-Type: application/xml
< Date: Tue, 16 Mar 2021 10:39:15 GMT
< Content-Length: 243
<
<?xml version="1.0" encoding="UTF-8"?><subscriptionsList>
  <subscriptionId>e964a3f1f72bf61675</subscriptionId>
  <subscriptionId>9b566b3c71f07d20539c</subscriptionId>
  <subscriptionId>8877a778fe30171498</subscriptionId>
</subscriptionsList>
```

N.3.8.3.4 Subscription details

Get subscription details using curl (with verbose output: -v)

```
curl -v --user user1:pass1 --cacert ../pki/localhost_cert.pem
https://localhost:3443/subscriptions/
```

```
> GET /subscriptions/e964a3f1f72bf61675 HTTP/1.1
> Host: localhost:3443
> Authorization: Basic dXNlcjE6cGFzczE=
> User-Agent: curl/7.74.0
> Accept: */*
>
< HTTP/1.1 200 OK
< Content-Type: application/xml
< Date: Tue, 16 Mar 2021 10:42:31 GMT
< Content-Length: 180
<
<?xml version="1.0" encoding="UTF-8"?>
<subscriptionDetails>
  <address>topic://ACS.user1.e964a3f1f72bf61675</address>
  <filter>Address = 'ABCDEF'</filter>
```

```
</subscriptionDetails>
```

N.3.9 ADS-C Common Service Status Interface

N.3.9.1 Request/Reply API

N.3.9.1.1 API Overview

Operation	Resource endpoint	HTTP Method
Get status	/status?<Flight Identification>	GET
Get last report	/lastReport?<Flight Identification>	GET
Get contract settings	/contractSettings?<Flight Identification>	GET

<Flight identification> is made of set of following parameters

Parameter Name	Value
icao	ICAO 24bit address of the A/C (in HEX, uppercase, no prefix)
flightid	A/C Flight identification/Callsign
adep	Flight airport of departure
ades	Flight airport of destination

The following constraints apply on these parameters:

- All elements are optional individually, however
- Either the icao or flightid parameters needs to be provided.

N.3.9.1.2 Common Error conditions

All operations may return one of the following status codes:

Code	Reason Phrase	Description
400	Bad Request	Malformed request including the fact that constraints on the parameters are not fulfilled (icao and fligthid parameters are missing)
401	Unauthorized	Bad credentials or attempt to access a non-authorized resource.
405	Method Not Allowed	Method not provided on that specific endpoint
406	Not Acceptable	No matching ‘Accept’ content
415	Unsupported Media Type	Not compatible media type (application/xml)
500	Internal Server Error	Major application error.

In case of error, the response payload may contain additional (textual) information with Content-Type text/plain.

N.3.9.1.3 Get status

Request	Endpoint	/status?<Flight identification>
	Method	GET
	Headers	• Accept: application/xml
	Body	<NONE>
Reply	Success headers	• Status-Code: 200 • Reason-Phrase: OK • Content-Type: application/xml
	Success body	See N.3.9.2.1.2
	Specific error conditions	• 404 (Not Found): the parameters provided do not identify a flight known to the ACS

N.3.9.1.4 Get last report

Request	Endpoint	/lastReport?<Flight identification>
	Method	GET
	Headers	• Accept: application/xml
	Body	<NONE>
Reply	Success headers	• Status-Code: 200 • Reason-Phrase: OK • Content-Type: application/xml
	Success body	See N.3.9.2.1.3.
	Specific error conditions	• 404 (Not Found): the parameters provided do not identify a flight known to the ACS or no report is available

N.3.9.1.5 Get contract settings

Request	Endpoint	/contractSettings?<Flight identification>
	Method	GET
	Headers	• Accept: application/xml
	Body	<NONE>
Reply	Success headers	• Status-Code: 200 • Reason-Phrase: OK • Content-Type: application/xml
	Success body	See N.3.9.2.1.4.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

	Specific error conditions	• 404 (Not Found): the parameters provided do not identify a flight known to the ACS or the contract settings cannot be determined

N.3.9.2 Data Definition

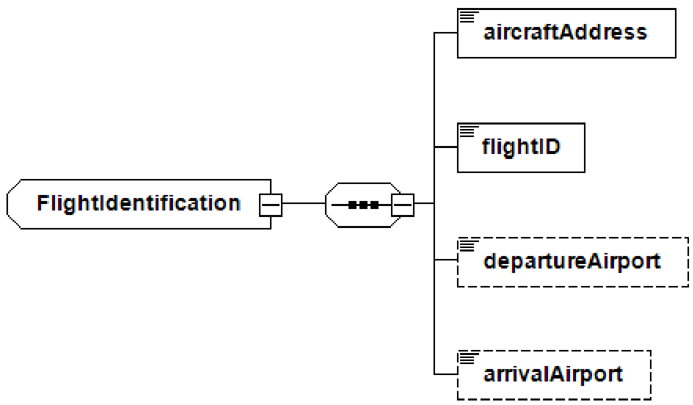
N.3.9.2.1 Reply payloads

N.3.9.2.1.1 Common types

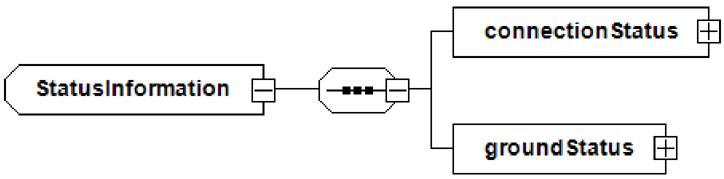
The following common types are used in the IFACS payloads:

- Flight identification
- Status information

N.3.9.2.1.1.1 Flight identification



N.3.9.2.1.1.2 Status information

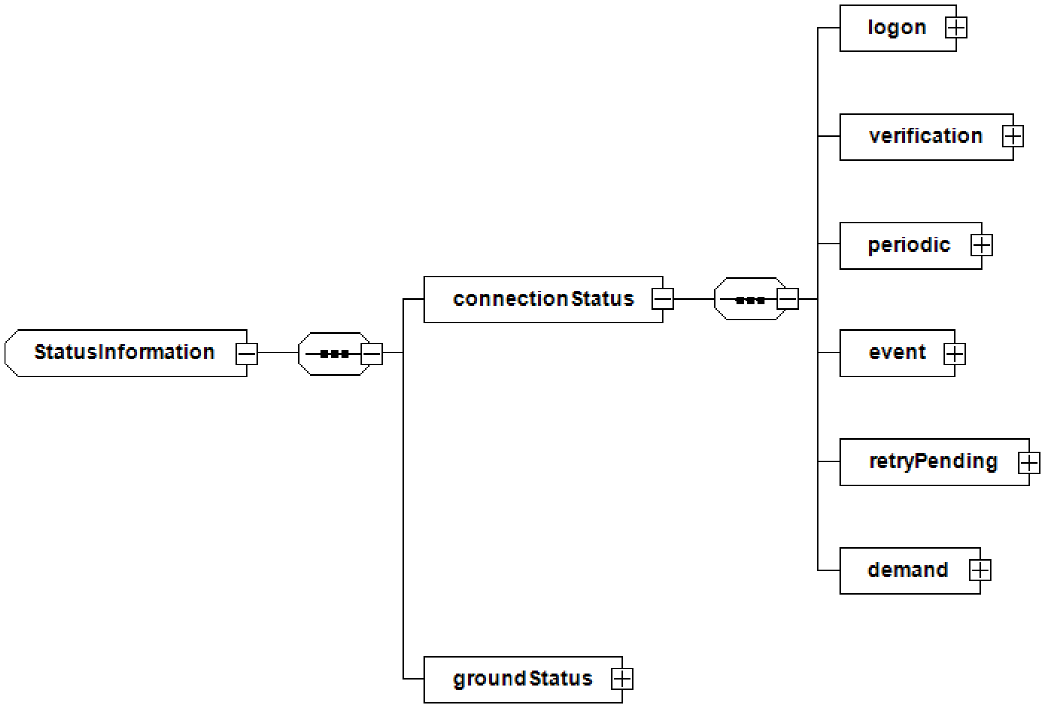


The StatusInformation type is made of two sub-elements: connectionStatus and groundStatus.

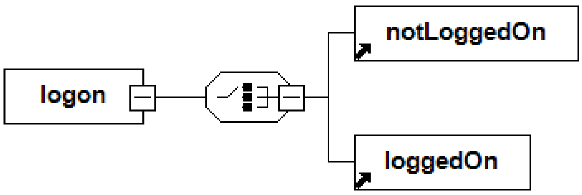
Connection Status

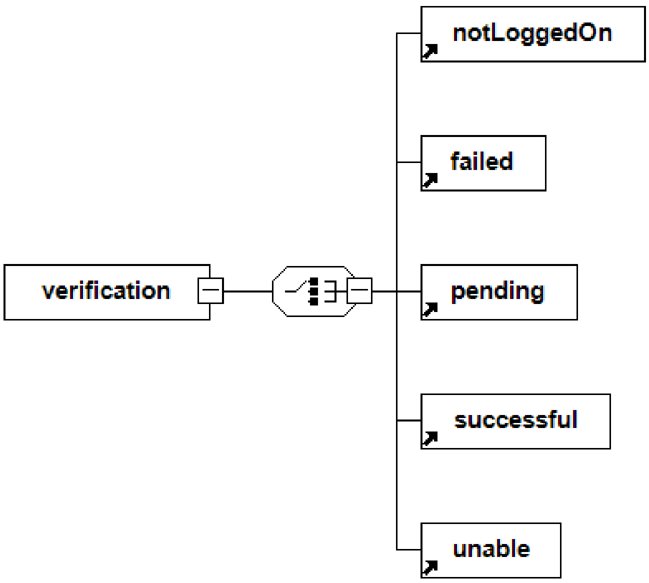
The connectionStatus element provides information about the status of the datalink connection: logon, flight plan verification, the ADS-C contracts (Periodic, Event and Demand) and the indication if connection retries are pending:

Co-funded by the European Union

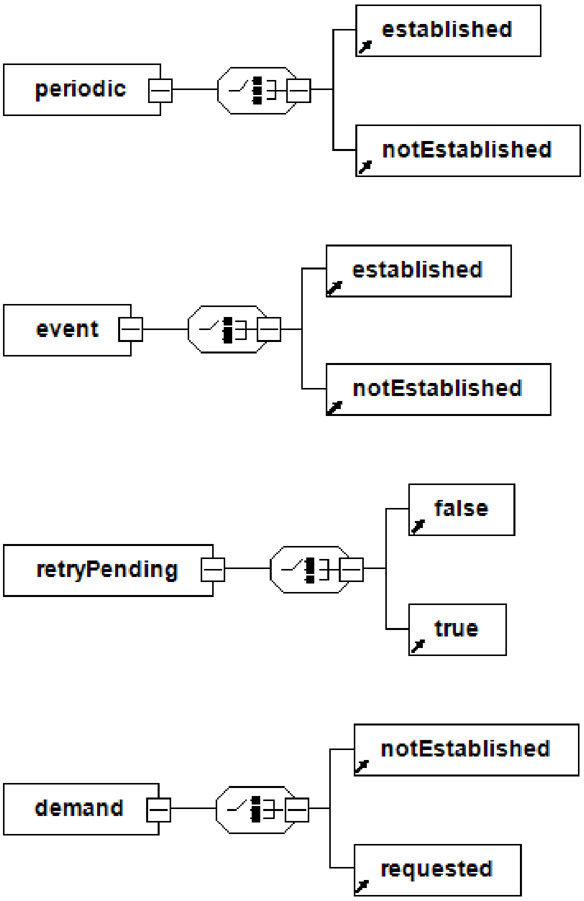


The logon element indicates if the aircraft has sent a logon notification while the verification element indicates the current state of the flight plan verification:





When the aircraft is logged on the periodic, event, demand and retryPending elements indicate the status of the contracts:



The following schema extract provides the full definition:

commonStatusTypes.xsd (extract)

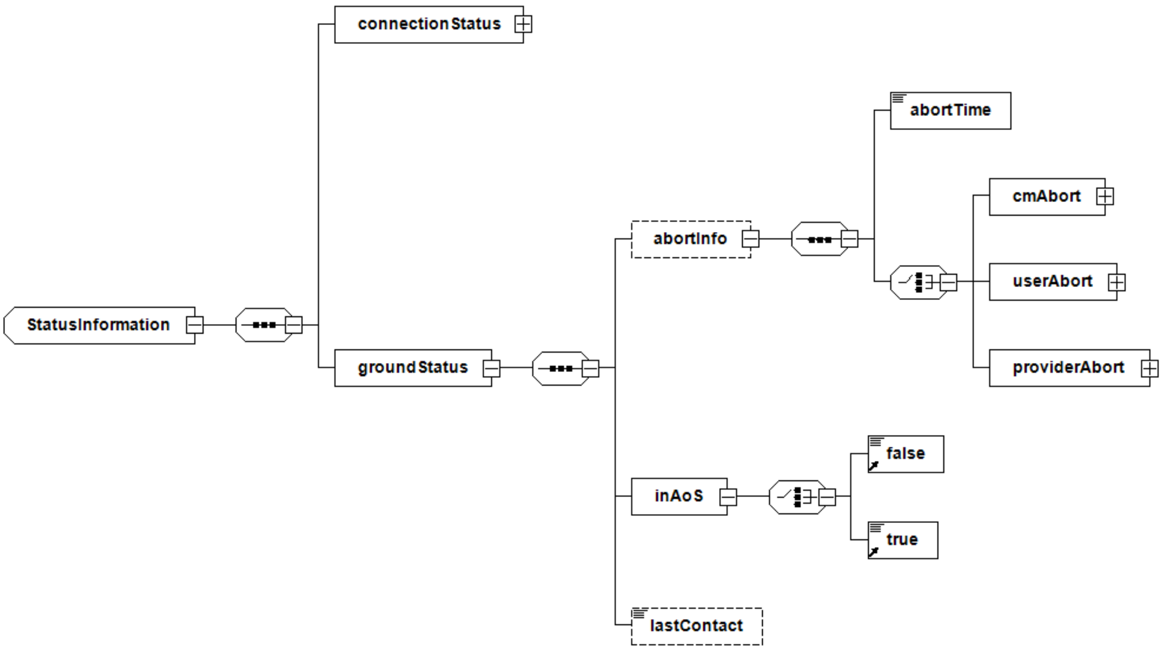
```
<xs:complexType name="StatusInformation">
  <xs:sequence>
    <xs:element name="connectionStatus">
      <xs:complexType>
        <xs:sequence>
          <xs:element name="logon">
            <xs:complexType>
              <xs:choice>
                <xs:element name="notLoggedOn">
                  <xs:complexType/>
                </xs:element>
                <xs:element name="loggedOn">
                  <xs:complexType/>
                </xs:element>
              </xs:choice>
            </xs:complexType>
          </xs:element>
          <xs:element name="verification">
            <xs:complexType>
              <xs:choice>
```

```
            <xs:element name="notLoggedOn">
              <xs:complexType/>
            </xs:element>
            <xs:element name="failed">
              <xs:complexType/>
            </xs:element>
            <xs:element name="pending">
              <xs:complexType/>
            </xs:element>
            <xs:element name="successful">
              <xs:complexType/>
            </xs:element>
            <xs:element name="unable">
              <xs:complexType/>
            </xs:element>
          </xs:choice>
        </xs:complexType>
      </xs:element>
      <xs:element name="periodic">
        <xs:complexType>
          <xs:choice>
            <xs:element name="established">
              <xs:complexType/>
            </xs:element>
            <xs:element name="notEstablished">
              <xs:complexType/>
            </xs:element>
          </xs:choice>
        </xs:complexType>
      </xs:element>
      <xs:element name="event">
        <xs:complexType>
          <xs:choice>
            <xs:element name="established">
              <xs:complexType/>
            </xs:element>
            <xs:element name="notEstablished">
              <xs:complexType/>
            </xs:element>
          </xs:choice>
        </xs:complexType>
      </xs:element>
      <xs:element name="retryPending">
        <xs:complexType>
          <xs:choice>
            <xs:element name="false">
              <xs:complexType/>
            </xs:element>
            <xs:element name="true">
              <xs:complexType/>
            </xs:element>
          </xs:choice>
        </xs:complexType>
      </xs:element>
      <xs:element name="demand">
        <xs:complexType>
          <xs:choice>
            <xs:element name="notEstablished">
              <xs:complexType/>
            </xs:element>
            <xs:element name="requested">
```

```
                <xs:complexType/>
              </xs:element>
            </xs:choice>
          </xs:complexType>
        </xs:element>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
```

Ground Status

The groundStatus element provides information about the last provider or user abort received (if any), the fact if the A/C is in the ACS area of service and if known the time of the last contact with the A/C.



commonStatusTypes.xsd (extract)

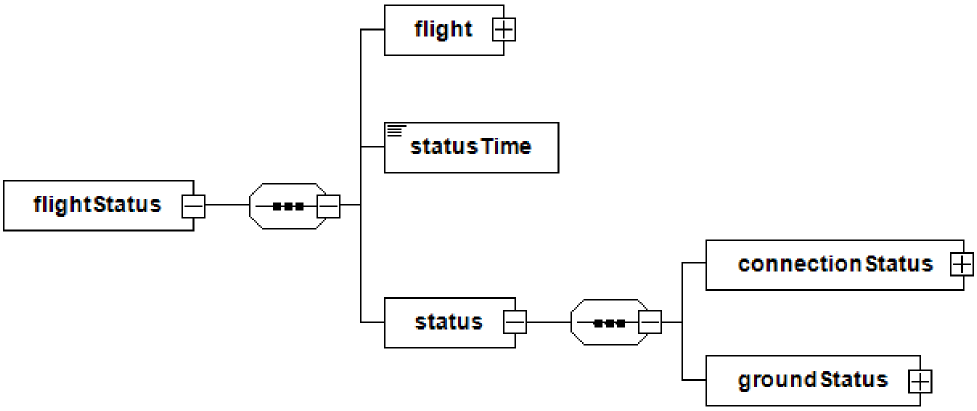
```
  <xs:element name="groundStatus">
    <xs:complexType>
      <xs:sequence>
        <xs:element minOccurs="0" name="abortInfo">
          <xs:complexType>
            <xs:sequence>
              <xs:element name="abortTime" type="xs:dateTime"/>
              <xs:choice>
                <xs:element name="cmAbort" type="CMAbortReason"/>
                <xs:element name="userAbort" type="AdsUserAbortReason"/>
                <xs:element name="providerAbort"
                            type="AdsProviderAbortReason"/>
              </xs:choice>
            </xs:sequence>
          </xs:complexType>
        </xs:element>
        <xs:element name="inAoS">
          <xs:complexType>
            <xs:choice>
```

```
                  <xs:element ref="false"/>
                  <xs:element ref="true"/>
                </xs:choice>
              </xs:complexType>
            </xs:element>
            <xs:element minOccurs="0" name="lastContact" type="xs:dateTime"/>
          </xs:sequence>
        </xs:complexType>
      </xs:element>
```

N.3.9.2.1.2 Status

The “status” payload provides the current state of a given flight. It contains three elements:

- The flight identification of type “FlightIdentification”.
- The time stamp at which the status information was collected.
- The status information of type “StatusInformation”

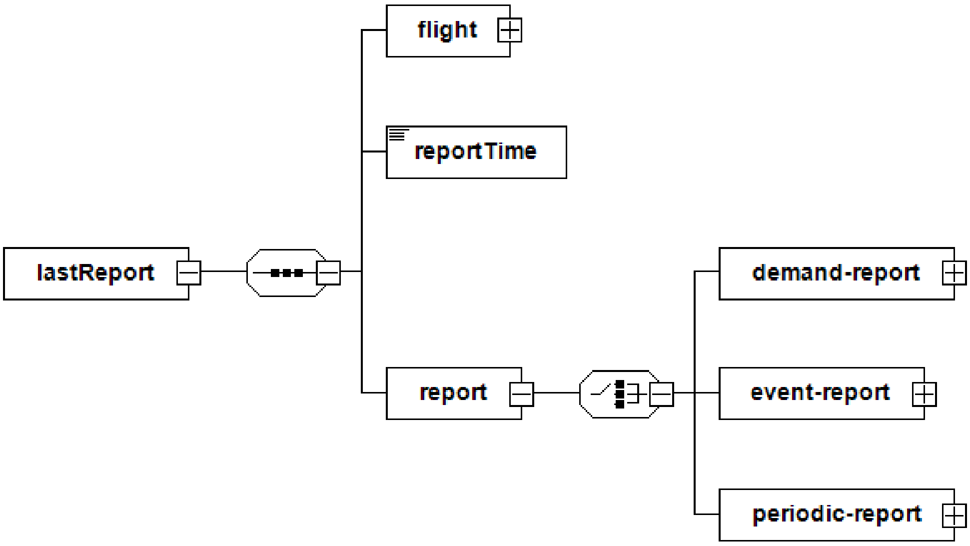


status.xsd (full)

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified">
  <xs:include id="Common_Types" schemaLocation="commonStatusTypes.xsd"/>
  <xs:element name="flightStatus">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="flight" type="FlightIdentification"/>
        <xs:element name="statusTime" type="xs:dateTime"/>
        <xs:element name="status" type="StatusInformation" />
      </xs:sequence>
    </xs:complexType>
  </xs:element>
</xs:schema>
```

N.3.9.2.1.3 Last report

The “lastReport” payload is a placeholder for one element of type `ADSReportType`.

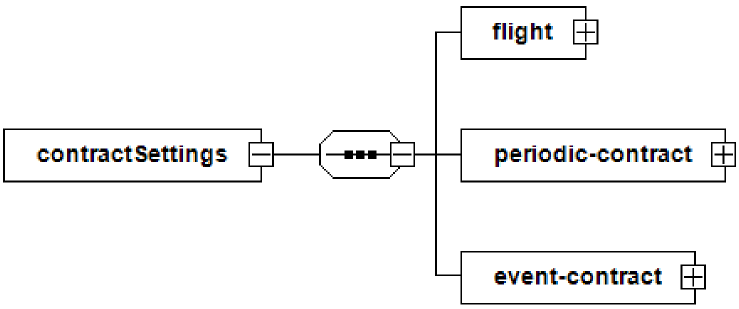


lastReport.xsd (full)

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified">
  <xs:import namespace="http://www.obj-sys.com/v1.0/XMLSchema"
schemaLocation="http://www.obj-sys.com/v1.0/XMLSchema/asn1.xsd" />
  <xs:include id="ADS_Message_set" schemaLocation="ADSMessageSetVersion1_ACS.xsd" />
  <xs:include id="Common_Types" schemaLocation="commonStatusTypes.xsd"/>
  <xs:element name="lastReport">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="flight" type="FlightIdentification"/>
        <xs:element name="reportTime" type="xs:dateTime"/>
        <xs:element name="report" type="ADSReportType" />
      </xs:sequence>
    </xs:complexType>
  </xs:element>
</xs:schema>
```

N.3.9.2.1.4 Contract settings

The “contractSettings” payload provides the definitions of the periodic and event contracts applied to the flight as contract requests.



contractSettings.xsd (full)

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified">
  <xs:import namespace="http://www.obj-sys.com/v1.0/XMLSchema"
schemaLocation="http://www.obj-sys.com/v1.0/XMLSchema/asn1.xsd" />
  <xs:include id="ADS_Message_set" schemaLocation="ADSMessageSetVersion1_ACS.xsd" />
  <xs:include id="Common_Types" schemaLocation="commonStatusTypes.xsd"/>
  <xs:element name="contractSettings">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="flight" type="FlightIdentification"/>
        <xs:element name="periodic-contract" type="PeriodicContractRequest" />
        <xs:element name="event-contract" type="EventContractRequest" />
      </xs:sequence>
    </xs:complexType>
  </xs:element>
</xs:schema>
```

N.3.9.2.1.5 Status along data distribution

Status information (as defined in N.3.9.2.1.1) is an optional element in the ACS data distribution payloads.

An optional status element (of type StatusInformation) is added to the ATC2FEPMessages and FEP2ATCMessages.

N.3.10 VarContracts – Variable management of periodic and event contracts

N.3.10.1 Introduction

This section describes the ACS API to support contract variability. It allows the ACS User to change specific elements of the periodic and event contracts of individual Aircraft.

Based on operational inputs, the elements currently subject to variability are:

- The TOA range of EPP points in periodic contracts.
- The periodicity of the periodic contracts.
- The EPP tolerances in event contracts.

The API uses two different patterns:

- The Request/Reply pattern for role management and the specification of the contract variable elements.
- The messaging pattern to subscribe to the role changes.

N.3.10.2 Request/Reply API

N.3.10.2.1 API Overview

Operation	Resource endpoint	HTTP Method
Set Role	/role/<icao>	POST
Get Role	/role/<icao>?	GET

List Roles	/roles	GET
Set TOA	/contracts/<icao>/toa	POST
Cancel TOA	/contracts/<icao>/toa	DELETE
Set Periodicity	/contracts/<icao>/periodicity	POST
Cancel Periodicity	/contracts/<icao>/periodicity	DELETE
Set Tolerance	/contracts/<icao>/epp-tolerance/<waypoint>	POST
Cancel Tolerance	/contracts/<icao>/epp-tolerance/<waypoint>	DELETE

Where <icao> is the ICAO 24-bit address of the subject Aircraft.

This API allows to set and cancel variable elements of the event and periodic contracts. The results of these changes (when/if accepted by the A/C) are retrieved by querying the current contracts through the IFACS API.

N.3.10.2.2 Common error conditions

All operations may return one of the following status codes:

Code	Reason Phrase	Description
400	Bad Request	Malformed request.
401	Unauthorized	Bad credentials or attempt to access a non-authorized resource.
405	Method Not Allowed	Method not provided on that specific endpoint
406	Not Acceptable	No matching ‘Accept’ content
415	Unsupported Media Type	Not compatible media type (application/xml)
500	Internal Server Error	Major application error.

In case of error, the response payload may contain additional (textual) information with Content-Type text/plain.

In several cases, user requests will have to be checked in term of role and priority. If the request cannot be granted, a 403 (Forbidden) error code will be returned. In that case, the body of the reply will contain the reason the request couldn’t be executed.

N.3.10.2.3 Role management

N.3.10.2.3.1 Set Role

This operation sets the role of the requesting user related to the flight identified by the <icao> ICAO address:

Request	Endpoint	/role/<icao>
	Method	POST
	Headers	• Accept: application/xml
	Body	See section N.3.10.4.1
Reply	Success headers	• Status-Code: 200 • Reason-Phrase: OK • Content-Type: application/xml
	Success body	See section N.3.10.4.1.1
	Specific error conditions	• 403 (Forbidden): The requested role cannot be granted to the user issuing the request

N.3.10.2.3.2 Get Role

The operation returns the current role of the requesting user related to the flight identified by the <icao> ICAO address. This parameter is optional if not specified the list of A/C for which the user has set a role will be returned:

Request	Endpoint	/role/<icao>?
	Method	GET
	Headers	• Accept: application/xml
	Body	<NONE>
Reply	Success headers	• Status-Code: 200 • Reason-Phrase: OK • Content-Type: application/xml
	Success body	See N.3.10.4.1.2.
	Specific error conditions	<NONE>

N.3.10.2.3.3 List roles

The roles endpoint gives access to list of current roles assigned for all users and all A/C:

Request	Endpoint	/roles
	Method	GET
	Headers	• Accept: application/xml
	Body	<NONE>
Reply	Success headers	• Status-Code: 200 • Reason-Phrase: OK • Content-Type: application/xml
	Success body	See N.3.10.4.1.3.
	Specific error conditions	• 403 (Forbidden): The user is not allowed to list roles

N.3.10.2.4 TOA Ranges in periodic contracts

N.3.10.2.4.1 Set TOA Range

Request	Endpoint	/contracts/<icao>/toa
	Method	POST
	Headers	• Accept: application/xml
	Body	See section N.3.10.4.2
Reply	Success headers	• Status-Code: 200 • Reason-Phrase: OK • Content-Type: application/xml
	Success body	See section N.3.10.4.2.1
	Specific error conditions	• 403 (Forbidden): The user issuing the request is not (currently) allowed to set a TOA range. • 404 (Not Found): The flight with ICAO address <icao> cannot be found

N.3.10.2.4.2 Cancel TOA Range

This endpoint allows a user to cancel its current TOA range request. If successful, the ACS reverts to the server default TOA range setting logic.

Request	Endpoint	/contracts/<icao>/toa
	Method	DELETE
	Headers	• Accept: application/xml
	Body	<NONE>
Reply	Success headers	• Status-Code: 204 • Reason-Phrase: No Content
	Success body	<NONE>
	Specific error conditions	• 403 (Forbidden): The user issuing the request is not allowed to clear a TOA range. • 404 (Not Found): The flight with ICAO address <icao> cannot be found or the TOA request cannot be found

N.3.10.2.5 Change periodic contract periodicity

N.3.10.2.5.1 Set Periodicity

Request	Endpoint	/contracts/<icao>/periodicity
	Method	POST
	Headers	• Accept: application/xml
	Body	See section N.3.10.4.3

Reply	Success headers	• Status-Code: 200 • Reason-Phrase: OK • Content-Type: application/xml
	Success body	See section N.3.10.4.3.1
	Specific error conditions	• 403 (Forbidden): The user issuing the request is not (currently) allowed to set a periodic contract periodicitys • 404 (Not Found): The flight with ICAO address <icao> cannot be found

N.3.10.2.5.2 Cancel Periodicity

This endpoint allows a user to cancel its current periodicity request. If successful, the ACS reverts to the server default periodicity setting logic.

Request	Endpoint	/contracts/<icao>/periodicity
	Method	DELETE
	Headers	• Accept: application/xml
	Body	<NONE>
Reply	Success headers	• Status-Code: 204 • Reason-Phrase: No Content
	Success body	<NONE>
	Specific error conditions	• 403 (Forbidden): The user issuing the request is not allowed to clear the periodic contract periodicity. • 404 (Not Found): The flight with ICAO address <icao> cannot be found or the periodicity request cannot be found

N.3.10.2.6 Set EPP Event Tolerance Monitoring

N.3.10.2.6.1 Set Tolerance

This endpoint allows to set EPP tolerance event on point <waypoint> for A/C <icao>.

Request	Endpoint	/contracts/<icao>/epp-tolerance/<waypoint>
	Method	POST
	Headers	• Accept: application/xml
	Body	See section N.3.10.4.4
Reply	Success headers	• Status-Code: 200 • Reason-Phrase: OK • Content-Type: application/xml
	Success body	See section N.3.10.4.4.1

	Specific error conditions	• 403 (Forbidden): The user issuing the request is not (currently) allowed to set event contract tolerance monitoring or the event tolerance resources are exhausted. • 404 (Not Found): The flight with ICAO address <icao> cannot be found

N.3.10.2.6.2 Cancel Tolerance

This endpoint cancels the EPP tolerance event on point <waypoint> for A/C <icao>.

Request	Endpoint	/contracts/<icao>/epp-tolerance/<waypoint>
	Method	DELETE
	Headers	• Accept: application/xml
	Body	<NONE>
Reply	Success headers	• Status-Code: 204 • Reason-Phrase: No Content
	Success body	<NONE>
	Specific error conditions	• 403 (Forbidden): The user issuing the request is not (currently) allowed to clear event contract tolerance monitoring. • 404 (Not Found): The flight with ICAO address <icao> cannot be found or the tolerance request cannot be found

N.3.10.3 Role updates subscriptions

The messaging pattern is used to allow authorized ACS Users to listen to role updates. The AMQP (amqps) address of this link is provided as configuration information.

When connected as a receiver to this address, ACS Users will receive a message each time a role is changed in the ACS.

The body of the message is an XML `acsUserRoles` element as defined in section N.3.10.4.1.3.

The subject of the message will be `ACS/RoleChange`. The message properties (except the subject) will follow the rules set in section 5.1.4 of the ACS ICD. No specific application properties are defined.

N.3.10.4 Payloads

N.3.10.4.1 Role management

The following schema defines the different elements and types used by the ‘Role management’ API. The central type is the `ACSRoleEnumeration` type that enumerates the different possible roles (including ‘none’ the absence of a specific role).

ACS-Roles.xsd (full schema)

```
<?xml version="1.0" encoding="UTF-8"?>
```

```
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            elementFormDefault="unqualified">
  <xsd:element name="acsRole" type="ACSRoleEnumeration"/>

  <xsd:element name="acsRoles" type="ACSRoles"/>

  <xsd:element name="acsUserRoles" type="ACSUserRoles"/>

  <xsd:complexType name="ACSRoles">
    <xsd:sequence>
      <xsd:element name="acsACRole" type="ACSACRole"
                   minOccurs="0" maxOccurs="unbounded" />
    </xsd:sequence>
  </xsd:complexType>

  <xsd:complexType name="ACSACRole">
    <xsd:sequence>
      <xsd:element name="icao" type="xsd:string"/>
      <xsd:element name="role" type="ACSRoleEnumeration" />
    </xsd:sequence>
  </xsd:complexType>

  <xsd:complexType name="ACSUserRoles">
    <xsd:sequence>
      <xsd:element name="acsUser" type="ACSUser"
                   minOccurs="0" maxOccurs="unbounded" />
    </xsd:sequence>
  </xsd:complexType>

  <xsd:complexType name="ACSUser">
    <xsd:sequence>
      <xsd:element name="name" type="xsd:string"/>
      <xsd:element name="icao" type="xsd:string"/>
      <xsd:element name="role" type="ACSRoleEnumeration" />
    </xsd:sequence>
  </xsd:complexType>

  <xsd:complexType name="EnumerationValue" final="#all" />

  <xsd:complexType name="AcsRoleEnumeration">
    <xsd:choice>
      <xsd:element name="none" type="EnumerationValue"/>
      <xsd:element name="catsu" type="EnumerationValue"/>
      <xsd:element name="natsu" type="EnumerationValue"/>
      <xsd:element name="aman" type="EnumerationValue" />
      <xsd:element name="ansp" type="EnumerationValue" />
      <xsd:element name="airline" type="EnumerationValue" />
      <xsd:element name="met" type="EnumerationValue" />
      <xsd:element name="nm" type="EnumerationValue" />
      <!-- more possibilities ?? -->
    </xsd:choice>
  </xsd:complexType>

</xsd:schema>
```


N.3.10.4.1.1 Set Role payload

The ***Set Role*** payload is made of a single `acsRole` element (see above schema definition).

N.3.10.4.1.2 Get Role payload

The ***Get Role*** payload is made of a single `acsRoles` element (see above schema definition).

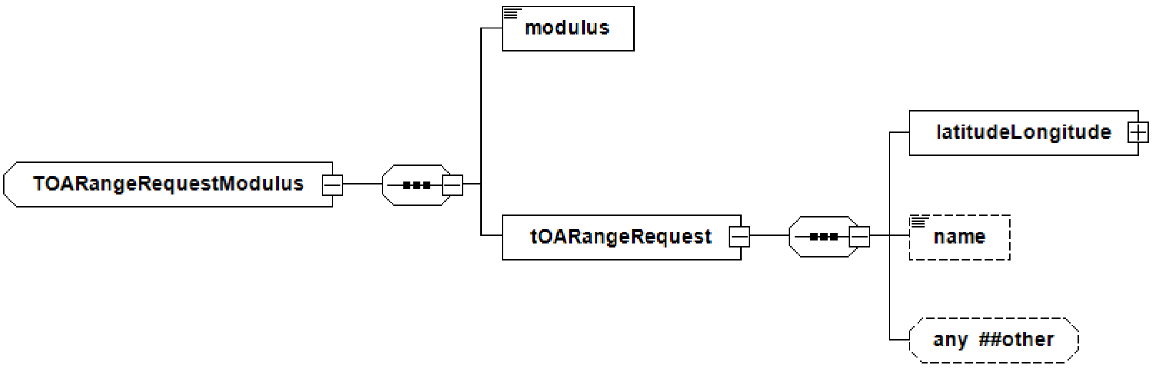
N.3.10.4.1.3 Roles payload

The ***List Roles*** payload is made of a single `acsUserRoles` element (see above schema definition).

N.3.10.4.2 TOA Ranges payloads

N.3.10.4.2.1 Set TOA payload

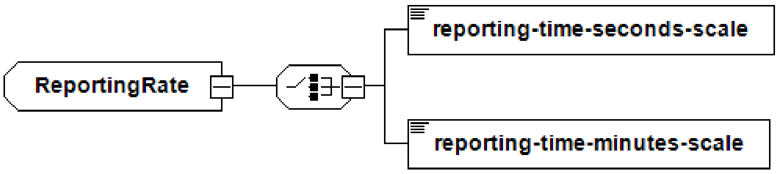
The payload of the Set TOA endpoint is a single toa-range-modulus element of type TOARangeRequestModulus (as defined in ED229A):



N.3.10.4.3 Periodicity payloads

N.3.10.4.3.1 Set Periodicity payload

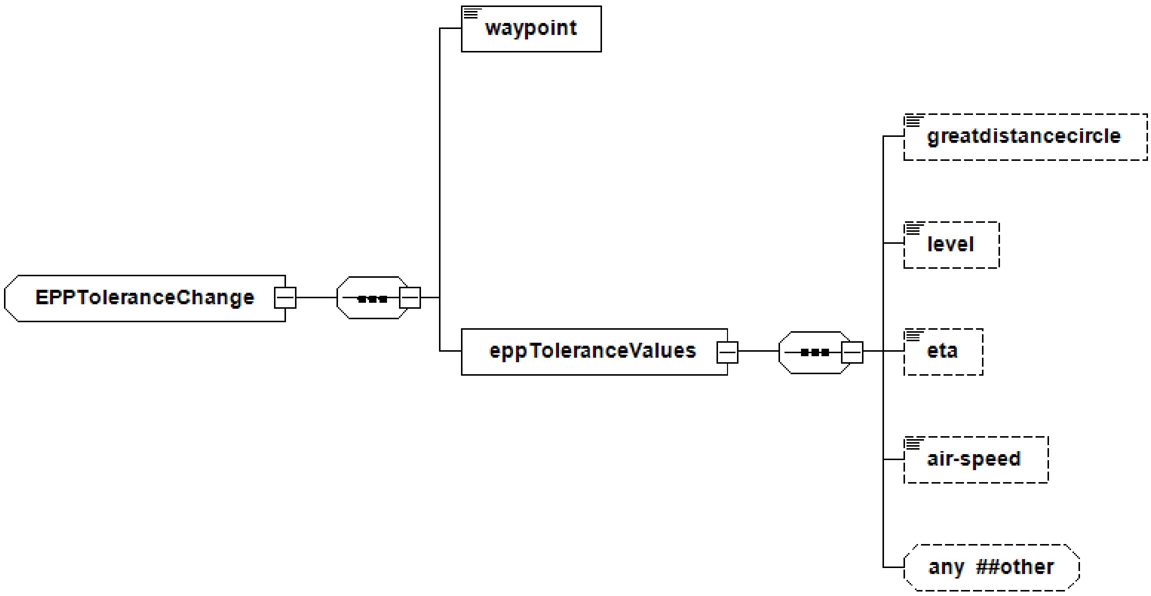
The payload of the Set Periodicity endpoint is a single reporting-rate element of type ReportingRate (as defined in ED229A):



N.3.10.4.4 Tolerance monitoring payloads

N.3.10.4.4.1 Set Tolerance payload

The payload of the Set Tolerance endpoint is a single epp-tolerance element of type EPPToleranceChange (as defined in ED229A):


waypoint
EPPToleranceChange
eppToleranceValues
greatdistancecircle
level
eta
air-speed
any ##other