ICATS Demonstration Report

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Abstract

This document constitutes the ICATS Demonstration Report. A summary of the ICATS project is provided detailing the project operational concept and demonstration objectives. However, the main part of the report is the description of how the execution activities have been carried out, the data gathered from the demonstration trials, and the results obtained from the analysis of that data. A summary of the results per demonstration objective and KPA is given. Deviations from the initial plan are also listed. Finally, the conclusions and recommendations obtained from the demonstration activities are presented. They pave the way for future related initiatives.

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00.00.08	30/06/2014	Preliminary V2	CRIDA + ICATS Consortium	Update of the 00.00.06 version with the inclusion of the 2nd review cycle comments.
01.00.00	11/07/2014	Final Version	CRIDA	2nd Analysis for Exercise 2 and comments from the final review added.

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This deliverable consists of SJU foreground.

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Executive summary

As part of the SESAR Demo Projects, ICATS Project (Interoperability Cross-north Atlantic TrialS) has conducted two demonstration exercises (EXE-02.09-D-001 and EXE-02.09-D-002) supported by a ground infrastructure based in Flight Object Interoperability technology built on US/EU FIXM/ED-133 concepts and models, complemented by a inter regional Global Flight Object model developed specifically for the project. The overall objective of the Project was to quantify the operational benefits that are achievable when flight object data is exchanged between stakeholders. The two exercises had different scopes and different areas of focus:

- EXE-02.09-D-001 scope was limited to the Air Europa flights of city pairs Madrid - certain Caribbean airports, (Westbound and Eastbound) flying across Lisbon, Santa María and New York Oceanic airspaces. Its objectives were focused on the reduction of the Fuel Consumption and the CO_2 emissions as well as on the reduction of the number of trajectory change rejections.
- EXE-02.09-D-002 scope was limited to all the Eastbound flights departing from Caribbean airports and North/Central America and entering in Madrid ACC Airspace The focus of this exercise was measuring the improvement of the accuracy of the sector load calculations as well as on the improvement of the predictability of the data.

This document constitutes the ICATS Demonstration Report. A full view of the project is included here with main focus on the trials execution and their results. The concept that the ICATS Consortium aimed to validated through these Demonstration Trials was that the Flight Information sharing between different ICAO Regions (in this case between the two sides of the North-Atlantic) provides benefits to the main aviation stakeholders. On the one hand, this provides benefits for the Airlines in terms of Fuel Savings, CO_2 emissions and reduction of the number of rejections. On the other hand, it also provides benefits for the ANSP in terms of improving the predictability and accuracy of the traffic entry times in their own airspace. This enables ANSPs to achieve better planning of their resources and optimization of their sector configurations.

For EXE-02.09-D-001, more than 40 trials were performed (39 Westbound and 2 Eastbound), although in not all of them trajectory optimization were found by the Airline Operations Centre (only 19). For EXE-02.09-D-002, more than 200 inbound flights were analysed. Based on the results of the trials, the following conclusions can be described:

EXE-02.09-D-001 - For the flights with optimizations:

1. The amount of fuel consumption and the CO_2 emissions saved was 1,40%, higher than the expected 1%.
2. The number of trajectory change requested and rejected was reduced by about 5% as expected. In addition after consulting pilots and controllers, their view is that the information exchanged through the IOP Chain provides clear benefits.
3. The reduction on the number of tactical conflicts couldn't be quantitatively measured due to the lack of data. However it was measured in a qualitative way through a set of questionnaires and the result was that the controllers appreciate having the information in advance to be able to adapt their action to their situational awareness.

EXE-02.09-D-002 - For the days with data subjected to analysis:

1. Considering only the cases where ICATS Data is better than PIV (current system) data, the analysis of the results show that ICATS accuracy of the sector load calculation and the unexpected sector overload is improved. In those cases, the results obtained clearly exceed the expected benefit defined in the project.
2. Regarding the predictability and the accuracy of the data, it is been proved that for the data analysed, the ICATS system is slightly more predictable and accurate than the current system (PIV). An average improvement around 18 minutes in predictability and around 8 minutes in accuracy is obtained from the analysis.

The Next Steps section summarises the conclusions obtained from the exercises detailed per KPAs and provides recommendations and enhancements that the ICATS Consortium seen as being important to ICATS in the future. The recommendations are grouped in three sections concerning how

to continue with the trials, what's needed in terms of further concept exploration and the identified system engineering developments. Some of the recommendations that are further described in section 8 are:

- The integration of the AOC and ATC via Trajectory Optimization Automation.
- Alignment with the Latest FIXM Standard.
- Better integration with evolving Regional SWIM implementations.
- ICATS Extension to a larger set of stakeholders.
- Consideration of the ICATS outcome as an input for SESAR RBT/SBT Discussions.

1 Introduction

1.1 Purpose of the document

This document is the Demonstration Report deliverable (B1) for ICATS Project whose objective is to demonstrates that sharing of Flight Objects including trajectory information between two different ICAO regions delivers benefits in terms of Fuel Efficiency, CO_2 emissions, Safety, Capacity and Predictability. It describes the results of demonstration exercises defined in [3] and how they have been conducted.

This document presents the exercises results as well as a deeper analysis of these results in order to measure achievement of the validation objectives defined in [3].

The document has been prepared using the SJU template provided for the Demonstration Projects. The document has been prepared by the ICATS partners, being their major contribution as follows:

- CRIDA has been responsible of publishing the complete document, integrating the different partners contribution, responsible also for the *Executive Summary* and *Introduction* sections, and for the analysis and presentation of the results in sections 5 and 6.
- AENA and Nav-Portugal have contributed to section 4, *Execution of Demonstration Exercises*.
- Lockheed Martin has contributed to section 2, *Context of the Demonstration*, and to the introductory part of section 4.
- Indra has contributed to section 3, *Programme Management*, to the parts *Exercise Scope* and *Conduct of Exercise* of section 6, and to section 7, *Communication activities*.
- CRIDA, AENA, Nav-Portugal, Lockheed Martin, Air Europa and Indra have contributed to section 8, *Next Steps*, and to the review of the entire document.

1.2 Intended readership

The **ICATS** Demonstration Report is primarily aimed at:

- SESAR Joint Undertaking, since this document describes the main results obtained from the demonstration trials and their analysis in order to establish if the project objectives have been successfully achieved;
- The SESAR WP4, WP10, and WP14 leaders, since this project demonstrates the operational concepts developed and validated by aforementioned SESAR Work Packages in an operational context;
- The SESAR OFAs OFA 03.01.08 - System Interoperability with air and ground data sharing, OFA 03.01.04 - Business and Mission Trajectory, OFA 05.03.04 - Enhanced ATFM Processes
- The consortium members participating in the project (AENA, Air Europa, CRIDA, Indra, Lockheed Martin, and NAV Portugal), since this document constitutes the report of the activities performed during the execution phase as well as the results obtained.;
- Additional parties involved in SESAR/NextGen coordination, since interoperability concepts between these two programs are demonstrated.

1.3 Structure of the document

The document is organised as follow:

- Section 1 introduces the document.
- Section 2 provides the context and scope of the demonstrations with reference to the overall SESAR programme and stakeholders involved.

- Section 3 provides the Project Management Plan for ICATS, including the work and resource breakdowns, project milestones and risks.
- Section 4 details the execution of the demonstration exercises.
- Section 5 presents the exercise results achieved for each demonstration exercise.
- Section 6 presents the reports for each demonstration exercise.
- Section 7 summarises the communication activities planned for the project.
- Section 8 provides the next steps identifying the most important conclusions and recommendations.

1.4 Glossary of terms

Term	Definition
Aeronautical Information Management (AIM) Data	Aeronautical Information Management Data needed by the System Instance, which are not included in (yet may be referenced by) the Flight Object. Some of those data are the IOP AIM object Data that are shared between the IOP stakeholders.
Flight Object (FO)	The system instance view of a flight. It is the flight object that is shared between the IOP stakeholders. The 'Flight Object' (FO) is a concept to support the sharing of consistent flight data between all stakeholders. Its purpose is to ensure that all systems have a consistent view of the flight in a timely manner, and that the data is widely and easily available, subject to appropriate access controls. It is the basis for the interoperability (IOP) mechanism defined by this document.
Interoperability (IOP)	The IEEE Standards Computer Dictionary defines interoperability as the ability of two or more systems or components to exchange information and to use the information that has been exchanged. In this context, we refer to IOP as a concept that allows a disparate set of Flight Data Processing Systems (FDPSs) to maintain a consistent view of the flight data, and enables them to coordinate changes to that flight data even between systems that are not yet operationally responsible for the flight.
IOP area	The area corresponding to the union of the AOR of each IOP stakeholder. This area is unique.
IOP stakeholder	Any entity that provides information to other entities or that consumes such information using the IOP capabilities. For example: A system instance working for a civilian ATSU (En-Route, Approach, or Tower), a system instance working for a military ATSU, or a combination of thereof. A system working for an Airport Authority. A system working for an Aircraft Operator. A system working for an aircraft (FMS). A Central Flow Management Unit (CFMU). Under the umbrella of the EUROCAE ED-133, the IOP stakeholder is limited to a system instance working for one or more civilian ATSUs.

Term	Definition
NextGen	NextGen is a comprehensive overhaul of the USA National Airspace System to make air travel more convenient and dependable, while ensuring your flight is as safe, secure and hassle-free as possible.
System Flight Plan (SFPL)	The internal core entity which stores the flight intention in each program for developing an advanced ATC system as well as all applicable constraints during the flight lifecycle of the flight within the area of interest.
System Wide Information Management (SWIM)	SWIM is not an ATM end-user application but rather an enabler that allows the information sharing between the different ATM systems to better fit business and operational requirements and ATM services management between ATM Systems (inter-systems) covering the Ground-Ground, air-ground, Civil-military segments. SWIM ensures a fully consistent, modern, efficient, safe, secure and interoperable solution for supporting the ATM information exchange and service management between different ATM stakeholders
Trajectory	Representation of the predicted 4D path of an aircraft.

1.5 Acronyms and Terminology

Term	Definition
A/G	Air/Ground
ABI	Advance Boundary Information
ACARS	Aircraft Communication Addressing And Reporting System
ACC	Area Control Centre
ACID	Aircraft Identification
4D	4 Dimensional
ADES	Destination Airport
ADEXP	ATS Data Exchange Presentation
ADS	Automatic Dependent Surveillance
ADS-C	Automatic Dependent Surveillance – Contract
ADSL	Asymmetric Digital Subscriber Line
AEA	Air Europa
AENA	Aeropuertos Españoles y Navegación Aérea
AFTN	Aeronautical Fixed Telecommunication Network

Term	Definition
AGDP	Air Ground DataLink Process
AI	Aircraft Intent
AIDC	ATS Inter-facility Data Communications
AIDL	Aircraft Intent Description Language
AIM	Aeronautical Information Management
AIRCOM	Communication server
AIRM	ATM Information Reference Model
AMAN	Arrival Manager
ANSP	Air Navigation Service Provider
AO	Air Operator
AOC	Airline Operations Centre
AOR	Area Of Responsibility
ARTCC	Air Route Traffic Control Centre
ASDI	Aircraft Situation Data to Industry
ASIS	Aircraft Intent Synchronization Infrastructure for SESAR
ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
ATCO	Air Traffic Control Organisation
ATFM	Air Traffic Flow Manager
ATIEC	Air Transportation Information exchange Conference
ATM	Air Traffic Management
ATOP	Advanced Technologies and Oceanic Procedures
ATS	Air Traffic Services
ATSU	Air Traffic Services Unit
AU	Airspace User
BT	Business Trajectory
CDM	Collaborative Decision Making

Term	Definition
CDR	Conditional Route
CDRL	Contract Data/Deliverables Requirements List
CED	Centro de Experimentación y Desarrollo (AENA's Research & Development Centre)
CFMU	Central Flow Management Unit
CFP	Call for Proposals
CHMI	Flow Control Position
CNS	Communications-Navigation-Surveillance
CONOPS	SESAR Concept of Operations
CP	Coordination Plan (SESAR/NextGen coordination)
CPDLC	Controller-Pilot Data Link Communications
CRIDA	Centro de Referencia de Investigación, Desarrollo e Innovación ATM (Centre of Referece for ATM Research, Development and Innovation)
CS	Consolidated Specification
CTA	Controlled Time of Arrival
CTO	Controlled Time Over
CTOT	Calculated Take Off Time
CWP	Controller Working Position
DBNTB	Daytona Beach Next Gen Test Bed
DFS	Deutsche FlugSicherung (German ANSP)
DL	Data Link
DMAN	Departure Manager
DOD	Detailed Operational Description
DoW	Description of Work
DSNA	Direction des Services de la Navigation Aérienne (French ANSP)
DST	Decision Support Tool
DTB	Daytona Beach Test Bed
E-ATMS	European Air Traffic Management System

Term	Definition
ELDT	Estimated Landing Time
ENAV	Ente Nazionale di Assistenza al Volo (Italian ANSP)
E-OCVM	European Operational Concept Validation Methodology
EOBT	Estimated Off-Block Time
EPP	Extended Projected Profile
ERAM	En-Route Automation Modernization (ERAM) system
ERAU	Embry-Riddle Aeronautical University
ETA	Estimated Time of Arrival
ETO	Estimated Time Over
ETOT	Estimated Take Off Time
EU	European Union
FAA	Federal Aviation Administration
FANS	Future Air Navigation System
FAT	Factory Acceptance Test
FC	Flight Crew
FDM	Flight Data Monitoring
FDPS	Flight Data Processing System
FIR	Flight Information Region
FIXM	Flight Information eXchange Model
FL	Flight Level
FLX	Flexibility
FMP	Flow Management Position
FMS	Flight Management System
FO	Flight Object
FOC	Full Operational Capability
FOID	Flight Object Interoperability Definition
FOQA	Flight operations Quality Assurance

Term	Definition
FOXS	Flight Object Exchange Server
FPL	Flight Plan (Air Traffic Services)
FS	Final Specification
FTB	Florida Test Bed
FUSA	Fuel Savings Analysis (CRIDA tool)
GFO	Global Flight Object
GGDC	Ground Ground Data Communications
GIPV	Gestor de Información del Plan de Vuelo (A Sub-System of the Spanish Automated ATC System – AENA's SACTA – in charge to feed external systems with real time Flight Plan updated information)
HFIR	Time of entry in a Flight Information Region
HMI	Human Machine Interface
I-SWIM	Inter-SWIM (i.e. integrated across various implementations)
IAIS	Initial Aircraft Intent Specification
IBP	Industry Based Prototype
ICAO	International Civil Aviation Organization
ICATS	Interoperability Cross Atlantic TrialS
ICD	Interface Control Document
ICOG	Interoperability Consultancy Group
IEEE	Institute of Electrical and Electronics Engineers
IFPS	Initial Flight Plan Processing System
IM	Information Management
INDRA	INDRA Systems
IOC	Initial Operational Capability
IOP	InterOperability (ICOG)
iTEC	interoperability Through European Collaboration
KPA	Key Performance Area
KPI	Key Performance Indicator

Term	Definition
MET	Meteorological
MFA	Multilateral Framework Agreement
MT	Mission Trajectory
MUAC	Maastricht Upper Area Control
NAS	National Airspace System of the United States
NAV Portugal	Portuguese Air Navigation Services
NOP	Network Operations Plan
OCAT	Oceanic Conflict Advisory Trial
OCC	Operations Control Centre
OCD	Operational Concept Definition
OFA	Operational Focus Areas
OFP	Operational Flight Plan
OLDI	On-Line Data Interchange
OPTIMI	Oceanic Position Tracking Improvement and Monitoring
PDV	Posición de Datos de Vuelo (Flight Data Position)
PENS	Pan-European Network Service
PERSEO	Plataforma de análisis de los Efectos de Red debidos a la Sectorización En Operación (Analysis Platform for the Network Effects of Sectorisation In Operation)
PIV	Posición Información de vuelo (Flight Information Position)
PMP	Project Management Plan
PTR	Problem Tracking Report
R&D	Research & Development
RBT	Reference Business Trajectory
RMT	Reference Mission Trajectory
SACTA	Automated System for Air Traffic Management used in AENA Centres
SBT	Shared Business Trajectory
SEMP	System Engineering Management Plan

Term	Definition
SEROS	Semmerkaze Radar Operating System
SESAR	Single European Sky ATM Research
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SFPL	System Flight Plan
SITA	Communications Service Provision Company
SJU	SESAR Join Undertaking
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
SMT	Shared Mission Trajectory
SoS	System of Systems
SPR	Safety and Performance Requirements
SSR	Secondary Surveillance Radar
SUT	System Under Test
SWIM	System Wide Information Management
SWP	Sub Work Package
SYSCO	System-Supported Coordination
SYSRED	AENA Unit in charge to mantain a global overview of the status of Air Navigation Services across all the Spanish Air Navigation Network
TBO	Trajectory Based Operations
TBFM	Time Based Flow Management
TCSD	Test Cases and Scenarios Document
TFMS	Traffic Flow Management System
TFV	Traffic Volume
TM	Trajectory Management
TMA	Terminal Manoeuvring Area
TMF	Trajectory Management Framework
TMR	Trajectory Management Requirements
TMS	Trajectory Management System

Term	Definition
TP	Trajectory Prediction/Predictor
USA	United States of America
UTC	Universal Time Coordinate
VPLAN	Verification Plan
V&V	Validation & Verification
VPD	Verification Plan Definition
WBS	Work Breakdown Structure
WOC	Wing Operations Centre
WP	Work Package

2 Context of the Demonstrations

The main objective of the ICATS project is to demonstrate, by means of flight trials (more than 40 cross Atlantic flights have been directly involved plus the daily usual eastbound oceanic traffic with destination Spain), that the sharing of Flight Object related data between international air traffic control systems, oceanic and domestic, across the two sides of North Atlantic, and airlines, produces measurable benefits in flight efficiency, environment, safety and capacity management for the users (ANSPs, AOs).

The Project has been executed by the consortium made up of AENA, Air Europa, CRIDA, Indra (acting as coordinator), Lockheed Martin, and NAV Portugal, in response to the SJU Call for Proposals (CFP) ref. SJU/LC/0070 under Lot 2, with the project title Interoperability Cross-Atlantic Trials (ICATS).

2.1 Scope of the demonstration and complementarities with the SESAR Programme

The concept of operations focuses on the following principal areas:

- **System Interoperability with Air and Ground Data Sharing:** operations of technology capabilities enabling the exchange of digital ATM information, as a backbone for the implementation of the SESAR Concept of Operations (CONOPS) and System Wide Information Management (SWIM). This includes SWIM based ground data exchange between ATS Units and/or Airline Operation Centres (AOC), aiming at sharing the same representation of flights. Air/ground data sharing will be done using current methods including voice and datalink in the parallel real ATC systems.
- **CDM Trajectory negotiation between Airspace User (AU) and Controller:** Advance receipt of user preferred flight intent data (route/speed/level modification) from the AOC will allow the relevant Air Traffic Services (ATS) Unit to respond to expectations considering surrounding traffic.

The geographical coverage is inter-continental, extending from one coast to the other across the Central-Northern part of the Atlantic Ocean, involving the United States of America (USA) and those countries that make up the Iberian Peninsula (Spain and Portugal). In the Central-Northern part of the Atlantic Ocean, formed mainly by Santa Maria and New York Oceanic Airspaces, aircraft usually follows random routes which are more convenient for this sort of trials where optimizations (changes) on the trajectories are the key objective. The operational context includes Oceanic air traffic management operations and the En-Route part of the oceanic flights in both the US and European regions and Airline Operations Centre (AOC) operations conducted by Air Europa.

The Project is fully complementary with the SESAR Programme, as it has used and adapted Industry prototypes coming from System Projects of Work Packages 10 (En-Route & Approach ATC Systems) and 14 (SWIM Technical Infrastructure), it validated Operational concepts related to Work Package 4, En-Route Operations, and it is aligned with Release 3, 4 and 5 exercises and with OFAs related to Trajectory Management and Demand and Capacity, OFA 03.01.08 - System Interoperability with air and ground data sharing, OFA 03.01.04 - Business and Mission Trajectory, and OFA 05.03.04 - Enhanced ATFM Processes.

The following summary tables identify the high-level exercises that are described and discussed in this Demonstration Report. The Live Flight Trial consisted of two separate scenarios as highlighted in Tables 1 and 2 below. Additional detail on the exercises can be found in the following ICATS project documents:

- ICATS CDRL A1 – ICATS Demonstration Plan
- ICATS CDRL B3 – ICATS Concept of Operations

Demonstration Exercise ID and Title	**EXE-02.09-D-001: Enhancing of trajectory of Air Europa flights analyzing how the advanced sharing of information improves the flight efficiency.**
Leading organization	Indra leading a consortium that includes AENA, NAV Portugal, Air Europa, CRIDA, Indra, Lockheed Martin.
Demonstration exercise objectives	Improvement in Efficiency, Environment and Safety
OFA addressed	OFA 03.01.01 - Trajectory Management Framework OFA 03.01.08 - System Interoperability with air and ground data sharing OFA 03.01.04 - Business and Mission Trajectory
Applicable Operational Context	The operational context is inter-continental, including domestic and oceanic airspace and air traffic management operations extending from one coast to the other across the Northern part of the Atlantic Ocean, involving the United States of America (USA) and those countries that make up the Iberian Peninsula (Spain and Portugal). It also includes Airline Operations Centre (AOC) operations conducted by Air Europa.
Demonstration Technique	Scenario 1 – Live Flight Trial involving Air Europa traffic
Number of trials	One Live Flight Trial conducted over an interval going from mid April to early June 2014 encompassed two separate Exercises/Scenarios 1 and 2. The intent of Scenario 1 is to explore trajectory optimization for at least 40 cross-Atlantic flights including both eastbound and westbound traffic. Scenario 1 focuses on Air Europa flights (e.g., ACID=AEA***) that fly trans-Atlantic routes between the following city pairs: Madrid and Santo Domingo (LEMD / MDSD), Madrid and Havana (LEMD / MUHA), Madrid and Caracas (LEMD / SVCS), Madrid and San Juan Puerto Rico (LEMD / TJSJ).

Table 1: ICATS Live Flight Trial Scenario 1 Overview

Demonstration Exercise ID and Title	**EXE-02.09-D-002: Exchange of information on Flight Departures, for improving predictability of traffic load**
Leading organization	Indra leading a consortium that includes AENA, NAV Portugal, Air Europa, CRIDA, Indra, Lockheed Martin.
Demonstration exercise objectives	Improvement on Capacity and Predictability
OFA addressed	OFA 03.01.08 - System Interoperability with air and ground data sharing OFA 03.01.04 - Business and Mission Trajectory OFA 05.03.04 - Enhanced ATFM Processes
Applicable Operational Context	The operational context is inter-continental, including domestic and oceanic airspace and air traffic management operations extending from one coast to the other across the Northern part of the Atlantic Ocean, involving the United States of America (USA) and those countries that make up the Iberian Peninsula (Spain and Portugal). It also includes Airline Operations Centre (AOC) operations conducted by Air Europa.

Demonstration Technique	Scenario 2 – principally offline analysis of data recorded during conduct of the Live Flight Trial
Number of trials	In total, more than 200 flights have been analysed. One Live Flight Trial conducted over an interval going from mid April to early June 2014 encompassed two separate Exercises/Scenarios 1 and 2. The intent of Exercise/Scenario 2 is to collect as much Flight Object data as possible to perform offline analysis of various metrics and associated operational benefits. Scenario 2 included all flights with ICAO departure airport designators C*, K*, M* and S*[1] (e.g., Canada, United States, and Latin America) entering in Madrid ACC, always they crossed NY and SM Oceanic centres. If not the case, the IOP chain didn't update their flight plans..

Table 2: ICATS Live Flight Trial Scenario 2 Overview

The following figures present the operational context of the trials, how the GFO has been defined within the project and which is the composition of the ICATS GFO.

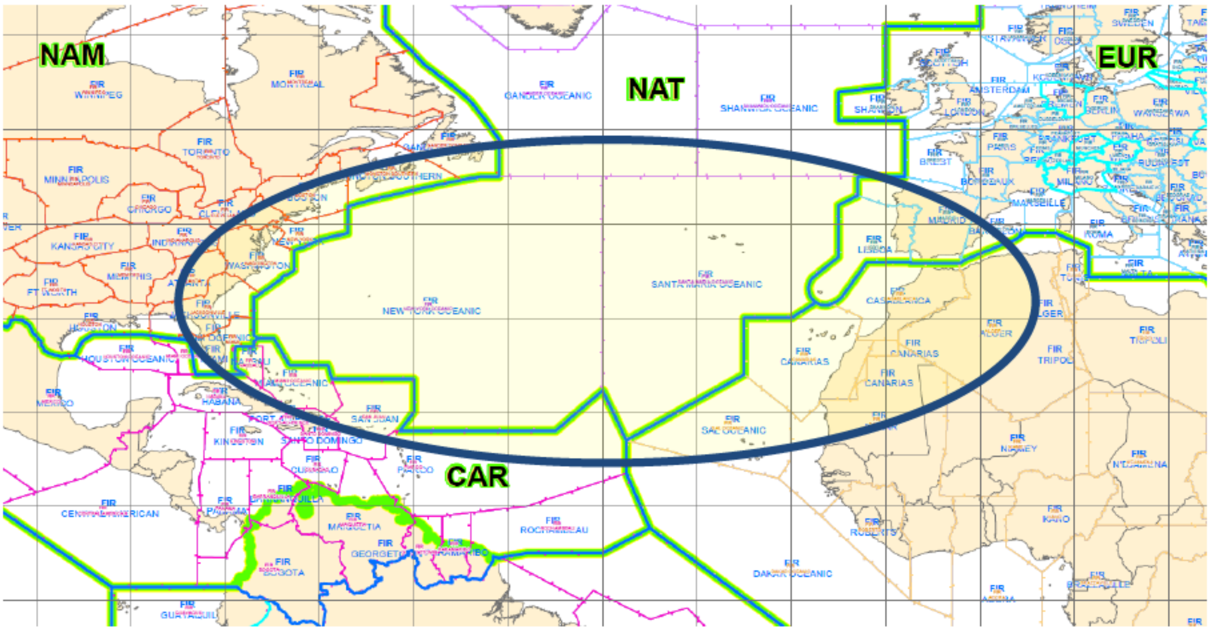


Figure 1: ICATS Operational Context

[1] From the 22nd of May onwards, the traffic with origin S* was also considered.

Figure 2: ICATS Global Flight Object

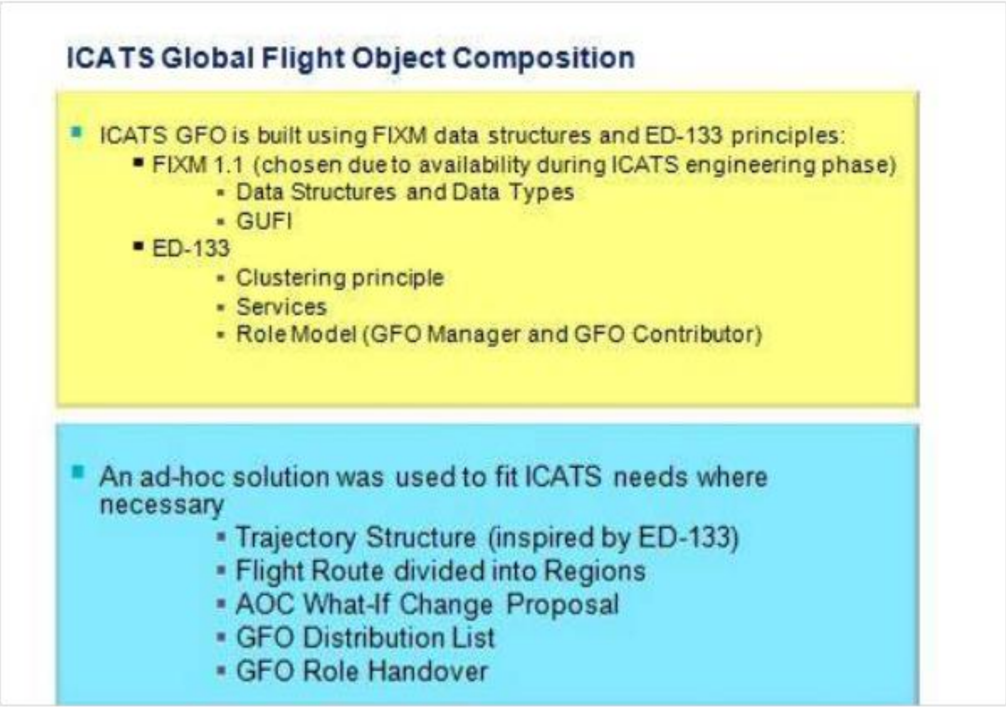


Figure 3: ICATS Global Flight Object Composition

3 Programme management

This section provides a summary of the Project Management activities performed for the project, indicating the relevant changes occurred during the execution phase of the trials.

3.1 Organisation

3.1.1 ICATS Consortium

To execute the ICATS project, a consortium of companies was established. The participating companies are AENA, Air Europa, CRIDA, Indra (acting as Consortium leader in front of SJU), Lockheed Martin and NAV Portugal.

Figure 4: ICATS Consortium Members

The role played for each member is as follows:

Indra is the Project Leader of the Consortium, acting as Project Manager and Coordinator, Quality Manager and also responsible for External Interfaces and Communications.

AENA, CRIDA, NAV Portugal, Lockheed Martin and Air Europa, are Project Members and perform complementary roles within the different working activities and tasks which are described in the WBS. See section 3.2.2 of ICATS Demonstration Plan [3].

In particular, all the above-mentioned members have contributed to the added value to the output of this Project in line with their stakeholder's defining characteristics:

- AENA (supported by CRIDA) and NAV Portugal, as ANSPs, contributed to the Project with the definition of the Concept of Operations and definition and execution of demonstration activities, including a detailed plan for the flight trials. CRIDA performed the analysis of trials results and led the elaboration of the Trials report.
- Indra and Lockheed Martin, as Ground Industry Suppliers, provided the technical support to the flight trials, being in charge of deploying any necessary updates to the Interoperable infrastructure.
- Air Europa, as Mainline Carrier, was the "airborne" part of the flight trials, providing the flights that will be the subject of the demonstration, aimed at proving clear benefits for airspace users.

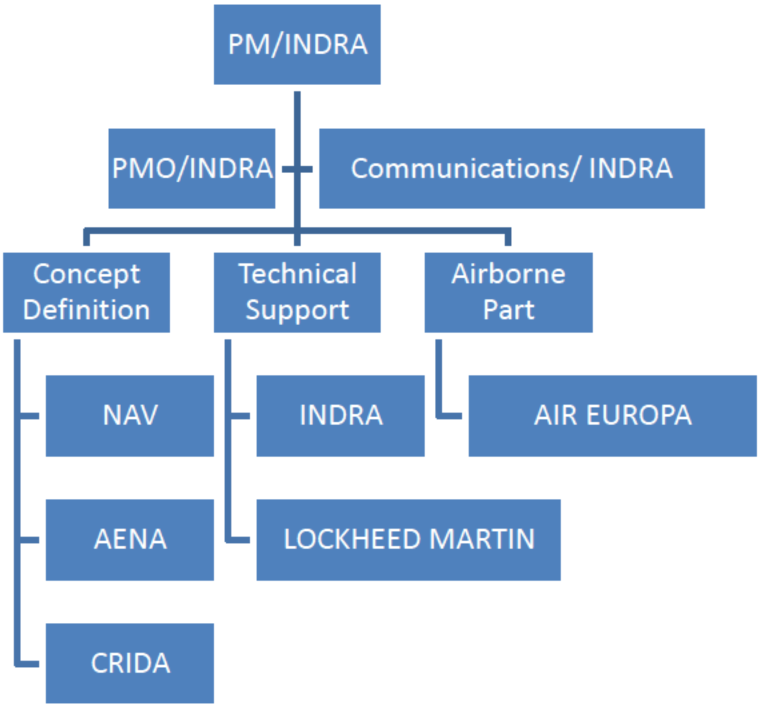


Figure 5: ICATS Consortium Organization per activities

To accomplish the objectives of the project, each member had allocated certain amount of budget (50% co-financed by SJU). The partners contribution, in terms of budget, is distributed in the following way:

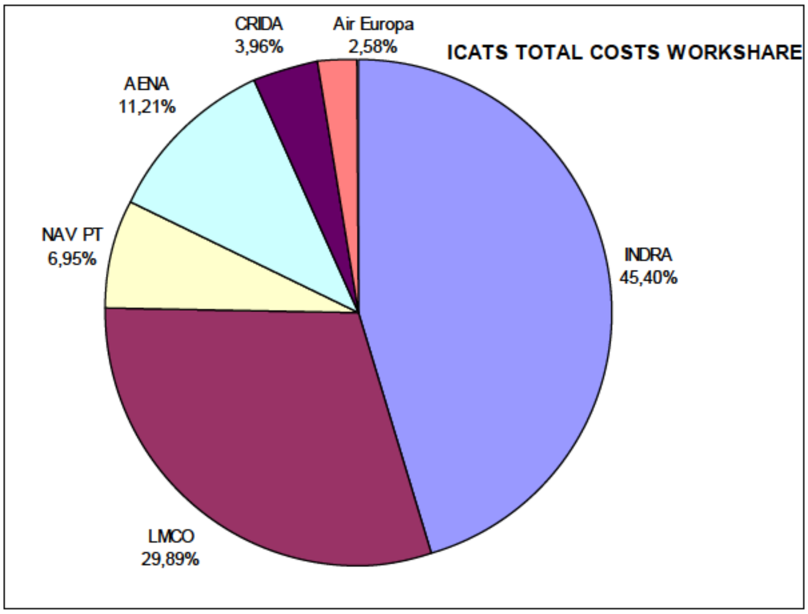


Figure 6: ICATS Consortium Members cost work share

The higher volume of the Industry contribution is due to the costs associated to the development/deployment of the trials infrastructure, and in addition, to the Project Management (by Indra).

In evaluating the performance of the consortium, the following must be noted: the strong collaboration among all members, their openness in supporting the project activities, and their flexibility in order to achieve the goals. All of these items contributed to a successful project.

3.1.2 ICATS Stakeholders Demonstration Expectations

The main expectations of the ICATS consortium partners are summarised in the next table:

Stakeholder	Role	Why it matters to stakeholder	Performance expectations
Air Europa	Airspace User (Airline)	Expected to have evidence of an improvement of fuel consumption efficiency. Emissions and fuel burn reduction	Accommodation of the aircraft on its desired: - lateral reroutes - flight level - Mach number
NAV Portugal	ANSP	To expect a controller capacity workload management reduction; flight data plan sharing integrity increase; better predictability and improved efficiency.	No negative impact on safety (slight increase due to better information sharing) Optimum flight profile (business trajectories) support enhancement No negative impact on workload
AENA	ANSP	To expect a controller capacity workload management reduction; flight data plan sharing integrity increase; better predictability and improved efficiency.	No negative impact on safety (slight increase due to better information sharing) Optimum flight profile (business trajectories) support enhancement No negative impact on workload Improved capacity based on an early planning of more accurate sectors configuration
CRIDA	R&D supporting ANSP	To expect to elaborate a suitable report using the adequate tools and methods	Report covering all metrics based in adequate methodology
Lockheed Martin	Industry	To expect to have a technical solution able to interoperate between US/EU by means of the Flight Object	Technical infrastructure supporting the Technical Requirements
Indra	Industry	To expect to have a technical solution able to interoperate between US/EU by means of the Flight Object	Technical infrastructure supporting the Technical Requirements

Table 2: ICATS Stakeholders Expectations

3.1.3 Project Coordination

The interaction with the SJU was performed by Indra's Project Management. The interface for SJU Programme duties between the Project and each company member of the consortium was carried out by the respective member project Points of Contact (PoCs) or project representatives.

Table 3 presents the PoC from each company:

Name	Company	Role	Contact
[redacted]	Indra	[redacted]	[redacted]
[redacted]	Air Europa	[redacted]	[redacted]
[redacted]	AENA	[redacted]	[redacted]
[redacted]	CRIDA	[redacted]	[redacted]
[redacted]	Lockheed Martin	[redacted]	[redacted]
[redacted]	NAV Portugal	[redacted]	[redacted]

Table 3: PoC in ICATS

Project coordination within the consortium for the different activities was performed mostly via WebEx, typically every two weeks for follow-up, and weekly for the periods requiring relevant attention to achieve the milestones.

3.1.4 Coordination with SESAR Programme and other Initiatives

ICATS outcome has resulted in interest from several SESAR projects, including B4.2, 4.3, 4.5/5.5.1, etc. To ease the coordination between ICATS and the rest of SESAR projects, ICATS has provided the deliverables of interest to OFA 03.01.01, Trajectory Management Framework.

In the area of the coordination SESAR / NextGen, as ICATS project is in such context, SESAR Persons of contact in the CPs 2.1, 3.1 and 3.2 have been be periodically informed about the project.

ICATS Global Flight Object model has been used as input by Indra for in the FIXM 2.0/3.0 review work performed by CP3.1/CP3.2 [8].

ICATS has been presented to FAA Mini-Global project and it has been categorised by FAA in the Mini Global material presentations as an existing solution to interface with.

ICATS was presented at the Air Transportation Information Exchange Conference. It was categorised in the context of its use of both SWIM and FIXM.

3.2 Work Breakdown Structure

The Work Breakdown Structure of the tasks performed by the project is as follows:

- WA0 – Management
    - T01 – Project Management
- WA1 - Operational
    - T02 – Demonstration Planning
    - T04 – Operational Concept
    - T10 – Demonstration Preparation
    - T11 – Demonstration Trials
    - T12 – Demonstration Analysis and Report
- WA2 - Infrastructure

- T05 – Infrastructure Specification
- T06 – Verification Planning
- T07- Verification Procedures
- T08 - Infrastructure Production
- T09 - Verification Execution

- WA3 - Dissemination
  - T3 – Dissemination Plan
  - T13 - Dissemination

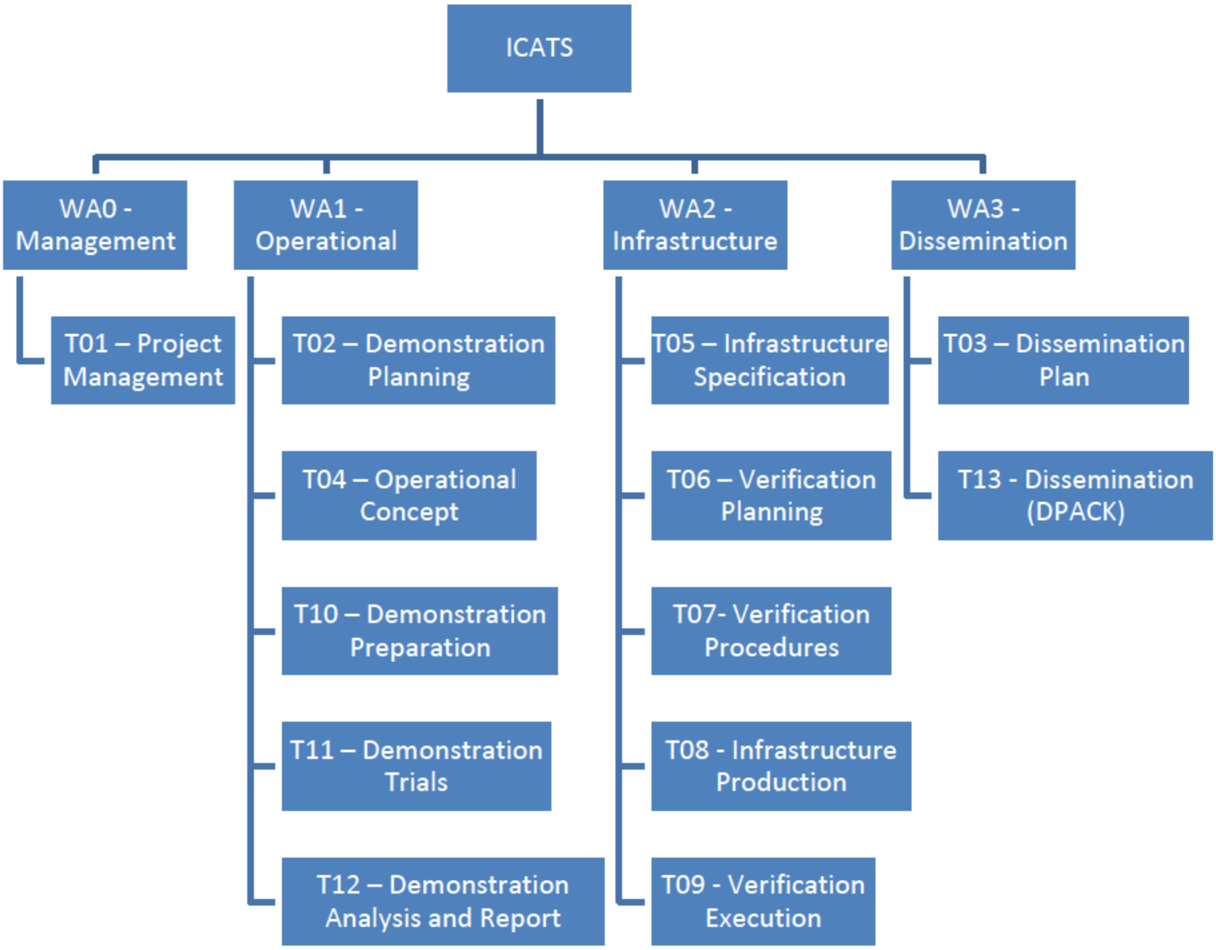


Figure 7: WBS Chart

Consult section 3.2 of ICATS Demonstration Plan [3], for detailed description of the tasks.

3.1.1 Task Allocation

The allocation of the ICATS tasks to the Project members, according to their role, is as follows.

Work Package	Task Id	Task Name	Indra	AENA	NAV PT	LM	AE	CRIDA
0	T01	Project Management	L	C	C	C	C	C
1	T02	Demonstration Planning	C	L	C	C	C	C
3	T03	Dissemination plan	L	C				

Work Package	Task Id	Task Name	Indra	AENA	NAV PT	LM	AE	CRIDA
1	T04	Operational Concept	C	L	C	C	C	C
2	T05	Infrastructure Specification	L	C	C	C	C	
2	T06	Verification Planning	L			C		
2	T07	Verification Procedures	L			C		
2	T08	Infrastructure Production	L			C		
2	T09	Verification Execution	L	C	C	C	C	
1	T10	Demonstration Preparation	C	L	C	C	C	C
1	T11	Demonstration Trials	C	L	C	C	C	C
1	T12	Demonstration Analysis and Report	C	C	C	C	C	L
3	T13	Dissemination [2]	L	C	C	C	C	C

L: Leader, C: Contributor

Table 4: Tasks Allocation

3.2 Allocated Resources

To support the different activities and achieve the goals of the project, all partners have allocated the appropriate human and material resources. In the practice, this has involved many people from the different companies and organizations performing the different activities.

3.2.1 Indra

Indra has allocated the following resources for the execution of the project:

- Human resources (Project Manager, Chief Engineer, Systems Engineering and SW Development Teams, V&V Test Team, Trials support Team.
- Indra SESAR Interoperability and SWIM prototypes.
- Diverse HW-COTS and SW Licences, for the infrastructure adaptation and deployment, including the IOP HMI positions deployed at Madrid-ACC, Lisbon-ACC, Santa María-ACC.
- Renting of Internet/ADSL connection facilities.

3.2.2 AENA – CRIDA

AENA and CRIDA have allocated the following resources for the execution of the project:

- Madrid ACC centre, with the appropriate staff and facilities, including in service SACTA system and on duty technical and operational staff.
- CED: Research and Development Centre.
- Internet connections.
- Key Staff from SYSRED unit.
- Live Flight Plan messages from SACTA system (GIPV server) to feed the IOP system for flight data synchronization.
- Flight Plan information and Flow tools (PIV and C-HMI).
- Analysis tools.

3.2.3 NAV Portugal

NAV Portugal has provided the following resources for the execution of the project:

[2] Each partner is contributing to its own internal dissemination

- Santa Maria and Lisbon ACCs centres, with the appropriate staff and facilities, including in service SATL & LISATM systems and on duty technical and operational staff.
- Internet connections
- Live Flight Plan messages from NAV-P ATC systems (AFTN connections from Lisbon and Santa Maria ACCs) to feed the IOP system for synchronization).

3.2.4 Lockheed Martin

Lockheed Martin has provided the following resources for the execution of the project:

- Human Resources: (Project Manager, Chief Engineer, Systems Engineering, Software Development Teams, V&V Test Team located in Maryland, Minnesota and Florida, and an Expert in ATC control, located at Florida Test bed supporting the Trials)

  -Factory facilities at Maryland and Minnesota.

  -Software Prototypes

  -Florida Test bed at Embry-Riddle Aeronautical University in Daytona, including internet connection.

3.2.5 Air Europa

Air Europa has allocated the following resources for the execution of the project:

- Human resources (Project coordinator, A330's Pilots, Flight dispatchers, Maintenance engineering personnel)
- Operations Control Centre (OCC) facilities including internet connection.
- Flight Planning System (LIDO)
- AOC Data Link System (AIRCOM Server)
- FDM/FOQA System
- Aircraft to carry out the demonstrations: Airbus A330-200, equipped with FANS

3.3 Schedule

The high level schedule of the project is depicted in Figure 8.

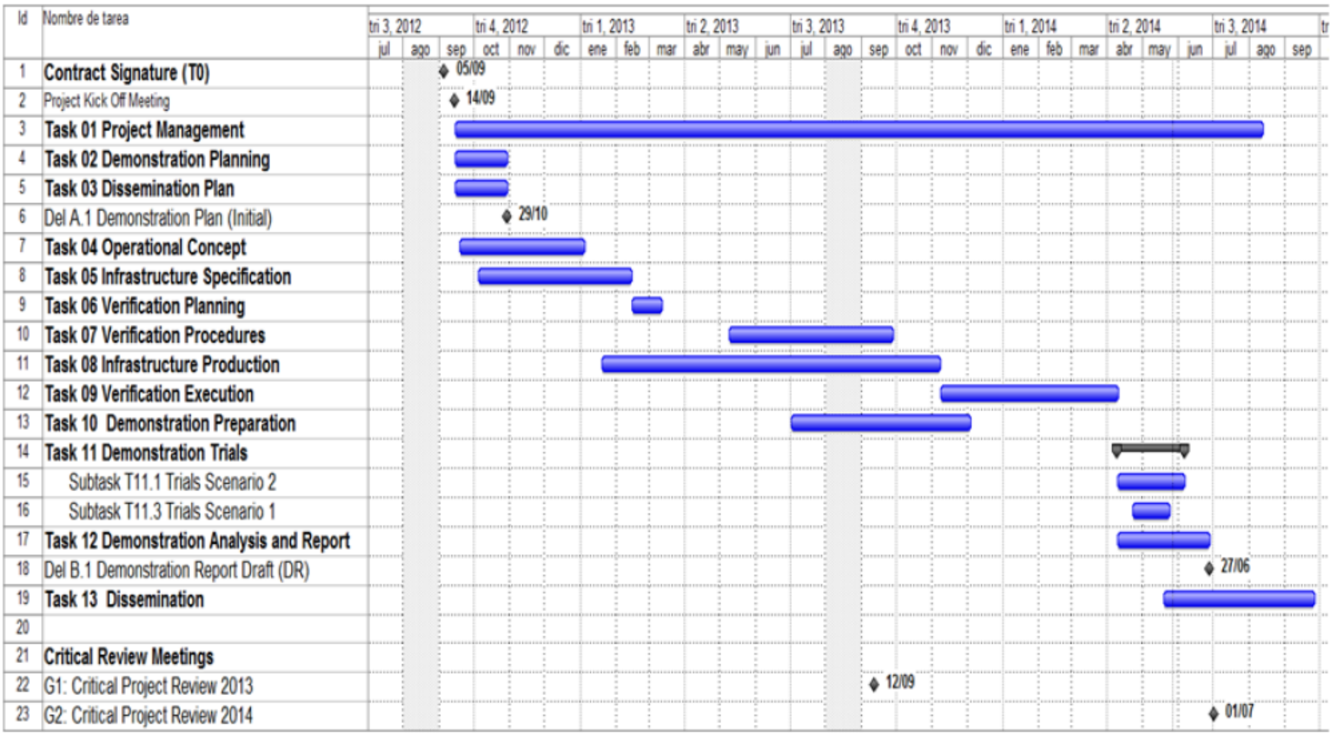


Figure 8: Schedule

The major differences against the initial plan are:

- the extension of the Site Integration task (as part of the Verification Execution), planned initially to end on February 14, was extended until April14, due to the complexity of the integration.
- As a consequence of the above extension, the postponement of the start of trials from early March to mid April 14, and the trials completion by early June 14, with all trials conducted in one sequence. This resulted in skipping the interim period between the first and second period of trials, initially planned, in order to finish the trials during June.

3.4 Deliverables

3.4.1 Formal Deliverables

As it is defined in the SJU Execution Guidelines, the project manager has submitted a progress report on a quarterly basis in the format specified in the SJU extranet.

The formal deliverables produced by the project have been stored in the execution library of the project site. These are listed in the next table.

Deliverable name	Date of the latest edition available
Demonstration Plan (A1)	18/01/2013
Demonstration Report (B1)	30/06/2014
Progress Report (B2)	Quarterly

Table 5: ICATS Formal Deliverables

3.4.2 Other Available Deliverables

ICATS informal deliverables declared of interest by other SESAR participants have been uploaded to the ICATS Project SJU website (Demo Projects section). These deliverables provide significant added value in terms of flight object concept definition, and practical infrastructure solutions for trials.

Note that the Operational Concept Definition (OCD) (B3) and Flight Object Interoperability Definition (FOID) (B4) documents were passed to FAA per their request, and upon permission of SJU.

DELIVERABLE	CONTENTS
Operational Concept Definition (OCD) (B3)	It describes in detail the Operational procedures to be followed in the trials, and the comparison between the actual real procedures and the ICATS procedures
Flight Object Interoperability Definition (FOID) (B4)	It describes the approach chosen for the Global Flight Object, based on ED-133/ FIXM concepts
I-SWIM Flight Object Interface (FO-I-ICD) (B5)	It describes the Global Flight Object model, based on ED-133/FIXM, the extensions needed to support the trials; and the I-SWIM services.
Technical Specifications (TS) (B6)	It contains the technical requirements to be fulfilled by the infrastructure deployed to support the trials

Table 6: ICATS Other Deliverables

3.5 Risk Management

Project risks were created initially upon elaboration of the Demonstration Plan, and reviewed during the Project execution, with a particular focus on their evolution. Once the risks were not considered as such, were closed in coordination with SJU. The table below outlines the initial risks identified in the project:

Risk description	Probability	Severity	Mitigation actions	Owner
Risk 01: Possibility of re-planning to lower volume of flights, by the involved airlines, as the actual airline flight programming covers one-year horizon.	Low	Low	1. Ask for the airline yearly plan when available. 2. If needed, extend the flight trials period.	ICATS PM
Risk 02: Unavailability of flights due to rescheduling of airline operations plans	Low	High	1. Ask for the airline yearly plan when available. 2. Contact another airline to perform the trials.	ICATS PM
Risk 03: Unavailability of PENS for the trials preparation and the flight trials.	Low	Low	Dedicated lines will be leased if needed, at an appropriate decision point in time.	ICATS PM

Table 7: ICATS Project Risks

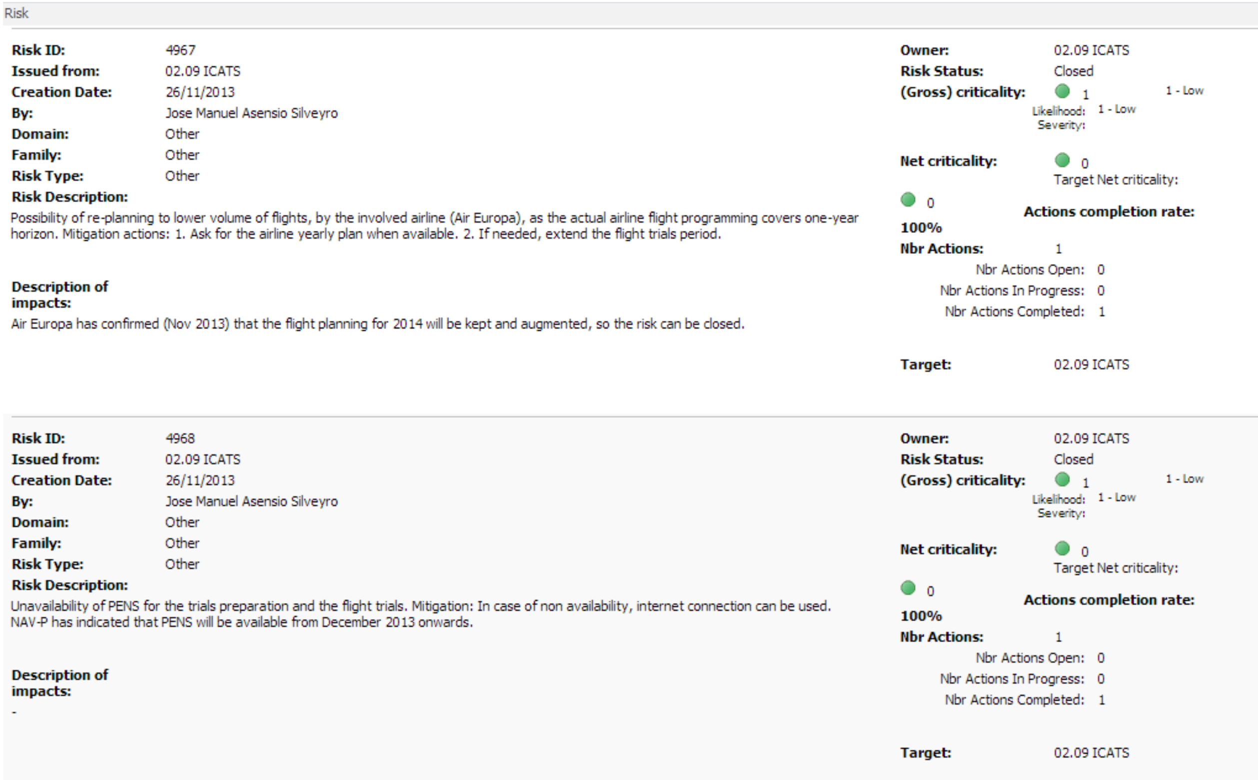
Probability and Severity assessment choices were selected among Low, Medium, High, Very High.

After Project Kick-off, Risk Management was performed using the tools and procedures provided by the SJU. The existing Risks were associated with actions for mitigation, and closed once they were no longer applicable.

In the case of Risk 01 and 02, the flight programming of Air Europa was periodically reviewed, at a given point in time the Airline declared that their flight programming had increased the number of flights, so the risk probability went to low. In addition, a detailed trials plan was elaborated and periodically reviewed with Air Europa.

In the case of Risk 03, NAV-P had foreseen already from the beginning of the project the choice of renting Internet connections as alternative to PENS. In fact, PENS was not used due to the limited Bandwidth available at ANSPs, so Internet connections were rented for the trials.

The next figure shows the Risks created in the SJU Extranet database:


Risk

Risk ID: 4967
Issued from: 02.09 ICATS
Creation Date: 26/11/2013
By: Jose Manuel Asensio Silveyro
Domain: Other
Family: Other
Risk Type: Other
Risk Description:
Possibility of re-planning to lower volume of flights, by the involved airline (Air Europa), as the actual airline flight programming covers one-year horizon. Mitigation actions: 1. Ask for the airline yearly plan when available. 2. If needed, extend the flight trials period.

Description of impacts:
Air Europa has confirmed (Nov 2013) that the flight planning for 2014 will be kept and augmented, so the risk can be closed.

Owner: 02.09 ICATS
Risk Status: Closed
(Gross) criticality: 1 Likelihood: 1 - Low Severity: 1 - Low
Net criticality: 0 Target Net criticality: 0
Actions completion rate: 100%
Nbr Actions: 1
Nbr Actions Open: 0
Nbr Actions In Progress: 0
Nbr Actions Completed: 1
Target: 02.09 ICATS

Risk ID: 4968
Issued from: 02.09 ICATS
Creation Date: 26/11/2013
By: Jose Manuel Asensio Silveyro
Domain: Other
Family: Other
Risk Type: Other
Risk Description:
Unavailability of PENS for the trials preparation and the flight trials. Mitigation: In case of non availability, internet connection can be used. NAV-P has indicated that PENS will be available from December 2013 onwards.

Description of impacts:
-

Owner: 02.09 ICATS
Risk Status: Closed
(Gross) criticality: 1 Likelihood: 1 - Low Severity: 1 - Low
Net criticality: 0 Target Net criticality: 0
Actions completion rate: 100%
Nbr Actions: 1
Nbr Actions Open: 0
Nbr Actions In Progress: 0
Nbr Actions Completed: 1
Target: 02.09 ICATS

Figure 9: ICATS Risks register in the SJU Extranet

4 Execution of Demonstration Exercises

In order to provide an overview of the systems defined and developed for the demonstration exercises, Figure 10 depicts the high level ICATS architecture and a summary of the operational concept and how it is supported by the ICATS architecture.

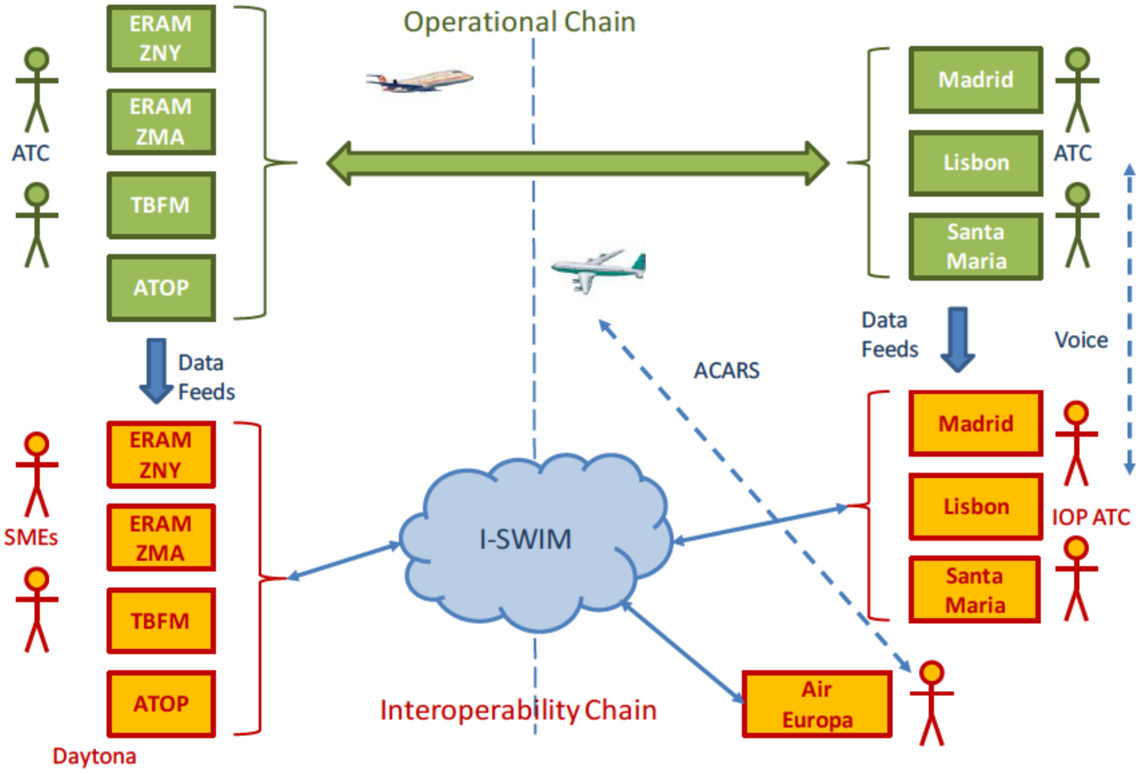


Figure 10: High level ICATS architecture

As depicted, the architecture incorporates an Operational Chain (shown across the top of the figure in green) that consists of existing operational systems in both the EU and US. A parallel Interoperability Chain (shown across the bottom of the figure in yellow) incorporates automation systems for both ANSP and AOC users, the regional SWIM systems in both the EU and US, and the I-SWIM infrastructure that provides global inter-regional interoperability.

The Interoperability Chain automatically receives all data necessary to maintain situational awareness from the Operational Chain by means of data feeds in both the EU and US regions. The continuous and automatic flow of data to the Interoperability Chain ensures that it always contains up to date data that mirrors the current operational situation in the Operational Chain. The Interoperability Chain further implements flight object based data sharing by means of its regional SWIMs and the I-SWIM interoperability infrastructure. Because of this, the Interoperability Chain will have access to timely, high quality flight object data whereas the Operational Chain will contain the same data that it does today. The Interoperability Chain, with its improved access to higher quality flight object data, provides the environment for exploring and quantifying the operational benefits associated with SWIM based information exchange of flight object data.

Using the timely and highly accurate flight object data in the Interoperability Chain, the IOP controllers on the EU side, SMEs on the US side, and AOC Users can more effectively and efficiently spot and assess changes of route, level or speed that would optimise the planned and actual movement of flights. Such optimizations are identified using the automation systems in the Interoperability Chain in conjunction with existing tools in order to increase safety and efficiency, proactively assure separation, or reduce fuel burn and environmental impact.

The Interoperability Chain supports AOC in developing “What-if” type proposed changes to route, level or speed that can be proposed, distributed for evaluation, and assessed in the Interoperability Chain by IOP controllers on the EU side and SMEs in the FTB on the US side. In the EU half of ICATS, the side by side physical integration of the IOP controllers with Operational Chain ATC staff permits the proposed changes to be verbally evaluated, assessed, and coordinated. When a “What-if” change proposal is fully assessed as acceptable and conflict free by all impacted parties, the Change can be proposed to the Operational Chain using ACARS and CPDLC as is done today. To ensure safety, Flight Crew and Operational Chain ATC provide the final evaluation and implementation of any such proposed change where it is still viable and acceptable. Once the Operational Chain systems and data are updated, the change is reflected through to the Interoperability Chain to complete the cycle.

Any proposed changes have a high probability of success in the Operational Chain because of the “pre-evaluation and coordination” of changes in the Interoperability Chain using the What-if change proposal mechanism. Further, the iterative cycle of 1) identify a what-if proposed change that optimises flight movements, 2) pre-evaluate and coordinate the change to determine whether it is acceptable, 3) implement the change in the Operational Chain when it is acceptable, and 4) update the Interoperability Chain with the results of the change can be repeated as often as needed for any given flight of interest.

In addition, the side by side parallel Operational and Interoperability Chains provide a means for comparison of the data available in both chains. Recorded data in the Operational Chain is readily compared with data recorded in the Interoperability Chain in order to characterise the improvements in accuracy, precision, and timeliness that can be achieved using flight object based information exchange.

4.1 Exercise 1

4.1.1 Exercises Preparation

The following activities were performed during the preparation for the execution of Demonstration Exercises:

- Procedures based on scenario 1 use case were created by NAV Portugal to help the people involved in the IOP and Operational positions to know what to do during the trials.
- Questionnaires were prepared by CRIDA and agreed between the ICATS partners to complement the information to be extracted from the logs of the operational and IOP systems.
- A presentation on IOP position HMI was performed by Indra.
- A User Manual for the IOP position HMI was prepared by Indra.
- A schedule including the westbound and eastbound flight trials was prepared by Air Europa and agreed between the partners.
- The Operational Systems’ logs format needed for the ICATS analysis were provided and adapted by NAV Portugal for better processing by the CRIDA’s analysis tools.
- The IOP logs format were agreed between Indra / Lockheed Martin and CRIDA.
- The Aircraft logs format needed for the ICATS analysis were provided by Air Europa to CRIDA.
- The dates for the different partners having the logs available to CRIDA in order to process them in time to write the Demonstration Report were agreed.

4.1.2 Exercises Execution

The following table shows the exercise EXE-02.09-D-001 actual dates:

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise start analysis date	Actual Exercise end analysis date
EXE-02.09-D-001	Enhancing of trajectory of Air Europa flights analyzing how the advanced sharing of information improves the flight efficiency.	22-04-2014	06-06-2014	18-05-2014	09-06-2014

Table 8: Exercises execution/analysis dates

For reasons of a more user friendly time of operation the exercise started with sessions of westbound flights. Due to staff constraints we did not plan sessions of westbound and eastbound flights in the same day. For the same reason we avoided using more than two flights per day. The demonstration period was concentrated on the first four to five hours of flight, where the possibility of trajectory improvements normally emerges. At the end of the trials, 41 flights were addressed.

See Section 6.1.1.2 for details of exercise execution.

4.1.3 Deviations from the planned activities

In anticipation of possible problems obtaining information from the logs to measure objectives Capacity M03 and Safety M06 for exercise EXE-02.09-D-001, questionnaires were created to complement the logs. Despite this, the measurement of the objectives might be compromised due to the following reasons:

- The impossibility of having all the traffic situation in the IOP positions as in the Operational positions – to assess the traffic situation the IOP controller has to use the information from the Operational System before deciding on the acceptance or rejection of a trajectory change request;
- The SATL and ATOP are already receiving and processing accurate flight data before the flights entering their area of responsibility, mainly for flights departing from Madrid – the oceanic clearance is requested not long after the take-off of the flight.

The third week was initially planned for the eastbound flight trials. For technical reasons, no outcomes were achieved from the trials performed during this week. In order to demonstrate that the interoperability concept works in both directions, it was agreed to use the last planned session for eastbound flights.

The trials continued on the fourth and fifth weeks with westbound flights as was planned. To avoid delays of the actual end date for the execution of the exercise, it was agreed to increase when possible to three or four daily flights subjected to trials.

Finally, it is noted that it was not possible to find trajectory improvements for all the flights addressed during the trials due to the fact the trajectories initially planned by the Flight Planning System from the AOC were already optimised upon flight dispatching, and the further change in the METEO conditions during the execution of the flight did not offer any possibility for trajectory improvement.

4.2 Exercise 2

4.2.1 Exercises Preparation

Scenario 2 of ICATS (Interoperability Cross-Atlantic System) Project, amongst other objectives, assesses the benefits of the continuous update of information on the predictability of the flights.

The following activities were performed during the preparation for the execution of Demonstration Exercises:

- A system has been deployed (ICATS HMI), in parallel with the operational ones, to receive updates of flight data from all the centres across the Atlantic (initially not limited to New York Oceanic, Santa Maria and Lisbon) for flights coming from North/Central America entering in Madrid ACC airspace.
- Procedures based on scenario 2 use case were created by AENA to establish the activities to be executed from Madrid ACC premises for collecting information as result of ICATS trials.
- Training was provided to staff in charge of the data collection
- Information was obtained from CHMI (Flow Control Position) and ICATS HMI (both installed in SYSRED) and from SACTA PIV terminal (Flight Data position, installed in PDV room).
    - Note 1: SYSRED staff is in charge of maintaining a global overview of the status of Air Navigation Services across all the Spanish Air Navigation Network
    - Note 2: PDV staff is in charge of collection of FDP messages providing of any or both, IFPS or collateral centres. SACTA PIV provides information on Flight Plans existing in SACTA, mainly for Network management (traffic load, traffic flows, ...)
- Predefined reports have already been created for simplifying the information capture process. The information gathering process consists of launching predefined queries, and saving the obtained results as excel files.
- The Data collecting timetable was prepared by AENA specifying:
    - Trials should run on the same schedule than Scenario 1. Changes in the foreseen schedule should be coordinated on a day by day basis. During the week starting on 31/03/2014 could be executed some trials for fine tuning[3]
    - The gathering of information took place on the next schedule:
        - From Monday to Friday (inclusive), samples of traffic were collected 6 times per day, at: 00:00, 02:00, 04:00, 06:00, 08:00 and 10:00, all of them expressed in UTC
        - Queries were launched in the three systems, and files containing the collected information will be stored with a clearly identifiable name.
        - The files of each operation day were collected and stored on a shared repository for post-processing on a daily basis. CRIDA had access to that repository.

4.2.2 Exercises Execution

The following table shows the exercise EXE-02.09-D-002 actual dates:

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise start analysis date	Actual Exercise end analysis date
EXE-02.09-D-002	Exchange of information on Flight Departures, for improving predictability of traffic load	08/04/2014	07/06/2014	05/05/2014	20/06/2014

Table 9: Exercises execution/analysis dates

After the execution of this scenario, the data existing in SACTA (not updated until the reception of ABI messages from Santa Maria or Lisbon) has been compared with the data in ICATS system, that it is

[3] Actually, the trials ran from 08/04/2014 till 12/04/2014 and from 22/04/2014 to 06/06/2014. The deviations and their causes are detailed in section 4.2.3.

much more frequently updated, and with the data in CHMI (updated more frequently than SACTA, but less than ICATS).

Traffic samples have been extracted during the days of trials, at the times specified in section 4.2.1, from the three different systems (SACTA, through PDV, CHMI and ICATS), and they have been later compared for the purpose of assessing the improvement in the sector entry times information, and how it could benefit the predicted workload.

The data was collected from each system in the following way:

- Data Collection from SACTA PIV: Four different queries have been created, one for flights that meet the ICATS criteria, and three others to calculate the nominal traffic affecting the entry sectors for eastbound traffic (AS, SAN and ZM), in order to calculate the estimated traffic load in those sectors and compare it with the one they would have had if they had received ICATS updates. See section 3.4 in the ICATS Concept of Operations document for further details about airspace configuration [4]

  Considering the 6 daily captures and the 4 different queries, at the end of the day 24 files should have been created. Once the data was ready, it was exported into an Excel file and recorded with the following names: ICATS_nnn, LIS-ICATS_AS_nnn, LIS-ICATS_SAN_nnn and LIS-ICATS_ZM_nnn. Each day, at the end of the tests (after 10:00 UTC data capture) the created files were uploaded to the corresponding folder of the defined repository.

- Data Collection from ICATS Server: Data collected included all the flights being continuously updated as a result of ICATS Flight Object exchange. One file was generated at each of the 6 times mentioned before. Each file was saved in the folder documents/REPORT_ICATS with a different name, representing the day and time when the report was launched (i.e.: ATSUs_Times_yymmdd_00).

  Each day, at the end of the tests (after 10:00 UTC data capture) the created files were uploaded to the corresponding folder of the defined repository.

- Data Collection from CHMI: It encompassed the traffic forecasted by Network Manager departing from airports which ICAO designator starts by C, K or M and with destinations to airports which designator starts by LE or LI, based on the existing Network Manager procedures for information updates. This should represent an intermediate step between the expected accuracy of ICATS data, and the one existing in SACTA PIV.

- In order to extract this information the tool used was the Network Manager CHMI and the traffic volumes to be considered were LECMSAN, LECMZMI and LECMASI. The obtained files (one per the 6 times and 3 traffic volumes) were renamed according to the following example scheme: 20140407_CHMI_LECMSAN_00.txt (for TFV LECMSAN at 00:00). Each day, at the end of the tests (after 10:00 UTC data capture) the created files were uploaded to the corresponding folder of the defined repository.

The execution of the Exercise EXE-02.09-D-002 scope considered the flights departing from "K", "C" or "M" and arriving to "LE" and "LI" from Monday to Friday between the 08/04/2014 to the 07/06/2014 with the exception of the Easter Week (13/04/2014 to 20/04/2014).

4.2.3 Deviations from the planned activities

The ICATS HMI needs to be connected to the Internet and required that the ICATS servers were up and running in order to be able to provide the needed data. Due to technical reasons (complexity of the technical integration), there were some delays regarding the initial scheduled detailed in the Demonstration Plan [3].

Unfortunately, the complexity of the scenario involving different systems, companies and technical/staffing resources made impossible that all the data capture process works properly along all the sessions. This led to the decision to eliminate some days from the data to be considered for the analysis.

The next table presents the different situations of the days based in the availability of data.

Week	Date	Initially Valid for data Analysis	Valid for Analysis considering A-14 (see section 6.2.3.1.8)
1	08/04/2014	No	No
1	**09/04/2014**	**Yes**	**Yes**
1	**10/04/2014**	**Yes**	**Yes**
1	**11/04/2014**	**Yes**	**Yes**
1	**12/04/2014**	**Yes**	**Yes**
2	**22/04/2014**	**Yes**	**Yes**
2	23/04/2014	Yes	No
2	**24/04/2014**	**Yes**	**Yes**
2	25/04/2014	Yes	No
2	26/04/2014	No	No
3	**29/04/2014**	**Yes**	**Yes**
3	30/04/2014	Yes	No
3	01/05/2014	Yes	No
3	02/05/2014	No	No
3	03/05/2014	Yes	No
4	06/05/2014	Yes	No
4	07/05/2014	Yes	No
4	08/05/2014	No	No
4	09/05/2014	No	No
4	10/05/2014	No	No
5	13/05/2014	Yes	No
5	**14/05/2014**	**Yes**	**Yes**
5	**15/05/2014**	**Yes**	**Yes**
5	**16/05/2014**	**Yes**	**Yes**
5	17/05/2014	Yes	No
6	20/05/2014	Yes	No (Only 1 flight)
6	21/05/2014	Yes	No
6	**22/05/2014**	**Yes**	**Yes**
6	**23/05/2014**	**Yes**	**Yes**
6	24/05/2014	Yes	No
7	28/05/2014	No	No
7	**29/05/2014**	**Yes**	**Yes**
7	30/05/2014	Yes	No
7	**31/05/2014**	**Yes**	**Yes**
8	**03/06/2014**	**Yes**	**Yes**
8	**04/06/2014**	**Yes**	**Yes**
8	**05/06/2014**	**Yes**	**Yes**

Table 10: Summary of incidents when collecting the data in EXE-02.09-D-002

The following days are disregarded for the analysis because of the quality of the data recorded (usually because there is information from some call missed):

- April: the 8th & the 26th
- May: the 2nd, from 8th to 10th & the 28th.

For the remaining days, the following dates were also disregarded due to the fact that the amount of flights to be analysed that days constitutes less that the 70% of the total flights of that day (See A-14, section 6.2.3.1.7).

From May the 22nd onwards, also flights departing from "S" airports were collected.
In total, there are more than 200 flights analysed.

5 Exercises Results

5.1 Summary of Exercises Results

Table 11 shows the summary of results obtained against each of the success criteria identified in [3] and considering the baseline scenario where it is applicable. The summary of results covers all the Demonstration Objectives embedded in the two demonstration exercises and defined in [3] plus two additional metrics related to Exercise 2 (M07 and M08). M07 and M08 are included in Table 12.

Exercise ID	Demonstration Objective ID	Demonstration Objective Description	Success Criterion	Exercise Results	Demonstration Objective Status
EXE-02.09-D-001	OBJ-0209-003	Capacity - Coordination Revision/Rejection. Number of Coordination revisions or rejections for a given amount of flights.	Reduction of at least 5% comparing with the baseline scenario.	4,78% as result of the quantitative analysis. Qualitative assessments via questionnaires demonstrates a positive impact due to ICATS.	OK
	OBJ-0209-004	Efficiency - Fuel Consumption.	>= 1% of fuel saving	1,40% of fuel saving	OK
	OBJ-0209-005	Environment - The use of optimised flight profile will lead to a reduction of CO2 emissions and reduced environment impact. CO2 Emission.	>= 1% of reduction of CO_2 Emission	1,40% of reduction of CO_2 emissions	OK
	OBJ-0209-006	Safety - An earlier activation of the conflict detector and conflict probe tools due to a more accurate traffic situation and an earlier resolution of conflicts delivers safety improvement by reducing Tactical Conflicts.	Reduction of at least 10 % of the Tactical Conflicts	No means to measure this in a quantitative way. Qualitative assessment via questionnaires demonstrates a positive impact due to ICATS.	OK (Partial Assessment)

Exercise ID	Demonstration Objective ID	Demonstration Objective Description	Success Criterion	Exercise Results	Demonstration Objective Status
EXE-02.09-D-002	OBJ-0209-001	Capacity - Load-Hourly Sector Entry Rate (Hourly Entry Rate). Number of aircraft predicted to enter the sector within one hour (i.e. in a sliding window of one hour from current time onwards).	1. Data provided by the ICATS HMI is closer to the actual times than the PIV data. 2. ICATS HMI Data is more predictable than the current PIV Data	The ICATS HMI results provide an improvement on the accuracy of sector load calculations over the 15% expected. This is limited to the cases where ICATS HMI provides better results than the PIV system, which happen only on the 47% of the cases. For those cases, ICATS HMI Data is more predictable than the PIV data.	NOK Partially Achieved. Limitations due to the quality of data obtained from the ICATS Server
	OBJ-0209-002	Capacity - Load-Sector Occupancy This is the number of aircraft in the sector per hour	Reduction on a 10% of Unexpected sector overload due to Oceanic traffic	The % Hours where ICATS improves sector load occupancy is over the 10% expected. However, this is limited to the cases when ICATS HMI data is better than PIV system, which means, the 49% of the cases.	NOK. Partially Achieved. Limitations due to the quality of data obtained from the ICATS Server

Table 11: Summary of Demonstration Exercises Results

5.2 Metrics and Indicators

According to the ICATS Demonstration Plan [3] the project aims to demonstrate to the whole ATM community and, in particular, to the Airspace Users, the operational and performance benefits that are obtained by the introduction of key SESAR Programme concepts and technical enablers. Examining the data collected in the demonstration exercises, the ICATS project consortium further refined the metrics. The final indicators, metrics and the results obtained from its analysis in terms of achievement of the demonstrations are summarised in Table 12:

KPA	Objective ID	KPI	Metric	Measuring Process and Criteria	Expected Benefit	ICATS Results
CAPACITY	OBJ-0209-001	M01. Load-Hourly Sector Entry Rate (Hourly Entry Rate)	**1.1. Estimated (PIV) Sector load per hour - Estimated (PIV compared with ICATS) Sector Load per hour**	Source of the reference data and trials data for comparison: ANSP	Improve the accuracy of sector load calculations by 15% of oceanic traffic	The ICATS HMI results provide an improvement on the accuracy of sector load calculations over the 15% expected. This is limited to the cases where ICATS HMI provides better results than the PIV system, which happen only on the 47% of the cases. For those cases, ICATS HMI Data is more predictable than the PIV data.
	OBJ-0209-002	M02. Load-Sector Occupancy.	**2.1. Estimated (PIV) Oceanic Traffic per hour - Actual Oceanic Traffic per hour** **2.2. Estimated (ICATS) Oceanic Traffic per hour - Actual Oceanic Traffic per hour**	Source of the reference data and trials data for comparison: ANSP	Reduction on a 10% of Unexpected sector overload due to Oceanic traffic	The % Hours where ICATS improves sector load occupancy is over the 10% expected. However, this is limited to the cases when ICATS HMI data is better than PIV system, which means, the 49% of the cases.
	OBJ-0209-001	M03. Coordination Revision/Rejection.	Two sources of data to analyse: **3.1. Using Questionnaires distributed to Pilots and ATCOs: qualitative analysis** of results according to the following criteria: 1-disagree, 2-slightly disagree, 3-slightly agree, 4-agree, 5-strongly agree; 0%-high improvement, 25%-improvement, 50%-minor improvement. Similar to current operations, 75%-no improvement, 100%-worse than current operations. **3.2. Using the data link communications files from the Airline & ANSP: Actual N# of rejections - Baseline N# of rejections**	Source of the reference data and trials data for comparison : ANSP and Pilots	Reduction of at least 5%	Quantitative Analysis: 13,82% Qualitative Analysis: positive impact of ICATS Result: Objective successfully achieved.

EFFICIENCY	OBJ-0209-004	M04.Fuel Consumption	Source of the reference data and trials data for comparison: **4.1. Estimated fuel (TRIP) as per the FPL - Actual Fuel (from Take-off to Landing) as per FOQA Data (corrected by a +8,5%)**	Source of the reference data and trials data for comparison: Airline Logging of estimated fuel burn from the Operational Flight Plan Logging of the actual fuel burnt from the Flight Data Monitoring Calculate the difference	>= 1% of fuel saving	Quantitative Analysis: 1,40% of fuel saving in the optimised flights Result: Objective successfully achieved
ENVIRONMENT	OBJ-0209-005	M05.CO2 Emission	The CO_2 emissions are derived from the Estimated/Actual fuel using a conversion factor defined by Eurocontrol: CO_2 = 3,149 Kg per Kg fuel. **5.1. Estimated CO_2 Emissions as per the FPL - Actual CO_2 Emissions as per the FOQA data**	This figure is calculated using a conversion factor from the fuel burnt.	>= 1% of reduction of CO_2 Emission	Quantitative Result: 1,40% of reduction of CO_2 emission in the optimised flights Result: Objective successfully achieved
SAFETY	OBJ-0209-006	M06.Tactical Conflicts	**6.1. Qualitative analysis of the questionnaires** following the same criteria than in 3.1.	Source of the reference data and trials data for : comparison ANSP	Reduction of at least 10 %	Quantitative Analysis: No means to measure this result. Qualitative Analysis: positive impact of ICATS.
PREDICTABILITY	OBJ-0209-001	M07. Predictability	All the following metrics apply to the 6 calls done (at 00:00, 02:00, 04:00, 06:00, 08:00, 10:00 UTC). **7.1. PIV HFIR - Log time** **7.2. ICATS HFIR - Log time**	ICATS HMI Data is more predictable than the current PIV Data	Improvement in data predictability	The statistical analysis shows that ICATS HMI is slightly more predictable than PIV system in 5 of the 6 queries done (calls).

	OBJ-0209-001	M08. Data Accuracy	**8.1. PIV HFIR - Actual HFIR** **8.2. ICATS HFIR - Actual HFIR**	ICATS HMI Data accuracy is higher than the current PIV Data. This metric should be considered jointly with M07 to get sense.	Improvement in data accuracy	The statistical analysis shows that ICATS HMI is slightly more accurate than PIV system in 4 of the 6 queries done (calls).

Table 12: Table of KPAs addressed

5.3 Summary of Demonstration Conduct Assumptions

When the ICATS Project was defined, a number of assumptions were made with respect to various risks that could have impacted our ability to successfully conduct various project activities.

Table 13 contains the list of Demonstration Conduct assumptions that were defined in [3]. The table includes an assessment of any issues associated with the original Demonstration Conduct assumptions. In summary, no significant issues impacted conduct of the ICATS Project and the demonstration.

Identifier	Description	Justification	Flight Phase	KPA Impacted	Source	Value	Owner	Impact on Assessment	Issues
A-1	The FTB facilities will be available and with the required infrastructure installed when starting the tuning for the project.	In order to execute properly the Demonstration trials.	CRUISE	NA	NA	NA	ICATS CONSOR TIUM	VH	No
A-2	It will be possible to put in shadow mode the IOP chain with real European ATC systems (AENA and NAV Portugal).	In order to test some objectives of the Demonstration trials.	CRUISE	NA	NA	NA	ICATS CONSOR TIUM	VH	No
A-3	The PENS communication infrastructure will be available or, as an alternative, leased lines.	In order to execute properly the Demonstration trials.	CRUISE	NA	NA	NA	ICATS CONSOR TIUM	VH	PENS was not used but we used Internet links as a suitable alternative
A-4	There will be enough flights to achieve more than the required	In order to be able to extrapolate	CRUISE	NA	NA	NA	ICATS CONSOR	VH	No. we exceed the

Identifier	Description	Justification	Flight Phase	KPA Impacted	Source	Value	Owner	Impact on Assessment	Issues
	minimum of 40	statistically valid information					TIUM		40 flights requirement
A-5	The aircraft and ATC involved are equipped with both ADS-C and CPDLC functionalities	In order to provide accurate surveillance reports in oceanic areas and good communication capabilities	CRUISE	NA	NA	NA	ICATS CONSOR TIUM	VH	No
A-6	That the flexible routes planned by each airline (Air Europa) are delivered	That there are no glitches in the data collection and transfer	CRUISE	FLX	NA	NA	ICATS CONSOR TIUM	VH	No
A-7	That the flights will be able to follow their flight plan at least for some, if not all, the planned route	In order to be compared with the baseline	CRUISE	*ENV & EFF*	NA	NA	ICATS CONSOR TIUM	H	No
A-8	Possibility that any restriction, which may be known in advance, can be included by the flight planning system in advance.	NA	CRUISE	*ENV & EFF*	NA	NA	ICATS CONSOR TIUM	H	No
A-9	Use the latest weather forecast in the flight planning.	In order to take de maximum advantage of implementing flexible routes.	CRUISE	*ENV & EFF*	NA	NA	ICATS CONSOR TIUM	VH	No
A-10	The flight planning 2012 will be used (as a reference) in this document.	Air Europa does not yet have the flight planning (summer or winter season) for 2014.	CRUISE	*ENV & EFF*	NA	NA	ICATS CONSOR TIUM	VH	No
A-11	The communication system between the aircraft and the airline HQ (AOC) should be guaranteed thanks ACARS.	In order to execute properly the Demonstration trials.	CRUISE	NA	NA	NA	ICATS CONSOR TIUM	VH	No

Table 13: Demonstration and Analysis Assumptions

5.3.1 Results per KPA

See section 5.1 and section 5.2.

5.3.2 Impact on Safety, Capacity and Human Factors

Although the impact on those KPAs is not sufficient for developing a Safety, Capacity or Human Factors Performance report, some points may be highlighted:

- Safety: The Safety-related objective it was very difficult to measure considering how the exercises were defined. The only possible method for measuring the safety impact was through a series of questionnaires distributed to the actors involved in the trials: Pilots, IOP and Operational Controllers. The analysis of those questionnaires was performed to derive a qualitative assessment of safety impact. Unfortunately, poor answers were given to the questions applying to Safety.
- Capacity: the expected impact on the sectors capacity is partially analysed by OBJ-0209-001 and OBJ-0209-002. However the current sector overload issue in the Spanish Airspace (the one studied in Scenario 2) does not happen often, except for the integrated sectors. That means that currently the impact of the unexpected traffic on the sector capacity is minor, because it is not often exceeded. However, for the integrated sectors case, the expected benefit is more related to the data accuracy. Then, the analysis is more oriented to the predictability and the accuracy of the data.
- Human Factors: this KPA is out of the scope of the project. Nevertheless ATCOs involved in the demonstration trials in Scenario 1 confirmed that their workload was not higher during the trials.

5.3.3 Description of assessment methodology

Figure 11 shows the assessment methodology followed for analysis of **Scenario 1**.

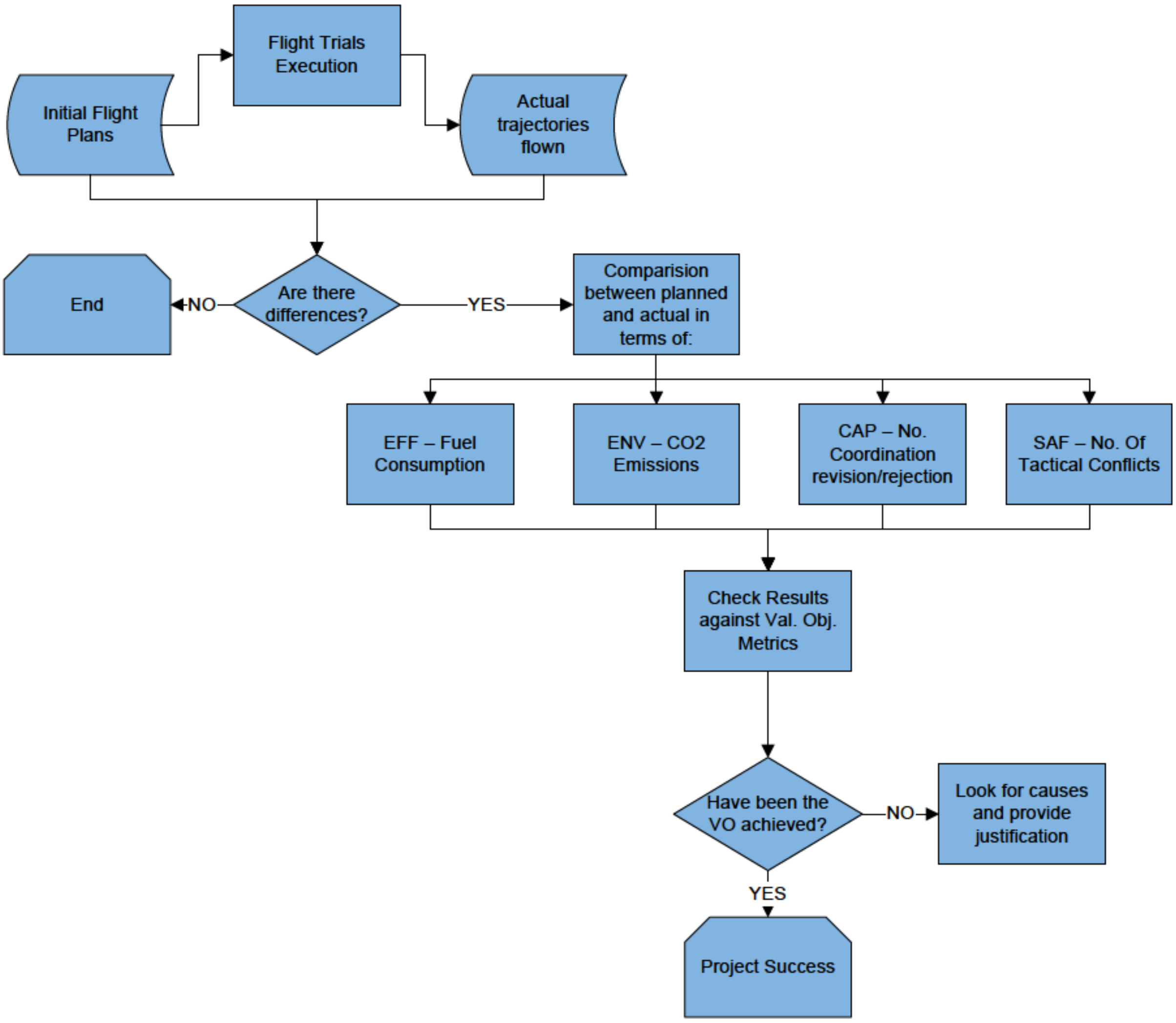


Figure 11: Scenario 1 assessment methodology[4]

Regarding the **Scenario 2**, the assessment methodology is described below:

1. Every day, the data from SACTA PIV and ICATS HMI was received. In the PIV case, there were 18 files, one call for each of the three sectors analysed at 00:00, 02:00, 04:00, 06:00, 08:00 and 10:00 UTC. In the ICATS HMI case, 6 files per day, one per call.
2. Once received, it was initially analysed by CRIDA and forwarded to Indra in order to assess if there was any flight that should be excluded from the analysis due to technical issues (e.g. sometimes test flights were introduced in the system to test new functionality).
3. In parallel, CRIDA downloaded the real data from the flights obtained from GIPV in order to be able to compare the information given by PIV and ICATS HMI with the real operational situation each day. In addition, from GIPV, CRIDA was able to obtain the time each aircraft spent crossing each sector.
4. Once all the information was ready to be analysed, it was processed in automated Excel Templates developed by CRIDA. The calculated outputs provided by the templates are (per sector and day):
    a. Crossing the information from PIV and GIPV, the template calculated the Entry Time for each flight in each sector.
    b. With the result of the previous calculation, the predicted number of aircraft entering each sector (as per PIV) hourly is calculated. In addition the number of Oceanic

[4] In order to measure the Capacity and Safety metrics, in addition to the comparison between the planned and actual trajectory, the data link communications and the questionnaires distributed to the actors involved in the trials were analysed.

flights (whose departure airport has an ICAO designator of M*, C*, K* or S*) is derived from the total number of flights. The actual count of traffic in each sector per hour is also derived. These calculations provide a means to measure accuracy of the system today.

   c. Using the HFIR given by the ICATS HMI and using the information from GIPV, the template calculates the number of predicted aircraft to be entered in each sector considering the information provided by the ICATS HMI, which is the added value to today's operations. The representation is the same than the one explained in b.

5. Thanks to the previous representation, M01 and M02 are measured. The comparison made was (per call):
   a. PIV $HFIR_{xx}$[5] – Actual HFIR
   b. ICATS HMI_{xx} – Actual HFIR
6. The results on M07 and M08 are obtained using the same data aforementioned, but using a different template developed by CRIDA with focus only on the oceanic flights.

5.3.4 Results impacting regulation and standardisation initiatives

N/A

5.4 Analysis of Exercises Results

See section 5.1 and section 5.2 for the general analysis of the results for each exercise and objective. See also section 6.1.3 and 6.2.3 for more detail regarding the rationale for the results.

5.4.1 Unexpected Behaviours/Results

During ICATS integration testing and conduct of our live flight trial we experienced a number of system issues that required significant engineering effort to localize, investigate, and resolve. The following material summarises the kind of issues we encountered, describes the tools we used to help examine the detailed cause of the issue, and how we resolved each.

Communications Infrastructure between EU and US System Components – the system configuration integrates regional Interoperability Chain systems from the US and the EU using region specific NextGen and SESAR adapters and distributed set of I-SWIM nodes that interact to update and publish Global Flight Object (GFO) updates. Additionally, the basic communications infrastructure utilised VPN secured internet links where the appropriate VPN connections were established by routers configured compatibly on the both the US and EU sides.
It took a while to get the basic communications end-to-end thread up and running reliably owing to the complex configuration comprising many components and the fact that the team was working remotely on both sides of the Atlantic using telephone, Webex, and e-mail intercommunication.

Basic Message Exchange for GFOs – the message exchanges were defined by a detail Interface Control Document that detailed the GFO structure and content. Because the data model for GFO exchanges was quite complex, we conducted an early exchange of message log data so that each side could inspect the kinds of data message that would be received in order to identify and resolve message structure and content issues before the start of integration testing. A set of significant issues were identified from the desk inspection of the messages and resolved collaboratively by the engineering team.
Although this step identified a large subset of the GFO message exchange issues before integration testing, we did continue to discover issues during the integration testing interval. Some of those were caused by differences in interpretation of the ICD by US and EU engineering staff. Another set of these were discovered when we began using live data feeds and tried to work with imperfect data supplied by the Operational chain.
In general, we resolved the GFO message exchange ICD collaboratively using the full resources of our combined engineering teams. Where necessary, we adjusted the ICD to resolve interface definition issues. Live data issues were generally resolved by making work-around changes to our processing logic to accommodate imperfections in the operational data while still adhering to the ICD requirements.

[5] Being $_{xx}$ the different call times (00:00, 02:00, 04:00, 06:00, 08:00 and 10:00 UTC)

GFOM Handover Issues – during integration testing we encountered some issues with the implementation of our protocol for handing over the GFO Manager role from region to region. The GFOM Handover was defined in our ICD to enforce true distributed management and control of the GFOs in the ICATS system. By design for ICATS, the handover process occurs when the Last Reported Position in the GFO indicates that the flight has exited one region and entered the next region. The Handover process permits the GFO Manager role to be passed from one region to the next region when the flight crossed the geographic region between regions. The protocol is designed to be seamless and failsafe for a most typical transitions from one region to another.
During integration and testing we encountered issues with the GFOM Handover processing logic. We employed an offline message analysis capability to extract data from various system logs on both the US and EU sides in order to examine the detail of message exchanges and the content of individual messages. Based on this analysis we found two factors that contributed instability to the GFOM Handover process:

1) instability in the Last Reported Position data contained in the GFO, and
2) instability in the GFOM Handover logic used to initiated and complete GFOM Handovers.

Both issues were resolved using the combined resources of our joint engineering team to identify and correct the sources of instability in the system processing logic.

Processing of What-If Flight Change Proposals for Eastbound Flights – During conduct of the trial we encountered issues that prevented us from processing What-If flight change proposals for eastbound flights. As this thread worked correctly for Westbound flights, we used this information to help us narrow in on issues that were specific to processing of Eastbound flights.
We had included provision in our ICATS Technical Requirements to ensure that routine changes to the GFO would not invalidate approval of a What-If flight change proposal. Our requirements dictated that if a significant GFO update was received during assessment of a What-If flight change, the What-If assessment would be cancelled and withdrawn from assessment. In practice we found that our threshold for “significant” GFO updates was being triggered inappropriately, causing premature cancellation of any What-If for an eastbound flight.
The behaviour that was peculiar to eastbound flights was generally caused by the fact that eastbound flights generally initially have the US region acting as GFO Manager. Upon close inspection of the system behaviour using the offline message analysis capability, we found that a large number of small regional trajectory changes within the US region was causing fairly frequent GFO updates by the GFOM. These were interacting with the What-If processing logic, causing premature cancellation of the What-If assessment.
To resolve this, we inserted some additional special logic to defer GFO updates when assessment of a What-If flight change was in progress.

System Workload and Performance/Response Time - Resolution of this above What-If issue led us to identification of a second issue related to system performance and workload. From offline analysis of message exchanges, we discovered that performance constraints associated with our VPN connection, caused build-up of a large backlog of GFO update messages during peak hours of operation. We used our offline message analysis capability to investigate how much message traffic was generated between cooperating I-SWIM nodes in the US and EU regions. We found that a peak message workload of nearly 600 message an hour was causing serious degradation of the system throughput.
During development of our Technical Requirements, we had anticipated that system performance could be a problem and we built-in functionality for a set of adaptable filers that could be easily adjusted to control the system message exchange workload. We also found that the US region was generating a large number of GFO updates in response to very small changes in the trajectory times that routinely occur within each region. To mitigate the excess system workload, we added some filters to establish an adjustable threshold for changes to times in the regional trajectory. This filter was used to limit the GFO updates to significant changes in the trajectory times within the region. The net effect was a significant reduction in the system workload for GFO updates.
We put these changes into the ICATS System in early June and they ultimately enabled us to successfully process What-If flight changes for eastbound flights. As a result, our data sample for Scenario 1 includes a large set of westbound flights and a much smaller, but non-zero set of eastbound flights.

5.5 Confidence in Results of Demonstration Exercises

5.5.1 Quality of Demonstration Exercises Results

The quality of the Demonstration Exercise Results is limited due to several constraints faced during the execution of the exercises. Those constraints are listed in section 6.1.3.1.8 for Exercise 1 and in section 6.2.3.1.8 in Exercise 2.

Nevertheless a summary of the main constraints is given below:

- For the data analysed in Exercise 1, the most important constraints are related to:
  - the traffic sample size which is not big enough to extrapolate global conclusions.
  - the correction factor applied to the actual amount of fuel consumed may limit the representativeness of the values obtained.
  - the qualitative results obtained for M03 and M06 analysis through the questionnaires, limit the impartiality of the results.
  - concerns from LPPO controllers regarding the added value of the ICATS system in the decision making process.
- For the data analysed in Exercise 2, the most important constrains are related to:
  - The quality of the ICATS server data, understanding by “poor quality” the lack of ICATS HMI information in some calls (gaps) or the difference between the ICATS HFIR and the Actual HFIR.
  - The amount of days analysed. From the 37 candidate days to collect data for Scenario 2, the data was collected in 30 cases. And, from those 30, only 19 days were subjected to be analysed due to different issues occurred: lack of information recorded, number of flights disregarded each day over the 30% of the total, etc.

5.5.2 Significance of Demonstration Exercises Results

For Scenario 1, the level of representativeness is very high as the demonstration trials used real commercial flights operating from their origin airport to their destination without any disturbance caused by the validation activities. The interoperability chain used during the flight trials was operated in shadow mode and thus minimised the possible impact for ATC or flight crew during the execution of the trials.

In addition, the information needed to assess the results is almost all gathered automatically from the airline and the ATC centres.

The only thing to be considered is that the human actors’ assessments may sometimes impacted due to subjective points of view. Nevertheless as the main information is automatically gathered quantitative data, the impact of any subjective view will be minor.

For Scenario 2, the level of representativeness is high enough to consider the expected results as valid and valuable. The set of data analysed is large enough to provide representative results. At the same time, the information provided by the ATM Systems is by definition accurate and no human influence on those results is expected.

5.5.3 Conclusions and recommendations

This section presents the summary of the conclusions and recommendations after the execution of the exercises and the analysis of the results. Further details are included in each Metric Results analysis sections (6.1.3.1.1, 6.1.3.1.2, 6.1.3.1.3, 6.1.3.1.4, 6.2.3.1.1, 6.2.3.1.2 and 6.2.3.1.4) as well as in section 8 where the Next Steps are described.

CONCLUSIONS

The analysis of the results for both exercises show a common trend indicating than the expected benefits derived from the flight information sharing between both sides of the North-Atlantic are achieved or at least partially achieved.

1. The expected fuel reduction is achieved. An average of 1,40% of fuel is saved thanks to ICATS IOP Chain.
2. As a consequence, the amount of CO_2 emissions is also reduced and the objective achieved.
3. The number of coordination rejections have been decreased thanks to the exchange of information facilitate by the IOP Chain. And then, the objective is also achieved. In addition, in general it can be said that the feeling of pilots and controllers is positive.
4. The reduction on the number of tactical conflicts could not be fully measured with the data collected. However, the results got from the questionnaires to pilots and controllers shows a trend indicating that thanks to ICATS all the actors involved in the process has the information much more in advance and this allows them facilitating the desired trajectory. As a consequence, the number of tactical conflicts can be reduced.
5. The comparison between the information given by the ICATS server with the current system (PIV) shows that the accuracy of the sector load calculations is improved thanks to the ICATS data. The same situation happened for the unexpected sector overload due to Oceanic Traffic. However, this is a partial result limited to the fact that the results are better with the ICATS system, only on those cases where ICATS works better than PIV, which means the 47% of the cases for M01 and the 49% of the cases for M02.
6. Regarding the predictability and the accuracy of the data, for those flights considered, the ICATS systems is slightly more predictable in 5 of 6 calls, and more accurate in 4 of 6 calls. As average the predictability with ICATS is 18 min better and the accuracy is around 8 min. The best value (biggest difference between ICATS and PIV) is frequently obtained in the 04:00 call.

RECOMMENDATIONS

The first and most important recommendation for the future is to extend the Demonstrations trials period in order to obtain a higher data sample which would imply a higher level of representativeness.

Below some other recommendations regarding how to improve future and similar demonstration exercises in order to obtain results with a higher level of confidence are listed:

1. The testing period should be longer in order to put all the systems in place and check the interoperability between them.
2. Improve the human training in order to avoid gaps on the information recorded.
3. Increase the number of airlines involved in order to have a more representative sample of flights and traffic.
4. Increase the airspace covered by the demonstrations trials to ensure that many of the flights performed are subjected to be optimised. E.g. coverage of Shanwick or Gander airspaces.
5. When defining a trials activity, it is recommended to perform a theoretical analysis to justify the rationale of the metrics and goals to be achieved. This will help to raise non foreseen factors that later may affect to the trials execution and results. In the case of ICATS, for instance, it had been valuable a study about the factors that may influence the trajectory optimizations (Meteorological situation in each season of the year, past experiences already known...). Also it had been interesting a study about the accuracy of the data used for feeding the IOP chain, etc."
6. Use accurate additional live data for keeping updated the IOP chain from live ATC systems, to enable a better output of the ICATS calculations.
7. Automate as much as possible the capture of data to avoid human errors in the process.
8. Include a technical/operational supervision to monitor the status of the systems for the users.
9. All the previous recommendations should lead to improve the reliability of the system in order to be closer to real operations.

6 Demonstration Exercises reports

6.1 Demonstration Exercise #1 Report

6.1.1 Exercise Scope

6.1.1.1 Exercise Overview

Next table summarises the exercise information:

Demonstration Exercise ID and Title	EXE-02.09-D-001: Enhancing of trajectory of Air Europa flights analyzing how the advanced sharing of information improves the flight efficiency.
Leading organization	NAV Portugal and Air Europa
Demonstration exercise objectives	Improvement of Efficiency, Environment and Safety
High-level description of the Concept of Operations	Please see section 5.1.1.2 of Demonstration Plan for further details. For predetermined flights and city pairs the AOC will be allowed to request a flight plan trajectory update, based on the most up to date existing information. The request is shared with all the affected stakeholders by interchanging Flight Objects through the IOP chain, which will permit the controllers to be aware of the new flight intentions well in advance, in order to increase the chance to grant the aircraft to follow the optimum profile.
Applicable Operational Context	En-route Oceanic flights through the North Atlantic Area.
Expected results per KPA	• M03: Reduction of at least 5% the number of Coordination Revision/Rejection. • M04: Fuel saving >= 1%. • M05: Reduction of CO2 Emission >= 1% • M06: Reduction of at least 10 % of the Tactical Conflicts.
Number of flight trials	41 achieved (Not less than 40)
Partners Involved	**Operations:** Air Europa AOC and Pilots, Lockheed Martin ATCO experts (New York Oceanic and New York/Miami En-Route), Nav-Portugal (Santa Maria Oceanic and Lisbon En-Route) **Live data providers**: AENA, Nav-Portugal, Lockheed Martin **Infrastructure monitoring:** Lockheed Martin and Indra **Trials logs archiving:** CRIDA
Airspace/ATSUs involved	Lisbon ACC, Santa Maria ACC, New York Oceanic CC, New York/Miami En-Route

Table 14: Exercise EXE-02.09-D-001 Overview

6.1.1.2 Operational Concept

Previous Operating Method

The "previous operating methods" considered in the scope of ICATS are represented by the current situation, where interoperability is based on NAT/AIDC and OLDI mechanisms.

This situation is characterised by the fact that the same flight has different local representations Moreover the interoperability is based on bilateral adjacent ATSU coordination without dissemination of the flight data to third ATSU involved in the trajectory of the flight.

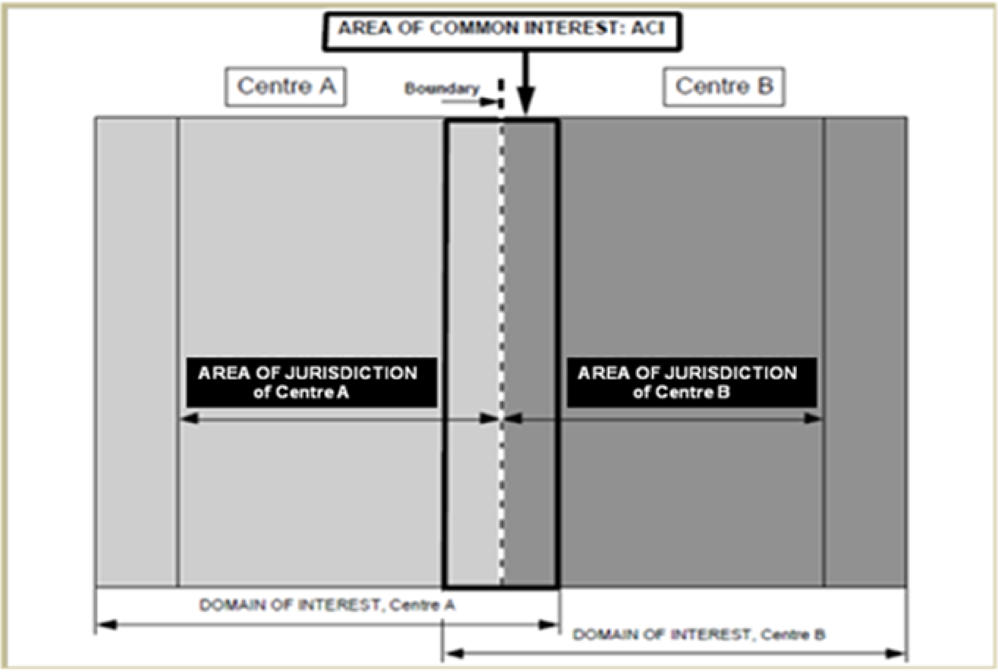


Figure 12: Previous Operating Method

This leads to situations where a trajectory change requested by the flight crew to a controller implies several bilateral sequential coordination between adjacent ATSU to be accepted.

Operating Method during ICATS

In order to cope with the existing limitations, during the ICATS trials the new trajectory requests triggered by the AOC were displayed at the IOP chain working positions of all the centers affected by the modifications. The staff working at those positions analysed if the airline proposal was feasible, providing feedback via IOP chain.

Once confirmed the feasibility of the proposal to the AOC via the IOP chain, the flight dispatcher informed via ACARS to the flight crew, who will formally requested the trajectory change via CPDLC (or voice in the case of the Lisbon ACC)to the involved controllers at the Operational positions.

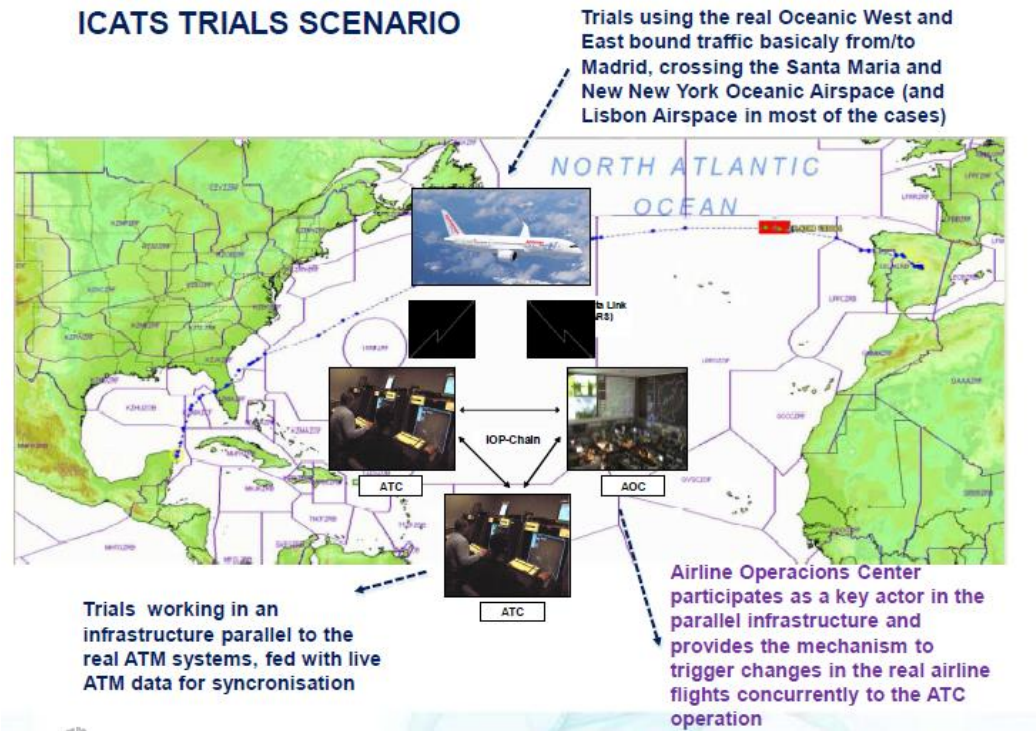


Figure 13: ICATS Scenario 1 Exercise

6.1.2 Conduct of Demonstration Exercise EXE-0209-D-001

6.1.2.1 Exercise Preparation

This section provides the configuration of the Platform/systems/tools used for this exercise.

The infrastructure deployed used for the trials is depicted in the next figure at high level. It was composed of:

- Equipment deployed at AENA CED, mainly for communications interface between the live ATC systems (AFTN from Lisbon and Santa María forwarded to Madrid CED, FP information from SACTA GIPV server) and the ICATS processing servers, located at Indra.
- ICATS Web HMI positions, deployed at ACCs Madrid, Lisbon, Santa Maria, and Air Europa AOC (this last working position was owned by Air Europa, the HMI Web was executed on that).
- ICATS processing servers, to support the IOP Madrid, Lisbon, Santa Maria IOP nodes, the EU and AOC I-SWIM nodes, and the HMI Web Server node.
- Equipment deployed at FTB: USA I-SWIM node, Adaptor node and the legacy USA En-Route/Oceanic parallel systems (ATOP/ERAM).

VPN connections and Internet secure access mechanisms were put in place on top of the internet connections used for the trials. PENS, initially planned in the ICATS Demonstration Plan to connect Nav PT and AENA ICATS infrastructure, was finally not used due to the limited bandwidth available at ANSPs, so all connections went thru internet links.

For conducting the trials, the infrastructure was loaded at the beginning of the period with the adaptation data of the scenario (airspace definition, nav-aids, etc), see section 3.4 of the ICATS Operational Concept Document, [4]. MET data (current and forecast) was daily loaded also. The AFTN and GIPV connections were enabled/disabled upon convenience from the Indra facilities.

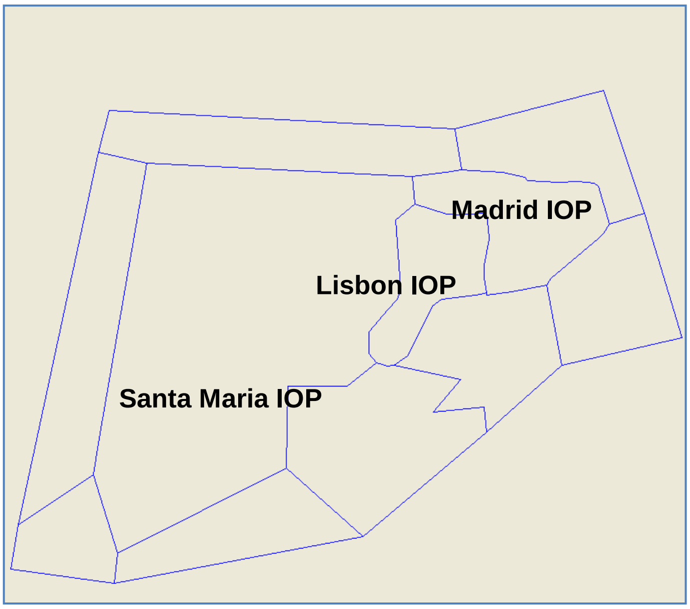


Figure 14: ICATS European Regional IOP Areas

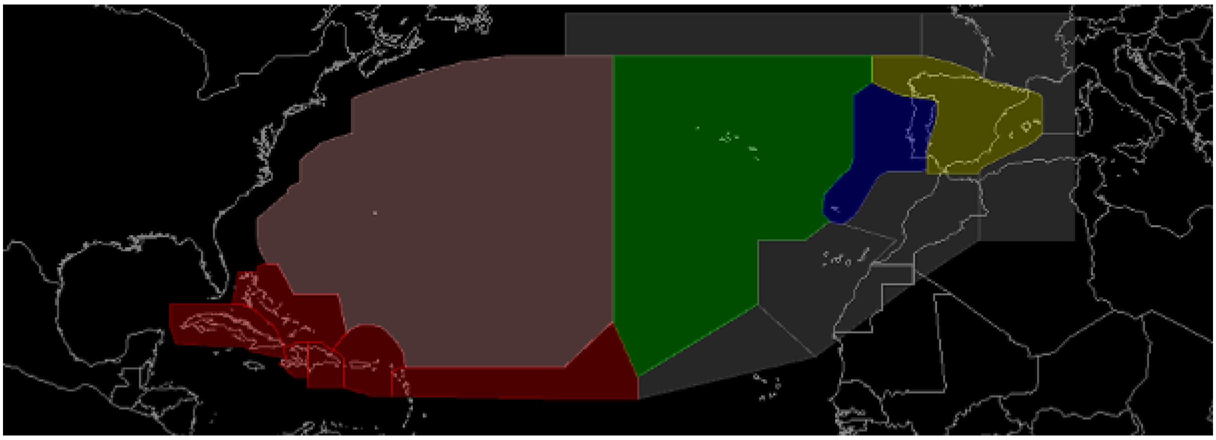


Figure 15: ICATS US/European IOP Regions and FIRs

The link with SESAR SWIM work is guarantee as the SESAR SWIM prototypes (developed in P14.02.09) are used in each Madrid, Lisbon and SATL SWIM nodes representing in Figure 16.

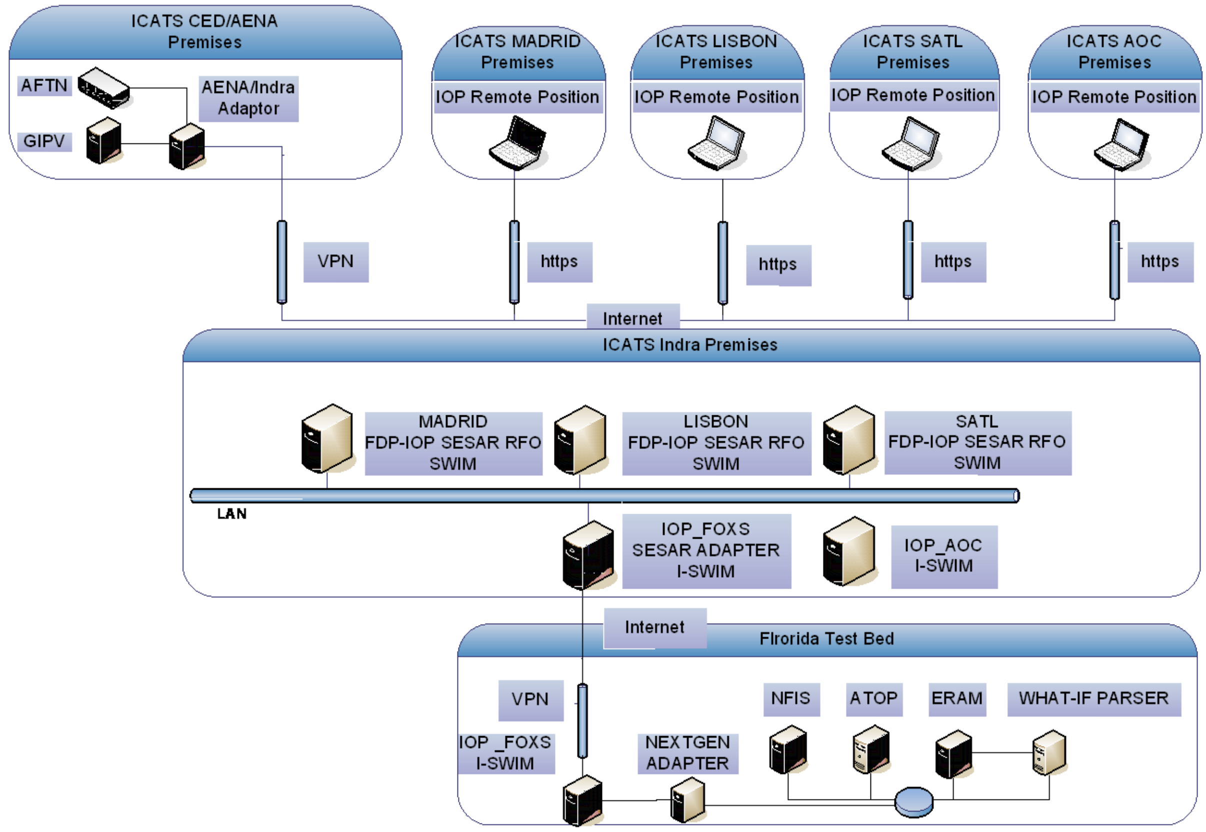


Figure 16: ICATS Physical Infrastructure

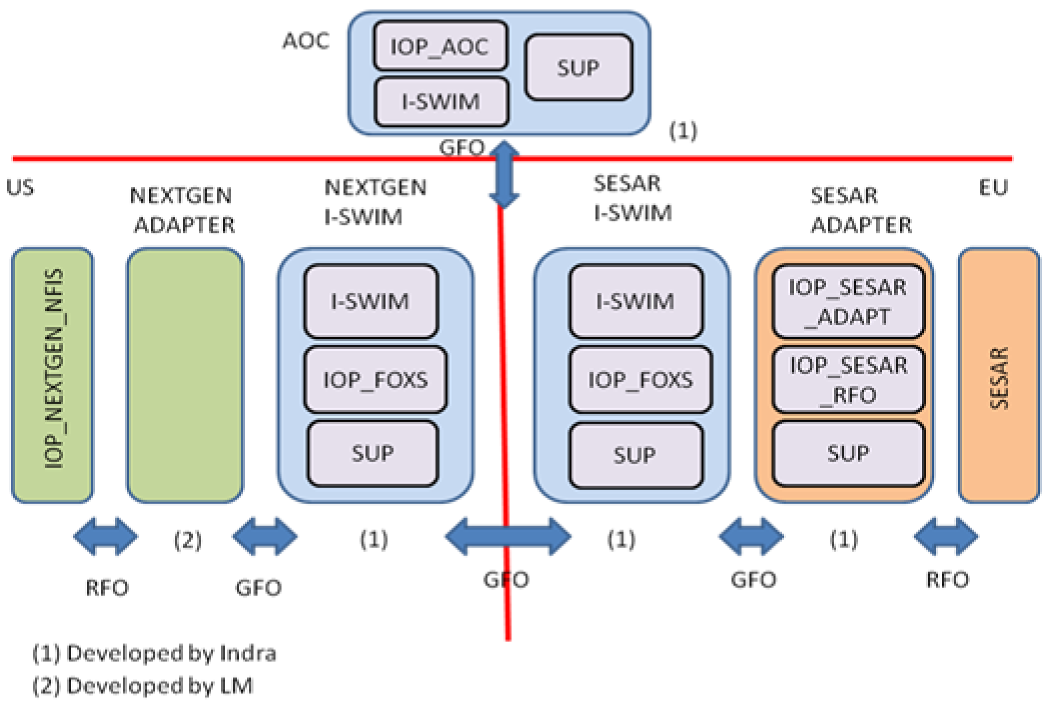


Figure 17: ICATS Software Infrastructure

Figure 18: ICATS Indra Trials monitoring infrastructure

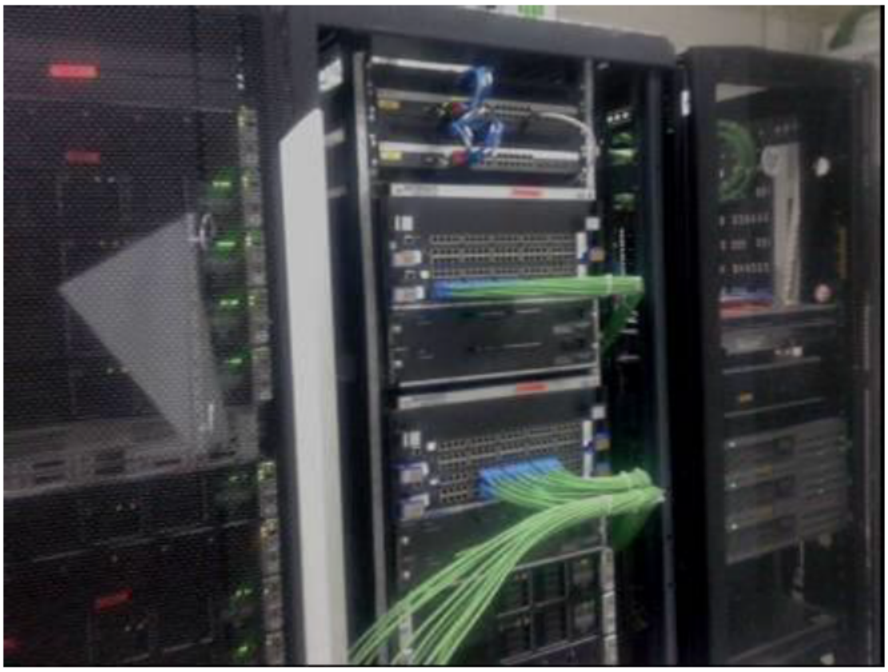


Figure 19: ICATS Indra servers infrastructure

6.1.2.1.1 Questionnaires Development

In order to be able to measure (at least in a qualitative way) the M03 and M06 a series of questionnaires were distributed among the actors involved in the trials. The questionnaires are presented here below:

DATE	
Flight ID	
Origin	
Destination	

ETOT	

Considering your experience flying an ICATS Trial		
QUESTIONS		ANSWERS
Question 1	How often did you get an approval for a proposed change in the trajectory? (1=never, 5=always)	
Question 2	From your viewpoint, what is the percentage of change requests rejected from the total number of change requests? (0-100%)	
Question 3	Where have you proposed most of the change requests? (LPPO or KZNY)	
Question 4	In case you ticked Within LPPO in Question 3, it was: (Closer to KZNY boundary, In the middle, Closer to LPPC/LECM boundary)	
Question 5	Which was the most frequent type of trajectory change proposed? (Re-route, FL, Mach, Other)	
Question 6	In case you ticked *Other* in Question 5, what was it?	
Question 7	From your point of view, how often did the controller facilitate the user preferred trajectory? (1=never, 5=always)	

Table 15: Questionnaires for Pilots

TRIAL DATE	
YOUR NAME	

Considering the ICATS Flight Trials and the IOP chain…		
QUESTIONS		ANSWERS
Question 1	How often did you approve a proposed change in the trajectory? (1=never, 5=always)	
Question 2	From your viewpoint, and considering only the AEA flights, what is the percentage of trajectory changes rejected from the total number of changes you were requested? (0-100%)	
Question 3	Do you think that the additional information provided by ICATS is enough to approve/reject a change request? (1=never, 5=always)	
Question 4	Where did most of the change requests occur in the Eastbound flights? (LPPO, KZNY)	
Question 5	Where did most of the change requests occur in the Westbound flights? (LPPO, KZNY)	
Question 6	What were the most common reasons for rejecting a proposed change? (Open text answer)	
Question 7	The information you got from the IOP chain allowed you to facilitate the trajectories preferred by the Aircraft Operator (1=never, 5=always)	
Question 8	Did the IOP Chain provide you more accurate flight information much more in advance? (1=never, 5=always)	

Table 16: Questionnaires for IOP Controllers

TRIAL DATE	
YOUR NAME	

Considering the ICATS Flight Trials and the Operational chain…		
QUESTIONS		ANSWERS
Question 1	How often did you approve a proposed change in the trajectory? (1=never, 5=always)	
Question 2	Where did most of the change requests occur in the Eastbound flights? (LPPO, KZNY)	
Question 3	Where did most of the change requests occur in the Westbound flights? (LPPO, KZNY)	
Question 4	What were the most common reasons for rejecting a proposed change? (Open text answer)	
Question 5	The number of tactical conflicts that you dealt with compared to current operations was (Greater, Equal to, Fewer).	
Question 6	In case your ticked *Greater* or *Fewer* in Question 6, by which percentage?	
Question 7	The information you got from the IOP controller allowed you to facilitate the trajectories preferred by the Aircraft Operator (1=never, 5=always)	

Table 17: Questionnaires for Operational Controllers

6.1.2.2 Exercise execution

For performing a week trials, one week in advance Air Europa provided the weekly schedule for the flights selected for the trial.

For performing the exercise, the following daily procedure was applied:

- The Infrastructure was restarted and the connection with the ATC live data sources established.
- MET data (actual and forecast) was loaded into the ICATS infrastructure.
- Air Europa provided the detailed flight planning for each flight (Flight dispatching information).
- Air Europa communicated the event when each flight was taxing and airborne.
- When airborne, Air Europa communicated in advance the intention for performing a trajectory change proposal, when each flight was in the appropriate geographical position and again after MET changes received in the AOC. The flight crew does not have the full set of MET information update on board.
- The trajectory change request was evaluated by the affected IOP positions (Lisbon, Santa Maria or Florida). If accepted by both partners, it was communicated by the AOC to the pilot, for request to ATC in the Operational chain.
- The CPDLC communications between pilots and controllers were recorded in live and distributed to CRIDA by AEA.
- At the end of the trials, Air Europa summarised the results.
- Questionnaires for Pilots, Nav PT Operational Controllers, LM pseudo-controllers and Nav PT IOP Controllers were completed and submitted by participants.
- Technical Logs were recorded.
- NAV PT process the data link communications occurred during each flight and pass them to CRIDA.
- All data was archived and put to disposition for later analysis.

For further details, see section 5.1 of ICATS Operational Concept Document [4]

The detailed trials schedule for every day was as follows (time is UTC):

Westbound AEA day	From	To		Indra Lab	Aena ACC	NAV-P	FTB	AEA AOC
	13:00	14:00	Systems start-up (if needed), Readiness check	X			X	
	14:00	18:00	Scenario 1 Westbound AEA flights trial	X		X	X	X
	0:00 day+1	10:00 day+1	Live data data capture for Scenario 2 (all Eas bound ICATS)		X			
Eastbound AEA day	**From**	**To**		**Indra Lab**	**Aena ACC**	**NAV-P**	**FTB**	**AEA AOC**
	15:00 day-1	16:00 day -1	Systems start-up (if needed), Readiness check	X			X	
	0:00	4:00	Scenario 1 Eas bound AEA flights trial			X	X	X
	0:00	10:00	Live data data capture for Scenario 2 (all Eas bound ICATS)		X			
Data downlad at 00:00, 02:00, 04:00, 06:00, 08:00, 10:00 AM by Aena ACC for Scenario 2 purposes								

Table 18: ICATS Daily Trials time table

The detailed execution of the trials for Exercise 1 per day was as follows:

Date	Westbound/Eastbound	AEA Flights Addressed	Call-signs
22-Apr-14	Westbound	2	AEA051, AEA089
23-Apr-14	Westbound	2	AEA051, AEA089
24-Apr-14	Westbound	2	AEA051, AEA089
25-Apr-14	Westbound	2	AEA089, AEA051
28-Apr-14	Westbound	2	AEA051, AEA089
29-Apr-14	Westbound	2	AEA033, AEA089
30-Apr-14	Westbound	2	AEA051, AEA089
02-May-14	Westbound	2	AEA089, AEA051
05-May-14	Westbound	1	AEA089
12-May-14	Westbound	3	AEA051, AEA071, AEA089
13-May-14	Westbound	2	AEA089, AEA051
15-May-14	Westbound	2	AEA071, AEA089
16-May-14	Westbound	2	AEA089, AEA051
19-May-14	Westbound	2	AEA089, AEA071
20-May-14	Westbound	2	AEA033, AEA089
21-May-14	Westbound	3	AEA071, AEA089, AEA051
22-May-14	Westbound	4	AEA011. AEA071, AEA089, AEA051
23-May-14	Westbound	2	AEA089, AEA063
05-Jun-14	Eastbound	2	AEA088, AEA052
Total		41	

Table 19: Flights Addressed for Exercise 1

The flights corresponding to the above Call-sign are:

Fight ID	Origin	EOBT	ELDT	Destination
AEA033	LEMD	15.55	01.20	MDPC
AEA089	LEMD	13:00	23.55	MDSD
AEA063	LEMD	14.15	01.10	MMUN

Fight ID	Origin	EOBT	ELDT	Destination
AEA051	LEMD	14.00	00.45	MUHA
AEA071	LEMD	13:00	22:25	SVCS
AEA011	LEMD	15:00	0:00	TJSJ
AEA088	MDSD	00.30	08.50	LEMD
AEA052	MUHA	01.45	10.45	LEMD

Table 20: Flight Plans corresponding to the Flights Addressed

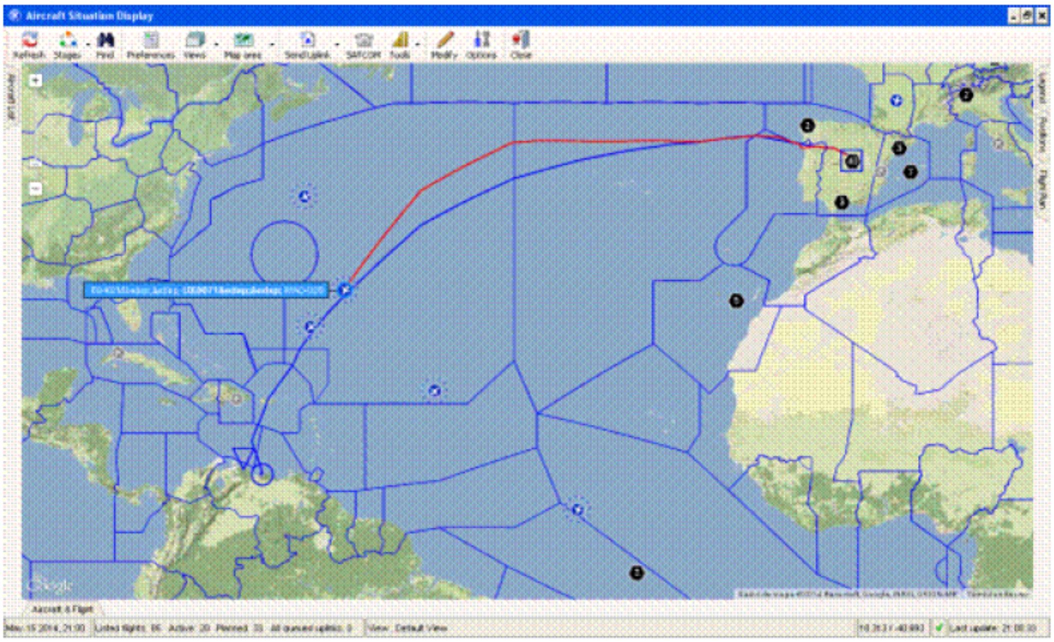


Figure 20: ICATS Trajectory change request implemented, seen in the AOC flight monitoring system (AEA071 Madrid-Caracas 15-May-14)

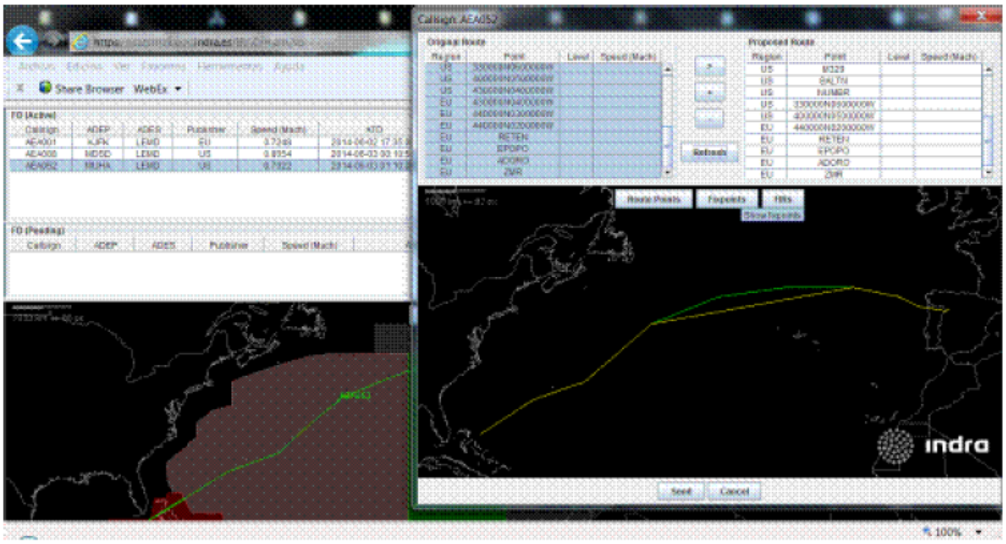


Figure 21: ICATS Trajectory change request from the ICATS Web HMI

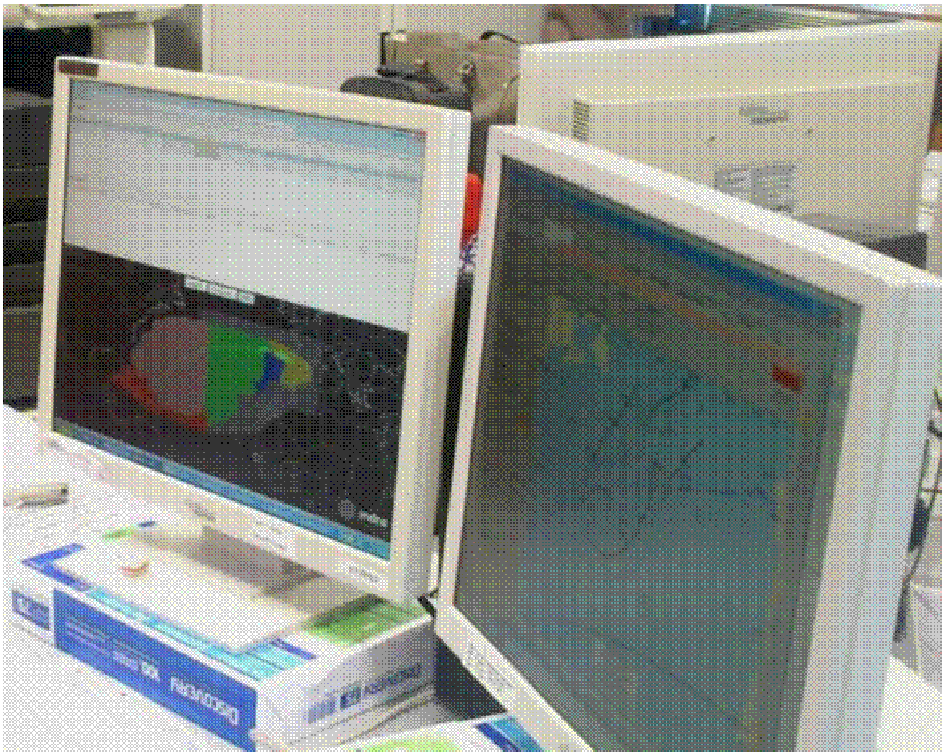


Figure 22: ICATS Web HMI and Air Europa Flight monitoring system at AOC

6.1.2.2.1 Baseline Scenarios Definition

Each expected benefit has its own success criteria, but in order to analyse whether or not it has been achieved, a reference to compare with is needed. That's why before the execution of the trials, CRIDA requested that all the stakeholders involved in the trials provide the same sort of information for current day operations in order to calculate a reference baseline scenario for each indicator.

The baseline scenarios have been developed for M03, M04 and M05. We didn't have data to develop a Baseline Scenario for M06. Regarding the M01, M02, M07 and M08, a baseline scenario is not needed because the results given by ICATS are directly compared with the results without ICATS (current situation).

<u>Baseline Scenario for M03</u>

In order to set a baseline scenario to compare with, the data link communications provided by the Airline were analysed. Luckily, the airline, and all the FIR Systems involved in the trials, was linked via SITA, what facilitated the collection of recorded data. The files represent the communications episodes between the Flight Crew and the Controllers in current operations when aircraft fly across the North Atlantic.

The following sequence describes the process followed:

1. Collect all the data link communications from as many flights as possible during a four week period (end of February 2014 to mid March 2014).
2. Once all the data was put together, the process followed was to go through all the files counting how many communications asking for trajectory changes coming from the Flight Crew occurred during the period analysed.
3. The next step was to calculate the number of trajectory change rejections from the total trajectory changes occurred.
4. The percentage of rejections from the total is considered as the baseline.

The trajectory changes requested by the Flight Crew may be: flight level change, Mach change, re-route change or other. The type of change is always included in the request, however for this objective and scenario, the sort of change is not important, so all the changes are considering together without further categorization.

Table 21 shows the calculations and the baseline scenario:

No. of flights analysed	22
No. of Trajectory Changes asked by the FC	74
No. of Rejections	14
Baseline Scenario	**18,60% changes rejected**

Table 21: Baseline Scenario for M03

Considering this, the measure of M03 will provide benefits if the number of trajectory change rejections when sharing the FO is minor than: 18,60%. Additionally the objective will be successfully achieved if it is reduced by a 5%.

This means, **that the percentage of changes rejected from the coordination episodes occurred should be minor than** (18,60% - 5%) **13,60%**

Baseline Scenario for M04

In order to define a baseline scenario for M04, the FPL information and the FOQA data were used. AEA provided the FPL information for 20 flights during October & November 2013. In addition, the airline provided the FOQA data where the actual information of each flight was recorded. As stated in Table 29, a correction factor of +8,5% is applied to the amount of fuel burnt given by the FOQA data because in the test phase, it was detected a divergence in the amount of fuel consumed between the FOQA data and the airline consumption of an 8,5%.

The following sequence describes the process followed to set a baseline scenario:

1. Firstly, each FPL was analysed in order to get the estimated TRIP[6] fuel to be burnt during that flight.
2. Secondly, the FOQA data associated to the same flight was analysed too. The FOQA data collects all the information related to the flight since the aircraft turn up its engines. In order to be able to compare the actual amount of fuel burnt during each flight with the estimated flight, a filter in the FOQA data was needed. Only the fuel burnt from take-off to landing was considered in the analysis. The fuel burnt in other phases (taxi-in, taxi-out, etc.) was disregarded.
3. The comparison between the actual and the estimated fuel burnt on these flights set the baseline scenario to compare with.

Different analyses were done depending on the city-pairs. All flights were westbound departing from Madrid (LEMD) with multiple destinations, e.g. Havana (MUHA), New York (KJFK), etc. Following tables reflects the number of flights per city-pairs as well as an analysis of the differences between the estimated and actual fuel burnt per city-pair too.

City Pair	No. of flights analysed
Madrid – La Havana	6
Madrid – New York	7
Madrid – Santo Domingo	7

Table 22: Number of flights used for setting the Baseline Scenario for M04

Table 23 shows the actual consumption (FOQA), the estimated (FP) and the relative error between the estimated and the real value of fuel burnt for the 20 flights analysed.

City Pair	Actual(Kg)	Estimated(Kg)	Difference (%)
MADSDQ	44253	49486	10,57%

[6] The TRIP fuel refers only to the fuel burn from Take-off to Landing.

City Pair	Actual(Kg)	Estimated(Kg)	Difference (%)
MADHAV	45097	48689	7,38%
MADSDQ	42086	47748	11,86%
MADJFK	41315	46102	10,38%
MADJFK	37939	42169	10,03%
MADSDQ	43822	48813	10,22%
MADSDQ	42429	47940	11,50%
MADHAV	48581	53901	9,87%
MADHAV	50105	55097	9,06%
MADJFK	41530	46332	10,36%
MADSDQ	38450	43007	10,60%
MADJFK	37279	42246	11,76%
MADHAV	49376	53170	7,14%
MADSDQ	44752	49450	9,50%
MADHAV	52117	56219	7,30%
MADJFK	38550	43068	10,49%
MADJFK	37390	41173	9,19%
MADSDQ	44761	49445	9,47%
MADJFK	36652	41452	11,58%
MADHAV	48654	52862	7,96%
Average Difference (%)			9,81%

Table 23: Fuel comparison.

Moreover, an individual analysis per city-pair was done and these were the results:

City-Pair	Average Difference (%)
MADRID –HAVANA	8,12%
MADRID – NEW YORK	10,54%
MADRID – SANTO DOMINGO	10,53%

Table 24: Comparison between the Actual and Estimated Fuel Burnt per City Pair

Figure 23, shows a representation of the comparison between the estimated and the actual fuel burnt. What can be observed in the graphic is that the estimated fuel is always higher than the actual, as it is shown in previous tables.

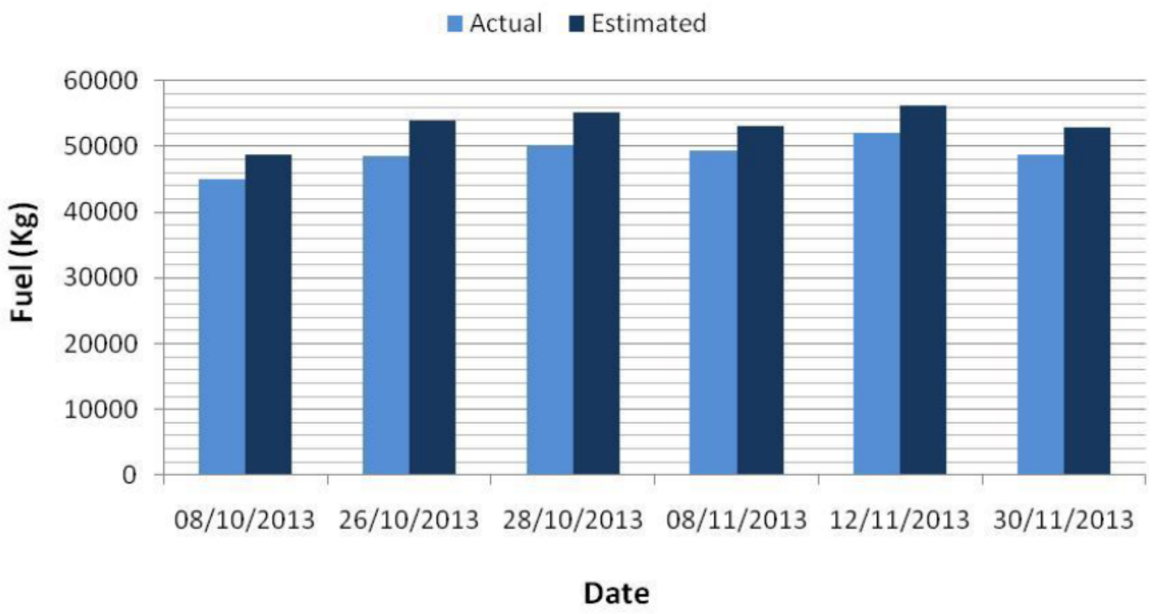


Figure 23: Estimated fuel burnt vs. Actual fuel burnt for one city-pair

It can be assumed that the airlines usually follow a conservative method to calculate the estimated fuel, but as checked with AEA, the margin is never so big. Looking at those results, the airline was consulted and the airline noticed the onboard data the system provides (FOQA Data) was not as accurate as expected.
As a consequence of that misalignment, an assumption was made: it is assumed that the FOQA data provide an error about 8,5% regarding the fuel consumption. This assumption was agreed with AEA and the project leader, Indra. This means that the amount of fuel consumption given by the FOQA data (the Actual fuel) should be increased by 8,5%. In other words, **a correction factor of +8,5% should be applied**.

Applying that assumption to the data showed in Table 23 and Table 24, the average difference between the estimated and the actual fuel burnt for the city-pairs studied was:

City-Pair	Average Difference (%)
MADRID – LA HAVANA	-0,38%
MADRID – NEW YORK	2,04%
MADRID – SANTO DOMINGO	2,03%
ALL	**1,31%**

Table 25: Comparison between the Actual and Estimated Fuel Burnt after correction

The information contained in Table 25 should be considered as the baseline scenario for M04 to compare with. Considering this, **the M04 will be successfully achieved if the actual amount of fuel burnt is reduced by a percentage equal or higher than 1,31% of the initial planned.**

Baseline Scenario for M05

Once we have the baseline for M04, the derivation of a baseline scenario for M05 is easy. After consulting different standards used world-wide, it was decided to use the European most extended conversion factor provided by Eurocontrol [2].

The values given in [2] for the amounts of pollutants released by fuel burnt are:

- **CO_2: 3,149 kg per kg fuel**
- H_2O: 1,230 kg per kg fuel
- SO_2: 0.84 g per kg fuel

Considering the values given in Table 25, and applying the conversion factor aforementioned, the results obtained in terms of differences between the estimated and the actual CO_2 emissions are the same than for the fuel burnt. This makes sense, as the emissions conversion factor used is a constant.

City-Pair	ACTUAL (Kg)	Actual CO_2 Emissions (Kg/kg)	ESTIMATED (Kg)	Estimated CO_2 Emissions (Kg/kg)	Difference (%)
MADSDQ	44253	139352,70	49486	155831,41	10,57%
MADHAV	45097	142010,45	48689	153321,66	7,38%
MADSDQ	42086	132528,81	47748	150358,45	11,86%
MADJFK	41315	130100,94	46102	145175,20	10,38%
MADJFK	37939	119469,91	42169	132790,18	10,03%
MADSDQ	43822	137995,48	48813	153712,14	10,22%
MADSDQ	42429	133608,92	47940	150963,06	11,50%
MADHAV	48581	152981,57	53901	169734,25	9,87%
MADHAV	50105	157780,65	55097	173500,45	9,06%

City-Pair	ACTUAL (Kg)	Actual CO_2 Emissions (Kg/kg)	ESTIMATED (Kg)	Estimated CO_2 Emissions (Kg/kg)	Difference (%)
MADJFK	41530	130777,97	46332	145899,47	10,36%
MADSDQ	38450	121079,05	43007	135429,04	10,60%
MADJFK	37279	117391,57	42246	133032,65	11,76%
MADHAV	49376	155485,02	53170	167432,33	7,14%
MADSDQ	44752	140924,05	49450	155718,05	9,50%
MADHAV	52117	164116,43	56219	177033,63	7,30%
MADJFK	38550	121393,95	43068	135621,13	10,49%
MADJFK	37390	117741,11	41173	129653,78	9,19%
MADSDQ	44761	140952,39	49445	155702,31	9,47%
MADJFK	36652	115417,15	41452	130532,35	11,58%
MADHAV	48654	153211,45	52862	166462,44	7,96%
Average Difference(%)					9,81%

Table 26: CO_2 emissions calculations for OBJ-003 Baseline Scenario Definition

Applying the same assumptions as in M04, the conclusion is the same; M05 **will be successfully achieved if the actual CO_2 emissions is reduced by a percentage equal or higher than 1,31% of the initial planned.**

Something important to be considered is that the success criteria for M04 and M05 are to reduce the fuel consumption and the CO_2 emissions by at least a 1%. However the baseline scenario results shows that currently the reduction of those two elements (comparing FPL and FOQA data) is already of 1,31% as average. And thus in order to be successful, the trial result should be higher than 1,31%.

6.1.2.3 Deviation from the planned activities

The relevant deviations compared to the Plan for Exercise 1 were the following:

1. As indicated in section 3.2.3 of the present document, Schedule, the start of the Exercise 1 trials was postponed from 3rd of March to 22nd April 14 due to the complexity found in the integration of the infrastructure. The trials period, initially scheduled for almost 3 months including an interim period of 1 month, was performed all in one sequence, in 1 month and half.
2. The amount of Eastbound flight trials was reduced, due to the difficulty of performing simultaneously the Scenario 1 and Scenario 2 caused mainly by the low response of the VPN connection for managing the high rate of updates produced by US region for all the traffic after several hours of run. However, the total amount of the flights was kept (41 flights performed in total), so additional westbound flights were tried to accomplish the minimum figure (40).
3. In terms of the Scenario, flights Madrid-New York initially planned in the Demonstration Plan were not addressed in the trials due to the fact the actual planned route was in most of the cases northern to ICATS airspace, crossing Shanwick and Gander Oceanic Centers instead of Santa Maria and New York (NAT routes instead of random routes), In other hand, additional flight routes to the initially planned, such as Madrid-Caracas and Madrid San-Juan Puerto Rico were included in the trials.
4. Before starting the demonstration trials there was a debate on how to measure M03 and M07 due to the difficulty to extract accuracy data from the trials. The decision made was to create and distribute a set of questionnaires (see section 6.1.2.1.1) among the actors involved in the trials in order to get their viewpoint and also to analysed the Data Link communications between ATC and Pilots in order to get a quantitative way of demonstrate if the expected benefits were reached or not.

5. No use of PENS to connect Nav PT and AENA ICATS facilities was performed, due to the limited bandwidth available. As alternate mechanism, internet links were used.

In terms of adaptation data prepared for the trials, it was suitable for the real traffic not requiring adjustments on the course of the days of the trials.

In terms of other external situations that could affect to the trials, no relevant delays or special circumstances (adverse meteorology, strikes, etc) existed so there was no impacted in the trials.

6.1.3 Exercise Results

6.1.3.1 Summary of Exercise Results

During the execution of EXE-02.09-D-001, 41 trials were performed. From those, 39 were Westbound flights and 2 were Eastbound flights.

Westbound Flights (39)	• 17 flights were optimised • For 20 flights, we couldn't find any optimization • In 2 cases, although some optimization was found it was not applied due to system problems (e.g. Error messages, time-out window, etc.)
Eastbound Flights (2)	• 1 flight was optimised • For 1 flight, we couldn't find any optimization

Table 27: Flight Trials breakdown

A detailed explanation of the ICATS Trajectory Optimization Outcomes is given below:

- ICATS Optimization Successful
  - What If Proposal Processed by ICATS IOP Chain
  - What If Accepted in both ICATS Regions (EU and US)
  - Flight Change Proposal Implemented in the Operational Chain

- ICATS Optimization Not Successful
  - What If Proposal Processed by ICATS IOP Chain
  - What If Rejected or Timed Out in at least one ICATS Region (EU or US)
  - No Change Implemented in the Operational Chain

- No ICATS Optimization Opportunity Found
  - Flight Details (route, level, speed) were examined by the AOC
  - No opportunity for reduced fuel burn or flight time was identified
  - No What If Proposal was generated

The route optimizations using ICATS were possible in 17 of them. The following sections provide the results of the analysis of those 17 flights but also the impact over the whole amount of trials performed when the ICATS system is put in place.

The objective of this exercise was to provide evidence of improvement in the following KPAs: Environment/Fuel Efficiency (M04), Environment/CO_2 emissions (M05), Safety/Tactical Conflicts (M06) and Flexibility/Coordination revisions and rejections (M03). Table 12 details the indicators and metrics to be used in order to measure the benefits obtained from the data analysed. Here below, an analysis of these data is provided.

6.1.3.1.1 M03 Results

Two sources of data were used to measure M03: the questionnaires distributed to Pilots, IOP Controllers and ATCO Controllers and the data link communications provided by the Airline and the ANSPs.

As an example, the following pictures present an example of the information provided by the Airline system logs and by the ANSP system logs.

```
DOWNLINK MSG ID: 1  @: 15:18:24

67-  FREE TEXT:
        REQ AFTER N30W050 DCT N27W056 TKS
```

Figure 24: Example of a change request as appears in the Airline system

```
Pri        Origem                    OrigemTime   30-04-2014  16:45:00
Destino
TextoGlobal
  message: U20: CLIMB TO AND MAINTAIN F360,
  U129: REPORT LEVEL F360
```

Figure 25: Example of a change request as appears in the ANSP system

Results from Questionnaires

The questions distributed among the pilots and the controllers are described in section 6.1.2.1.1. Before continue with the analysis it is worthwhile to detail which questions referred to the M03:

- Pilot questionnaires: Questions 1 to 6.
- IOP Controllers questionnaires: Questions 1 to 6.
- Operational Controllers questionnaires: Questions 1 to 4.

The answers to the questionnaires provide a qualitative way of measuring M03. As the questionnaires gathered the Pilots and Controllers (humans) viewpoint, the results may have a subjective component. In addition, as not all the controllers and pilots involved in the trials replied to the questionnaires, there might be some deviations regarding the results got from similar questions posed to pilots and controllers.

The global results from the questionnaires can be summarised as:

1. Most of the pilots confirmed they always had an approval for any proposed change requested in the trajectory. This is confirmed by the IOP Controllers answers.
2. Most of the change requests occurred in the first part of the flight: within Lisbon or Santa María airspaces. And they most frequent change request in order are: re-routings, FL change and Mach Number change.
3. Regarding the information provided by ICATS, there is no agreement among the IOP Controllers regarding if the additional information provided by ICATS is enough to approve/reject a change request.
4. There is no feedback from the Operational Controllers.

The detailed results obtained from the questionnaires are included in Appendix B.

Results from Data Link Communications Review

An exhaustive review of the Data Link communications provided by the Airline and the ANSP is shown in Appendix B.

According to Table 11, the objective will be achieved if it provides a reduction of at least 5% of the trajectory changes requested comparing with today operations. The baseline scenario defined in section 6.1.2.2.1 for M03, shows that nowadays the total number of refusal episodes is of 18,60%. And thus the M03 will be achieved if the number of refusal episodes in the ICATS trials is around 13,60% of refusal episodes.

Considering that reference value and the two sources of data analysed (questionnaires & DL communications), the average % of refusal episodes during the ICATS trials is:

- DL Communications analysis for optimised flights: **13,82%**
- Questionnaires results: Most of the pilots involved in the trials highlighted the benefit delivered by the IOP system. Same result obtained for the American IOP Controllers. There were some concerns expressed by LPPO Controllers applying to both M03 and M06 which are detailed in section 6.1.3.1.4 .

The quantitative analysis is 0,22 higher than the expected result, however the qualitative analysis offers a complementary positive analysis and thus why regarding those results, the ICATS consortium agreed that the **M03 has been successfully achieved**.

6.1.3.1.2 M04 Results

There are two main sources to measure this objective:

- Initial Flight Plans (FP) provided by the airline 3 hours before the departure time.
- FOQA Data, which is downloaded from the aircraft after the flight. This data has been processed with a Matlab tool, which analyses the amount of fuel consumed and also provides a representation of the amount of fuel consumed in its phase of the flight.

The extraction of the FOQA data is not an easy process as the data needs to be downloaded from the aircraft. The airlines would like to be close to the 100% of the data. Some of the AEA aircraft have a wireless system which allows the downloading of the data in an easier and faster way. In the meanwhile, the limitations of the current system are:

- the data can be corrupted and thus the system disregard them;
- the data download process can be interrupted and then the data is lost.

The following tables shows a summary per flight of the estimated fuel to be burnt and the actual fuel consumption provided by the FOQA data (with the correction factor +8,5% already applied):

Day	Flight ID	DEP	ARR	Estimated Fuel (TRIP fuel - FLP) (Kg)	Actual Fuel (Take-off to Landing - FOQA) (Kg)[7]	Difference (corrected by a 8,5% factor) (%)
22/04/2014	AEA089	LEMD	MDSD	51519	46298	1,63%
22/04/2014	AEA051	LEMD	MUHA	58159	52970	0,42%
23/04/2014	**AEA089**	**LEMD**	**MDSD**	**52158**	**46761**	**1,85%**
23/04/2014	AEA051	LEMD	MUHA	60971	N/A	--
24/04/2014	**AEA089**	**LEMD**	**MDSD**	**50600**	**46022**	**0,55%**
24/04/2014	AEA051	LEMD	MUHA	59843	53706	1,76%
25/04/2014	AEA089	LEMD	MDSD	49546	44146	2,40%
25/04/2014	AEA051	LEMD	MUHA	58992	53483	0,84%
28/04/2014	AEA089	LEMD	MDSD	48445	43160	2,41%
28/04/2014	AEA051	LEMD	MUHA	57612	N/A	--

[7] N/A means that AEA was not able to extract the FOQA data from the aircraft.

Day	Flight ID	DEP	ARR	Estimated Fuel (TRIP fuel - FLP) (Kg)	Actual Fuel (Take-off to Landing - FOQA) (Kg)[7]	Difference (corrected by a 8,5% factor) (%)
29/04/2014	**AEA089**	**LEMD**	**MDSD**	**45821**	**41411**	**1,12%**
29/04/2014	**AEA033**	**LEMD**	**MDPC**	**47938**	**43181**	**1,42%**
30/04/2014	**AEA089**	**LEMD**	**MDSD**	**47793**	**42516**	**2,54%**
30/04/2014	**AEA051**	**LEMD**	**MUHA**	**55159**	**49650**	**1,49%**
02/05/2014	**AEA089**	**LEMD**	**MDSD**	**45617**	**40369**	**3,00%**
02/05/2014	**AEA051**	**LEMD**	**MUHA**	**56561**	**51849**	**-0,17%**
05/05/2014	AEA089	LEMD	MDSD	45583	42027	-0,70%
12/05/2014	AEA089	LEMD	MDSD	49195	43758	2,55%
12/05/2014	AEA071	LEMD	SVMI	51210	45816	2,03%
12/05/2014	AEA051	LEMD	MUHA	55049	N/A	--
13/05/2014	**AEA089**	**LEMD**	**MDSD**	**41741**	**37649**	**1,30%**
13/05/2014	**AEA051**	**LEMD**	**MUHA**	**55209**	**50450**	**0,12%**
15/05/2014	**AEA089**	**LEMD**	**MDSD**	**45246**	**41251**	**0,33%**
15/05/2014	**AEA071**	**LEMD**	**SVMI**	**53085**	**46251**	**4,37%**
16/05/2014	AEA089	LEMD	MDSD	42434	39120	-0,69%
16/05/2014	AEA051	LEMD	MUHA	52087	47017	1,23%
19/05/2014	**AEA089**	**LEMD**	**MDSD**	**46821**	**42898**	**-0,12%**
19/05/2014	**AEA071**	**LEMD**	**SVMI**	**51697**	**45019**	**4,42%**
20/05/2014	AEA089	LEMD	MDSD	47358	43614	-0,59%
20/05/2014	AEA033	LEMD	MDPC	49520	N/A	--
21/05/2014	AEA089	LEMD	MDSD	46902	41959	2,04%
21/05/2014	AEA071	LEMD	SVMI	49688	N/A	--
21/05/2014	**AEA051**	**LEMD**	**MUHA**	**50096**	**46636**	**-1,59%**
22/05/2014	AEA089	LEMD	MDSD	48009	N/A	--
22/05/2014	AEA071	LEMD	SVMI	50503	44918	2,56%
22/05/2014	AEA051	LEMD	MUHA	49330	N/A	--
22/05/2014	AEA011	LEMD	TJSJ	40396	36935	0,07%
23/05/2014	**AEA089**	**LEMD**	**MDSD**	**45951**	**41252**	**1,73%**
23/05/2014	**AEA063**	**LEMD**	**CUN**	**60970**	N/A	--
Fuel Consumption - Average Difference (All flights)						**1,30%**
Fuel Consumption - Average Difference (Optimised flights)						**1,40%**

Table 28: Comparison between Estimated and Actual Fuel Consumed per Flight

According to Table 28, the FOQA data is available for 32 flights from 39 (82% of the flights).

There was also an Eastbound traffic with optimizations done on the 6th of June, but due to the limitations with regards to the FOQA data download, it is not possible to analyse it.

The flights in bold in Table 28 refers to those that had En-route optimizations that were processed through the ICATS system. Those flights were processed with FUSA (a CRIDA Matlab tool) and apart from the total amount of fuel figure more information can be extracted as shown in the next figures:

- Figure 26: shows the actual fuel consumed (already corrected by a +8.5%) vs. the height of each aircraft with destination MDSD. the Figure shows the different FL changes done in each flight and the big differences in terms of fuel consumed. The average fuel consumed in those flights is around 4.500kg of fuel, however considering the best and worst cases, the difference between them is around 1000kg of fuel. The results shown in Figure 26 are aligned with the data detailed in Table 28.

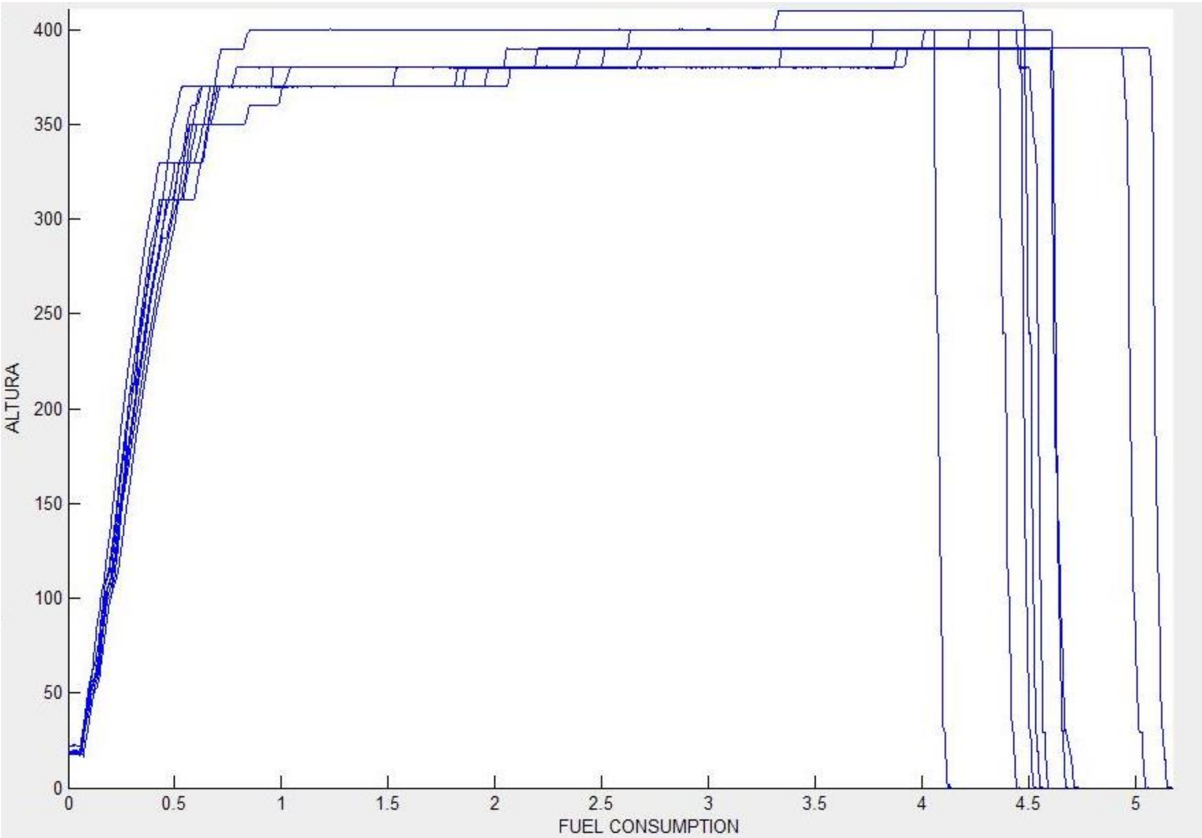


Figure 26: Fuel Consumption (Actual fuel corrected by a +8,5%) vs. Height for Optimised flights with Destination MDSD[8]

- Figure 27 shows for the flights origin LEMD and destination SVMI the initial route followed by the aircraft. It can be seen that the two of them exit the Spanish Airspace through Zamora Sector. This is something common for most of the flights involved in the trials. What can be concluded is that most of the AEA Oceanic flights leave the Spanish Airspace through Zamora sector and not through Santiago, as use to happen in flights to the US.

[8] In the y-axis when it says “Altura” it should say “Height”. The figure is automatically generated by FUSA and it is not possible to change it.

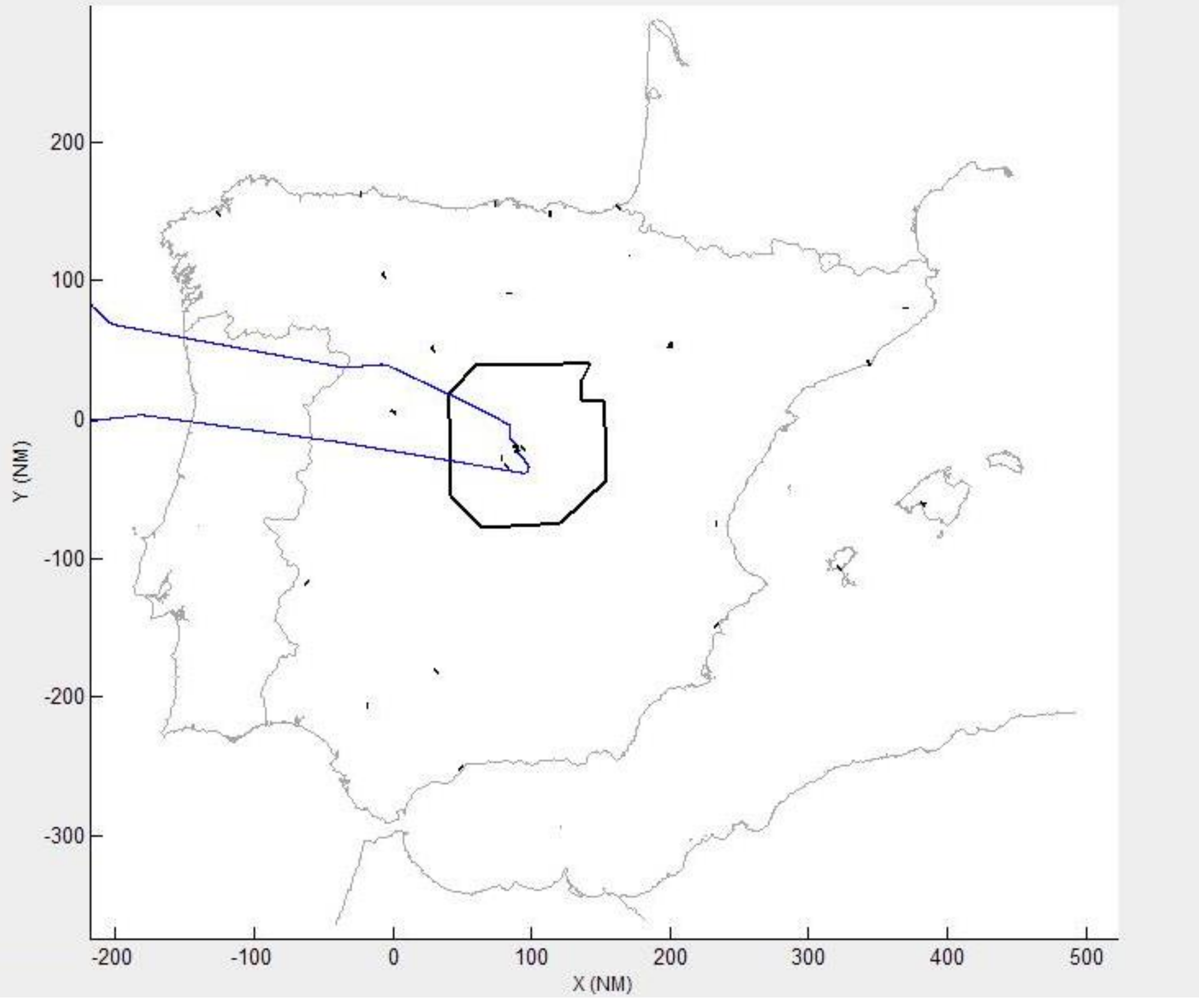


Figure 27: Map showing the first part of the trajectory for Optimised Flights with Destination SVMI

Other comparisons and representations can be obtained thanks to FUSA but they are out of the scope of this metric.

According to Table 11, the objective will be achieved if it provides a benefit higher than a 1% of fuel saving. However, the baseline scenario defined in section 6.1.2.2.1 for M04, the results from the ICATS trials should provide a benefit higher than a 1,31% of fuel saving.

Considering those two reference values, the average difference for all the flights involved in the trials is 1,30% a similar value than the one obtained in the baseline scenario.

However, **the average fuel saving considering only the optimised flights is of 1,40%.** This value is higher than the one defined by the objective success criteria and the one set by the baseline scenario.

In terms of absolute numbers, it can be said that for the optimised flights **the average fuel saved in Kg has been of 1107 Kg per flight**.

This means the M04 has been successfully achieved and thus the ICATS concept is been proved in terms of reduction of fuel consumption when the trajectory information is sharing across the system and among all the stakeholders at the same time.

6.1.3.1.3 M05 Results

M05 is fully aligned with M04, as the figure of the CO_2 emissions savings is calculated using a conversion factor from the fuel burnt.

There was also an Eastbound traffic with optimizations done on the 6th of June, but due to the limitations with regards to the FOQA data download, it is not possible to analyse it.

Section 6.1.2.2.1 presents the conversion factor defined by Eurocontrol: CO_2 = 3,149 Kg per Kg fuel and used in this project.

As M04 has been achieved, **M05 is also successfully achieved**. The ICATS concept is been proved in terms of CO_2 emissions reduction.

This means that for the flights who had optimizations during the ICATS trials, **the reduction of CO_2 emissions is of 1,40%** and thus, it is higher than the expected benefit (>1%) and higher than the figure defined in the baseline scenario (1,31%)

6.1.3.1.4 M06 Results

The ICATS consortium understand the M06 as the trajectories preferred by the Aircraft Operator that cannot be achieved to avoid loss of separations that ATC didn't anticipate due to lack of more accurate information and that might have been solved in a better way if information was available with much more time in advance (e.g. Sharing the FO)

There was one source of data to measure M06: the questionnaires distributed to Pilots, IOP Controllers and ATCO Controllers.

Results from Questionnaires

The questions distributed among the pilots and the controllers are described in section 0. Before presenting the analysis it is worthwhile to detail which questions referred to the M06:

- Pilot questionnaires: Question 7.
- IOP Controllers questionnaires: Questions 7 & 8.
- Operational Controllers questionnaires: Questions 5 to 7.

The answers to the questionnaires provide a qualitative way of measuring M06. As the questionnaires gathered the Pilots and Controllers (humans) viewpoint, the results may have a subjective component. In addition, as not all the controllers and pilots involved in the trials replied to the questionnaires, there might be some deviations regarding the results got from similar questions posed to pilots and controllers.

PILOT QUESTIONNAIRES RESULTS

Q7: From your point of view, how often did the controller facilitate the user preferred trajectory? (1=never, 5=always)

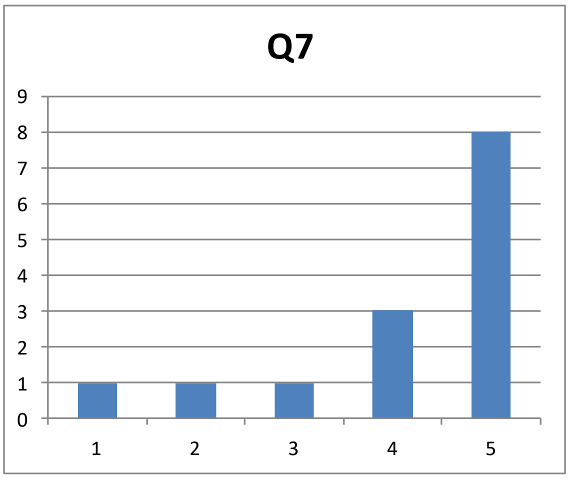


Figure 28: Answers from Pilots to Q7

Almost 80% of the pilots consulted agreed that the controllers facilitate always the user preferred trajectory.

According to the ICATS consortium understanding of this objective, the results presented in the graphic reflects that as most of the preferred trajectories have been facilitate, the tactical conflicts have been reduced.

IOP CONTROLLERS QUESTIONNAIRES RESULTS

Q7: The information you got from the IOP chain allowed you to facilitate the trajectories preferred by the Aircraft Operator (1=never, 5=always)

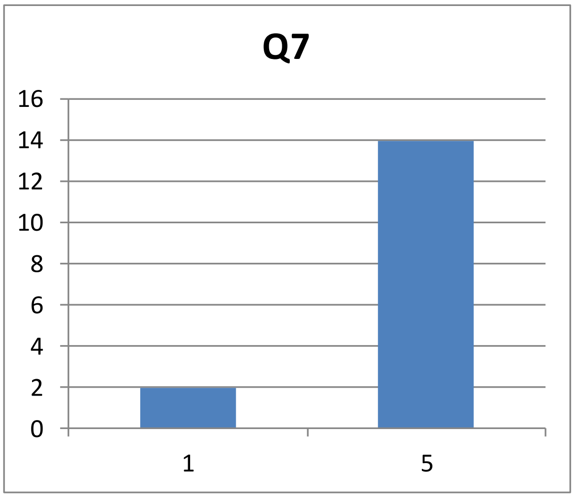


Figure 29: Answers from IOP Controllers to Q7

The answers to this question are totally aligned with the ones provided by the pilots in Q7. And the meaning is exactly the same: if the preferred trajectories are facilitate is because having the information much more in advance the possible tactical conflicts are minimised.

Q8: Did the IOP Chain provide you more accurate flight information much more in advance? (1=never, 5=always)

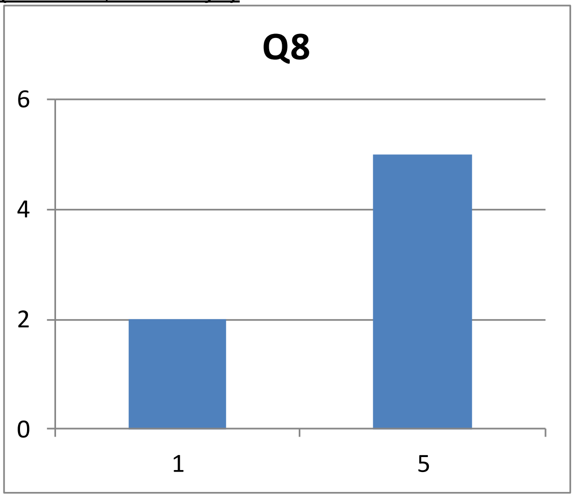


Figure 30: Answers from IOP Controllers to Q8

The answers given to this question fully depend on the ATC dependence of the IOP Controller. The KZNY controllers agreed that ICATS provide more accurate flight information, while the LPPO controllers' viewpoint is that they are able to provide the trajectories today using current methods.

The feeling expressed by the LPPO controllers was justified because of the data models they used and their way of working. They affirmed that any of the What-if proposals which were submitted through the IOP workstation could've been done at that time directly to the controller in the operational workstation and a clearance would've been issued right away.

However, after consulting KZNY controllers too, it seems that although the controllers have the option of receiving any proposal, the current system may produce a waste of controllers time when he/she should separating airplanes, and a waste of pilots time, when he/she should be flying the airplane. Having the data is a valuable tool keeping ATC out of any "guess game".

The fact that the trials were performed using a very limited number of flights, may have impacted the level and quality of the results.

OPERATIONAL CONTROLLERS QUESTIONNAIRES RESULTS

There was no feedback from Operational Controllers on the questionnaires.

The results from the questionnaires analysis do not allow a quantitative analysis, but leads to a qualitative positive result.

Most of the pilots and IOP controllers that answered the Safety-related questions agreed that during the ICATS trials the Operational Controllers tended to facilitate the user preferred trajectory.

According to the Operational Controllers involved in the project point of view, the results are aligned to the fact that when a controller knows in advance the trajectory information is usually able to solve the future tactical conflicts between two traffics. Consequently, they can facilitate the preferred trajectory in most cases.

Summing up, the number of tactical conflicts during the ICATS trials is reduced and thus the user preferred trajectories have been facilitated. However, it cannot be concluded if the M06 have been successfully achieved as there is not mean to measure the improvement.

6.1.3.1.5 Results per KPA

See Table 11.

6.1.3.1.6 Results impacting regulation and standardisation initiatives

N/A

6.1.3.1.7 Unexpected Behaviours/Results

The deviations from the plan are listed in section 4.1.3.

Regarding the results of the trials, it was expected to have a higher number of flights with trajectory optimizations, but it is true that there was no available figure as reference to know what could be expected

Regarding the analysis of the data collected, some assumptions were made as reflected in Table 29.

6.1.3.1.8 Quality of Demonstration Results

The quantitative analysis performed to measure results of the ICATS Project against numerical targets relies on a series of assumptions. These appear in Table 29 below. These assumptions were conservative in nature in order to minimise any impact on the quantitative results measured.

Identifier	Description	Justification	Flight Phase	KPA Impacted	Source	Value	Owner	Impact on Assessment	Issues
A-12	A correction factor of +8,5% will be applied to the amount of fuel burnt given by the FOQA data.	In the test phase, it was detected a divergence in the amount of fuel consumed between the FOQA data and the airline consumption of an 8,5%	NA	Fuel EFF	Agreem ent between Airline & CRIDA	+8,5%	ICATS CONSOR TIUM	VH	No
A-13	When calculating the amount of emissions, it is consider an CO_2 Emission Factor (Kg/Kg): 3,149	The total emissions are calculated applying a conversion factor to the amount of fuel burnt	NA	ENV	ECTL [2]	3,149	ECTL	L	No

Table 29: Quantitative Analysis Assumptions for Exercise 1

6.1.3.1.9 Significance of Demonstration Results

See section 5.5.2

6.1.4 Conclusions and recommendations

6.1.4.1 Conclusions

The Demonstration trials occurred during common days of operations without any impact of the operational controllers workload. The actors involved in the trials were the Flight Crew and the AOC on the Airline side and the Controllers in the IOP chain on the ANSP side.

The first conclusion that can be extracted is that the ICATS concept of operations to be validated in the Exercise 1 has been successfully validated, in spite of some issues regarding the data availability. The conclusions obtained from the analysis of the results are:

1. Thanks to the exchange of information between the two sides of the North-Atlantic (corresponding to two different ICAO Regions), the airlines are able to fly trajectories closer to their optimum profile with the benefits it causes:
    a. An average reduction of fuel consumption per flight of 1,40% between the plan fuel to be burnt and the actual fuel burnt. This result is over the today's operations saving and over the expected benefit identified in the project.
    b. A reduction of the CO_2 emissions per flight of 1,40% too. This result is over the today's operations saving and over the expected benefit identified in the project.
2. A second benefit of this information sharing is that the number of trajectory change requests demanded by the Flight Crew and rejected have been decreased by a 5% comparing with today's operations. The results have been obtained from the analysis of the Data Link communications provided by the Airline and by the ANSP and from the answers to the questionnaires distributed among pilots and controllers.
3. A global conclusion is that having the information much more time in advance, the controllers reduce their "guess" or "what-if" situations which may imply a higher confidence when making decisions. In addition, this will allow that the controllers facilitate the Airline desired trajectory in more cases than nowadays. This would cause a reduction on the tactical conflicts and thus, an improvement in Safety.
4. The Operational Controllers workload didn't increase due to the trials, as they were run in shadow mode.
5. The main benefits are Airline-oriented.

6.1.4.2 Recommendations

As expressed in section 5.5.3, the main recommendation would be to extend the trials in duration and number of airlines involved. In that case, the quantity of data would be higher and the representativeness of the results too.

A second recommendation for the future is to improve the accuracy of the Fuel Consumption data provided by the Airline. The analysis of the FOQA Data in terms of Fuel should be done enough time in advanced in order to check the accuracy of the data. In case, it is not accurate enough, an alternative should be found in order to minimise the impact of the assumption made in this study.

Other recommendations in terms of future initiatives and additional trials scope are detailed in section 8.2.

6.2 Demonstration Exercise #2 Report

6.2.1 Exercise Scope

6.2.1.1 Exercise Overview

Next table summarises the exercise information:

Demonstration Exercise ID and Title	**EXE-02.09-D-002: Exchange of information on Flight Departures, for improving predictability of traffic load**
Leading organization	AENA
Demonstration exercise objectives	Improvement of Capacity, Efficiency and Safety
High-level description of the Concept of Operations	Please see section 5.2.1.2 of Demonstration Plan for further details. The interchange through the IOP of flight objects containing updated information of all departing flights crossing the Atlantic Ocean will improve the quality of information for those kinds of flights in the ATC units of the other continent, which enhances their predictability.
Applicable Operational Context	En-route Oceanic flights through the North Atlantic Area.
Expected results per KPA	• M01: Improve the accuracy of sector load calculations by 15% of oceanic traffic • M02: Reduction on a 10% of Unexpected sector overload due to Oceanic traffic • M07 & M08: Improved predictability and accuracy of the entry times of cross-oceanic traffic which facilitates an early resolution of detected conflicts that will be determined by comparing the recorded operational data to the recorded IOP chain data.
Number of flight trials	More than 200 Oceanic flights entering into Madrid ACC from North and Central America were taken into account.
Partners Involved	**Operations:** AENA for capturing the data from ICATS HMI, and live ATM sources (PIV and CHMI) **Live data providers**: AENA, Nav-Portugal, Lockheed Martin **Infrastructure monitoring:** Lockheed Martin and Indra **Trials logs archiving:** CRIDA
Airspace/ATSUs involved	Madrid ACC entry sectors for Oceanic traffic

Table 30: Exercise EXE-02.09-D-002 Overview

6.2.1.2 Operational Concept

PREDICTABILITY OF TRAFFIC. Early sectorisation planning case (adjust ATC sectorisation)

The current ATM systems, which show workload in the different Flow Management Positions (FMP), calculate sector loading based either on aircraft takeoff estimated hour or on takeoff calculated hour for regulated flights. However, once an aircraft takes off and is detected by surveillance, the air traffic systems send a message updating the time calculated by the flow management (CFMU in Europe, TFMS in the US) system. Currently, for the air traffic coming from America, there are only a few notifications, and later, updates when the aircraft enters the European airspace area. For instance in Madrid ACC the first FIR entry time update information is provided not less than 90 minutes before the flight is predicted to enter the Spanish airspace, by reception of ABI messages from Santa Maria or Lisbon ACCs.

The use of the flight object (FO) allows knowledge of the position of the transatlantic traffic well in advance, with a real time of entry into the continental air space, in both directions of flight.

This provides a more accurate information which can be used to calculate what the workload will be, allowing appropriate actions for a specific sector, with enough lead time, to combine or to split sectors and even to include small changes on route to avoid regulations or restrictions.

Being able to more accurately predict the workload for a particular air space will allow a more efficient use of the air traffic controllers (ATCOs) on duty; at the same time, this will avoid unexpected overloads –with the associated safety risks-, as well as avoid airborne holding or inefficient flight movements requiring a lot of radar vectors. All tactical separation techniques increase carbon dioxide emissions due, simply, to the increase of flight time.

For measuring the benefits in predictability, flights entering Madrid airspace are monitored by comparing estimated entry time according to flight plan estimates versus actual times based on updated entry time provided by FO. This has been done for all traffic departing from American airports crossing New York and Santa Maria airspace flying to Madrid airspace (information provided by USA/Europe IOP chain). Note: The objective is to show how accurate the forecast based on the first and subsequent updates after taking off are to have an early planning of the sectors configuration.

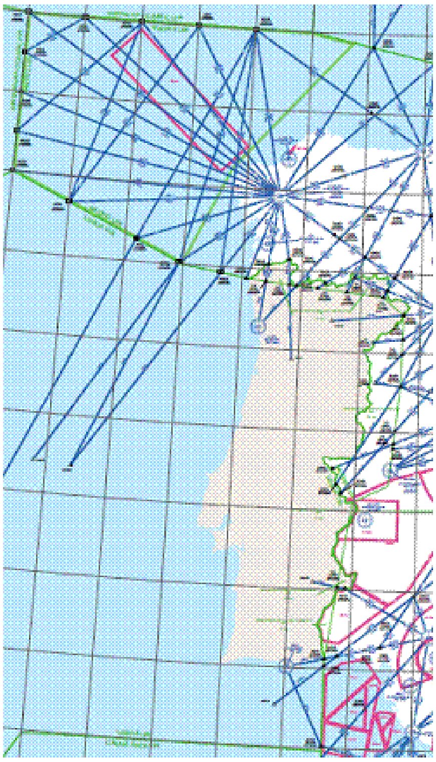


Figure 31: Entry Points to Madrid ACC from Lisbon and Santa Maria ACCs, involved in Exercise 2

6.2.2 Conduct of Demonstration Exercise EXE-02.09-D-002

6.2.2.1 Exercise Preparation

The configuration used is the same than the one used for Exercise 1, see 6.1.2.1.

6.2.2.2 Exercise execution

For performing the exercise, the following daily procedure was applied:

- The Infrastructure was restarted and the connection with the ATC live data sources established.
- MET data (actual and forecast) was loaded into the ICATS infrastructure.
- At 00:00, 02:00, 04:00, 06:00, 08:00, 10:00 UTC, Madrid ACC personnel downloaded the ATSU Entry times of all Eastbound flights, via the ICATS HMI Web. At the same time, the Flight Data and Flow Management personnel of the Madrid ACC captured the flight and Flow data from PIV and CHMI positions.
- The technical data was recorded and put to disposition for later analysis.

For further details, see section 5.2 of ICATS Operational Concept Document [4].

Callsign	ADEP	ADES	Stakeholder	EntryTime	ExitTime
IBE6346	MPTO	LEMD	SATL	16/05/2014 3 22	16/05/2014 6 31
IBE6346	MPTO	LEMD	LISB	16/05/2014 6 32	16/05/2014 7 28
IBE6346	MPTO	LEMD	SACT	16/05/2014 7 30	16/05/2014 7 55
AVA026	SKBO	LEMD	SATL	16/05/2014 0 27	16/05/2014 3 36
AVA026	SKBO	LEMD	LISB	16/05/2014 3 37	16/05/2014 4 32
AVA026	SKBO	LEMD	SACT	16/05/2014 4 32	16/05/2014 4 59
IBE6586	SKBO	LEMD	SATL	16/05/2014 3 30	16/05/2014 3 30
IBE6586	SKBO	LEMD	SATL	16/05/2014 3 32	16/05/2014 6 46
IBE6586	SKBO	LEMD	LISB	16/05/2014 6 48	16/05/2014 7 44
IBE6586	SKBO	LEMD	SACT	16/05/2014 7 44	16/05/2014 8 12
IBE6400	MMMX	LEMD	SATL	15/05/2014 23 56	16/05/2014 2 51
IBE6400	MMMX	LEMD	LISB	16/05/2014 2 52	16/05/2014 3 48
IBE6400	MMMX	LEMD	SACT	16/05/2014 3 48	16/05/2014 4 15
LPE2706	SPIM	LEMD	SATL	16/05/2014 6 28	16/05/2014 6 28
LPE2706	SPIM	LEMD	SATL	16/05/2014 6 30	16/05/2014 9 46
LPE2706	SPIM	LEMD	LISB	16/05/2014 9 47	16/05/2014 10 48
LPE2706	SPIM	LEMD	SACT	16/05/2014 10 48	16/05/2014 11 18
AEA052	MUHA	LEMD	SATL	16/05/2014 6 05	16/05/2014 9 06
AEA052	MUHA	LEMD	LISB	16/05/2014 9 07	16/05/2014 10 00
AEA052	MUHA	LEMD	SACT	16/05/2014 10 00	16/05/2014 10 23
AEA088	MDSD	LEMD	SATL	17/05/2014 2 30	17/05/2014 6 17
AEA088	MDSD	LEMD	LISB	17/05/2014 6 19	17/05/2014 7 28
AEA088	MDSD	LEMD	SACT	17/05/2014 7 28	17/05/2014 7 55
DAL109	LEMD	KATL	SACT	16/05/2014 9 09	16/05/2014 9 34
DAL109	LEMD	KATL	LISB	16/05/2014 9 35	16/05/2014 10 26
DAL109	LEMD	KATL	SATL	16/05/2014 10 28	16/05/2014 12 50
AAL69	LEMD	KMIA	SACT	16/05/2014 10 54	16/05/2014 11 19
AAL69	LEMD	KMIA	LISB	16/05/2014 11 20	16/05/2014 12 14
AAL69	LEMD	KMIA	SATL	16/05/2014 12 15	16/05/2014 14 33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ENTRY,ARCID,ATYP,ADEP,ADES,D,T,ARF,IOBT,U,E/CTOT,X,F,S,M,AT,A/TTOT,Delay,E/C/ATA,R,Opp,W,MSG,REGUL+,O,TI,EFL,TM,XFL,T
00:06A,TOM747,B738,GMMX,EGCC,,A,360,22:35,,22:45E,,N,I,,S,22:43 ,,01:59A,N,,N,,,,  ,360,  ,360,
01:03A,TOM479,B752,GMMX,EGKK,,A,380,23:10,,23:20E,,f,I,,S,23:34 ,,02:38A,N,,N,,,,  ,380,  ,380,
02:59A,ORB3501,B738,ULLI,LPPT,,A,360,23:15,,23:25E,,f,I,,S,23:28 ,,03:59A,N,,N,,,,  ,350,/,360,\
03:11E,SRR6646,B762,EDDK,LPPR,,I,380,01:40,,01:50E,,N,I,,S,     ,,04:02E,N,,A,,,,  ,370,\,245,\
03:54A,IBE6166,A333,KBOS,LEMD,,A,370,21:30,,21:50E,,f,I,,S,21:59 ,,04:31A,N,,N,,,,  ,370,  ,370,
03:56A,IBE6250,A333,KJFK,LEMD,,A,350,21:05,,21:40E,,f,I,,S,21:38 ,,04:35A,N,,N,,,,  ,350,  ,350,/
04:17E,TAY246C,B734,EBLG,LPPR,,I,350,02:44,,02:54E,,N,I,,S,     ,,04:57E,N,,A,,,,  ,350,\,245,\
04:32E,TUI9AC,B738,EDDF,GCFV,,I,370,02:45,,03:04E,,N,I,,C,03:04e,,07:04E,N,,A,,,,  ,370,  ,370,/
04:43E,TRA87U,B738,EHAM,LPFR,,I,390,03:05,,03:19E,,N,I,,S,     ,,05:55E,N,,A,,,,  ,390,  ,390,
04:47E,SXD2813,B738,EDDV,GCFV,,I,390,03:00,,03:05E,,N,I,,S,     ,,07:18E,N,,A,,,,  ,390,  ,390,
04:57A,IBE6274,A333,KORD,LEMD,,A,340,21:35,,22:00E,,N,I,,S,21:56 ,,05:39A,N,,N,,,,  ,340,  ,340,
05:02E,IBS3961,A320,LEVX,LEMD,,I,290,04:45,,04:50E,,N,I,,S,     ,,05:40E,N,,A,,,,/,245,/,290,/
05:09E,IBS3895,A320,LEST,LEMD,,I,290,04:45,,04:55E,,N,I,,S,     ,,05:46E,N,,A,,,,/,245,/,290,/
05:10E,TRA201,B738,EHAM,GCTS,,I,390,03:30,,03:44E,,N,I,,S,     ,,07:57E,N,,A,,,,  ,390,  ,390,
05:11E,AEA7232,E190,LECO,LEMD,,I,320,04:50,,04:55E,,N,I,,S,     ,,05:46E,N,,A,,,,/,245,/,320,
05:14E,VLG1293,A320,LECO,LEBL,,I,320,05:00,,05:05E,,N,I,,S,     ,,06:27E,N,,A,,,,/,216,/,320,
```


INDICATIVO	ORIG	DEST	IOBT	UOBT	ATOT	EOBT	ELDT	ALDT	HFIR	ESTADO
AAL112	KMIA	LEBL	22:15	22:15		22:15	07:13		05:30	PEN
AAL36	KDFW	LEMD	22:40	22:40		22:40	07:43		06:26	PEN
AAL66P	KJFK	LEBL	21:15	21:15		21:15	04:38		02:55	PEN
AAL68P	KMIA	LEMD	22:15	22:15		22:15	06:42		06:11	PEN
AAL94	KJFK	LEMD	22:50	22:50		22:50	06:04		04:44	PEN
AEA052	MUHA	LEMD	01:00	01:00		01:00	09:41		09:10	PEN
AEA088	MDSD	LEMD	00:15	00:15		00:15	07:50		07:18	PEN
AMX001	MMMX	LEMD	23:40	23:40		23:40	10:10		09:37	PEN
AWE740	KPHL	LEMD	22:40	22:40		22:40	05:48		04:31	PEN
AWE742	KPHL	LEBL	22:45	22:45		22:45	06:17		04:35	PEN
DAL108	KATL	LEMD	21:48	22:19		22:19	06:42		06:09	PEN
DAL114	KATL	LEBL	21:27	22:45		22:45	07:23		06:01	PEN
DAL414	KJFK	LEMD	23:27	23:27		23:27	06:41		06:09	PEN
DAL476	KJFK	LEBL	23:36	23:36		23:36	07:02		05:41	PEN
IBE6118	KMIA	LEMD	02:10	02:10		02:10	10:51		10:18	PEN
IBE6124	KMIA	LEMD	00:45	00:45		00:45	09:19		08:48	PEN
IBE6166	KBOS	LEMD	21:30	21:30		21:30	04:04		02:45	PEN
IBE6250	KJFK	LEMD	21:05	21:05		21:05	04:00		02:41	PEN
IBE6252	KJFK	LEMD	00:55	00:55		00:55	07:56		06:37	PEN
IBE6274	KORD	LEMD	21:35	21:56		21:56	05:52		04:33	PEN
IBE6314	MROC	LEMD	22:55	22:55		22:55	08:50		08:20	PEN
IBE6342	MSLP	LEMD	01:50	01:50		01:50	12:11		11:40	PEN
IBE6346	MPTO	LEMD	22:10	22:10		22:10	07:18		06:48	PEN
IBE6400	MMMX	LEMD	17:25	17:25		17:25	03:48		03:18	PEN
ROU1914	CYYZ	LEBL	00:25	00:25		00:25	07:45		06:22	PEN
UAL120	KEWR	LEBL	23:05	23:05		23:05	06:33		05:11	PEN
UAL62	KEWR	LEMD	00:25	00:25		00:25	07:29		06:24	PEN

Figure 32: Flight Entry data captured from ICATS, CHMI and PIV

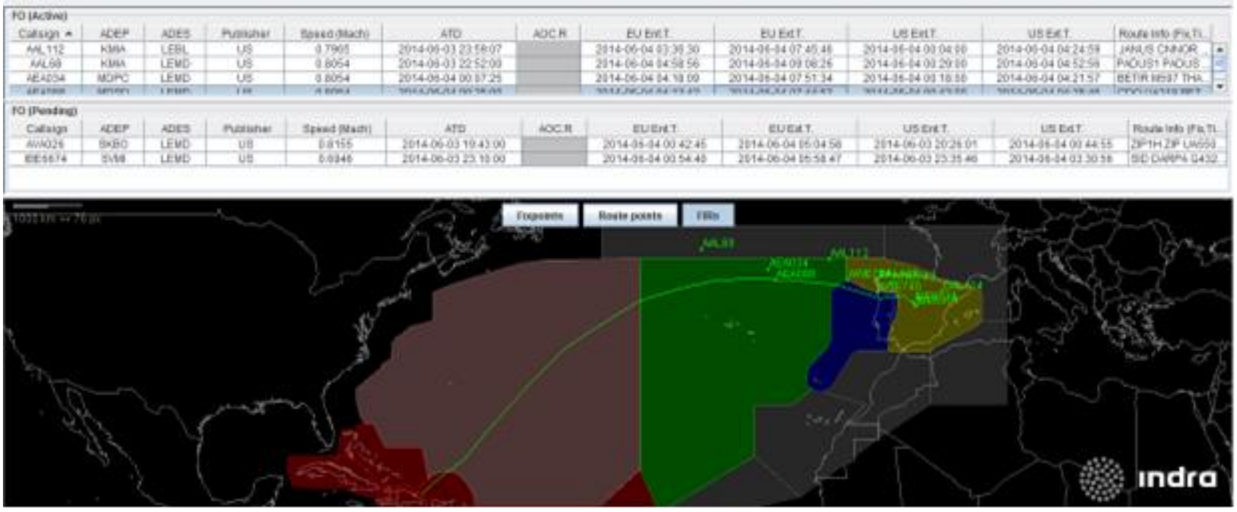

Figure 33: ICATS HMI showing the entry flights at Madrid ACC

6.2.2.3 Deviation from the planned activities

The deviation in the scope/execution of exercise 2 compared to the Plan were as follows:

1. No entry time was measured for Westbound flights as access to the Operational systems on the US side was not granted.
2. Additional flights (flights from South America) were taken into account in the exercise from the 22nd of May onwards, to have greater volume of flights for analysis,
3. For a few days of the exercise period It was not possible to perform the data capturing from ICATS Web HMI, due to technical unavailability of ICATS Web services. However, this was not a problem as there were available many days of logged data for analysis.
4. Some logged flights were discarded due they were not suitable for ICATS analysis (the flights flew via Gander/Shanwick airspace instead of New York/Santa Maria).
5. It was decided to discard some complete days of data logged, when the quantity of discarded flights per day was significant.

6.2.3 Exercise Results

6.2.3.1 Summary of Exercise Results

Before detailing the exercise results, some considerations regarding how the statistical analysis of the data has been done are listed below:

- Only one-hour intervals where sector load calculation from PIV and ICATS is different will be considered in the analysis. For exercise EXE-02.09-D-002 M01& M02, if there are no changes between PIV and ICATS sector load calculation no improvement can be measured.
- PIV and ICATS are considered different source of data. For exercise EXE-02.09-D-002 M01& M02, PIV is not updated with ICATS Server information but the information provided by each source is compared. The aim of the M01&M02 is not to evaluate in which specific cases ICATS data is more accurate than PIV data but compare both sources.
- In M02 analysis, all the differences of load-sector occupancy between PIV and ICATS has been considered, not only the overload cases. Actual levels of traffic very rarely cause an overload so the accuracy of the sector load occupancy is evaluate, not only when an overload occurs.

Taken into account the previous considerations, the following sections detail the analysis of results for the metrics belonging the Exercise 2.

6.2.3.1.1 M01 Results

The load-hourly sector entry rate is the number of aircraft predicted to enter the sector within one hour. A sliding window of one hour (without overlapping) has been considered to perform the analysis.

M01 expected benefit is to improve the accuracy of sector load calculations by 15% of oceanic traffic. Two sources of data are used to asses this improvement. The first one is the predicted entry rate provided by SACTA PIV at 00:00, 02:00, 04:00, 06:00, 08:00 and 10:00 UTC. The second one is the information provided by the ICATS Server at the same hours.

Both sources of data provide the estimated HFIR hour. Using the final flight plan from GIPV, the estimated entry time to each sector can be calculated (See 5.3.3).

Three En-Route sectors from Madrid ACC, Santiago (SAN), Asturias (ASI) and Zamora (ZMI) are considered in the analysis.

The improvement of the sector load calculations is only considered regarding oceanic flights since only oceanic flights estimated entry times are sensitive to improve due to the ICATS operational procedure. This means that the sector load refers only to oceanic flights (those flights departing from "K","C" or "M" and arriving "LE" and "LI").

For each day, sector, sliding window (00:00-01:00,01:00-02:00,…) and PIV call (00:00; 02:00, 04:00, 06:00, 08:00, 10:00 UTC) the following data are collected:

- Number of oceanic flights predicted to enter the sector from the call time onwards using PIV data.
- Number of oceanic flights predicted to enter the sector from the call time onwards using ICATS HMI data.
- Number of oceanic flights that entered to the sector during real day operation obtained from GIPV (Real).
- Absolute value of the difference between PIV forecast and real traffic; ABS(Real-PIV).
- Absolute value of the difference between ICATS Server forecast and real traffic; ABS(Real-ICATS).

If the number of oceanic flights predicted to enter the sector using PIV and ICATS data is equal for a one-hour window, it is not possible to analyse if there is an improvement in sector load calculation.

Only hourly intervals where ICATS introduces a change in the number of predicted traffic entering the sector will be considered in the analysis of M01.This does not mean that ICATS does not modify the estimated HFIR entry hour of any flights but the number of flights entering the sector in an hour remains unchanged.

When the difference between real and forecast traffic is smaller using the ICATS server than using PIV information, it can be considered that there is an improvement in the accuracy of the sector load. M01 is evaluated using the following metric:

$$M01\ Improvement\ of\ accuracy = \frac{ABS(Real - PIV) - ABS(Real - ICATS)}{ABS(Real - PIV)}$$

The difference between $ABS(Real - PIV) - ABS(Real - ICATS)$ is not calculated over the real number of flights in the sector because this number is equal to zero in some cases.

For each day, sector, sliding window (00:00-01:00, 01:00-02:00,…) and PIV call the following data are calculated:

- Number of one-hour sliding windows where ICATS forecast is different from PIV forecast.
- Number of one-hour sliding windows where ICATS forecast is better than PIV forecast.
- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS provides a better forecast than PIV.
- Improvement of the accuracy of sector load calculation for each sliding window.
- Number of one-hour sliding windows where ICATS forecast is worse than PIV forecast.

- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS provides a forecast worse than PIV.
- Number of one-hour sliding windows where ICATS forecast is better than PIV forecast and the improvement is bigger than a 15% (objective target)
- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS accuracy improvement is bigger than a 15%.
- Mean value of the improvement of the accuracy of sector load per day/sector/PIV call.
- Standard deviation of the improvement of the accuracy of sector load per day/sector/PIV call.

Table 31 shows an example of the values obtained on May, 31th in sector ZMI and PIV calls at 00:00,02:00 and 04:00.

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	μ of the improvement of the accuracy	σ of the improvement of the accuracy
31/05/2014	0:00	5	3	60%	2	40%	3	60%	61,1	34,7
31/05/2014	2:00	5	1	20%	4	80%	1	20%	33,3	
31/05/2014	4:00	5	2	40%	3	60%	2	40%	75,0	35,4

Table 31: M01 values for May, 31th at 00:00,02:00 and 04:00 PIV calls.

Appendix C includes a detailed table with all the values calculated for each day sector and PIV call.

Table 32 shows the global results of M01.

	M01		
	SECTOR		
	SAN	ZMI	ASI
% Hours where ICATS improves the accuracy of sector load (of the number of hours where ICATS and PIV forecasts are different)	51%	43%	46%
% Hours where ICATS improves the accuracy of sector load more than 15% (of the number of hours where ICATS improves the accuracy of sector load)	100%	100%	98%
Mean value of the improvement of the accuracy	72,73	79,19	54,50
Mean value of the standard deviation of the improvement of the accuracy	16,19	21,60	27,83
% Hours where ICATS forecast is worse than PIV	44%	51%	48%

Table 32: Global results for M01.

Appendix C contains a similar table detailing these data for each day of trials.

When ICATS forecast is better than PIV forecast, the improvement in the accuracy of sector load calculations by oceanic traffic reaches the target objective of a 15% for almost all the sliding one-hour window analysed (for ASI sector, the 98% of the hours reached the objective.)

However, ICATS forecast is only better than PIV forecast in around 47% of the sliding windows analysed. Moreover, the number of hours where ICATS forecast is worse than PIV is similar to the number of hours where ICATS forecast improves PIV calculations (48%). The ICATS forecast being worse than the PIV one, means that the estimated HFIR calculated by ICATS are far from the Actual HFIR given by GIPV than the estimated HFIR calculated by PIV. This means that the ICATS HMI would not improve the current systems situational awareness.

This result has been influenced by the following issues.

- PIV information is not "updated" with the information received form ICATS Server for each call and flight. ICATS and PIV are considerer different sources of data and we are evaluating the differences in the sector load calculation in each system.
- PIV oceanic flights are obtained by filtering the complete list of flights predicted to enter the sector for each PIV call.
- ICATS Server provides a list of oceanic flights for each call. However, not all flights in this list have an estimated HFIR. The HFIR data can be empty due to different reasons (technical problems, the HFIR has not changed from the last call but the last known HFIR value is not maintained…). For each call, if the HFIR is empty, the flight is not taken into account in the sector load calculation. This means that a flight that enters to a sector at 06:30 can "appear" at 02:00 call, "disappear" in 04:00 call (because the HFIR data is empty) and the same flight can "appear" again in 06:00 call. In this example, this flight should show an HFIR hour at 02:00, 04:00 and 06:00 because the flight is in the system from 02:00 call but has not enter the FIR before 06.00. The impact of this is that the number of flights to be taken into account may vary when it should not.
- The ICATS sector load calculation is strongly influenced by the quality (gaps of data and accuracy of the existent data) of the data from the ICATS Server.

6.2.3.1.2 M02 Results

The load-sector occupancy is the number of aircraft predicted to be in the sector within one hour. A sliding window of one hour (without overlapping) has been considered to perform the analysis.

M02 expected benefit is to reduce on a 10% unexpected sector overloads due to oceanic traffic. Current levels of traffic very rarely produce an overload in integrated sectors. For this reason, M02 will measure the accuracy of sector load occupancy not only when PIV forecast produced an overload but also when PIV forecast is exceeded (PIV forecast was bigger than real traffic was).

Two sources of data are used to asses this improvement. The first one is the predicted sector occupancy from SACTA PIV at 00:00, 02:00, 04:00, 06:00, 08:00 and 10:00 UTC. The second one is the information provided by the ICATS Server at the same hours.

Both sources of data provide the estimated HFIR time. Using the final flight plan from GIPV, the estimated entry and exit time to each sector can be calculated (See 5.3.3). Using the entry and exit time it is easy to calculate how many aircrafts will be in a sector in an hour.

As in M01, three En-Route sectors from Madrid ACC, Santiago (SAN), Asturias (ASI) and Zamora (ZMI) are considered in the analysis.

The improvement of the sector load occupancy only considers oceanic flights for the same reason explained for M01.

For each day, sector, sliding window (00:00-01:00,01:00-02:00,…) and PIV call (00:00; 02:00, 04:00, 06:00, 08:00, 10:00 UTC) the following data are collected:

- Number of oceanic flights predicted to be in the sector from the call time onwards using PIV data.
- Number of oceanic flights predicted to be in the sector from the call time onwards using ICATS HMI data.
- Number of oceanic flights that were in the sector during real day operation obtained from GIPV (Real).
- Absolute value of the difference between PIV forecast and real traffic; ABS(Real-PIV).
- Absolute value of the difference between ICATS Server forecast and real traffic; ABS(Real-ICATS).

If the number of oceanic flights predicted to be in the sector using PIV and ICATS data is equal for a one-hour window, it is not possible to analyse if there is an improvement.

Only hourly intervals where ICATS introduces a change in the number of flights that will be in the sector will be considered in the analysis of M02. This does not mean that ICATS does not modify the estimated entry hour of any flights but the number of flights that are in the sector in that window remains unchanged.

When the difference between real and forecast traffic is smaller using the ICATS server than using PIV information, it can be consider that there is an improvement in the accuracy of the sector occupancy. M02 is evaluated using the following metric:

$$M02\ Occupancy\ accuracy\ improvement = \frac{ABS(Real - PIV) - ABS(Real - ICATS)}{ABS(Real - PIV)}$$

The difference between $ABS(Real - PIV) - ABS(Real - ICATS)$ is not calculated over the real number of flights in the sector because this number is equal to zero in some cases.

Similar to M01, for each day, sector, sliding window (00:00-01:00, 01:00-02:00,…) and PIV call the following data are calculated:

- Number of one-hour sliding windows where ICATS forecast is different from PIV forecast.
- Number of one-hour sliding windows where ICATS forecast is better than PIV forecast.
- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS provides a better forecast for the occupancy than PIV.
- Improvement of the accuracy of sector load occupancy for each sliding window.
- Number of one-hour sliding windows where ICATS forecast is worse than PIV forecast.
- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS provides a forecast worse than PIV.
- Number of one-hour sliding windows where ICATS forecast is better than PIV forecast and the improvement is bigger than a 10% (objective target).
- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS accuracy improvement is bigger than a 10%.
- Mean value of the improvement of the accuracy of sector occupancy per day/sector/PIV call.
- Standard deviation of the improvement of the accuracy of sector occupancy per day/sector/PIV call.

Table 33 shows an example of the values obtained on May, 31th in sector ZMI and PIV calls at 00:00,02:00 and 04:00.

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	µ of the improvement of the accuracy	σ of the improvement of the accuracy
31/05/2014	0:00	7	3	43%	4	57%	3	43%	100,0	0,0
31/05/2014	2:00	6	1	17%	4	67%	1	17%	50,0	NA
31/05/2014	4:00	5	1	20%	4	80%	1	20%	100,0	NA[9]

Table 33: M02 values for May, 31th at 00:00,02:00 and 04:00 PIV calls.

Appendix D includes a detailed table with all the values calculated for each day sector and PIV call.

[9] Mean value of the standard deviation is calculated using the results of the standard deviation of each day and PIV call. For this day, a maximum of one window improves its accuracy so it is not possible to calculate the standard deviation.

Table 34 shows the global results of M02.

	M02		
	SECTOR		
	SAN	ZMI	ASI
% Hours where ICATS improves sector load occupancy	51%	44%	52%
% Hours where ICATS improves sector load occupancy more than 10% (of the number of hours where ICATS improves the sector load occupancy)	100%	100%	100%
% Hours where ICATS forecast is worse than PIV	44%	50%	41%
Mean value of the improvement of the sector load occupancy	70	73	62
Mean value of the standard deviation of the improvement of the sector load occupancy	22,51	20,21	30,51

Table 34: Global results for M02

Appendix D contains a similar table detailing these data for each day of trials

Results from M02 present the same behaviour as M01. For the sliding windows where ICATS forecast of the occupancy is better than then PIV forecast, the improvement of the accuracy exceeds the target objective. However, ICATS forecast is only better than PIV in around 49% of the cases. In addition, in sector ZMI the number of sliding windows where ICATS forecast is worse than PIV is bigger than the number of windows where ICATS improves the occupancy.

Data show that it is possible to obtain an improvement bigger than 10%. However, the number of cases where ICATS seems to be worse than PIV is high enough to consider the M02 objective as not reached.

6.2.3.1.3 2nd Analysis for M01 & M02

Looking at the results obtained for both indicators, M01 (Sector Load) and M02 (Occupancy), it was decided to investigate a second option analysing the data obtained from the SACTA-PIV and ICATS HMI Systems.

The new approach followed was to keep the last entry time (HFIR) provided by ICATS HMI when there is a gap in the data obtained from that system. The aim is to minimise the number of gaps (in terms of missed HFIR) existing in the first analysis done described in sections 6.2.3.1.1 and 6.2.3.1.2.

Regarding the PIV data, the same approach as identified in sections 6.2.3.1.1 and 6.2.3.1.2 is followed. The metrics used and the calculations done are also the same.

The following tables summarise the results obtained in this second analysis.

	M01		
	SECTOR		
	SAN	ZMI	ASI
% Hours where ICATS improves the accuracy of sector load (of the number of hours where ICATS and PIV forecasts are different)	46%	43%	48%
% Hours where ICATS improves the accuracy of sector load more than 15% (of the number of hours where ICATS improves the accuracy of sector load)	100%	99%	98%
Mean value of the improvement of the accuracy	70,58	75,41	54,98
Mean value of the standard deviation of the improvement of the accuracy	20,30	20,93	23,97
% Hours where ICATS forecast is worse than PIV	47%	51%	45%

Table 35: Global Results for M01 - 2nd Analysis

	M02		
	SECTOR		
	SAN	ZMI	ASI
% Hours where ICATS improves sector load occupancy	55%	45%	53%
% Hours where ICATS improves sector load occupancy more than 10% (of the number of hours where ICATS improves the sector load occupancy)	100%	100%	100%
% Hours where ICATS forecast is worse than PIV	41%	48%	40%
Mean value of the improvement of the sector load occupancy	65	72	70
Mean value of the standard deviation of the improvement of the sector load occupancy	20,46	17,51	31,80

Table 36: Global Results for M02 - 2nd Analysis

The results obtained for M01 in the second analysis show a worse behaviour regarding the % of hours where ICATS improves the accuracy of sector load comparing with the results obtained in the first analysis (46% vs. 49%). The % of hours where ICATS forecast is worse than PIV is similar (47% vs. 48%).

The results obtained for M02 in the second analysis are slightly better than the ones obtained in the first analysis. The % of hours where ICATS improves the sector occupancy is better now than in the previous analysis (51% vs. 49%). The % of hours where ICATS forecast is worse is also slightly reduced (43% vs. 45%).

The fact that the differences between the two analysis are so small, drives to the conclusion that the option of keeping the latest ICATS HFIR available to avoid the gaps has no impact on the results. This means that the previous ICATS HFIR introduces a similar uncertainty than having a gap. In other words, for the cases where ICATS HMI data has a gap, the previous HFIR is not accurate enough compared with the HFIR given by SACTA-PIV.

6.2.3.1.4 M07 & M08 Results

The data used for the analysis of these metrics has been obtained from three sources:

- PIV (Flight Data Position).
- ICATS HMI.
- GIPV (Flight Plan Information Manager).

Before starting with the analysis of the results it is worth to highlight the following points considered for the analysis:

- In the analysis of M07 and M08, only those values of HFIR with positive predictability has been considered, i.e. those whose log time is previous to their FIR estimated entry time. This is because the HFIR that are interesting for the study are those received by the system while the flight is not yet inside the FIR.
- For the analysis, only the flights with a value in the two systems (PIV and ICATS HMI) are taken into consideration. To make a good analysis of the data being able to compare what both systems are given, it is necessary to have the same amount of data in the two systems.

<u>PREDICTATIBILITY DEFINITION</u>

The *Predictability* indicator is defined as the difference between the time at which is recorded the information (00:00; 02:00; 04:00; 06:00; 08:00; 10:00) and the FIR entering time (HFIR) indicated in PIV or ICATS HMI for each call.

$$Predictability = (HFIR)_{\substack{in\ each\\ call}} - (Log\ time)_{\substack{in\ each\\ call}}$$

This indicator measures, for both PIV and ICATS HMI systems the anticipation with which we may know the HFIR, respect to the time at which the call (log time) was made.

<u>ACCURACY DEFINITION</u>

On the other hand, the *Accuracy* indicator is defined as the difference between the indicated FIR entering time (HFIR) for a flight included in PIV or ICATS HMI systems, and the actual FIR entering time (HFIR), obtained from post-flight information (GIPV):

$$Accuracy = (HFIR)_{\substack{in\ each\\ record}} - (HFIR)_{actual}$$

This indicator gives us a valuable measure of how precise the information in the PIV system and in the ICATS HMI system was on the light of real behavior of the flight. When the difference is negative it means that the flight entrance to the FIR was delayed from what was initially planned in PIV or ICATS HMI systems; it has been decided not using absolute values for better illustration of the system way of working.

The results obtained for M07 and M08 metrics are shown hereafter in form of a set of graphics which represents the predictability and accuracy analysis done for the data collected during all the days of trials at the 00:00 call. The analysis results for the rest of the calls was included in the Appendix E in order to avoid so many graphics in the main body of the document. However, what was added is a summary of the total results obtained for all the flight data in each call. This summary is given in a table format. See Table 37.

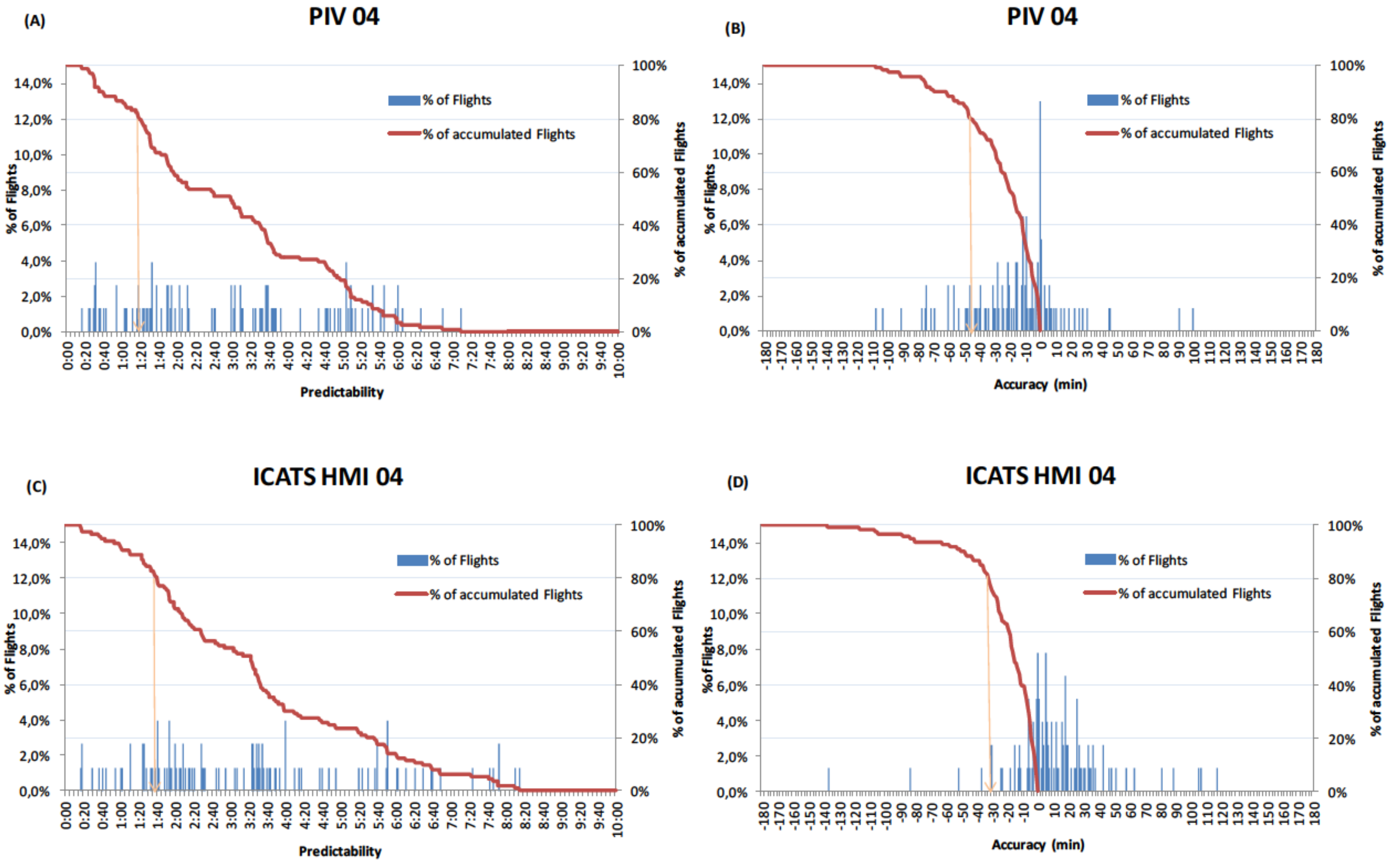

Figure 34:(A) Distribution of predictability (in hours) for PIV´s call made at 04. (B) Distribution of accuracy for PIV´s call made at 04. (C) Distribution of predictability (in hours) for ICATS HMI´s call made at 04. (D) Distribution of accuracy for ICATS HMI´s call made at 04.

Figure 34 shows the analysis for predictability and accuracy of the two systems to the call made at 04:00 hours. Every graph contains a vertical orangey arrow, indicating the 80% value of accumulated flights, which has been considered as a representative value.

- For predictability graphs, Figure 34(A) and Figure 34(C), it can be observed that the values for the predictability for ICATS HMI system is a slightly better than the predictability for the PIV system, as the 80% of accumulated flights in ICATS HMI is slightly larger than the value for the PIV (1:21 hours of anticipation for ICATS HMI versus 1:41 hours for PIV).
- Regarding accuracy graphs, it can be observed, Figure 34(B) and Figure 34(D), that the 80% of accumulated flights in ICATS HMI, 33 minutes, is around 13 minutes better than the value for PIV system, 46 minutes. This means that for the call made at 04:00 hours ICATS HMI is more accurate than PIV. Observation of the histogram shapes also shows that ICATS HMI flights are more right-shifted on the graph (positive values), meaning that typically flights tend to anticipate their entrance to the FIR, while PIV flights tend to delay their entrance to the FIR (left-shifted histogram shape of the graph). Both effects have and obvious impact on the system.

Table 37 shows all the data collected from the graphics included in the Appendix E:

Summary Table		00:00		02:00		04:00		06:00		08:00		10:00	
Metric	% of accumulated Flights	PIV	ICATS HMI	PIV	ICATS HMI	PIV	ICATS HMI	PIV	ICATS HMI	PIV	ICATS HMI	PIV	ICATS HMI
Predictability (hours)	80%	4:10	4:05	2:38	2:59	1:21	1:41	1:14	1:29	0:35	0:58	0:24	0:39
	50%	5:21	5:58	3:54	4:30	2:59	3:13	2:38	2:38	1:37	2:39	1:23	1:25
Accuracy (min)	80%	42	57	39	42	46	33	45	45	25	20	19	11
	50%	24	26	21	20	18	16	18	14	11	7	5	7

Table 37: Summary of all data recollected for metrics M07 and M08.

With the results shown in Table 37, if a comparison between PIV and ICATS HMI results is made it can be seen that ICATS HMI is slightly more predictable than PIV for the calls taken at 2:00, 4:00, 6:00, 8:00, 10:00 (5 of 6 calls).

Regarding accuracy, and considering the results in Table 37, it can be said that the ICATS HMI is slightly more accurate (or equal in some case) than PIV for the calls taken at 4:00, 6:00, 8:00, 10:00 (4 of 6 calls).

Table 38 shows the improvement of ICATS HMI, in percentage, with regards to PIV.

	% of accumulated Flights	00:00	02:00	04:00	06:00	08:00	10:00
Predictability % improvement against PIV	80%	-2%	13%	25%	20%	66%	63%
	50%	12%	15%	8%	0%	64%	2%
Accuracy % improvement against PIV	80%	-36%	-8%	28%	0%	20%	42%
	50%	-8%	5%	11%	22%	37%	-40%

Table 38: % of improvement.

Table 38 and Table 39 also includes the information related to the 50% of accumulated flights. This information shows that ICATS HMI reached the 50% with more anticipation than PIV in all the cases. Accuracy also improved, for the 50%, however PIV is more accurate than ICATS HMI at 00:00 and 10:00. This behaviour may be explained due to in most of the cases at 00:00 the flight ID was not in the ICATS HMI system because the aircraft had not yet taken off. On the other hand, at 10:00 the HFIR given by PIV is in almost cases the actual entry time.

6.2.3.1.5 Results per KPA

See Table 12.

6.2.3.1.6 Results impacting regulation and standardisation initiatives

N/A

6.2.3.1.7 Unexpected Behaviours/Results

Some issues are listed at the beginning of section 6.2.3.1.

6.2.3.1.8 Quality of Demonstration Results

Some considerations are needed to understand how the analysis of the results of the Exercise 2 has been done:

- Only one-hour intervals where sector load calculation from PIV and ICATS is different will be considered in the analysis. For exercise EXE-02.09-D-002 M01& M02, if there is no change between PIV and ICATS sector load calculation no improvement can be measured.
- PIV and ICATS are considered different source of data. For exercise EXE-02.09-D-002 M01 & M02, PIV is not updated with ICATS Server information but the information provided by each source is compared. The aim of the M01 & M02 is not to evaluate in which specific cases ICATS data is more accurate than PIV data but compare both sources.
- In M02 analysis, all the differences of load-sector occupancy between PIV and ICATS has been considered, not only the overload cases. Actual levels of traffic very rarely causes an overload so the accuracy of the sector load occupancy is evaluate, not only when an overload occurs.
- Taking the last message of each flight from GIPV, it can be obtained the crossing time per sector for each individual flight. This will allow counting how many flights are in each hour in each sector. PIV and ICATS only provides the HFIR to the Spanish airspace but not the entry time in each of the sector to be analysed. Thanks to the GIPV information, the Entry time to each sector can be calculated.
- Two analysis have been performed to analyse the data obtained for M01 & M02. The first one took the information provided by SACTA-PIV and ICATS HMI as it was. The second analysis, covered the existing HFIR gaps in some calls of the ICATS HMI data with the latest HFIR available corresponding to the previous call. The results presented in section 6.2.3.1.3 shows that the impact of the second approach in the final results is minor.

Also some quantitative analysis assumptions were made:

Identifier	Description	Justification	Flight Phase	KPA Impacted	Source	Value	Owner	Impact on Assessment	Issues
A-14	It is assumed that only the days with at least 70% of the ICATS HMI flights considered as corrected are analysed.	There were some issues at the beginning of the Scenario 2 trials due to technical problems in the ICATS HMI. In order to avoid the possible impact it may have on the results, only the days presented a higher level of representativeness are considered.	NA	NA	ICATS HMI	NA	CRIDA & INDRA	L	No

Table 39: Quantitative Analysis Assumptions for Exercise 2

6.2.3.1.9 Significance of Demonstration Results

Table 40 shows the data collected for each of the calls, in all the days suitable for the analysis. It can be seen that as you progress through the call time, the number of collected data decreases, this is because most of the oceanic flights available enter the Spanish airspace between 4:00 and 8:00 UTC. Also in this table we can appreciate the number of useable data and discarded data we have for each call.

	00:00	02:00	04:00	06:00	08:00	10:00
Total data collected	215	215	204	164	103	54
Useable data	78	119	119	77	21	16
Negative predictability[10]	1	0	9	47	42	24
Discarded data[11]	136	96	79	40	40	14

Table 40: Total data collected useable data and data discarded.

The following table shows the discarded data, broken down by the system that caused it.

	00:00	02:00	04:00	06:00	08:00	10:00
PIV	17	25	12	1	6	0
ICATS HMI	75	65	64	38	24	14
PIV & ICATS HMI	44	6	3	1	10	0
Total data discarded	136	96	79	40	40	14

Table 41: System by which the data were discarded.

As shown in Table 41, the system that caused most discards was ICATS HMI. On average, data discarded by HMI ICATS account for 28% to the total of the data collected for each call. The causes that led to these discards are due to:

- the excel files that were recorded were empty to certain calls,
- the flights did not appear in a certain call but later appeared
- or the call was not made at that time for any of the systems.

6.2.4 Conclusions and recommendations

6.2.4.1 Conclusions

Results regarding if ICATS Server really provides an improvement in sector load accuracy cannot be considered concluding enough. When ICATS entry rate is more accurate than PIV information, the improvement on accuracy is bigger than the initial objective. However, the number of analysed windows where ICATS information is less accurate than PIV information is similar to the ones in which ICATS shows an improvement.

[10] Refers to section 0 - list of points to be considered before starting the analysis
[11] Refers to section 0 - list of points to be considered before starting the analysis

If ICATS information (estimated HFIR) substitutes completely the information of the oceanic flights in PIV, global results of the sector load calculations will not show a global improvement. For this reason, M01 has been considered as partially reached.

This conclusion does not imply that ICATS Operational Concept is not able to improve the accuracy of sector load calculations but data quality from ICATS Server and the assumptions taken in the analysis do not allow obtaining concluding outcomes. In fact, when ICATS provides accurate data the improvement in the accuracy of sector load calculation is quite high (around 68.8%).

Results from M07 and M08 support this conclusion. In the analysis of M07 and M08, only flights with a value in the two systems (PIV and ICATS HMI) are taken into consideration. This means that the effect that empty data have in the analysis of M01 (and M02) disappeared here. Without this effect, ICATS shows an improvement in the predictability and accuracy of the estimated HFIR. This outcome seems coherent with the improvement in the sector load accuracy for several windows.

It would be necessary to isolate the effect of empty data or correct it (for example, maintaining the last HFIR available in the ICATS Server when there are no changes in the estimated HFIR) to quantify ICATS improvement in sector load calculations.

Results from M02 are similar to M01 ones. When ICATS forecast improves PIV calculations, the improvement is bigger than the initial target of a 10%. However, the number of hours where ICATS forecast is worse than PIV is similar to the number of hours where ICATS introduces an improvement in a sector. For this reason, M02 has been considered as partially reached.

Assumptions regarding missing HFIR data from ICATS Server in some calls were applied in the assessment of M02 too. This makes that the conclusions and data obtained from M02 cannot be consider concluding. The same issues detailed in the previous paragraph should be solved in order to assess the real improvement in sector load occupancy provided by ICATS.

In an attempt to minimise the impact of the missing ICATS data, a second analysis was done, filling the gaps of ICATS data with the previous HFIR given by the system in the previous call. As shown in 6.2.3.1.3 this analysis represented no significant improvement of the metrics M01 and M02.

An explanation for the similar behavior of M01 and M02 in the two different analysis done may be explained due to the few updates received per flight ID (in the best case, 5). A bigger number of instantiations would made more accurate the results.

In terms of predictability and accuracy (metrics M07 and M08) ICATS shows to be more predictable and accurate than PIV. ICATS predictability results to be better than PIV in 5 of the 6 calls. Accuracy improves in 4 of the 6 calls. It is true that these improvements are not very large, but an average of 18 minutes in predictability and an average of 8 minutes in accuracy will introduce an improvement in nowadays calculations. In summary, if we consider predictability and accuracy together we can conclude that ICATS HMI is better than PIV, for the calls made at: 04:00, 06:00, 08:00, 10:00 because of predictability is always larger and the accuracy is better or equal. More anticipation time and increased accuracy will allow specific measured to be taken in advance to optimise sector workload.

Results from M07 and M08 are not directly impacted by the missing data from ICATS Server (see initial considerations given in section 6.2.3.1.4). Only flights with available data in both systems are used when calculating M07 and M08. This allows to confirm that ICATS introduces an improvement when data from ICATS Server is recorded properly.

The higher impact of ICATS occurs in sector ZMI. ICATS improved the sector load forecast in a total of 268 sliding windows. A 60% of these windows correspond to ZMI sector, 19% to ASI and 21% to sector SAN. Occupancy calculation modifications have the biggest impact on sector ZMI too. A total of 325 sliding windows show an improvement in the occupancy values. 54% of them belongs to ZMI, 21% to ASI and 25% to SAN.

Something similar occurs if we take the second analysis. *F*or the sector load forecast 265 sliding windows are improved, 61% of these windows correspond to ZMI sector, 19% to sector ASI and 20% to sector SAN. Regarding occupancy the number of sliding windows that shown an improvement is 328, 55% of them belongs to ZMI, 20% to ASI and 25% to SAN".

6.2.4.2 Recommendations

In order to eliminate the impact of the quality of the data in the assessment of M01 and M02 the next approach could be followed:

Instead of considering PIV and ICATS Server as independent source of data, the information of both sources could be integrated. For each call, the estimated HFIR available at ICATS Server could replace the information in PIV. This approach would eliminate the effect that the flights that “appear” and “disappear” in consecutive PIV calls have on the global results. However, this approach will make impossible to track the evolution of the estimated HFIR in each system.

With the aim of being able to compare both systems, a new technical requirement to the ICATS Server could be established. Once a flight has been registered in the ICATS Server, the flight and its estimated HFIR should be maintained in the system at least until the flight enters into the FIR. If there is not an update of the HFIR between calls, the last available HFIR from the ICATS System should be maintained.

Sector entry load and occupancy calculations have been calculated in a sliding one-hour window without overlapping due to time constraints in the analysis phase. An overlapping sliding window could show in a more precise way how ICATS modify PIV calculations. Any case, this analysis will be useless if there are still missing HFIR data from several flights in ICATS Server.

In order to avoid so many missed HFIR from the ICATS Server, a “Re-try” technical mechanism should be put in place in order to guarantee that the system provides an answer to any query done.

The answer from the system will be improved if the HFIR field is included in the GFO design. Actually, the HFIR is not included, so any time a query is done to the system, the system have to calculate the HFIR for any of the GFO existing in the system.

7 Summary of the Communication Activities

ICATS Project has been already presented in the following forums:

- ICATS was presented to public audience at the Air Transportation Information exchange Conference (ATIEC) held on August 29, 2013 in Silver Spring MD, USA, during the FIXM breakout session.

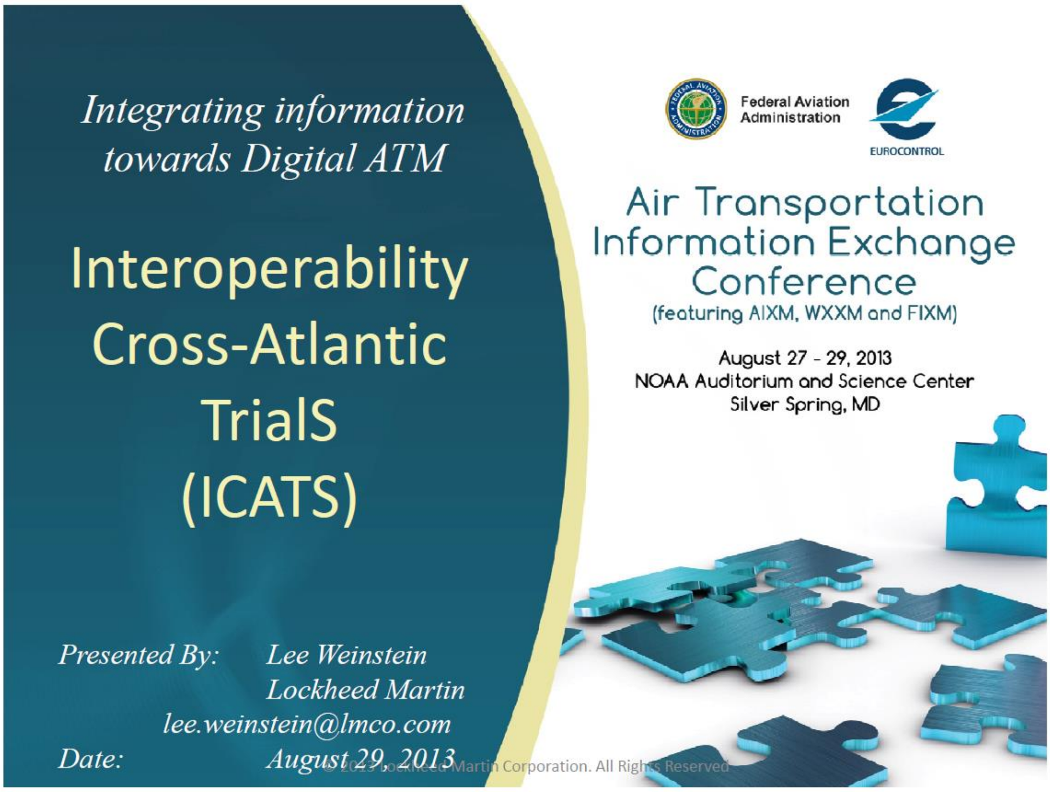

Figure 35: ICATS presentation in ATIEC Conference, MD, USA

- ICATS mock-up was available in the Indra booth at the Madrid World ATM Congress, on March 2014. The mock-up was also presented in the SESAR SWIM forum, held on May 2014, hosted by WP14.

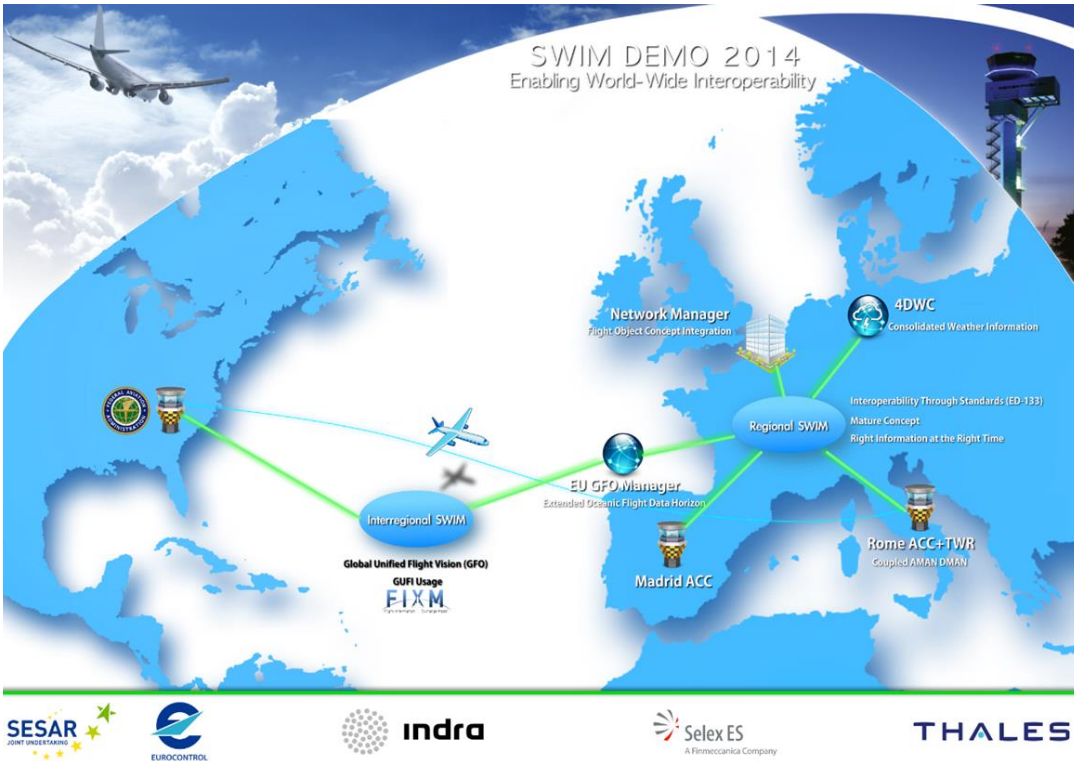

Figure 36: ICATS presentation in WP14 SWIM Demo

- The ICATS project initiative has been presented inside the SESAR community (TMF OFA, TOPFLIGHT Demo project) and to external audience (Mini-Global FAA).

As the results of ICATS are already available, it is planned to:

- Publish an internal information note at Indra and LMCO intranets for announcing the completion of the trials and showing the relevant results, and also to coordinate with SJU an announcement of the completion of the trials and the results, to be shown in the SJU public Web Site.
- Present the ICATS achievements and results to the SESAR Trajectory Management OFA, in the course of their meeting organised for early July 14. A wider dissemination session for SESAR partners could be organised, if requested by SJU.
- Brief key technical staff from the FAA and NATS on the ICATS Project, conduct of the demonstration exercises, and result achieved.
- Submit a paper for consideration to the Air Traffic Control Association (ATCA) Annual Conference held September 29, 2014 through October 1, 2014 in National Harbor, Md, USA. The paper will summarise the ICATS goals, challenges, and results.
- Publish a short article in the Air Europa In-flight magazine describing the project, the Air Europa participation and the results achieved.
- Present the ICATS results, previous coordination with SJU, to Mini Global FAA visit to Indra, on end July 2014.
- Present a Technical paper on ICATS to the adequate international forum.

8 Next Steps

This section explains, at high level, how the ICATS partners envisage having the tested solutions implemented and what kind of follow up work is needed.

The ICATS trials have demonstrated a significant set of benefits. To actually deliver this benefit, the concepts and solutions explored in ICATS would require not only the implementation in Europe but also in the United States. It is known that a SESAR – NextGen cooperation of work schema already exists, sponsored by SJU in the case of Europe.

The Operational concept demonstrated by ICATS would require being included into the Operational Concept of the ANSPs and airlines, to be part of it as a whole.

Once the Operational concept is implemented for the USA/EU Interoperability via Flight Object is agreed, the further phases of Industrialisation and Deployment would be required at both sides to put the concept into operation. Besides the development of operational units, this phase shall include many supporting activities such as standardisation activities and development of procedures and systems (until certification based on availability of regulatory material). The elapsed time for this phase is dependent on several factors including:

- industrial cycles and decision processes;
- the time needed for development and validation of standards;
- the capacity of manufacturing industry.

Depending on the outcome of the safety and business case the deployment decision may also be based on agreed financial and regulatory instruments.

Following confirmation of the operational performance needs and successful completion of the industrialisation phase, the Deployment phase would start. This will imply a number of separate local deployments in Europe and USA. Appropriate financial and regulatory instruments, shall be available to ensure synchronised deployment. Then the Initial Operational Capability (IOC) will be achieved, permitting the function and service to enter into Operations.

The Operations phase can start once all integration, commissioning and certification tasks have been successfully completed.

It will be required to ensure that all necessary items are in place for the different views of the Deployment roadmaps (ANSPs, CNS).

8.1 Conclusions

This section summarises the project conclusions after the execution of the two exercises performed in the project and the analysis of the results obtained.

The main objective of the project was to validate the ICATS Concept defined in [3]. The operational concept says that the exchange of information between the two sides of the North-Atlantic would produce benefits for:

- The airline in terms of Fuel Efficiency and CO_2 emissions
- The ANSPs in terms of Capacity and Predictability of their operations.
- The global system in terms of Safety, Coordination and Interoperability.

With the data from the Demonstration Trials and the limitations it has, the conclusions are the following:

1. The Airlines would obtain an important benefit in terms on **Environmental Issues** (Fuel savings and CO_2 emissions savings). This will have a direct impact on their costs. It is estimated an average fuel saving of about 1100kg per oceanic flight. This would mean a reduction on the CO_2 emissions of 3464kg per oceanic flight.

2. The ANSPs benefit, in terms of **Capacity**, is partially proved due to the system limitations. Considering only the cases when the ICATS data is better (closer to the actual data) than the PIV data the results show a clear benefit in terms of improvement on the accuracy of the sector load and a reduction of the unexpected oceanic traffic variations. For both metrics, M01 and M02 the results are much higher than the expected benefits. However, the quality of these results is limited to the few cases analysed. In the first analysis done, for M01, only in the 47% of the cases ICATS HMI is better than PIV while for the M02, this happens only in the 49% of the cases. In the second analysis done, avoiding the effect of the empty data, for M01 only in the 46% of the cases, ICATS HMI is better than PIV while for the M02, this happens in the 51% of the cases. Results are so similar than any conclusion regarding which approach is better can be taken.
3. Regarding the **Predictability** and the **Accuracy** of the data, the expected benefit is also achieved but only for the cases analysed. That is the cases with a positive predictability and with information in both systems (ICATS HMI and PIV). The Predictability is increased about 18 minutes while the accuracy about 8 min.
   Table 41: System by which the data were discarded. Table 41 shows the total data disregarded which is, in some cases, higher than the total data analysed, in most of the cases due to the lack of information provided by the ICATS HMI system.
4. In terms of **Safety** few conclusions can be extracted.
5. In terms of Flight Efficiency, there is a positive feeling from the pilots and most of the controllers regarding the benefits that ICATS could provide in order to facilitate the users preferred trajectory.
6. In terms of **Coordination**, the analysis of the results shows that the number of trajectory change requests rejected have been reduced thanks to the information sharing. This is linked with the **Flexibility** of the system, which allows trajectory changes without impacting the rest of the operations.
7. In terms of **Interoperability**, the demonstrations trials have shown that the systems developed by two industrial partners and used by two ANSPs located in different ICAO regions plus one Airline crossing from one ICAO region to another, have been connected and were able to exchange information through the system (IOP Chain).

8.2 Recommendations

Here is a summary write-up of some of the next steps and enhancements that the ICATS consortium sees as being important to be considered in the ICATS concepts further developments:

8.2.1 Continued Trials

This section includes recommendations for larger trials and access to better data.

Improved Data Feeds from the Operational Chain – for ICATS we explored the availability of high quality data feeds from the operational chain including four broad classes of data: Surveillance data, Flight data, Weather data, and Restriction data. We were unable to obtain access to this data from the Operational chain ERAM and ATOP systems in the US. Instead we utilised the existing Aircraft Situation Data to Industry (ASDI) data feed that is normally delayed for security reasons. Access to high quality real-time data feeds from the Operational chain would enhance fidelity and accuracy of the system and of the data being exchanged between ICATS regions. We recommend that any subsequent demonstration/ flight trial activities be performed using such data feeds from the relevant operational systems. Furthermore, the use of Eurocontrol B2B services to subscribe to the information they provide (e.g. MET) should be considered.

Extend ICATS to a Larger Set of Stakeholders – The ICATS capability was designed focusing on the needs of the ICATS project. In doing so we provided Flight Object Data Exchange capabilities to support interactions between a small number of stakeholders of the EU region, the US region, and the Air Europa AOC. At the same time, we designed the capabilities to ensure that it could be extended to a larger community of stakeholders without a large and expensive level of re-design or new development. We recommend conduct of a larger trial that includes additional regions and AOCs. Such an activity would produce a larger cross section of data supporting the user benefits case and would effectively demonstrate that the basic ICATS Flight Object management and distribution function can be extended to a larger set of participating stakeholders.

Study and propose additional Technical Requirements in view of larger demonstrations and industrialization - If larger demonstrations based on ICATS will be launched, it would be necessary to incorporate to ICATS additional technical requirements to make the platform capable enough to support technical and operational monitoring, resilience, 24 hour operations, Safety, etc.

Involve Traffic Load tools for Predictability Exercise – On ICATS the analysis of improvement in the sector entry/load has been performed by off line calculation of the data captured. In view of a more automatic and error free process, and to manage additional indicators and metrics, the involvement of tools such as Trajectory Management System (TMS) is recommended. These tools would be fed with live FO data to perform the calculations.

Develop Offline Analysis and Problem Investigation Tools – during conduct ICATS system integration and execution of the live trial we encountered some significant problems with operation of the fairly complex ICATS end-to-end thread. In all of the cases we encountered, it was necessary to examine the messages exchanged within the thread at a fairly detailed level. A specific number of issues we examined required us to analyse the details of message content and in particular the sequence of messages exchanged between the two regions as flights progressed through the airspace. Other cases related to performance and system workload and required us to closely look at the volume of message traffic being exchanged within the system. Fortunately, we had anticipated these needs and we were able to export data from various ICATS system logs and conduct the required analysis using spreadsheet based analysis techniques to identify and successfully investigate system issues. For a subsequent full scale implementation, we recommend that a suite of offline analysis tools be developed to facilitate problem analysis and investigation in the end state implementation. A large multi-region implementation will be significantly more demanding and more complex and such tools will provide necessary assistance for problem investigation, analysis, and resolution.

8.2.2 Concept Exploration

This section includes the recommendations in terms of further concept exploration, which might be proved with continued trials in larger demonstrations.

Integrate the AOC and ATC via Trajectory Optimization Automation (link with SESAR P11.01) - As ICATS results have shown benefits for the airline, it is worth considering a concept of an integrated Trajectory Optimization tool that makes use of both ATC and AOC provided information and automates identification of Trajectory Optimization opportunities. Such a tool would integrate the basic ATC positional and intent data with information provided by the AOC/airlines (e.g., flight diversion routes, constraints, airline business rule preferences, etc), to optimise the operation process (e.g., turn around, flight crew optimization). While ICATS has shown that ATC flight object is of interest to the AOC, information available at AOC may also be of great interest for ATC processing (aircraft actual position, aircraft intent, airline constraints and preferences, etc). Such a Trajectory Optimization tool would help automate the identification of potential flight path, speed, level optimizations for all stakeholders, thus increasing the likelihood that flights would take an optimum path through the airspace.

Extend the Operational Concept used in the Trajectory Optimization Exercise – The ICATS Trajectory Optimization process relies on the use of an independent and parallel IOP chain ATC system and IOP ATC staff to evaluate AOC proposed flight changes via the What-If mechanism. The objective was to demonstrate that earlier and more accurate data in the IOP chain would permit the acceptance of some proposed trajectory changes not approved today with the current systems.

That independence was not always possible in the ICATS when assessing the proposed trajectory changes due to an incomplete traffic situation in the IOP positions originated by various reasons (the only sources of planned flight data were Madrid and New York, number of ATSU involved in the demonstration, limited actual flight data updates).

Furthermore, it was noted that, as each FIR in the world may have different CNS-ATM services/implementations in use, separation minima standards, etc., it would be too complex to probe every What-if assessment without the conflict detection and resolution tools only available at each ATSU's operational system, therefore, the added value of the IOP chain is to allow the ATSU controlling a flight to anticipate the traffic situation in the following FIR (or FIRs) and issue a clearance even before coordination is initiated with the next ATSU.

In future demonstrations, it is important that all flights in the area of responsibility / interest should be made available up-to-date to the ATSU IOP positions, particularly the response of downstream ATSUs for any What-if assessment proposed by the AOC. For this purpose, flight objects need to be created by the first ATSU involved in the trajectory of the flight within the area of responsibility/interest of the demonstration and ensure that actual flight data for all those flights are made available to the IOP chain. This can be extended with the use of AOC/aircraft data of the flight trials by the IOP chain as well as the availability to the AOC IOP position of the results of ATSU assessments and what-if tools.

Another alternative for the Operational Concept is to equip the AOC to make their assessment of the What-if on their own without assistance from ATC. This exact concept was used in the USA in a successful trial that was similar to what ICATS did, although in a very homogeneous and harmonised airspace. However, as stated before, when involving different FIRs, the complexity of local CSN-ATM applications and separation minima standards would render this assessment incomplete and even when a "good" What-if is returned by the IOP chain, it would always have to be submitted to Operational ATC via the Flight Crew as was done in ICATS and Operational ATC would have final responsibility for approving or rejecting the proposed change.

This extension of the Operational Concept requires full discussion of the pros and cons of involving the ATC on the assessment loop or only leaving the assessment to the AOC. Involvement of ATC should be only required if it provides additional benefits for ATC or secures improved safety where this cannot be achieved any other way. This thread opens the door to interesting discussions of future improvements to the operational concept of Trajectory Optimization by the User (e.g., Trajectory Optimization tools for AOC, additional roles in ATC, etc.). Note that this concept can readily be extrapolated from the oceanic traffic use case to continental/domestic traffic use cases as well.

Try additional use cases and operational concepts to be supported by FO – Other operational use cases that can benefit from the use of the FO as a key enabling technology should be tried, as extended AMAN to sequence from the last part of En Route Oceanic phase, using the IOP information provided by IOP ATSUs. Improvements to AIDC that take advantage from the IOP and its data (e.g., for SSR code assignment, skip of communications, Point session and sequencing, flight coordination information with third party organizations) should also be explored in the future.

Consider ICATS outcome as an input for SESAR RBT/SBT discussions - The involvement of the AOC in the optimization process has shown in ICATS as beneficial. The concept tried in ICATS should be taken into account for SESAR discussions in the Trajectory Management OFA in view of formulating the RBT/SBT for the Trajectory optimization use cases.

8.2.3 System Engineering and Development necessary for Operations

Incorporate Functional Enhancements – the ICATS and I-SWIM design provided a basic Flight Object exchange capability that was necessary and sufficient to meet the overall objective of the project and the live trial. Functional enhancements should be made to the basic infrastructure to enhance its functional capabilities. Some examples for functional enhancement would include items such as:

- GFO Exchange Mechanisms should be engineered to be fault tolerant and to provide means for failure detection and automatic recovery where this is feasible. The focus of these features should be to improve its ability to run uninterrupted in a stable fashion for extended time intervals.

- Enhancements to extend the Flight object data exchange should be considered as well in order to provide for functions such as coordination between ANSPs.
- The processing of progress triggers (i.e. time over point, boundary crossing, etc.) should not require that large, complex, or elaborate sets of stakeholder adaptation data be shared across region boundaries.
- A comprehensive and systematic program of integration and system testing is recommended after such time as these enhancements are incorporated.

Align With the Latest FIXM Standard – because of significant engineering effort required to develop and integrate the ICATS IOP chain capability, we had to choose a fairly early version of the FIXM standard for ICATS – version 1.1. Version 1.1 was a relatively early version of the standard, and because of the limited scope of this early version a significant number of ICATS specific extensions were implemented to address the particular capabilities needed for our live trial. Significant changes have subsequently been made to the standard and much of this work has made provision for ICATS specific extensions within the basic framework of the standard. The ICATS capability should be brought up to date to align with the latest version of the FIXM standard at a convenient point in time.

Incorporate Metering into the System and Demonstration – A major focus of ICATS was the delivery of user benefit through optimization of flight path. For the project we concentrated mainly on optimization in Domestic and Oceanic airspace and did not consider the impact that metering constraints at the point of arrival may have on optimizations performed while En-Route. Future versions of the system and associated demonstrations should incorporate knowledge of metering constraints into the optimization process. Ideally, a goal of En-Route optimization should be to ensure smooth traffic flows all the way to the destination airport and that necessarily will include knowledge and consideration of metering adjustments to the flight path.

Better Integration with Evolving Regional SWIM Implementations – The ICATS Flight Object data exchange capability was integrated with regional SWIM capabilities to provide a basic level of function that supported the ICATS Live Flight Trial. Within the US Region an active program of engineering is underway to develop an enterprise wide National Flight Information Service. The FAA has engaged a variety of stakeholders in comparable research projects such as Mini-Global to progress the state of the art and to demonstrate a range of user benefits. It would be advantageous to better integrate the ICATS capabilities with current and planned regional activities and projects to ensure an interoperable capability with broad utility.

9 References

9.1 Applicable Documents

The documents mentioned in the template are examples that can be removed

[1] EUROCONTROL ATM Lexicon https://extranet.eurocontrol.int/http://atmlexicon.eurocontrol.int/en/index.php/SESAR

[2] "Forecasting Civil Aviation Fuel Burn and Emissions in Europe, EEC Note No. 8/2001", Eurocontrol Experimental Centre, May 2001

[3] ICATS A1 Demonstration Plan

[4] ICATS B3 Operational Concept Document

[5] ICATS B4 Flight Object Concept Definition

[6] ICATS B5 I-SWIM Interface Document

[7] ICATS B6 Technical Specification

[8] SESAR FIXM v2.0/3.0 REVIEW, Key Point Summary for Coordination in CP3.1 and CP3.2

9.2 Reference Documents

N/A

Appendix A KPA Results

See sections 5.1, 5.2 and 8.1.

Appendix B M03 Results

<u>Pilot Questionnaires Results</u>

The following table provides the answers provided by 14 pilots involved in the trials:

Date	Flight ID	Q1	Q2	Q3	Q4	Q5
23/04/2014	**AEA089**	**5**	**0%**	**Within KZNY**		**Re-Routing**
24/04/2014	AEA051	3	50%	Within LPPO	Closer to LPPC/LECM boundary	Re-Routing
24/04/2014	AEA051[12]	2	50%	Within LPPO	In the middle	Re-Routing
28/04/2014	AEA051	1	0%	Within KZNY		FL Change
29/04/2014	**AEA033**	**4**	**25%**	**Within KZNY**		**FL Change**
30/04/2014	**AEA089**	**5**	**0%**	**Within LPPO**	**In the middle**	**Mach**
05/05/2014	AEA089	5	0%	Within LPPO	Closer to LPPC/LECM boundary	Re-Routing
12/05/2014	AEA071	4	25%	Within LPPO	Closer to KZNY boundary	FL Change
12/05/2014	AEA089	1	0%			
13/05/2014	**AEA051**	**5**	**25%**	**Within KZNY**		**Re-Routing**
14/05/2014	AEA071	5	0%	Within LPPO	In the middle	Mach
20/05/2014	AEA033	5	0%	Within KZNY		FL Change
21/05/2014	AEA051	2	0%	Within LPPO	Closer to LPPC/LECM boundary	Mach
21/05/2014	AEA089	2	50%	Within KZNY		Re-Routing

Table 42: Answers provided by Pilots involved in the demonstration trials

Q6 is not included because it appears always empty as there was not any trajectory change other than re-routing, Mach number or FL change.

On the other hand, the flights in bold refer to those ones with had optimizations.

The following graphics represents the results per question:

<u>**Q1:** How often did you get an approval for a proposed change in the trajectory? (1=never, 5=always)</u>

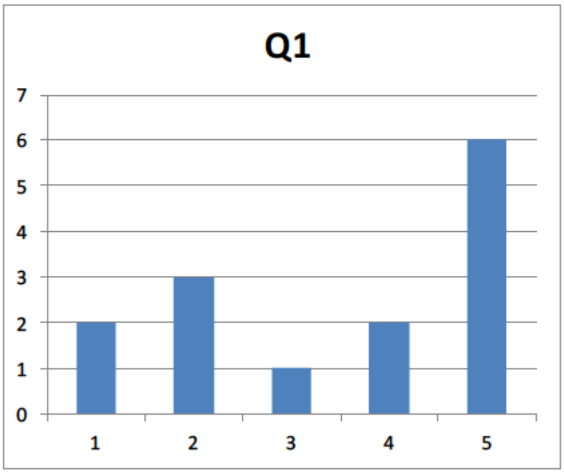

Figure 37: Answers from Pilots to Q1

From the 14 pilots that answered to this question, almost the <u>60% confirmed they always had an approval for any proposed change in the trajectory</u>.

Only a 35% of them said that never or few times got an approval.

These results confirmed the benefit provided by the ICATS system. In addition, it reflects the real operations when even knowing in advance the situation, it is not always possible to provide the changes requested.

[12] In this case, both Pilot and Co-Pilot replied to the questionnaire. That's why there are two results for the same flight in the same day.

Q2: From your viewpoint, what is the percentage of change requests rejected from the total number of change requests? (0-100%)

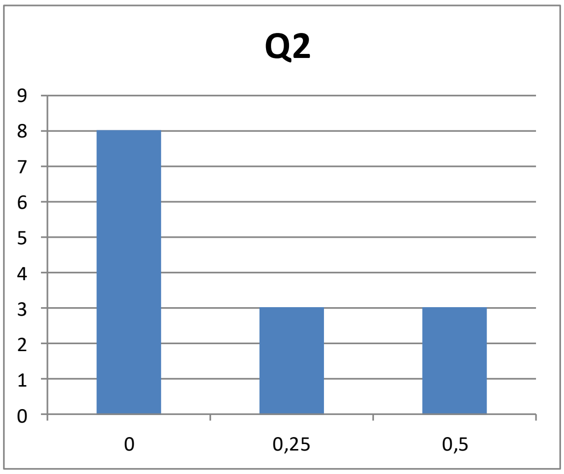

Figure 38: Answers from Pilots to Q2

60% of the pilots said that they never had a rejection on the trajectory changes they proposed.

Around 20% of them said that in few cases they got a rejection, so they noticed the improvement brought about by the IOP system.

Finally, another 20% of the pilots slightly appreciated any improvement comparing with current operations.

Q3: Where have you proposed most of the change requests? (LPPO or KZNY)

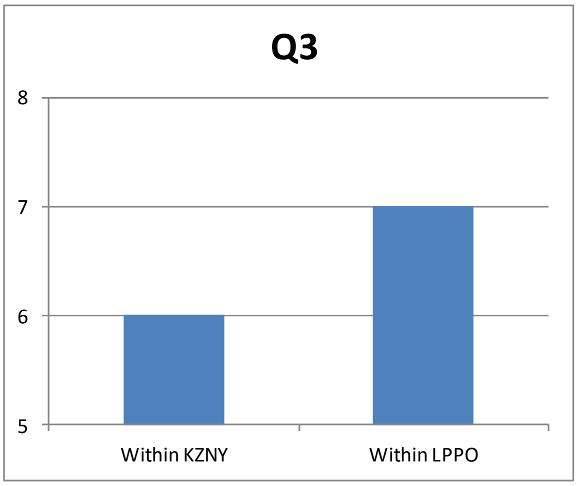

Figure 39: Answers from Pilots to Q3

Regarding where most of the change request occurred, the answers are similar: 55% said that they proposed most of the change requests in Santa María Oceanic (LPPO) while 45% of them said in New York Oceanic (KZNY).

It was expected that the pilots proposed most of the change requests in LPPO as it is closer to the departure (considering we have analysed only Westbound flights). However, the results are similar.

Q4: In case you chose “Within LPPO” in Question 3, it was: (Closer to KZNY boundary, In the middle, Closer to LPPC/LECM boundary)

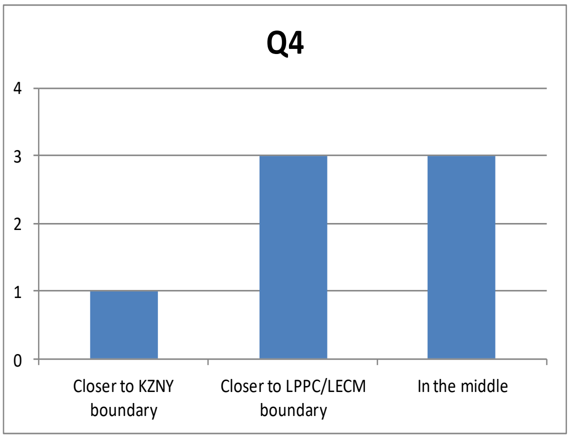

Figure 40: Answers from Pilots to Q4

For the 55% of the pilots saying that most of their change requests occurred in LPPO, most of them took place closer to the continental border (LPPC or LECM) or in the middle of the sector.

This is aligned with the initial assumption: most of the change request occurred close to the departure.

Q5: Which was the most frequent type of trajectory change proposed? (Re-route, FL, Mach, Other)

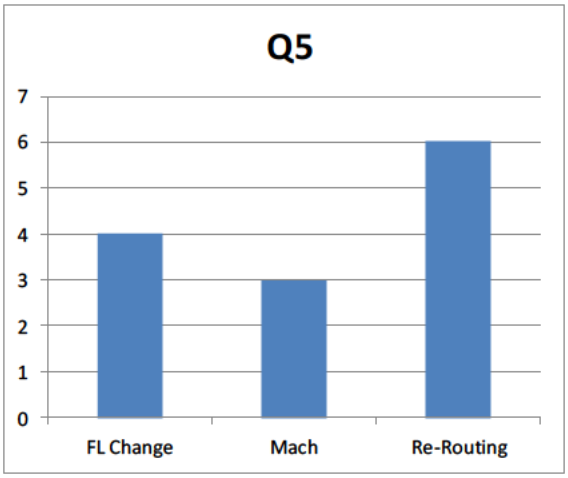

Figure 41: Answers from Pilots to Q5

Regarding the most common trajectory change request the graphic shows the most common change requested is the Re-routing (46%), followed by FL change (31%) and Mach number change (23%).

Some general comments got from the **pilots** involved in the trials are:

- The timing communication between aircraft, company and ATM is an important issue. There is a limited time window to analyse a proposed change and after that a "Time-out" message appears, and the process should re-start again.
- Some re-routings proposed had a minor impact on fuel or time saving.
- Although the ATC-Aircraft established communication mean is Data Link, on Lisbon the established communication is voice.

IOP Questionnaires Results

The following table provides the answers provided by 17 IOP Controllers per day of trials:

Date	Q1	Q2	Q3	Q5	Q6
23/04/2014	5	0%	3	US ATOP	None Rejected
24/04/2014	5	0%	3	US ATOP	None Rejected
29/04/2014	5	0%	-	US ATOP	-
30/04/2014	5	0%	-	-	-
02/05/2014	5	-	-	US ATOP	-
12/05/2014	-	-	-	US ATOP	-
13/05/2014	5	0%	-	Within LPPO	-
14/05/2014	5	0%	-	-	-
15/05/2014	5	0%	-	-	-
16/05/2014	5	0%	-	-	-
19/05/2014	5	0%	-	-	-
20/05/2014	5	0%	-	-	-
21/05/2014	5	0%	-	-	-
22/05/2014	5	0%	-	-	-
23/05/2014	5	0%	-	-	-
General NAV PT	5	0%	1	Closer to KZNY boundary	N/A
General NAV PT	5	0%	1	Closer to KZNY boundary	-

Table 43: Answers provided by IOP Controllers involved in the demonstration trials

Unfortunately the IOP Controllers from Santa Maria completed the questionnaires only once for each set of trials providing a single summarised answer for all the trials within each set. Due to this fact, the results from the American side (KZNY) have a higher weight.

Q4 is not included because it appears always empty as there was not any Eastbound trial operating with the systems up and properly running.

The following graphics represents the results per question (without considering the blank answers):

Q1: How often did you approve a proposed change in the trajectory? (1=never, 5=always)

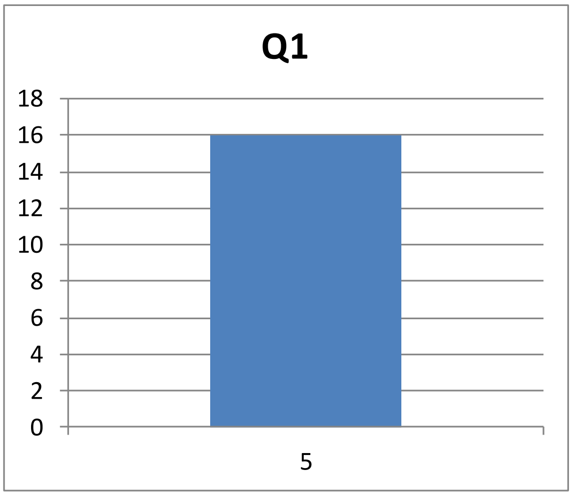

Figure 42: Answers from IOP Controllers to Q1

All the IOP Controllers replying to this question confirmed they always approved a proposed change in the trajectory.
This is almost aligned with the pilot's answers to Q1.

The reasoning given by the IOP Controllers was that all the proposals where made so much in advance that there was no reason to reject them.

Q2: From your viewpoint, what is the percentage of trajectory changes rejected from the total number of changes you were requested? (0-100%)

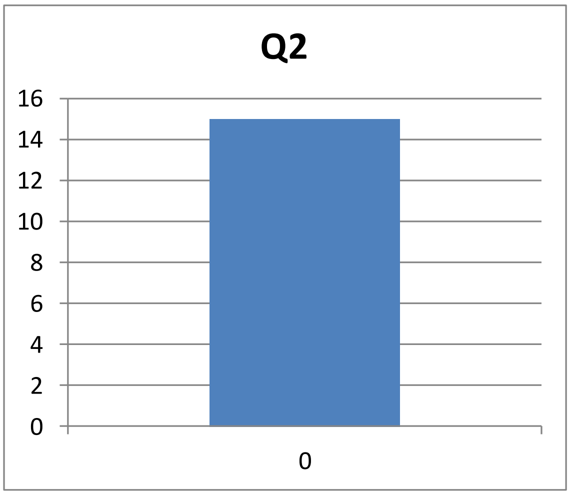

Figure 43: Answers from IOP Controllers to Q2

The answers for Q2 are totally aligned with the answers given in Q1. If the IOP controllers approved all the change requests proposed, it is common sense that they didn't reject any of them.

Q3: Do you think that the additional information provided by ICATS is enough to approve/reject a change request? (1=never, 5=always)

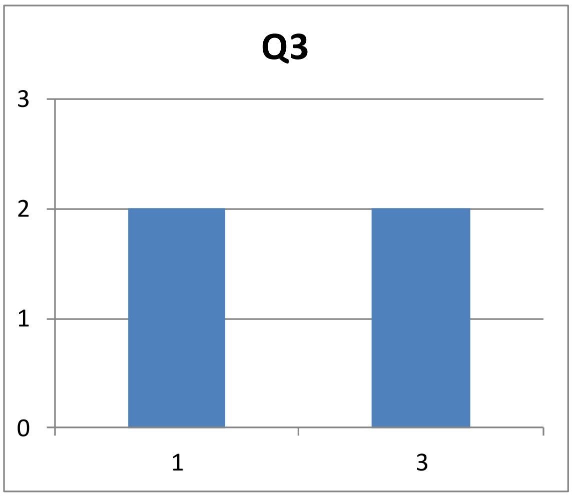

Figure 44: Answers from IOP Controllers to Q3

Few IOP Controllers answered this question (4 from 14), so it is difficult to extract a conclusion.

Nevertheless, 2 IOP controllers from Nav PT said the Santa Maria FDPS is already capable of handling the trajectories change requests, even without the IOP information.

The IOP Controllers from the American Side said the system have provided a slight benefit regarding current operations.

Q5: Where did most of the change requests occur in the Westbound flights? (LPPO, KZNY)

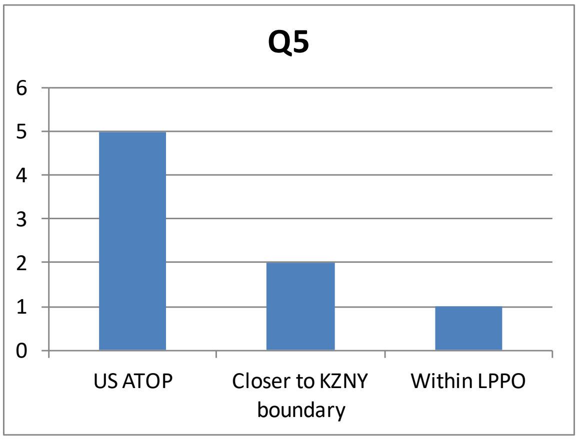

Figure 45: Answers from IOP Controllers to Q5

Considering the answers to Q5 it seems that most of the change request occurred in KZNY (62%).

However, as it was said at the beginning of the section, most of the questionnaires come from the American Side and thus the results are partial, and difficult to take into consideration.

Q6: What were the most common reasons for rejecting a proposed change?

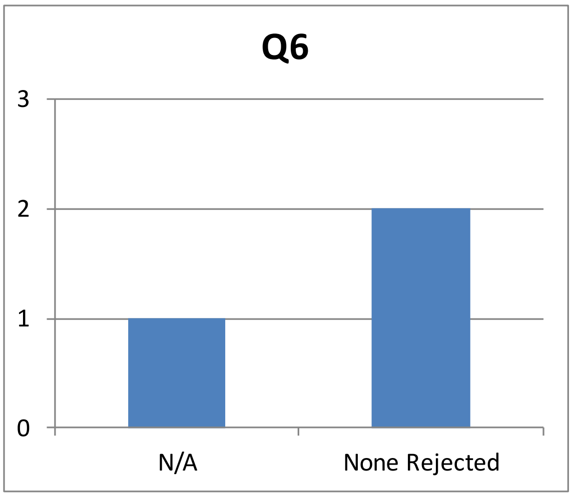

Figure 46: Answers from IOP Controllers to Q6

According to Q1 & Q2, as none change request was rejected, there was no reason provided in Q6.

Question to not be taken into account.

Operational Controllers Questionnaires Results

Unfortunately, no questionnaires from the operational controllers were received. However, they confirmed their workload didn't increase due to the trials.

Results from Data Link Communications Review

Date	Flight ID	DEP	ARR	N# Trajectory Changes Requested	N# Rejections	% of Rejections
23/04/2014	**AEA089**	**MAD**	**SDQ**	**2**	**0**	**0,00%**
23/04/2014	AEA051	MAD	HAV	5	1	20,00%
24/04/2014	**AEA089**	**MAD**	**SDQ**	**4**	**1**	**25,00%**
24/04/2014	AEA051	MAD	HAV	3	1	33,33%
25/04/2014	AEA089	MAD	SDQ	4	1	25,00%
25/04/2014	AEA051	MAD	HAV	2	1	50,00%
28/04/2014	AEA089	MAD	SDQ	1	0	0,00%
28/04/2014	AEA051	MAD	HAV	2	0	0,00%
29/04/2014	**AEA089**	**MAD**	**SDQ**	**6**	**0**	**0,00%**
29/04/2014	**AEA033**	**MAD**	**PUJ**	**6**	**2**	**33,33%**
30/04/2014	**AEA089**	**MAD**	**SDQ**	**3**	**0**	**0,00%**
30/04/2014	**AEA051**	**MAD**	**HAV**	**2**	**1**	**50,00%**
02/05/2014	**AEA089**	**MAD**	**SDQ**	**5**	**1**	**20,00%**
02/05/2014	**AEA051**	**MAD**	**HAV**	**3**	**0**	**0,00%**
12/05/2014	AEA089	MAD	SDQ	3	1	33,33%
12/05/2014	AEA051	MAD	HAV	4	0	0,00%
12/05/2014	AEA071	MAD	CCS	3	1	33,33%
13/05/2014	**AEA089**	**MAD**	**SDQ**	**0**	**0**	**0,00%**
13/05/2014	**AEA051**	**MAD**	**HAV**	**5**	**2**	**40,00%**
14/05/2014	AEA089	MAD	SDQ	2	0	0,00%
14/05/2014	AEA051	MAD	HAV	2	0	0,00%
14/05/2014	AEA071	MAD	CCS	4	0	0,00%
15/05/2014	**AEA089**	**MAD**	**SDQ**	**3**	**1**	**33,33%**
15/05/2014	**AEA071**	**MAD**	**CCS**	**4**	**0**	**0,00%**
16/05/2014	AEA089	MAD	SDQ	2	0	0,00%
16/05/2014	AEA051	MAD	HAV	2	0	0,00%
19/05/2014	**AEA089**	**MAD**	**SDQ**	**3**	**1**	**33,33%**
19/05/2014	**AEA071**	**MAD**	**CCS**	**2**	**0**	**0,00%**
20/05/2014	AEA089	MAD	SDQ	4	1	25,00%
20/05/2014	AEA033	MAD	PUJ	2	0	0,00%
21/05/2014	AEA089	MAD	SDQ	3	0	0,00%
21/05/2014	**AEA051**	**MAD**	**HAV**	**3**	**0**	**0,00%**
21/05/2014	AEA071	MAD	CCS	4	0	0,00%
22/05/2014	AEA089	MAD	SDQ	3	3	100,00%
22/05/2014	AEA051	MAD	HAV	2	0	0,00%
22/05/2014	AEA071	MAD	CCS	2	0	0,00%
22/05/2014	AEA011	MAD	SJU	1	0	0,00%
23/05/2014	**AEA089**	**MAD**	**SDQ**	**4**	**0**	**0,00%**
23/05/2014	**AEA063**	**MAD**	**CUN**	**3**	**0**	**0,00%**

Date	Flight ID	DEP	ARR	N# Trajectory Changes Requested	N# Rejections	% of Rejections
Average % Of Rejections (all flights)						14,23%
Average % Of Rejections (flights with optimizations)						**13,82%**

Table 44: Summary of Data Link Communications regarding the coordination episodes

The information showed in Table 44 reflects only the change requests demanded by the Flight Crew, not the ones asked for the Controllers. The flights in bold in Table 44 refers to those that had En-route optimizations that were processed through the ICATS system.

Appendix C Tables for M01

The following tables contain all the values obtained in order to analyse M01 in each sector.

For each day and PIV call the next data are shown:

- Number of one-hour sliding windows where ICATS forecast is different from PIV forecast.
- Number of one-hour sliding windows where ICATS forecast is better than PIV forecast(the difference with real traffic in ICATS is smaller than in PIV).
- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS provides a better forecast for the sector entry rate than PIV.
- Number of one-hour sliding windows where ICATS forecast is worse than PIV forecast.
- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS provides a worse forecast than PIV.
- Number of one-hour sliding windows where ICATS forecast is better than PIV forecast and the improvement is bigger than a 15% (objective target)
- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS accuracy improvement is bigger than a 15%.
- Mean value of the improvement of the accuracy (for all the sliding-windows of the day from the PIV call time onwards) .
- Standard deviation of the improvement of the accuracy of sector occupancy per day and PIV call(standard deviation is only calculated when the number of hours where ICATS forecast is better than PIV is greater than two).

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	µ of the improvement of the accuracy	σ of the improvement of the accuracy
09/04/2014	0:00	3	2	67%	1	33%	2	67%	100,0	0,0
09/04/2014	2:00	3	3	100%	0	0%	3	100%	100,0	0,0
09/04/2014	4:00	3	3	100%	0	0%	3	100%	100,0	0,0
09/04/2014	6:00	3	2	67%	1	33%	2	67%	100,0	0,0
09/04/2014	8:00	1	1	100%	0	0%	1	100%	100,0	
09/04/2014	10:00	0	0		0		0			
10/04/2014	0:00	3	0	0%	3	100%	0	0%		
10/04/2014	2:00	2	2	100%	0	0%	2	100%	75,0	35,4
10/04/2014	4:00	1	0	0%	1	100%	0	0%		
10/04/2014	6:00	0	0		0		0			
10/04/2014	8:00	0	0		0		0			
10/04/2014	10:00	0	0		0		0			
11/04/2014	0:00	0	0		0		0			
11/04/2014	2:00	0	0		0		0			
11/04/2014	4:00	0	0		0		0			

11/04/2014	6:00	0	0		0		0			
11/04/2014	8:00	0	0		0		0			
11/04/2014	10:00	0	0		0		0			
12/04/2014	0:00	1	0	0%	1	100%	0	0%		
12/04/2014	2:00	2	0	0%	1	50%	0	0%		
12/04/2014	4:00	2	0	0%	2	100%	0	0%		
12/04/2014	6:00	2	0	0%	2	100%	0	0%		
12/04/2014	8:00	2	0	0%	2	100%	0	0%		
12/04/2014	10:00	0	0		0		0			
22/04/2014	0:00	0	0		0		0			
22/04/2014	2:00	0	0		0		0			
22/04/2014	4:00	0	0		0		0			
22/04/2014	6:00	0	0		0		0			
22/04/2014	8:00	0	0		0		0			
22/04/2014	10:00	0	0		0		0			
24/04/2014	0:00	1	0	0%	1	100%	0	0%		
24/04/2014	2:00	1	0	0%	1	100%	0	0%		
24/04/2014	4:00	2	1	50%	1	50%	1	50%	100,0	
24/04/2014	6:00	0	0		0		0			
24/04/2014	8:00	0	0		0		0			
24/04/2014	10:00	0	0		0		0			
29/04/2014	0:00	4	1	25%	3	75%	1	25%	50,0	
29/04/2014	2:00	4	2	50%	2	50%	2	50%	41,7	11,8
29/04/2014	4:00	4	3	75%	1	25%	3	75%	58,3	38,2
29/04/2014	6:00	2	0	0%	2	100%	0	0%		
29/04/2014	8:00	1	0	0%	1	100%	0	0%		
29/04/2014	10:00	0	0		0		0			
14/05/2014	0:00	2	0	0%	2	100%	0	0%		
14/05/2014	2:00	2	0	0%	2	100%	0	0%		
14/05/2014	4:00	2	1	50%	1	50%	1	50%	25,0	
14/05/2014	6:00	0	0		0		0			
14/05/2014	8:00	0	0		0		0			
14/05/2014	10:00	0	0		0		0			
15/05/2014	0:00	3	2	67%	1	33%	2	67%	100,0	0,0
15/05/2014	2:00	3	3	100%	0	0%	3	100%	83,3	28,9
15/05/2014	4:00	3	3	100%	0	0%	3	100%	83,3	28,9
15/05/2014	6:00	2	2	100%	0	0%	2	100%	100,0	0,0
15/05/2014	8:00	1	1	100%	0	0%	1	100%	100,0	
15/05/2014	10:00	0	0		0		0			
16/05/2014	0:00	0	0		0		0			
16/05/2014	2:00	0	0		0		0			
16/05/2014	4:00	0	0		0		0			
16/05/2014	6:00	0	0		0		0			
16/05/2014	8:00	0	0		0		0			

16/05/2014	10:00	0	0		0		0			
21/05/2014	0:00	4	3	75%	1	25%	3	75%	83,3	28,9
21/05/2014	2:00	5	2	40%	2	40%	2	40%	100,0	0,0
21/05/2014	4:00	2	0	0%	1	50%	0	0%		
21/05/2014	6:00	0	0		0		0			
21/05/2014	8:00	1	0	0%	0	0%	0	0%		
21/05/2014	10:00	0	0		0		0			
22/05/2014	0:00	0	0		0		0			
22/05/2014	2:00	1	1	100%	0	0%	1	100%	25,0	
22/05/2014	4:00	1	0	0%	1	100%	0	0%		
22/05/2014	6:00	0	0		0		0			
22/05/2014	8:00	0	0		0		0			
22/05/2014	10:00	0	0		0		0			
23/05/2014	0:00	0	0		0		0			
23/05/2014	2:00	0	0		0		0			
23/05/2014	4:00	0	0		0		0			
23/05/2014	6:00	0	0		0		0			
23/05/2014	8:00	0	0		0		0			
23/05/2014	10:00	0	0		0		0			
29/05/2014	0:00	2	2	100%	0	0%	2	100%	35,0	21,2
29/05/2014	2:00	2	1	50%	1	50%	1	50%	50,0	
29/05/2014	4:00	1	1	100%	0	0%	1	100%	33,3	
29/05/2014	6:00	0	0		0		0			
29/05/2014	8:00	0	0		0		0			
29/05/2014	10:00	0	0		0		0			
31/05/2014	0:00	4	2	50%	1	25%	2	50%	100,0	0,0
31/05/2014	2:00	3	2	67%	1	33%	2	67%	100,0	0,0
31/05/2014	4:00	1	0	0%	1	100%	0	0%		
31/05/2014	6:00	0	0		0		0			
31/05/2014	8:00	0	0		0		0			
31/05/2014	10:00	0	0		0		0			
03/06/2014	0:00	3	0	0%	3	100%	0	0%		
03/06/2014	2:00	3	1	33%	1	33%	1	33%	50,0	
03/06/2014	4:00	2	1	50%	1	50%	1	50%	33,3	
03/06/2014	6:00	0	0		0		0			
03/06/2014	8:00	0	0		0		0			
03/06/2014	10:00	0	0		0		0			
04/06/2014	0:00	1	1	100%	0	0%	1	100%	50,0	
04/06/2014	2:00	3	3	100%	0	0%	3	100%	64,3	31,1
04/06/2014	4:00	2	2	100%	0	0%	2	100%	78,6	30,3
04/06/2014	6:00	0	0		0		0			
04/06/2014	8:00	0	0		0		0			
04/06/2014	10:00	0	0		0		0			
05/06/2014	0:00	2	2	100%	0	0%	2	100%	62,5	53,0

05/06/2014	2:00	1	0	0%	1	100%	0	0%		
05/06/2014	4:00	1	0	0%	1	100%	0	0%		
05/06/2014	6:00	0	0		0		0			
05/06/2014	8:00	0	0		0		0			
05/06/2014	10:00	0	0		0		0			

Table 45. M01 Results for sector SAN

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	μ of the improvement of the accuracy	σ of the improvement of the accuracy
09/04/2014	0:00	5	1	20%	4	80%	1	20%	100,0	
09/04/2014	2:00	4	0	0%	4	100%	0	0%		
09/04/2014	4:00	7	3	43%	4	57%	3	43%	100,0	0,0
09/04/2014	6:00	6	0	0%	5	83%	0	0%		
09/04/2014	8:00	4	2	50%	2	50%	2	50%	75,0	35,4
09/04/2014	10:00	0	0		0		0			
10/04/2014	0:00	7	4	57%	3	43%	4	57%	79,2	25,0
10/04/2014	2:00	5	5	100%	0	0%	5	100%	42,3	32,7
10/04/2014	4:00	4	2	50%	1	25%	2	50%	100,0	0,0
10/04/2014	6:00	5	3	60%	1	20%	3	60%	61,1	34,7
10/04/2014	8:00	2	1	50%	1	50%	1	50%	100,0	
10/04/2014	10:00	1	0	0%	1	100%	0	0%		
11/04/2014	0:00	0	0		0		0			
11/04/2014	2:00	1	1	100%	0	0%	1	100%	100,0	
11/04/2014	4:00	1	1	100%	0	0%	1	100%	100,0	
11/04/2014	6:00	1	0	0%	1	100%	0	0%		
11/04/2014	8:00	0	0		0		0			
11/04/2014	10:00	0	0		0		0			
12/04/2014	0:00	3	1	33%	2	67%	1	33%	100,0	
12/04/2014	2:00	4	1	25%	3	75%	1	25%	100,0	
12/04/2014	4:00	5	2	40%	3	60%	2	40%	75,0	35,4
12/04/2014	6:00	3	1	33%	2	67%	1	33%	100,0	
12/04/2014	8:00	3	1	33%	2	67%	1	33%	100,0	
12/04/2014	10:00	1	0	0%	0	0%	0	0%		
22/04/2014	0:00	8	4	50%	4	50%	4	50%	56,3	31,5
22/04/2014	2:00	7	4	57%	2	29%	4	57%	91,7	16,7
22/04/2014	4:00	5	3	60%	2	40%	3	60%	88,9	19,2
22/04/2014	6:00	3	1	33%	2	67%	1	33%	100,0	
22/04/2014	8:00	2	0	0%	2	100%	0	0%		

22/04/2014	10:00	0	0		0		0			
24/04/2014	0:00	7	3	43%	4	57%	3	43%	83,3	28,9
24/04/2014	2:00	6	1	17%	4	67%	1	17%	100,0	
24/04/2014	4:00	5	4	80%	1	20%	4	80%	91,7	16,7
24/04/2014	6:00	1	1	100%	0	0%	1	100%	100,0	
24/04/2014	8:00	2	2	100%	0	0%	2	100%	41,7	11,8
24/04/2014	10:00	1	1	100%	0	0%	1	100%	50,0	
29/04/2014	0:00	5	3	60%	2	40%	3	60%	83,3	28,9
29/04/2014	2:00	7	1	14%	5	71%	1	14%	100,0	
29/04/2014	4:00	6	1	17%	5	83%	1	17%	100,0	
29/04/2014	6:00	6	3	50%	3	50%	3	50%	100,0	0,0
29/04/2014	8:00	4	0	0%	4	100%	0	0%		
29/04/2014	10:00	2	0	0%	2	100%	0	0%		
14/05/2014	0:00	4	1	25%	2	50%	1	25%	100,0	
14/05/2014	2:00	3	0	0%	2	67%	0	0%		
14/05/2014	4:00	4	3	75%	1	25%	3	75%	72,2	25,5
14/05/2014	6:00	4	2	50%	1	25%	2	50%	100,0	0,0
14/05/2014	8:00	1	0	0%	1	100%	0	0%		
14/05/2014	10:00	0	0		0		0			
15/05/2014	0:00	9	4	44%	4	44%	4	44%	100,0	0,0
15/05/2014	2:00	6	2	33%	2	33%	2	33%	100,0	0,0
15/05/2014	4:00	6	3	50%	2	33%	3	50%	61,1	34,7
15/05/2014	6:00	5	1	20%	3	60%	1	20%	33,3	
15/05/2014	8:00	3	1	33%	2	67%	1	33%	100,0	
15/05/2014	10:00	1	0	0%	1	100%	0	0%		
16/05/2014	0:00	4	1	25%	3	75%	1	25%	33,3	
16/05/2014	2:00	2	2	100%	0	0%	2	100%	75,0	35,4
16/05/2014	4:00	3	3	100%	0	0%	3	100%	77,8	38,5
16/05/2014	6:00	3	2	67%	1	33%	2	67%	75,0	35,4
16/05/2014	8:00	2	2	100%	0	0%	2	100%	75,0	35,4
16/05/2014	10:00	1	1	100%	0	0%	1	100%	100,0	
21/05/2014	0:00	6	0	0%	6	100%	0	0%		
21/05/2014	2:00	6	0	0%	6	100%	0	0%		
21/05/2014	4:00	6	3	50%	2	33%	3	50%	100,0	0,0
21/05/2014	6:00	3	1	33%	1	33%	1	33%	100,0	
21/05/2014	8:00	3	3	100%	0	0%	3	100%	61,1	34,7
21/05/2014	10:00	1	1	100%	0	0%	1	100%	100,0	
22/05/2014	0:00	3	3	100%	0	0%	3	100%	38,9	19,2
22/05/2014	2:00	4	4	100%	0	0%	4	100%	45,8	8,3
22/05/2014	4:00	5	0	0%	5	100%	0	0%		
22/05/2014	6:00	2	0	0%	2	100%	0	0%		
22/05/2014	8:00	2	1	50%	1	50%	1	50%	100,0	
22/05/2014	10:00	2	1	50%	1	50%	1	50%	100,0	
23/05/2014	0:00	7	3	43%	4	57%	3	43%	46,7	5,8

23/05/2014	2:00	7	3	43%	4	57%	3	43%	56,7	40,4
23/05/2014	4:00	6	2	33%	4	67%	2	33%	100,0	0,0
23/05/2014	6:00	6	3	50%	2	33%	3	50%	77,8	38,5
23/05/2014	8:00	0	0		0		0			
23/05/2014	10:00	3	1	33%	2	67%	1	33%	100,0	
29/05/2014	0:00	0	0		0		0			
29/05/2014	2:00	7	2	29%	5	71%	2	29%	83,3	23,6
29/05/2014	4:00	7	3	43%	3	43%	3	43%	100,0	0,0
29/05/2014	6:00	7	1	14%	6	86%	1	14%	100,0	
29/05/2014	8:00	3	2	67%	1	33%	2	67%	100,0	0,0
29/05/2014	10:00	1	0	0%	1	100%	0	0%		
31/05/2014	0:00	5	3	60%	2	40%	3	60%	61,1	34,7
31/05/2014	2:00	5	1	20%	4	80%	1	20%	33,3	
31/05/2014	4:00	5	2	40%	3	60%	2	40%	75,0	35,4
31/05/2014	6:00	4	1	25%	2	50%	1	25%	100,0	
31/05/2014	8:00	3	1	33%	2	67%	1	33%	100,0	
31/05/2014	10:00	0	0		0		0			
03/06/2014	0:00	3	1	33%	2	67%	1	33%	50,0	
03/06/2014	2:00	3	0	0%	3	100%	0	0%		
03/06/2014	4:00	2	1	50%	1	50%	1	50%	50,0	
03/06/2014	6:00	0	0		0		0			
03/06/2014	8:00	0	0		0		0			
03/06/2014	10:00	0	0		0		0			
04/06/2014	0:00	1	1	100%	0	0%	1	100%	25,0	
04/06/2014	2:00	4	4	100%	0	0%	4	100%	53,5	37,1
04/06/2014	4:00	4	4	100%	0	0%	4	100%	52,1	33,6
04/06/2014	6:00	2	0	0%	2	100%	0	0%		
04/06/2014	8:00	1	0	0%	1	100%	0	0%		
04/06/2014	10:00	0	0		0		0			
05/06/2014	0:00	4	4	100%	0	0%	4	100%	39,6	22,9
05/06/2014	2:00	5	3	60%	2	40%	3	60%	69,4	33,7
05/06/2014	4:00	6	4	67%	2	33%	4	67%	81,3	37,5
05/06/2014	6:00	5	2	40%	1	20%	2	40%	58,3	11,8
05/06/2014	8:00	4	2	50%	2	50%	2	50%	58,3	11,8
05/06/2014	10:00	2	0	0%	2	100%	0	0%		

Table 46. M01 Results for sector ZMI

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	µ of the improvement of the accuracy	σ of the improvement of the accuracy
09/04/2014	0:00	3	2	67%	1	33%	2	67%	75,0	35,4
09/04/2014	2:00	3	1	33%	2	67%	1	33%	50,0	
09/04/2014	4:00	3	0	0%	3	100%	0	0%		
09/04/2014	6:00	3	0	0%	3	100%	0	0%		
09/04/2014	8:00	1	0	0%	1	100%	0	0%		
09/04/2014	10:00	0	0		0		0			
10/04/2014	0:00	4	3	75%	1	25%	3	75%	66,7	28,9
10/04/2014	2:00	3	3	100%	0	0%	3	100%	30,6	4,8
10/04/2014	4:00	2	1	50%	1	50%	1	50%	50,0	
10/04/2014	6:00	2	1	50%	0	0%	1	50%	50,0	
10/04/2014	8:00	0	0		0		0			
10/04/2014	10:00	0	0		0		0			
11/04/2014	0:00	0	0		0		0			
11/04/2014	2:00	0	0		0		0			
11/04/2014	4:00	0	0		0		0			
11/04/2014	6:00	0	0		0		0			
11/04/2014	8:00	0	0		0		0			
11/04/2014	10:00	0	0		0		0			
12/04/2014	0:00	2	1	50%	1	50%	1	50%	25,0	
12/04/2014	2:00	3	1	33%	2	67%	1	33%	25,0	
12/04/2014	4:00	2	1	50%	1	50%	1	50%	25,0	
12/04/2014	6:00	2	1	50%	1	50%	1	50%	33,3	
12/04/2014	8:00	1	0	0%	1	100%	0	0%		
12/04/2014	10:00	1	0	0%	0	0%	0	0%		
22/04/2014	0:00	0	0		0		0			
22/04/2014	2:00	0	0		0		0			
22/04/2014	4:00	0	0		0		0			
22/04/2014	6:00	0	0		0		0			
22/04/2014	8:00	0	0		0		0			
22/04/2014	10:00	0	0		0		0			
24/04/2014	0:00	1	0	0%	0	0%	0	0%		
24/04/2014	2:00	2	0	0%	2	100%	0	0%		
24/04/2014	4:00	2	0	0%	2	100%	0	0%		
24/04/2014	6:00	0	0		0		0			
24/04/2014	8:00	0	0		0		0			

24/04/2014	10:00	0	0		0		0			
29/04/2014	0:00	4	1	25%	2	50%	1	25%	33,3	
29/04/2014	2:00	4	2	50%	2	50%	2	50%	50,0	23,6
29/04/2014	4:00	3	3	100%	0	0%	3	100%	66,7	28,9
29/04/2014	6:00	1	0	0%	1	100%	0	0%		
29/04/2014	8:00	1	0	0%	1	100%	0	0%		
29/04/2014	10:00	0	0		0		0			
14/05/2014	0:00	2	2	100%	0	0%	2	100%	66,7	47,1
14/05/2014	2:00	2	2	100%	0	0%	2	100%	75,0	35,4
14/05/2014	4:00	2	2	100%	0	0%	2	100%	41,7	11,8
14/05/2014	6:00	1	1	100%	0	0%	1	100%	50,0	
14/05/2014	8:00	0	0		0		0			
14/05/2014	10:00	0	0		0		0			
15/05/2014	0:00	3	1	33%	2	67%	1	33%	50,0	
15/05/2014	2:00	3	0	0%	3	100%	0	0%		
15/05/2014	4:00	3	1	33%	2	67%	1	33%	50,0	
15/05/2014	6:00	3	1	33%	2	67%	1	33%	50,0	
15/05/2014	8:00	1	0	0%	1	100%	0	0%		
15/05/2014	10:00	0	0		0		0			
16/05/2014	0:00	0	0		0		0			
16/05/2014	2:00	0	0		0		0			
16/05/2014	4:00	0	0		0		0			
16/05/2014	6:00	0	0		0		0			
16/05/2014	8:00	0	0		0		0			
16/05/2014	10:00	0	0		0		0			
21/05/2014	0:00	1	0	0%	1	100%	0	0%		
21/05/2014	2:00	1	0	0%	0	0%	0	0%		
21/05/2014	4:00	3	1	33%	1	33%	1	33%	50,0	
21/05/2014	6:00	0	0		0		0			
21/05/2014	8:00	1	0	0%	0	0%	0	0%		
21/05/2014	10:00	0	0		0		0			
22/05/2014	0:00	0	0		0		0			
22/05/2014	2:00	1	1	100%	0	0%	1	100%	16,7	
22/05/2014	4:00	1	0	0%	1	100%	0	0%		
22/05/2014	6:00	0	0		0		0			
22/05/2014	8:00	0	0		0		0			
22/05/2014	10:00	0	0		0		0			
23/05/2014	0:00	0	0		0		0			
23/05/2014	2:00	0	0		0		0			
23/05/2014	4:00	0	0		0		0			
23/05/2014	6:00	0	0		0		0			
23/05/2014	8:00	0	0		0		0			
23/05/2014	10:00	0	0		0		0			
29/05/2014	0:00	2	2	100%	0	0%	1	50%	31,3	26,5

29/05/2014	2:00	0	0		0		0			
29/05/2014	4:00	1	1	100%	0	0%	1	100%	100,0	
29/05/2014	6:00	0	0		0		0			
29/05/2014	8:00	0	0		0		0			
29/05/2014	10:00	0	0		0		0			
31/05/2014	0:00	3	0	0%	3	100%	0	0%		
31/05/2014	2:00	5	2	40%	3	60%	2	40%	66,7	47,1
31/05/2014	4:00	3	2	67%	1	33%	2	67%	66,7	47,1
31/05/2014	6:00	1	1	100%	0	0%	1	100%	50,0	
31/05/2014	8:00	0	0		0		0			
31/05/2014	10:00	0	0		0		0			
03/06/2014	0:00	4	2	50%	2	50%	2	50%	41,7	11,8
03/06/2014	2:00	2	2	100%	0	0%	2	100%	100,0	0,0
03/06/2014	4:00	0	0		0		0			
03/06/2014	6:00	0	0		0		0			
03/06/2014	8:00	0	0		0		0			
03/06/2014	10:00	0	0		0		0			
04/06/2014	0:00	1	1	100%	0	0%	1	100%	50,0	
04/06/2014	2:00	2	1	50%	1	50%	1	50%	75,0	
04/06/2014	4:00	2	2	100%	0	0%	2	100%	45,8	41,2
04/06/2014	6:00	0	0		0		0			
04/06/2014	8:00	0	0		0		0			
04/06/2014	10:00	0	0		0		0			
05/06/2014	0:00	2	1	50%	1	50%	1	50%	50,0	
05/06/2014	2:00	1	1	100%	0	0%	1	100%	100,0	
05/06/2014	4:00	2	0	0%	2	100%	0	0%		
05/06/2014	6:00	1	1	100%	0	0%	1	100%	100,0	
05/06/2014	8:00	0	0		0		0			
05/06/2014	10:00	0	0		0		0			

Table 47. M01 Results for sector ASI

The following table shows the results of M01 for each day adding the number of hours (Nº hours where ICATS-PIV forecast are different, Nº hours where ICATS forecast is better than PIV,…) for the three sectors analysed, all PIV calls and all sliding windows. The aim of this table is to provide a view of the global behavior of the M01 per day. Note that all hours where ICATS modifies PIV forecast have been added for all PIV calls. If at 00:00 call ICATS modifies the sector entry rate between 06:00-07:00 and at 02:00 call ICATS maintains a difference with PIV between 06:00-07:00, that difference has been counted twice in the second row of this table.

For each day the table shows:

- Number of one-hour sliding windows where ICATS forecast is different from PIV forecast.
- Number of one-hour sliding windows where ICATS forecast is better than PIV forecast(the difference with real traffic in ICATS is smaller than in PIV).
- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS provides a better forecast for the sector entry rate than PIV.
- Number of one-hour sliding windows where ICATS forecast is worse than PIV forecast.

- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS provides a worse forecast than PIV.
- Number of one-hour sliding windows where ICATS forecast is better than PIV forecast and the improvement is bigger than a 15% (objective target).
- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS accuracy improvement is bigger than a 15%.
- Mean value of the improvement of the accuracy (for all the sliding-windows of the day from the PIV call time onwards).
- Standard deviation of the improvement of the accuracy of sector occupancy per day and PIV call(standard deviation is only calculated when the number of hours where ICATS forecast is better than PIV is greater than two).

Date	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	μ of the improvement of the accuracy	σ of the improvement of the accuracy
09/04/2014	52	20	38%	31	60%	20	38%	90,8	10,6
10/04/2014	41	25	61%	13	32%	25	61%	70,6	21,5
11/04/2014	3	2	67%	1	33%	2	67%	100,0	N/A[13]
12/04/2014	39	10	26%	26	67%	10	26%	68,3	35,4
22/04/2014	25	12	48%	12	48%	12	48%	84,2	22,5
24/04/2014	31	13	42%	16	52%	13	42%	78,5	19,1
29/04/2014	58	20	34%	36	62%	20	34%	73,6	20,0
14/05/2014	29	14	48%	12	41%	14	48%	69,9	25,3
15/05/2014	55	25	45%	25	45%	25	45%	80,2	11,6
16/05/2014	15	11	73%	4	27%	11	73%	72,7	36,1
21/05/2014	43	14	33%	21	49%	14	33%	86,6	15,9
22/05/2014	22	11	50%	11	50%	11	50%	67,0	13,8
23/05/2014	29	12	41%	16	55%	12	41%	76,2	21,2
29/05/2014	33	15	45%	17	52%	14	42%	75,5	11,9
31/05/2014	42	17	40%	23	55%	17	40%	78,6	27,4
03/06/2014	22	8	36%	13	59%	8	36%	54,2	5,9
04/06/2014	23	19	83%	4	17%	19	83%	54,9	34,6
05/06/2014	36	20	56%	14	39%	20	56%	70,8	26,5

Table 48. M01 Results per day

[13] Mean value of the standard deviation is calculated using the results of the standard deviation of each day and PIV call. A maximum of one window improves its accuracy so it is not possible to calculate the standard deviation on 11/04/14.

Appendix D Tables for M02

The following tables contain all the values obtained in order to analyse M02 in each sector.

For each day and PIV call the next data are shown:

- Number of one-hour sliding windows where ICATS forecast is different from PIV forecast.
- Number of one-hour sliding windows where ICATS forecast is better than PIV forecast(the difference with real traffic in ICATS is smaller than in PIV).
- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS provides a better forecast for the occupancy than PIV.
- Number of one-hour sliding windows where ICATS forecast is worse than PIV forecast.
- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS provides a worse forecast than PIV.
- Number of one-hour sliding windows where ICATS forecast is better than PIV forecast and the improvement is bigger than a 10% (objective target)
- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS accuracy improvement is bigger than a 10%.
- Mean value of the improvement of the accuracy (for all the sliding-windows of the day from the PIV call time onwards) .
- Standard deviation of the improvement of the accuracy of sector occupancy per day and PIV call(standard deviation is only calculated when the number of hours where ICATS forecast is better than PIV is greater than two).

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	μ of the improvement of the accuracy	σ of the improvement of the accuracy
09/04/2014	0:00	4	1	25%	3	75%	1	25%	100,0	
09/04/2014	2:00	4	1	25%	3	75%	1	25%	100,0	
09/04/2014	4:00	6	2	33%	4	67%	2	33%	100,0	0,0
09/04/2014	6:00	4	1	25%	3	75%	1	25%	100,0	
09/04/2014	8:00	2	1	50%	1	50%	1	50%	100,0	
09/04/2014	10:00	0	0		0		0			
10/04/2014	0:00	2	0	0%	2	100%	0	0%		
10/04/2014	2:00	4	4	100%	0	0%	4	100%	46,7	36,1
10/04/2014	4:00	3	1	33%	2	67%	1	33%	100,0	
10/04/2014	6:00	2	1	50%	1	50%	1	50%	50,0	
10/04/2014	8:00	0	0		0		0			
10/04/2014	10:00	0	0		0		0			
11/04/2014	0:00	0	0		0		0			
11/04/2014	2:00	0	0		0		0			
11/04/2014	4:00	0	0		0		0			

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	μ of the improvement of the accuracy	σ of the improvement of the accuracy
11/04/2014	6:00	0	0		0		0			
11/04/2014	8:00	0	0		0		0			
11/04/2014	10:00	0	0		0		0			
12/04/2014	0:00	2	0	0%	1	50%	0	0%		
12/04/2014	2:00	3	2	67%	0	0%	2	67%	62,5	53,0
12/04/2014	4:00	2	0	0%	1	50%	0	0%		
12/04/2014	6:00	2	0	0%	1	50%	0	0%		
12/04/2014	8:00	2	0	0%	2	100%	0	0%		
12/04/2014	10:00	1	0	0%	0	0%	0	0%		
22/04/2014	0:00	0	0		0		0			
22/04/2014	2:00	0	0		0		0			
22/04/2014	4:00	0	0		0		0			
22/04/2014	6:00	0	0		0		0			
22/04/2014	8:00	0	0		0		0			
22/04/2014	10:00	0	0		0		0			
24/04/2014	0:00	1	0	0%	1	100%	0	0%		
24/04/2014	2:00	2	0	0%	2	100%	0	0%		
24/04/2014	4:00	2	1	50%	1	50%	1	50%	100,0	
24/04/2014	6:00	0	0		0		0			
24/04/2014	8:00	0	0		0		0			
24/04/2014	10:00	0	0		0		0			
29/04/2014	0:00	6	3	50%	3	50%	3	50%	66,7	33,3
29/04/2014	2:00	4	3	75%	1	25%	3	75%	77,8	19,2
29/04/2014	4:00	3	3	100%	0	0%	3	100%	66,7	28,9
29/04/2014	6:00	2	1	50%	1	50%	1	50%	100,0	
29/04/2014	8:00	1	0	0%	1	100%	0	0%		
29/04/2014	10:00	0	0		0		0			
14/05/2014	0:00	3	2	67%	1	33%	2	67%	100,0	0,0
14/05/2014	2:00	3	2	67%	1	33%	2	67%	75,0	35,4
14/05/2014	4:00	3	2	67%	1	33%	2	67%	37,5	17,7
14/05/2014	6:00	1	1	100%	0	0%	1	100%	25,0	
14/05/2014	8:00	0	0		0		0			
14/05/2014	10:00	0	0		0		0			
15/05/2014	0:00	6	2	33%	4	67%	2	33%	50,0	0,0
15/05/2014	2:00	5	3	60%	2	40%	3	60%	66,7	28,9

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	µ of the improvement of the accuracy	σ of the improvement of the accuracy
15/05/2014	4:00	6	4	67%	2	33%	4	67%	62,5	25,0
15/05/2014	6:00	4	2	50%	2	50%	2	50%	75,0	35,4
15/05/2014	8:00	2	1	50%	1	50%	1	50%	100,0	
15/05/2014	10:00	0	0		0		0			
16/05/2014	0:00	0	0		0		0			
16/05/2014	2:00	0	0		0		0			
16/05/2014	4:00	0	0		0		0			
16/05/2014	6:00	0	0		0		0			
16/05/2014	8:00	0	0		0		0			
16/05/2014	10:00	0	0		0		0			
21/05/2014	0:00	4	2	50%	2	50%	2	50%	100,0	0,0
21/05/2014	2:00	3	1	33%	1	33%	1	33%	100,0	
21/05/2014	4:00	3	0	0%	2	67%	0	0%		
21/05/2014	6:00	0	0		0		0			
21/05/2014	8:00	1	0	0%	0	0%	0	0%		
21/05/2014	10:00	0	0		0		0			
22/05/2014	0:00	0	0		0		0			
22/05/2014	2:00	2	2	100%	0	0%	2	100%	18,8	8,8
22/05/2014	4:00	2	1	50%	1	50%	1	50%	100,0	
22/05/2014	6:00	0	0		0		0			
22/05/2014	8:00	0	0		0		0			
22/05/2014	10:00	0	0		0		0			
23/05/2014	0:00	0	0		0		0			
23/05/2014	2:00	0	0		0		0			
23/05/2014	4:00	0	0		0		0			
23/05/2014	6:00	0	0		0		0			
23/05/2014	8:00	0	0		0		0			
23/05/2014	10:00	0	0		0		0			
29/05/2014	0:00	2	2	100%	0	0%	2	100%	22,2	15,7
29/05/2014	2:00	2	1	50%	1	50%	1	50%	100,0	
29/05/2014	4:00	3	2	67%	1	33%	2	67%	66,7	47,1
29/05/2014	6:00	0	0		0		0			
29/05/2014	8:00	0	0		0		0			
29/05/2014	10:00	0	0		0		0			
31/05/2014	0:00	4	1	25%	3	75%	1	25%	100,0	

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	µ of the improvement of the accuracy	σ of the improvement of the accuracy
31/05/2014	2:00	4	2	50%	2	50%	2	50%	66,7	47,1
31/05/2014	4:00	4	2	50%	2	50%	2	50%	66,7	47,1
31/05/2014	6:00	1	1	100%	0	0%	1	100%	50,0	
31/05/2014	8:00	0	0		0		0			
31/05/2014	10:00	0	0		0		0			
03/06/2014	0:00	5	2	40%	3	60%	2	40%	41,7	11,8
03/06/2014	2:00	4	3	75%	1	25%	3	75%	72,2	25,5
03/06/2014	4:00	2	2	100%	0	0%	2	100%	41,7	11,8
03/06/2014	6:00	0	0		0		0			
03/06/2014	8:00	0	0		0		0			
03/06/2014	10:00	0	0		0		0			
04/06/2014	0:00	2	2	100%	0	0%	2	100%	41,7	11,8
04/06/2014	2:00	5	5	100%	0	0%	5	100%	39,5	15,8
04/06/2014	4:00	3	3	100%	0	0%	3	100%	42,3	25,0
04/06/2014	6:00	1	1	100%	0	0%	1	100%	50,0	
04/06/2014	8:00	0	0		0		0			
04/06/2014	10:00	0	0		0		0			
05/06/2014	0:00	3	3	100%	0	0%	3	100%	27,8	4,8
05/06/2014	2:00	1	0	0%	1	100%	0	0%		
05/06/2014	4:00	3	0	0%	3	100%	0	0%		
05/06/2014	6:00	1	1	100%	0	0%	1	100%	100,0	
05/06/2014	8:00	0	0		0		0			
05/06/2014	10:00	0	0		0		0			

Table 49. M02 Results for sector SAN

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	µ of the improvement of the accuracy	σ of the improvement of the accuracy
09/04/2014	0:00	8	4	50%	4	50%	4	50%	87,5	25,0
09/04/2014	2:00	5	1	20%	4	80%	1	20%	100,0	

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	μ of the improvement of the accuracy	σ of the improvement of the accuracy
09/04/2014	4:00	6	3	50%	3	50%	3	50%	100,0	0,0
09/04/2014	6:00	4	0	0%	3	75%	0	0%		
09/04/2014	8:00	4	2	50%	2	50%	2	50%	75,0	35,4
09/04/2014	10:00	0	0		0		0			
10/04/2014	0:00	6	3	50%	3	50%	3	50%	88,9	19,2
10/04/2014	2:00	6	5	83%	1	17%	5	83%	26,7	7,0
10/04/2014	4:00	4	2	50%	2	50%	2	50%	100,0	0,0
10/04/2014	6:00	5	4	80%	0	0%	4	80%	70,8	34,4
10/04/2014	8:00	3	1	33%	1	33%	1	33%	100,0	
10/04/2014	10:00	1	0	0%	1	100%	0	0%		
11/04/2014	0:00	1	1	100%	0	0%	1	100%	25,0	
11/04/2014	2:00	2	2	100%	0	0%	2	100%	66,7	47,1
11/04/2014	4:00	2	2	100%	0	0%	2	100%	66,7	47,1
11/04/2014	6:00	2	1	50%	1	50%	1	50%	100,0	
11/04/2014	8:00	1	0	0%	1	100%	0	0%		
11/04/2014	10:00	0	0		0		0			
12/04/2014	0:00	3	2	67%	1	33%	2	67%	75,0	35,4
12/04/2014	2:00	5	2	40%	3	60%	2	40%	75,0	35,4
12/04/2014	4:00	5	3	60%	2	40%	3	60%	66,7	28,9
12/04/2014	6:00	3	0	0%	3	100%	0	0%		
12/04/2014	8:00	3	0	0%	2	67%	0	0%		
12/04/2014	10:00	1	0	0%	0	0%	0	0%		
22/04/2014	0:00	7	5	71%	2	29%	5	71%	76,7	32,5
22/04/2014	2:00	7	5	71%	2	29%	5	71%	63,3	21,7
22/04/2014	4:00	6	3	50%	3	50%	3	50%	72,2	25,5
22/04/2014	6:00	3	1	33%	1	33%	1	33%	100,0	
22/04/2014	8:00	3	0	0%	3	100%	0	0%		
22/04/2014	10:00	0	0		0		0			
24/04/2014	0:00	7	3	43%	4	57%	3	43%	66,7	28,9
24/04/2014	2:00	7	2	29%	4	57%	2	29%	50,0	0,0
24/04/2014	4:00	7	4	57%	3	43%	4	57%	87,5	25,0
24/04/2014	6:00	1	1	100%	0	0%	1	100%	100,0	
24/04/2014	8:00	2	2	100%	0	0%	2	100%	50,0	0,0
24/04/2014	10:00	1	1	100%	0	0%	1	100%	50,0	
29/04/2014	0:00	6	3	50%	3	50%	3	50%	66,7	28,9

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	μ of the improvement of the accuracy	σ of the improvement of the accuracy
29/04/2014	2:00	7	1	14%	6	86%	1	14%	100,0	
29/04/2014	4:00	5	2	40%	2	40%	2	40%	100,0	0,0
29/04/2014	6:00	5	0	0%	4	80%	0	0%		
29/04/2014	8:00	4	0	0%	4	100%	0	0%		
29/04/2014	10:00	2	0	0%	2	100%	0	0%		
14/05/2014	0:00	4	2	50%	1	25%	2	50%	75,0	35,4
14/05/2014	2:00	3	1	33%	1	33%	1	33%	100,0	
14/05/2014	4:00	3	2	67%	0	0%	2	67%	58,3	11,8
14/05/2014	6:00	4	2	50%	1	25%	2	50%	58,3	11,8
14/05/2014	8:00	1	0	0%	1	100%	0	0%		
14/05/2014	10:00	0	0		0		0			
15/05/2014	0:00	8	2	25%	5	63%	2	25%	100,0	0,0
15/05/2014	2:00	7	2	29%	2	29%	2	29%	83,3	23,6
15/05/2014	4:00	8	3	38%	5	63%	3	38%	77,8	38,5
15/05/2014	6:00	5	1	20%	3	60%	1	20%	33,3	
15/05/2014	8:00	3	1	33%	2	67%	1	33%	100,0	
15/05/2014	10:00	1	0	0%	1	100%	0	0%		
16/05/2014	0:00	4	2	50%	2	50%	2	50%	66,7	47,1
16/05/2014	2:00	2	2	100%	0	0%	2	100%	75,0	35,4
16/05/2014	4:00	3	3	100%	0	0%	3	100%	66,7	28,9
16/05/2014	6:00	3	2	67%	1	33%	2	67%	50,0	0,0
16/05/2014	8:00	3	3	100%	0	0%	3	100%	66,7	28,9
16/05/2014	10:00	2	2	100%	0	0%	2	100%	75,0	35,4
21/05/2014	0:00	6	0	0%	5	83%	0	0%		
21/05/2014	2:00	6	1	17%	5	83%	1	17%	100,0	
21/05/2014	4:00	8	3	38%	4	50%	3	38%	100,0	0,0
21/05/2014	6:00	4	1	25%	2	50%	1	25%	100,0	
21/05/2014	8:00	3	2	67%	0	0%	2	67%	41,7	11,8
21/05/2014	10:00	2	1	50%	1	50%	1	50%	100,0	
22/05/2014	0:00	3	3	100%	0	0%	3	100%	38,1	20,6
22/05/2014	2:00	4	4	100%	0	0%	4	100%	44,6	10,7
22/05/2014	4:00	5	0	0%	5	100%	0	0%		
22/05/2014	6:00	4	1	25%	3	75%	1	25%	100,0	
22/05/2014	8:00	3	1	33%	2	67%	1	33%	100,0	
22/05/2014	10:00	2	1	50%	1	50%	1	50%	100,0	

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	µ of the improvement of the accuracy	σ of the improvement of the accuracy
23/05/2014	0:00	9	2	22%	7	78%	2	22%	36,7	4,7
23/05/2014	2:00	7	1	14%	6	86%	1	14%	20,0	
23/05/2014	4:00	6	1	17%	5	83%	1	17%	50,0	
23/05/2014	6:00	4	2	50%	1	25%	2	50%	58,3	11,8
23/05/2014	8:00	0	0		0		0			
23/05/2014	10:00	3	1	33%	2	67%	1	33%	100,0	
29/05/2014	0:00	0	0		0		0			
29/05/2014	2:00	7	2	29%	5	71%	2	29%	83,3	23,6
29/05/2014	4:00	7	3	43%	3	43%	3	43%	100,0	0,0
29/05/2014	6:00	7	1	14%	6	86%	1	14%	50,0	
29/05/2014	8:00	3	3	100%	0	0%	3	100%	100,0	0,0
29/05/2014	10:00	1	0	0%	1	100%	0	0%		
31/05/2014	0:00	7	3	43%	4	57%	3	43%	100,0	0,0
31/05/2014	2:00	6	1	17%	4	67%	1	17%	50,0	
31/05/2014	4:00	5	1	20%	4	80%	1	20%	100,0	
31/05/2014	6:00	5	2	40%	3	60%	2	40%	75,0	35,4
31/05/2014	8:00	1	0	0%	1	100%	0	0%		
31/05/2014	10:00	0	0		0		0			
03/06/2014	0:00	3	1	33%	2	67%	1	33%	50,0	
03/06/2014	2:00	4	2	50%	2	50%	2	50%	75,0	35,4
03/06/2014	4:00	3	2	67%	1	33%	2	67%	50,0	0,0
03/06/2014	6:00	0	0		0		0			
03/06/2014	8:00	0	0		0		0			
03/06/2014	10:00	0	0		0		0			
04/06/2014	0:00	2	2	100%	0	0%	2	100%	22,5	3,5
04/06/2014	2:00	5	5	100%	0	0%	5	100%	40,4	24,8
04/06/2014	4:00	4	4	100%	0	0%	4	100%	47,1	24,3
04/06/2014	6:00	2	2	100%	0	0%	2	100%	100,0	0,0
04/06/2014	8:00	1	0	0%	1	100%	0	0%		
04/06/2014	10:00	0	0		0		0			
05/06/2014	0:00	4	4	100%	0	0%	4	100%	38,3	14,5
05/06/2014	2:00	4	3	75%	1	25%	3	75%	83,3	28,9
05/06/2014	4:00	4	2	50%	2	50%	2	50%	66,7	47,1
05/06/2014	6:00	5	3	60%	1	20%	3	60%	83,3	28,9
05/06/2014	8:00	4	2	50%	2	50%	2	50%	58,3	11,8

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	μ of the improvement of the accuracy	σ of the improvement of the accuracy
05/06/2014	10:00	2	0	0%	2	100%	0	0%		

Table 50. M02 Results for sector ZMI

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	μ of the improvement of the accuracy	σ of the improvement of the accuracy
09/04/2014	0:00	4	2	50%	2	50%	2	50%	58,3	11,8
09/04/2014	2:00	3	1	33%	2	67%	1	33%	33,3	
09/04/2014	4:00	3	2	67%	1	33%	2	67%	100,0	0,0
09/04/2014	6:00	2	0	0%	2	100%	0	0%		
09/04/2014	8:00	1	0	0%	1	100%	0	0%		
09/04/2014	10:00	0	0		0		0			
10/04/2014	0:00	5	3	60%	2	40%	3	60%	83,3	28,9
10/04/2014	2:00	3	3	100%	0	0%	3	100%	28,9	7,7
10/04/2014	4:00	2	1	50%	1	50%	1	50%	50,0	
10/04/2014	6:00	2	1	50%	0	0%	1	50%	50,0	
10/04/2014	8:00	0	0		0		0			
10/04/2014	10:00	0	0		0		0			
11/04/2014	0:00	0	0		0		0			
11/04/2014	2:00	0	0		0		0			
11/04/2014	4:00	0	0		0		0			
11/04/2014	6:00	0	0		0		0			
11/04/2014	8:00	0	0		0		0			
11/04/2014	10:00	0	0		0		0			
12/04/2014	0:00	2	1	50%	1	50%	1	50%	25,0	
12/04/2014	2:00	3	1	33%	2	67%	1	33%	20,0	
12/04/2014	4:00	3	2	67%	1	33%	2	67%	60,0	56,6
12/04/2014	6:00	3	2	67%	1	33%	2	67%	66,7	47,1
12/04/2014	8:00	2	1	50%	1	50%	1	50%	100,0	
12/04/2014	10:00	1	0	0%	0	0%	0	0%		

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	μ of the improvement of the accuracy	σ of the improvement of the accuracy
22/04/2014	0:00	0	0		0		0			
22/04/2014	2:00	0	0		0		0			
22/04/2014	4:00	0	0		0		0			
22/04/2014	6:00	0	0		0		0			
22/04/2014	8:00	0	0		0		0			
22/04/2014	10:00	0	0		0		0			
24/04/2014	0:00	1	0	0%	0	0%	0	0%		
24/04/2014	2:00	2	0	0%	2	100%	0	0%		
24/04/2014	4:00	3	2	67%	1	33%	2	67%	100,0	0,0
24/04/2014	6:00	0	0		0		0			
24/04/2014	8:00	0	0		0		0			
24/04/2014	10:00	0	0		0		0			
29/04/2014	0:00	4	1	25%	3	75%	1	25%	100,0	
29/04/2014	2:00	5	3	60%	2	40%	3	60%	77,8	38,5
29/04/2014	4:00	4	4	100%	0	0%	4	100%	87,5	25,0
29/04/2014	6:00	2	0	0%	2	100%	0	0%		
29/04/2014	8:00	1	0	0%	1	100%	0	0%		
29/04/2014	10:00	0	0		0		0			
14/05/2014	0:00	3	2	67%	1	33%	2	67%	62,5	53,0
14/05/2014	2:00	3	2	67%	1	33%	2	67%	62,5	53,0
14/05/2014	4:00	2	2	100%	0	0%	2	100%	37,5	17,7
14/05/2014	6:00	1	1	100%	0	0%	1	100%	50,0	
14/05/2014	8:00	0	0		0		0			
14/05/2014	10:00	0	0		0		0			
15/05/2014	0:00	3	1	33%	2	67%	1	33%	50,0	
15/05/2014	2:00	2	1	50%	1	50%	1	50%	100,0	
15/05/2014	4:00	3	1	33%	2	67%	1	33%	33,3	
15/05/2014	6:00	3	1	33%	2	67%	1	33%	50,0	
15/05/2014	8:00	2	0	0%	2	100%	0	0%		
15/05/2014	10:00	1	0	0%	1	100%	0	0%		
16/05/2014	0:00	0	0		0		0			
16/05/2014	2:00	0	0		0		0			
16/05/2014	4:00	0	0		0		0			
16/05/2014	6:00	0	0		0		0			
16/05/2014	8:00	0	0		0		0			

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	µ of the improvement of the accuracy	σ of the improvement of the accuracy
16/05/2014	10:00	0	0		0		0			
21/05/2014	0:00	2	1	50%	1	50%	1	50%	100,0	
21/05/2014	2:00	3	2	67%	0	0%	2	67%	75,0	35,4
21/05/2014	4:00	2	1	50%	0	0%	1	50%	50,0	
21/05/2014	6:00	1	1	100%	0	0%	1	100%	100,0	
21/05/2014	8:00	2	1	50%	0	0%	1	50%	100,0	
21/05/2014	10:00	1	1	100%	0	0%	1	100%	100,0	
22/05/2014	0:00	0	0		0		0			
22/05/2014	2:00	1	1	100%	0	0%	1	100%	16,7	
22/05/2014	4:00	1	0	0%	1	100%	0	0%		
22/05/2014	6:00	0	0		0		0			
22/05/2014	8:00	0	0		0		0			
22/05/2014	10:00	0	0		0		0			
23/05/2014	0:00	0	0		0		0			
23/05/2014	2:00	0	0		0		0			
23/05/2014	4:00	0	0		0		0			
23/05/2014	6:00	0	0		0		0			
23/05/2014	8:00	0	0		0		0			
23/05/2014	10:00	0	0		0		0			
29/05/2014	0:00	2	2	100%	0	0%	2	100%	22,2	15,7
29/05/2014	2:00	0	0		0		0			
29/05/2014	4:00	1	0	0%	1	100%	0	0%		
29/05/2014	6:00	0	0		0		0			
29/05/2014	8:00	0	0		0		0			
29/05/2014	10:00	0	0		0		0			
31/05/2014	0:00	4	1	25%	2	50%	1	25%	33,3	
31/05/2014	2:00	5	2	40%	3	60%	2	40%	66,7	47,1
31/05/2014	4:00	2	1	50%	0	0%	1	50%	50,0	
31/05/2014	6:00	1	1	100%	0	0%	1	100%	50,0	
31/05/2014	8:00	0	0		0		0			
31/05/2014	10:00	0	0		0		0			
03/06/2014	0:00	4	1	25%	3	75%	1	25%	33,3	
03/06/2014	2:00	2	1	50%	0	0%	1	50%	66,7	
03/06/2014	4:00	1	1	100%	0	0%	1	100%	66,7	
03/06/2014	6:00	0	0		0		0			

Date	PIV call	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	μ of the improvement of the accuracy	σ of the improvement of the accuracy
03/06/2014	8:00	0	0		0		0			
03/06/2014	10:00	0	0		0		0			
04/06/2014	0:00	1	1	100%	0	0%	1	100%	50,0	
04/06/2014	2:00	2	1	50%	1	50%	1	50%	75,0	
04/06/2014	4:00	2	2	100%	0	0%	2	100%	44,6	42,9
04/06/2014	6:00	0	0		0		0			
04/06/2014	8:00	0	0		0		0			
04/06/2014	10:00	0	0		0		0			
05/06/2014	0:00	3	3	100%	0	0%	3	100%	58,3	38,2
05/06/2014	2:00	2	1	50%	1	50%	1	50%	50,0	
05/06/2014	4:00	1	0	0%	1	100%	0	0%		
05/06/2014	6:00	1	1	100%	0	0%	1	100%	100,0	
05/06/2014	8:00	0	0		0		0			
05/06/2014	10:00	0	0		0		0			

Table 51. M02 Results for sector ASI

The following table shows the results of M02 for each day adding the number of hours (Nº hours where ICATS-PIV forecast are different, Nº hours where ICATS forecast is better than PIV,…) for the three sectors analysed, all PIV calls and all sliding windows. The aim of this table is to provide a view of the global behavior of the M02 per day. Note that all hours where ICATS modifies PIV forecast have been added for all PIV calls. If at 00:00 call ICATS modifies the sector occupancy between 06:00-07:00 and at 02:00 PIV call ICATS maintains a difference with PIV between 06:00-07:00, that difference has been counted twice in the second row of this table.

For each the table shows:

- Number of one-hour sliding windows where ICATS forecast is different from PIV forecast.
- Number of one-hour sliding windows where ICATS forecast is better than PIV forecast(the difference with real traffic in ICATS is smaller than in PIV).
- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS provides a better forecast for the occupancy than PIV.
- Number of one-hour sliding windows where ICATS forecast is worse than PIV forecast.
- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS provides a worse forecast than PIV.
- Number of one-hour sliding windows where ICATS forecast is better than PIV forecast and the improvement is bigger than a 10% (objective target)
- % of hours (of the number of hours where ICATS and PIV forecasts are different) where ICATS accuracy improvement is bigger than a 10%.
- Mean value of the improvement of the accuracy (for all the sliding-windows of the day from the PIV call time onwards) .

- Standard deviation of the improvement of the accuracy of sector occupancy per day and PIV call(standard deviation is only calculated when the number of hours where ICATS forecast is better than PIV is greater than two).

Date	Nº hours where ICATS-PIV forecast are different	Nº hours where ICATS forecast is better	% Hours where ICATS forecast is better	Nº hours where ICATS forecast is worse	% Hours where ICATS forecast is worse	Nº hours where ICATS reaches the target objective	% Hours where ICATS reaches the target objective	μ of the improvement of the accuracy	σ of the improvement of the accuracy
09/04/2014	60	21	35%	38	63%	21	35%	89,4	17,9
10/04/2014	48	29	60%	16	33%	29	60%	72,1	18,8
11/04/2014	8	6	75%	2	25%	6	75%	64,6	47,1
12/04/2014	46	16	35%	22	48%	16	35%	66,5	42,4
22/04/2014	26	14	54%	11	42%	14	54%	78,1	26,6
24/04/2014	36	16	44%	18	50%	16	44%	68,8	10,3
29/04/2014	61	24	39%	35	57%	24	39%	86,9	26,0
14/05/2014	34	21	62%	9	26%	21	62%	61,8	25,3
15/05/2014	69	25	36%	39	57%	25	36%	72,1	23,3
16/05/2014	17	14	82%	3	18%	14	82%	66,7	29,3
21/05/2014	51	18	35%	23	45%	18	35%	89,6	11,8
22/05/2014	27	14	52%	13	48%	14	52%	77,5	15,2
23/05/2014	29	7	24%	21	72%	7	24%	53,0	8,2
29/05/2014	35	16	46%	18	51%	16	46%	69,4	15,7
31/05/2014	49	18	37%	28	57%	18	37%	67,4	32,4
03/06/2014	28	15	54%	12	43%	15	54%	55,2	16,0
04/06/2014	30	28	93%	2	7%	28	93%	52,3	14,7
05/06/2014	38	23	61%	14	37%	23	61%	65,5	27,2

Table 52. M02 Results per day

Appendix E Graphics for M07 and M08

As is mentioned in 6.2.3.1.4, this annex lists all the graphics obtained from the analysis of predictability and accuracy of the information included in PIV and ICATS HMI systems.

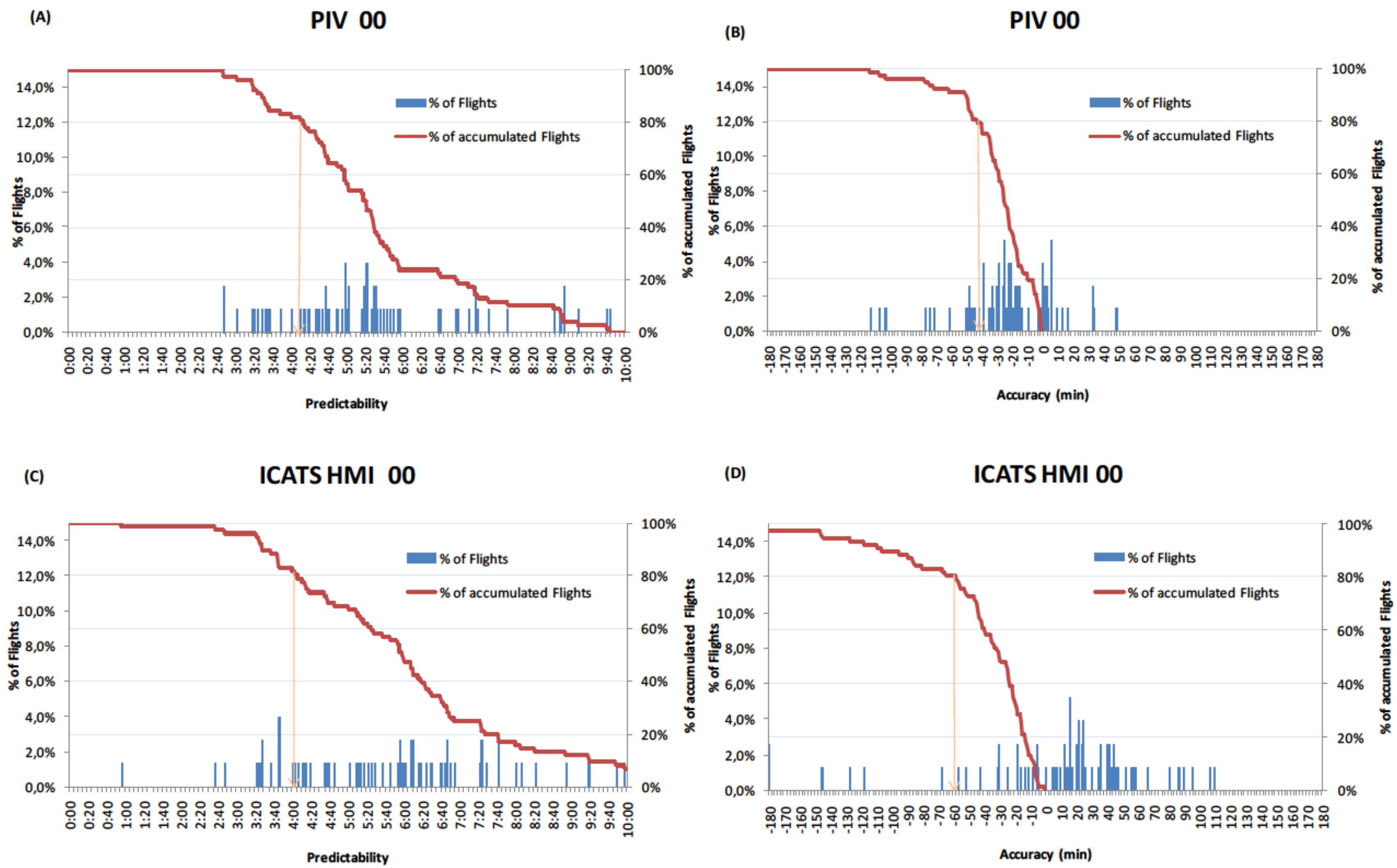

Figure 47: (A) Distribution of predictability (in hours) for PIV´s call made at 00. (B) Distribution of accuracy for PIV´s call made at 00. (C) Distribution of predictability (in hours) for ICATS HMI´s call made at 00. (D) Distribution of accuracy for ICATS HMI´s call made at 00.

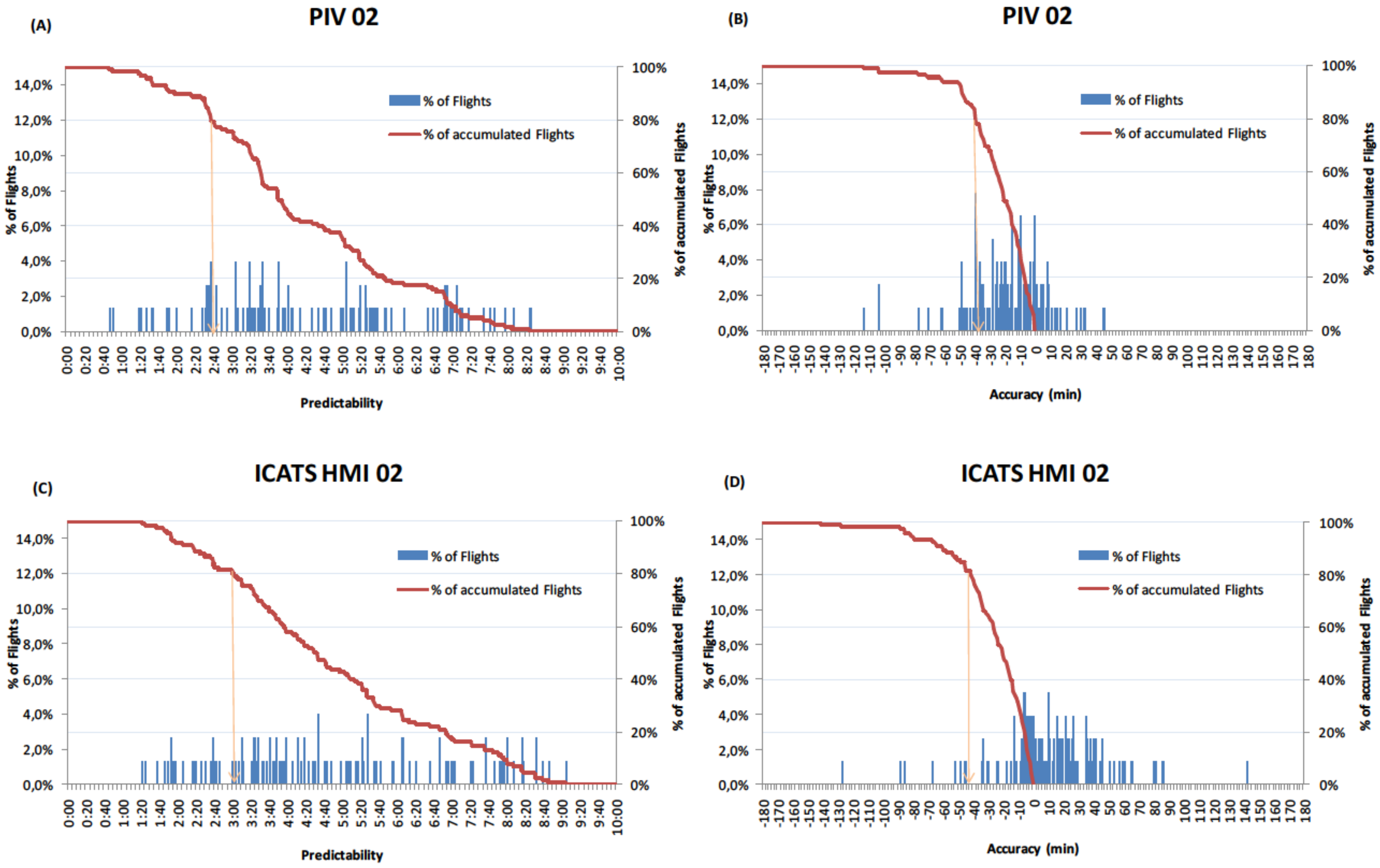

Figure 48: (A) Distribution of predictability (in hours) for PIV´s call made at 02. (B) Distribution of accuracy for PIV´s call made at 02. (C) Distribution of predictability (in hours) for ICATS HMI´s call made at 02. (D) Distribution of accuracy for ICATS HMI´s call made at 02.

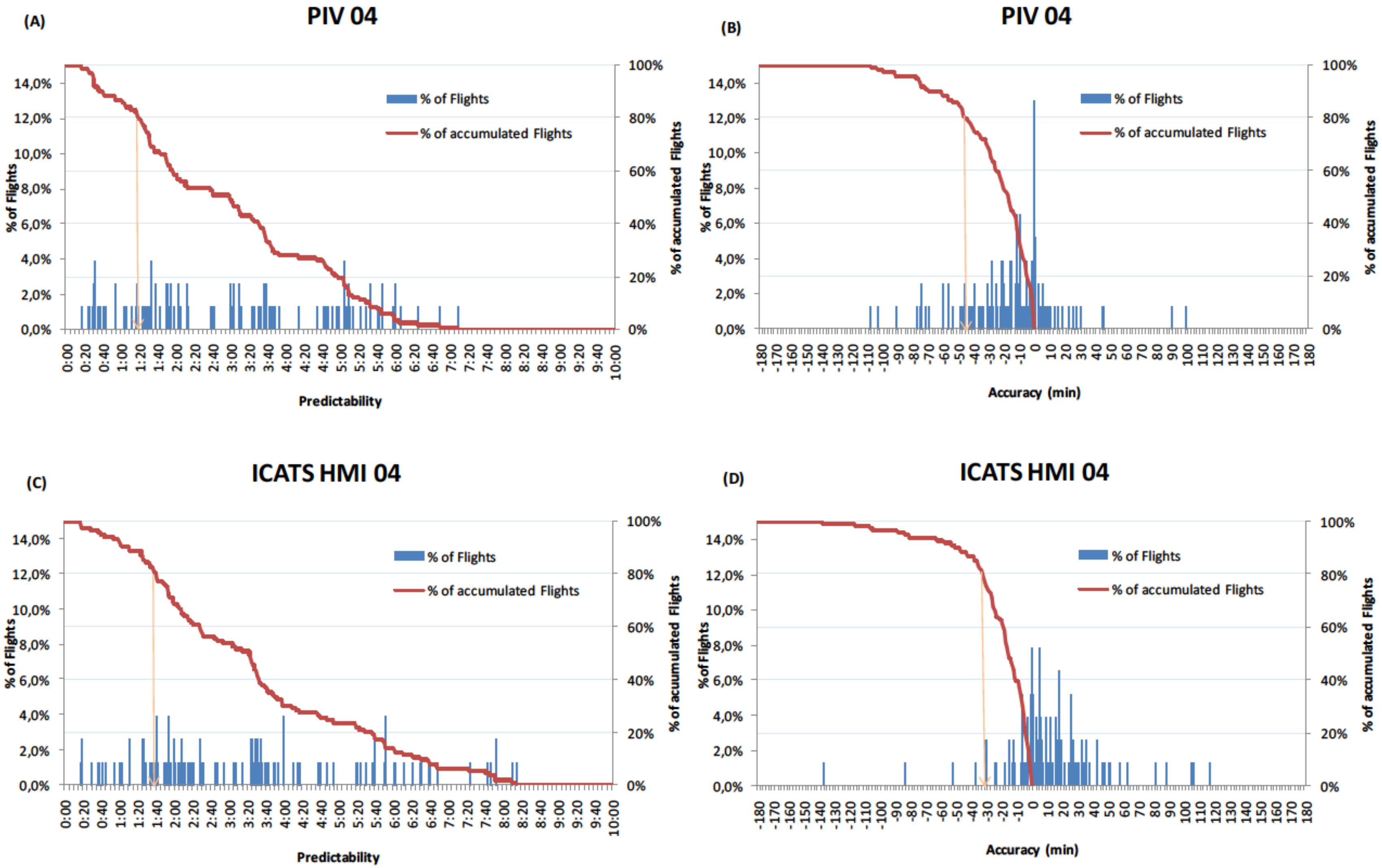

Figure 49: (A) Distribution of predictability (in hours) for PIV´s call made at 04. (B) Distribution of accuracy for PIV´s call made at 04. (C) Distribution of predictability (in hours) for ICATS HMI´s call made at 04. (D) Distribution of accuracy for ICATS HMI´s call made at 04.

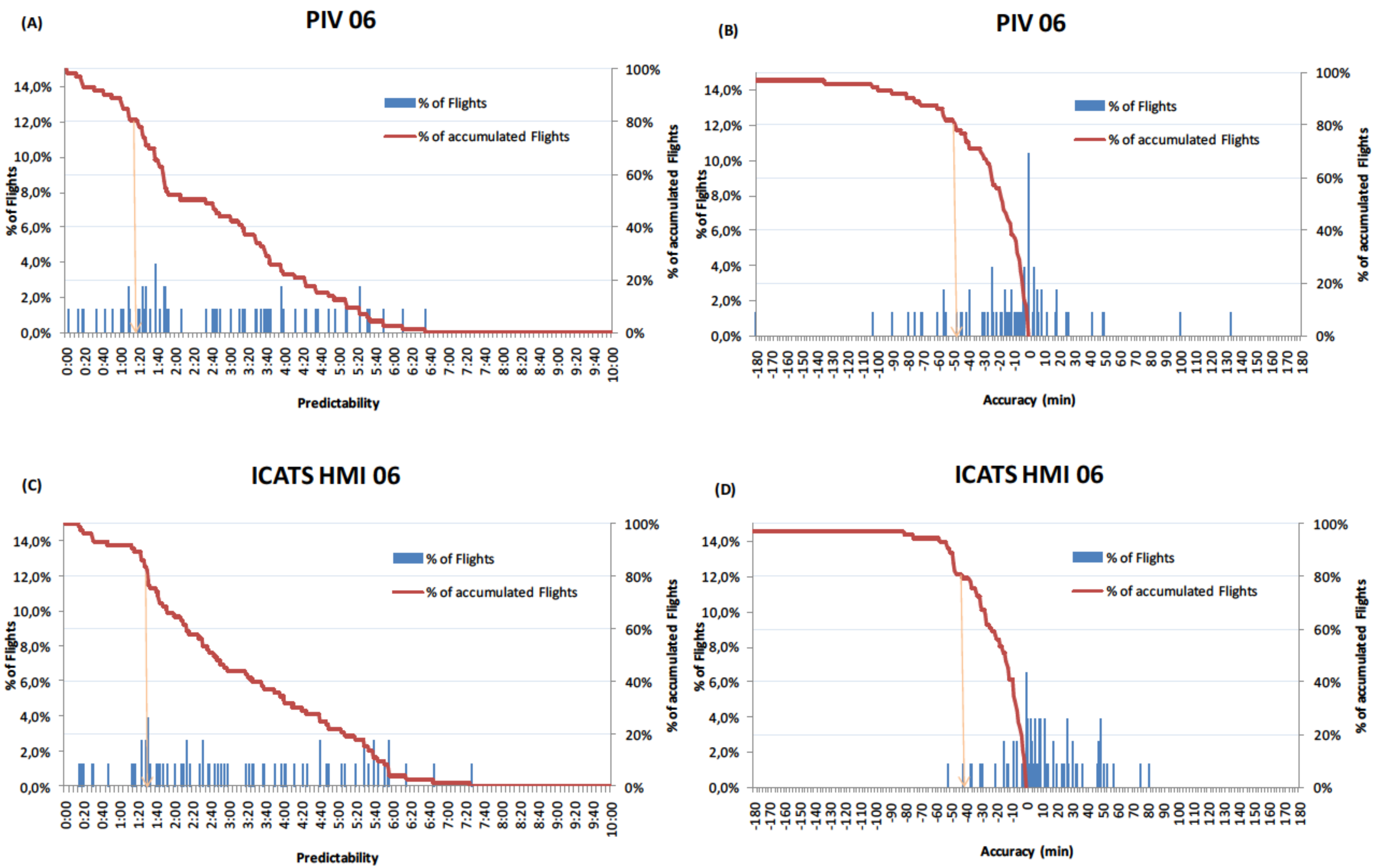

Figure 50: (A) Distribution of predictability (in hours) for PIV´s call made at 06. (B) Distribution of accuracy for PIV´s call made at 06. (C) Distribution of predictability (in hours) for ICATS HMI´s call made at 06. (D) Distribution of accuracy for ICATS HMI´s call made at 06.

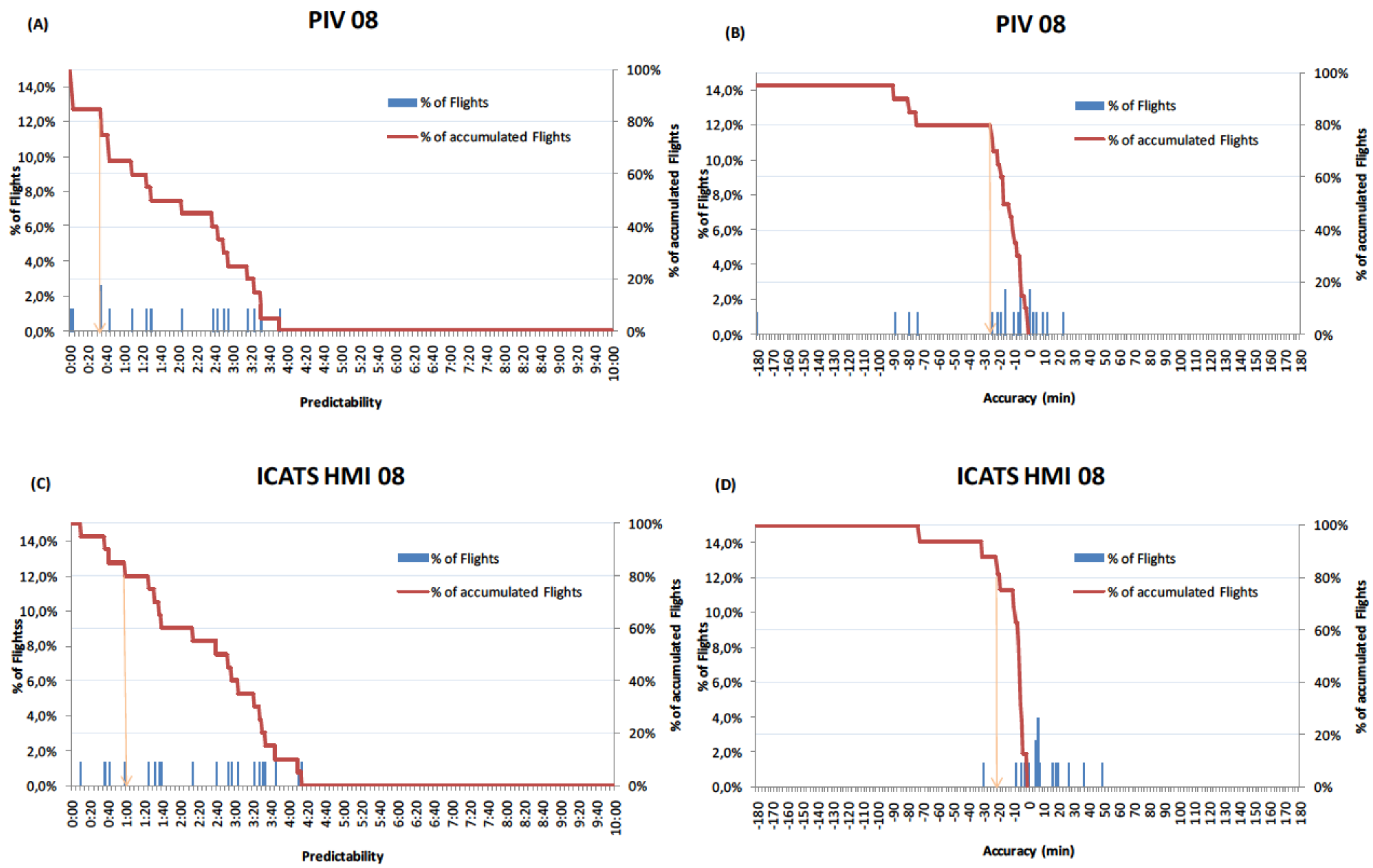

Figure 51: (A) Distribution of predictability (in hours) for PIV´s call made at 08. (B) Distribution of accuracy for PIV´s call made at 08. (C) Distribution of predictability (in hours) for ICATS HMI´s call made at 08. (D) Distribution of accuracy for ICATS HMI´s call made at 08.

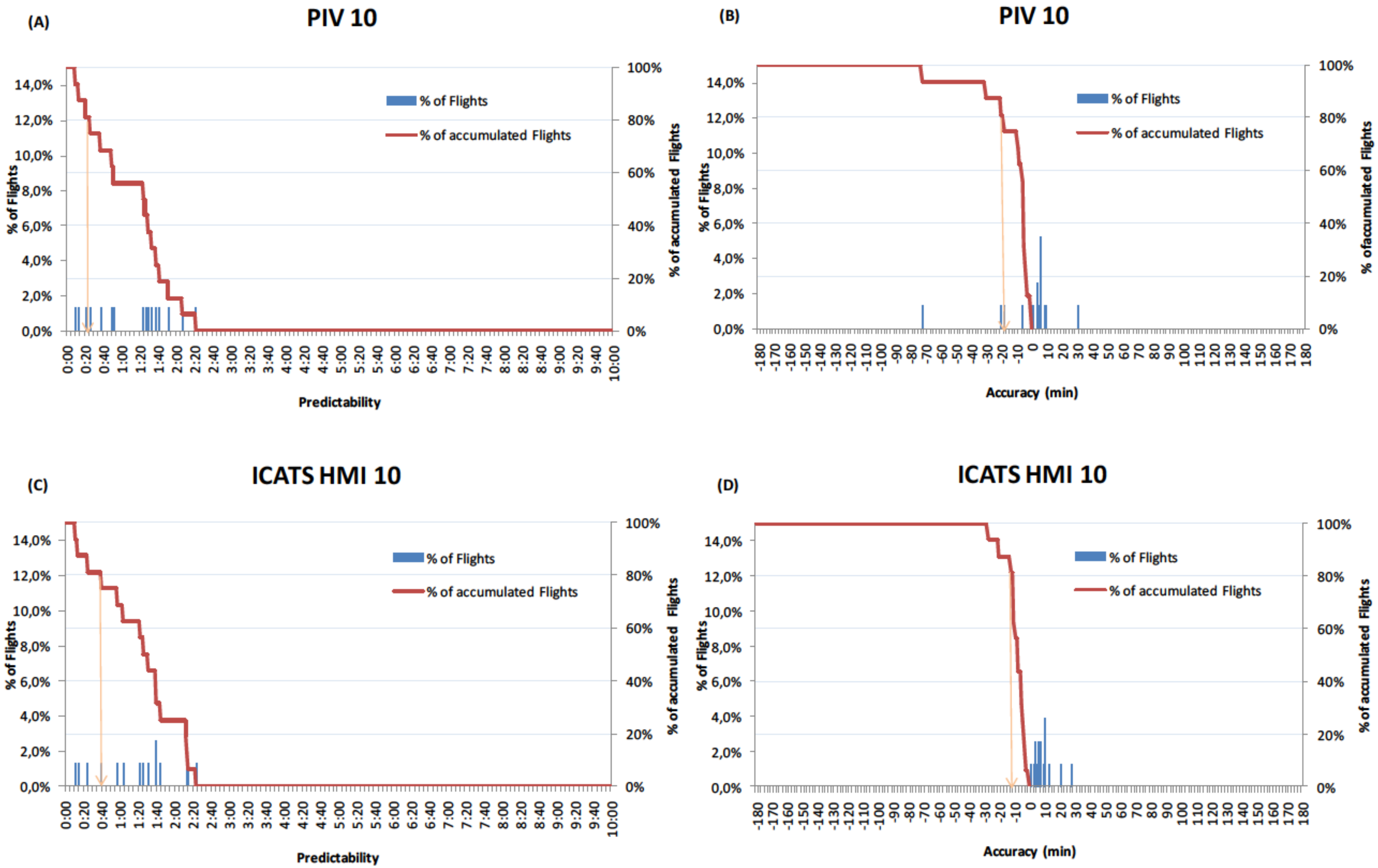

Figure 52: (A) Distribution of predictability (in hours) for PIV´s call made at 10. (B) Distribution of accuracy for PIV´s call made at 10. (C) Distribution of predictability (in hours) for ICATS HMI´s call made at 10. (D) Distribution of accuracy for ICATS HMI´s call made at 10.

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