TOPFLIGHT B1 Demonstration Report

Document information	
Project Title	TOPFLIGHT
Project Number	02.07
Project Manager	NATS
Deliverable Name	TOPFLIGHT B1 Demonstration Report
Edition	01.01.00
Template version	01.00.00
Task contributors	
NATS, NAV CANADA, British Airways, Barco Orthogon, Airbus ProSky, Boeing	

Abstract

This document forms the B1 Demonstration Report for TOPFLIGHT, providing a concise description of the activities conducted in the project. TOPFLIGHT has successfully demonstrated multiple elements of SESAR concept to create a gate-to-gate optimisation of transatlantic flights and identified the implications that these concept elements have on SWIM. This document presents the results, analysis and the derived conclusions. Based on these findings, recommendations are provided to define the next steps for the sustainable transition of the concept elements into operations at other airspace units. This document also provides details of the assessment methodologies undertaken and summarizes the project communication activities.

Authoring & Approval

Prepared By - *Authors of the document.*		
Name & Company	Position & Title	Date
[redacted] NATS	[redacted]	18/07/2014
[redacted] NATS	[redacted]	16/05/2014
[redacted] NATS	[redacted]	16/05/2014

Reviewed By - *Reviewers internal to the project.*		
Name & Company	Position & Title	Date
[redacted] NATS	[redacted]	23/05/2014
[redacted] NATS	[redacted]	23/05/2014
[redacted] NATS	[redacted]	23/05/2014
[redacted] NATS	[redacted]	23/05/2014
[redacted] NATS	[redacted]	21/05/2014
[redacted] British Airways	[redacted]	23/05/2014
[redacted] NAV CANADA	[redacted]	23/05/2014
[redacted] Airbus	[redacted]	23/05/2014
[redacted] Boeing	[redacted]	23/05/2014
[redacted] Barco Orthogon	[redacted]	23/05/2014

Reviewed By - *Other SESAR projects, Airspace Users, staff association, military, Industrial Support, other organisations.*		
Name & Company	Position & Title	Date
N/A	N/A	N/A

Approved for submission to the SJU By - *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
[redacted] NATS	[redacted]	28/05/2014
[redacted] NAV CANADA	[redacted]	28/05/2014
[redacted] British Airways	[redacted]	28/05/2014
[redacted] Airbus ProSky	[redacted]	28/05/2014
[redacted] Boeing	[redacted]	28/05/2014
[redacted] Barco Orthogon	[redacted]	28/05/2014

Rejected By - *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
None	-	-

Rational for rejection
None.

Document History

Edition	Date	Status	Author	Justification
00.00.01	16/05/2014	Initial Draft	[redacted]	New Document
01.00.00	30/05/2014	First Issue	[redacted]	First Issue to SJU

01.01.00	18/07/2014	Second Issue	[redacted]	Incorporate SJU comments

Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground.

Table of Contents

List of tables

List of figures

Executive summary

The TOPFLIGHT project has achieved its objectives of demonstrating multiple elements of the SESAR concept in the gate-to-gate optimisation of transatlantic flights between North America and Europe. The success of the project in demonstrating the feasibility and benefits of the SESAR concept has reinforced commitment regarding the early transition of elements of the concept into sustainable operations in complex TMA, high density en-route and oceanic environments.

TOPFLIGHT has effectively engaged with airline management, aircrew, ground support personnel, air traffic controllers at 13 different ATC units, airport operators and NSAs, promoting an understanding of the SESAR concept and demonstrating that the SESAR programme is already delivering benefits in daily operations.

Initially 100 transatlantic flights were optimised in Phase 1, which brought together several elements of the SESAR concept to optimise a single transatlantic flight at a time. The following elements were demonstrated;

- Reduced Engine Taxi,
- Oceanic Clearance Delivery for aircraft at gate, as a proxy for departures from a major airport to meet a CTO,
- Continuous Climb Operations,
- Free Routing,
- Advanced Flexible Use of Airspace,
- Optimised Oceanic Profiles including Continuous Cruise Climb,
- Continuous Descent Operations.

In Phase 2 of TOPFLIGHT, which focussed on demonstrating the feasibility and assessing the benefits of Extended AMAN / Cross Border AMAN (XMAN), up to 20,000 flights were involved in trials. Phase 2 resulted in the first operational use of a SWIM web-service and delivered sustainable operational improvement at London Heathrow airport.

High confidence was achieved regarding the feasibility of the SESAR concept elements demonstrated. Benefits analysis was performed through tailored methodologies, requiring data from many different sources, ranging from direct aircrew and air traffic controllers observations, to analysis of Flight Data Recorder, Surveillance Data Processing, Flight Data Processing and commercially available surveillance data.

The concept elements demonstrated were at different levels of maturity and therefore required different levels of effort in preparing for demonstrations, although it was determined that all of them offered efficiency benefits. In Phase 1 the project demonstrated fuel benefits of up to 834 Kg for a gate-to-gate optimised transatlantic flights, corresponding to 2652 Kg of CO_2 saved per flight. During the XMAN trials in Phase 2, it was demonstrated that effective queue management can save between 80 Kg (for an A321) to 490 Kg of fuel (for a B747) for each arrival.

The TOPFLIGHT project has confirmed the importance of accurate trajectory prediction and sharing, as the key mechanism for overcoming airspace capacity constraints. The project has also identified improvements that could be made to air and ground systems that would enhance the benefits that SESAR is delivering today and will deliver in future.

TOPFLIGHT has had a relevant presence in the airspace sector media, such as Aviation Week and International Airport Review, and had a prominent position at the NATS and [redacted] stands at the World ATM Congress 2014 in Madrid.

1 Introduction

1.1 Purpose of the document

This document forms the B1 Demonstration Report for TOPFLIGHT. It provides a concise description of the activities conducted in all three Phases of the project, focusing on the results and conclusions.

1.2 Intended readership

The main intended readership of this report is:

- The consortium members participating in the project,
- The SESAR Joint Undertaking,
- General stakeholders of the SJU,
- The SESAR OFA leaders and additional parties involved in demonstration and validation activities for SESAR,
- Other projects in the Demonstration Program.

1.3 Structure of the document

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 in the integration trial flights.

Section 3 provides an overview of the project management aspects of TOPFLIGHT; including the work and resource breakdowns, project milestones, pre-financing and risks.

Section 4 details the demonstration approach to be taken in the TOPFLIGHT integrated flight trials.

Section 5 summarises the results of the demonstration exercises undertaken within the 3 phases of the project.

Section 6 details the results of each of the demonstration exercises individually.

Section 7 describes the communications activities that were undertaken by the project.

Section 8 describes the overall conclusions and recommendations for the next steps.

Section 9 contains the references.

1.4 Glossary of terms

The following are the definitions relating to the main concept to be demonstrated in the project that are particular to this document and not of a more general nature:

Continuous Climb Departure – An aircraft operating technique in which a departing aircraft attains the optimal fuel efficient climb profile by avoiding ATC imposed level segments of flight prior to the cruise phase.

Continuous Climb Operations – An ATM operating method which utilises Continuous Climb Departures.

Continuous Descent Approach – An aircraft operating technique in which an arriving aircraft descends from an optimal top of descent with minimal thrust and avoids level flight to the extent permitted by the safe operation of the aircraft and compliance with published procedures and ATC instructions.

Continuous Descent Operations – An ATM operating method which utilises Continuous Descent Approaches.

Oceanic Metering - The ability of aircraft to lose or gain time during the oceanic phase of flight to meet a Controlled Time Over (CTO) restriction imposed at the Oceanic Exit Point.

1.5 Acronyms and Terminology

Term	Definition
ACARS	Aircraft Communications Addressing and Reporting System
A-CDM	Airport Collaborative Decision Making
AFUA	Advanced Flexible Use of Airspace
AIRE	Atlantic Interoperability Initiative to Reduce Emissions
AMAN	Arrival MANager
ANSP	Air Navigation Service Provider
AOC	Airline Operations Centre
ARP	Airport Reference Point
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATM	Air Traffic Management
CCD	Continuous Climb Departure
CCO	Continuous Climb Operations
CDA	Continuous Descent Approach
CDO	Continuous Descent Operations
CI	Cost Index
CO_2	Carbon Dioxide
COOPANS	CO-Operation of Air Navigation Service providers (IAA ATM System)
COP	Co-Ordination Point
CPDLC	Controller Pilot DataLink Communications
CTA	Controlled Time of Arrival
CTO	Controlled Time Over
CYUL	ICAO Identifier for Montreal Trudeau Airport
CYYZ	ICAO Identifier for Toronto Pearson Airport
DOD	Detailed Operational Description
E-AMAN	Extended Arrival MANager

Term	Definition
E-ATMS	European Air Traffic Management System
EAT	Expected Approach Time
EB	East Bound
ETA	Estimated Time of Arrival
ETMS	Enhanced Traffic Management System
ETFMS	Enhanced Tactical Flow Management System
EGLL	ICAO Identifier for London Heathrow airport
E-OCVM	European Operational Concept Validation Methodology
FAB	Functional Airspace Block
FABEC	Functional Airspace Block European Central
FANS	Future Air Navigation Systems (Communication System)
FDR	Flight Data Recorder
FL	Flight Level
FMC	Flight Management Computer
FMS	Flight Management System
GAATS	Gander Automated Air Traffic System
HMI	Human Machine Interface
IAA	Irish Aviation Authority
i4D	initial four Dimensional
IAF	Initial Approach fix
LAMP	London Airspace Management Programme
NAT	North Atlantic Track
NWMTA	North Wales Military Training Area
OCA	Oceanic Control Area
OEnP	Oceanic Entry Point
OExP	Oceanic Exit Point
OFA	Operational Focus Areas

Term	Definition
OTS	Organised Track System
PRNAV	Precision RNAV
RETI	Reduced Engine Taxi In
RETO	Reduced Engine Taxi Out
RNAV	ARea NAVigation
RNP	Required Navigation Performance
RNP AR	Required Navigation Performance Authorization Required
RTA	Required Time of Arrival
RWY	Runway
SAATS	Shanwick Automated Air Traffic System
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SID	Standard Instrument Departure
SJU	SESAR Joint Undertaking
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
STAR	STandard Arrival Route
SWIM	System Wide Information Management
Term	Definition
TMA	Terminal Manoeuvring Area
TOD	Top Of Descent
TTOT	Target Take-Off Time
UPR	User Preferred Routing
WB	West Bound
XMAN	Cross Border Arrival Management

2 Context of the Demonstrations

TOPFLIGHT aimed at developing, demonstrating and transitioning to operations several of the more mature concept elements developed in SESAR through a series of flight trials in live operations. In terms of E-OCVM, this means starting the transition from V3 (Pre-industrial development & integration) to V4 (Industrialisation).

It was focused on transatlantic flight between Northern Europe and Canada. The European origin/destination was London's Heathrow airport. The Canadian origins/destinations were Montreal Trudeau and Toronto Pearson airports.

2.1 Scope of the demonstration and complementarity with the SESAR Programme

Demonstration Exercise ID and Title	**EXE-02.07-D-101 : Phase 1: Transatlantic Gate-to-Gate Flight Demonstrations**
Leading organization	British Airways
Demonstration exercise objectives	The high level objectives of the Phase 1 exercise are to: • To develop, demonstrate (via flight trials) and transition to operations an airline-driven concept for the gate-to-gate optimisation of flights between North America and Europe based on multiple elements of the SESAR concept: A-CDM, RETO/RETI, CCO and CDA using on-board aspects of RNP in high density airspace, AFUA, optimised oceanic flight and Arrival Manager • To deliver sustainable operational change to both complex TMA and high density oceanic environment. • To identify the implications of such changes on the SWIM system required to fully exploit the potential of today's systems. • To synchronise concepts and intercontinental operational changes with both the FAA NextGen Programme and with NAV CANADA.
OFA addressed	• OFA02.01.01 Optimised 2D/3D Routes • OFA03.01.03 Free Routing • OFA04.01.02 Enhanced Arrival & Departure Management in TMA & En-route • OFA05.03.01 Airspace Management & AFUA
Applicable Operational Context	The activities of Phase 1 developed and demonstrated the relevant concept elements of SESAR Release 1 that will optimise the transatlantic flights by increasing significantly their efficiency.
Demonstration Technique	Live trials
Number of flight trials	100 single aircraft flights

Table 1: EXE-02.07-D-101

Demonstration Exercise ID and Title	**EXE-02.07-D-201 A: Phase 2: Oceanic Metering Flight Demonstration**
Leading organization	NATS
Demonstration exercise objectives	The objectives of this exercise are: • to understand the scope available within the oceanic operation to enable aircraft to lose or gain time in the oceanic phase of flight, • to quantify the potential benefits of the concept, and • to verify the accuracy of data in ATM systems required to implement Oceanic Metering.
OFA addressed	• OFA04.01.02 Enhanced Arrival & Departure Management in TMA & En-route • ENB03.01.01 Trajectory Management Framework & System Interoperability with Air and Ground Data Sharing
Applicable Operational Context	Flight Demonstrations will take place under normal operations.
Demonstration Technique	Data collection from flight trials and ground systems.
Number of trials	57 trial flights

Table 2: EXE-02.07-D-201 A

Demonstration Exercise ID and Title	**EXE-02.07-D-201 B: Phase 2: E-AMAN**
Leading organization	NATS
Demonstration exercise objectives	The high level objectives of this exercise are: • Assess the extension of the T4 horizon (furthest distance displayed) of AMAN to 85 minutes flight time from Heathrow and Oceanic Metering for arrivals and the impact this has on fuel consumption, greenhouse gas emissions, track miles and delay; • To assess the use of Extended AMAN and Oceanic Metering to enable CDOs from top of descent for all Heathrow Arrivals; • Produce metrics for delay, fuel burn, emissions and track mileage from the multiple aircraft trial flights; • Determine/refine the local procedures for multi-aircraft demonstration flights and for sustainable day to day operations after the conclusion of the project.

OFA addressed	- OFA04.01.02 Enhanced Arrival & Departure Management in TMA & En-route - ENB03.01.01 Trajectory Management Framework & System Interoperability with Air and Ground Data Sharing
Applicable Operational Context	The activities of Phase 2 developed and demonstrated the relevant concept elements of SESAR Release 1 that significantly increase the efficiency of arrival at EGLL.
Demonstration Technique	Live trials, fast-time and real-time simulations
Number of trials	All Heathrow inbounds during one month, except those arriving before 7am (local time). Approximately 20000 impacted flights.

Table 3: EXE-02.07-D-201 B

Demonstration Exercise ID and Title	**EXE-02.07-D-301: Phase 3: E-AMAN/DMAN & Oceanic Metering Flight Demonstration[1]**
Leading organization	Boeing

Demonstration exercise objectives	The high level objectives of the Phase 3 exercise are to;
	- Assess the benefits of the extension of arrival time constraints to the aircraft departure and climb out with point-in-space sequencing time windows at waypoints along the aircraft trajectory;
	- Assess the flight and system efficiency benefits of sharing aircraft sequencing constraints with oceanic ANSPs;
	- Demonstrate the use of pre-sorting of flights onto oceanic tracks to recover from departure time variability and changes in forecast winds. The demonstration will assess whether;
	  ○ The pre-sorting of flights by reallocation of ocean track leads to a reduction in fuel burn and emissions by efficiently and predictably meeting CTO OExP time constraints and extended AMAN sequencing;
	  ○ Pre-sorting reduces adverse impacts on other traffic and on controller workload, improving scalability to indicate the possibility of concurrently sequencing all North Atlantic flights with AMAN sequence times.
	- Identify the information flows required to support the pre-sorting and point-in-space time constraints using the existing communication systems, and define the information requirements for a future multi-national inter-domain SWIM;

---

[1] The flight trials were not part of the contracted scope.

	• Produce metrics for delay, fuel burn, emissions and track mileage from the multiple aircraft trial flights; Determine/refine the local procedures for multi-aircraft demonstration flights and for sustainable day to day operations after the conclusion of the project.
OFA addressed	• OFA03.01.03 Free Routing • OFA04.01.02 AMAN and Extended AMAN horizon • OFA04.01.02 Enhanced Arrival & Departure Management in TMA & En-route • OFA03.01.08 System Interoperability with air and ground data sharing
Applicable Operational Context	The activities of Phase 3 develop and demonstrate the relevant concept elements of: • Transatlantic gate to gate; • Initial 4D trajectory operations; • Integration of SESAR and FAA NextGen. Phase 3 maintains the efficiency of early morning arrivals at EGLL while reducing adverse impact on other OTS flights. This phase also demonstrates that pre-sorting of flights onto the OTS increases the scalability of the extended sequencing providing a basis for further trials with multiple European AMANs.
Demonstration Technique	Concept study. The flight trials were not part of the contracted scope of the Project.
Number of trials	N/A

Table 4: EXE-02.07-D-301

3 Programme management

3.1 Organisation

The TOPFLIGHT project was led by NATS' R&D Department. In addition, the project called upon resources and support from throughout the NATS organisation. This included operational controllers from NATS' airports, terminal, en-route, and oceanic centres, and other staff from NATS' SESAR Delivery and NATS System Engineering departments.

The airline partner was British Airways, who were responsible for leading the requirement definition for the TOPFLIGHT concept and the operation of trial flights in Exercises 101 and 201 A. The leadership of the airline partner in setting the requirements and then conducting the demonstrations ensured that the TOPFLIGHT project is Airspace User driven.

NAV CANADA, Boeing, Airbus ProSky and Barco Orthogon provided a valuable technical and operational contribution to the project. The Airbus ProSky contribution involved Airbus SAS, Airbus Operations SAS and Quovadis. For the sake of simplicity, the name Airbus will be used in the rest of the document when several of these companies are involved.

The following diagram illustrates the consortium structure and how the partners of the project were organised.

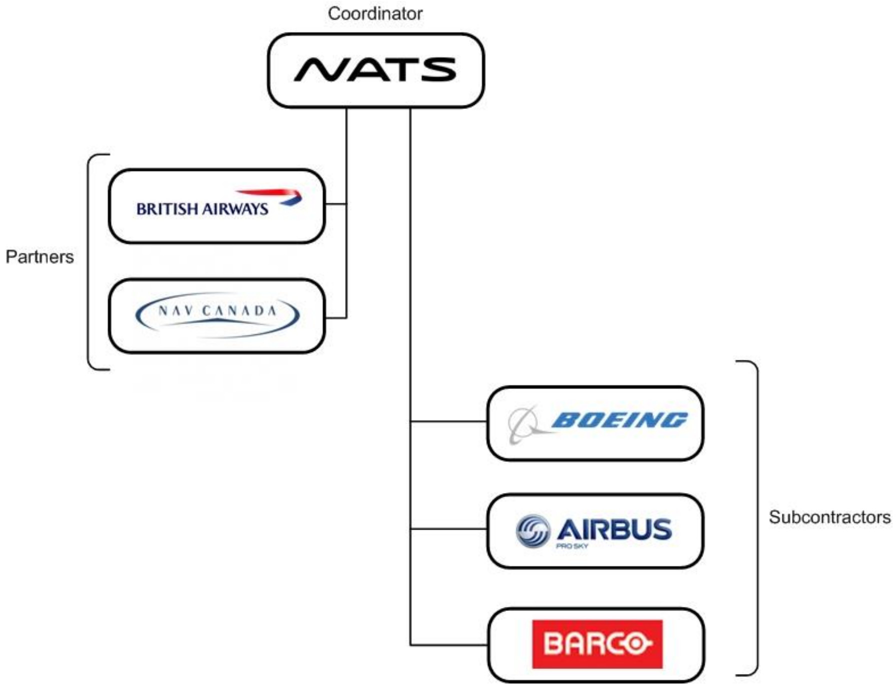


Figure 1: Organisation of the consortium

3.2 Work Breakdown Structure

The project was executed over a period of two-years starting in June 2012. The project consisted of three phases:

- Phase 1: Transatlantic Gate-to-Gate Flight Demonstrations,
- Phase 2: E-AMAN & Oceanic Metering Flight Demonstrations,
- Phase 3: E- AMAN/DMAN & Oceanic Metering Flight Demonstrations.

The three project phases were organised into eight work packages that delivered the necessary procedures required to facilitate the demonstration flights. In addition, the project management work package (WP 0) executed the necessary project monitoring & control and conduct communications activities relating to the project.

The guiding principle in the development of this work breakdown structure was to ensure that the concept integration is customer-led. Therefore the definition and objective identification activities were led by the airline partner, British Airways. Similarly, the flight demonstration activities, which confirmed the applicability and benefits of the concepts, were also customer-led. The development of the concepts and their testing was led by the ANSP partners (NATS and NAV CANADA) with SWIM related activities led by the industry partners (Boeing and Airbus ProSky) with support by Barco Orthogon with regard to AMAN.

For further details please refer to the TOPFLIGHT Demonstration Plan [1].

3.3 Deliverables

The two formal deliverables of the TOPFLIGHT integrated flight trials project are the Deliverable A.1 Demonstration plan [1] and the Deliverable B.1, the Demonstration Report (this document).

Deliverable name	Date
Demonstration Plan (A.1)	27/07/2012
Demonstration Report (B.1)	13/06/2014

Table 5: Formal Deliverable List

Other project deliverables are listed in the table below.

Deliverable name	Milestone number	Nature	Date
Concept Description	M.1	Internal Deliverable	27/07/12
Quarterly Reports	M.2, M.3, M.4, M.6, M.9, M.13, M.17	Quarterly Reports	See Demonstration Plan [1]
Phase 1 Summary Report	M.11	Internal Deliverable	31/12/2013
Phase 2 Summary Report	M.14	Internal Deliverable	30/05/14
Phase 3 Summary Report	M.16	Internal Deliverable	30/05/14
Draft Final Report D-B.1a	M.18	Draft Deliverable	30/05/14

Table 6: Other Project Deliverables

3.4 Risk Management

The risk management of Project TOPFLIGHT required a constant monitoring of the risks, due to the complexities associated with a large demonstration project in scope and time and the complexities of dependence of third parties. The mitigation actions were defined minding SJU and Consortium members' interest in producing a high quality work for all stakeholders, and these decisions were timely agreed with the SJU. The management of risks and its communication also provides a valuable exercise of lessons learnt.

For further details please refer to the TOPFLIGHT Demonstration Plan [1].

4 Execution of Demonstration Exercises

4.1 Exercises Preparation

Phase #1 required development of the operational concepts to be demonstrated and analysed. This included the development of safety-approved procedures to ensure consistent briefing of the following operational participants in Phase 1 trials:

- British Airways Pilots,
- British Airways Flight Planners,
- British Airways Traffic Managers,
- NATS ATCO in Heathrow Tower, Shanwick Oceanic, London ACC and London TMA,
- NAV CANADA ATCO in Gander Oceanic, Montreal, Moncton and Toronto Centres.

ATC Watch Managers of London ACC were regularly briefed and questionnaires for both pilots' and ATCOs' debriefing were defined, agreed, prepared and distributed.

Trial flights were selected using the following criteria:

- British Airways transatlantic services, westbound and eastbound flights, connecting London Heathrow with Canadian airports,
- Time of the day offering a balance between a less congested airspace while addressing at the same time some of the common implementation challenges,
- The North Atlantic Tracks were fully contained within Gander and Shanwick OCA, without entering Reykjavik or New York FIRs,
- Range of different aircraft types.

Phase #2A required a questionnaire to be deployed to British Airways pilots of trial flights. Preparations were also made to collect system data from various ground ATM systems for the period of the trial flights.

Phase #2B required the application of arrival constraints in the airspace controlled by Maastricht UAC, DSNA Reims UAC, IAA Shannon ACC, NATS Prestwick Centre and Swanwick Area Control. It required the definition of procedures in these units. New and enhanced controller displays (HMIs) were developed for use during the trial by external partners and the Shannon HMI was developed and funded by this Project.

The arrival delay information was based on BARCO AMAN data transmitted on Web-Service. AMAN provided an output to the 'SWIM Web Services' (SWIM-WS) system which is based on application software supplied by Snowflake Ltd. The SWIM-WS allows web services to be deployed for subscription by external users. Clients request the arrival sequence message using request reply (polling). A high level view of the architecture is shown in Figure 2.

The Shannon client was based on the BARCO HMI Application for Arrival Sequence Service. Both the NATS/Snowflake and BARCO solutions have won the top prizes in the 2013 SESAR SWIM Master Class Awards.

The ANSPs had slightly different methods of displaying the delay messages to ATCOs. Some had the information directly displayed to sectors via HMIs, while others have HMIs configured at supervisor positions and sector staff was consequently informed.

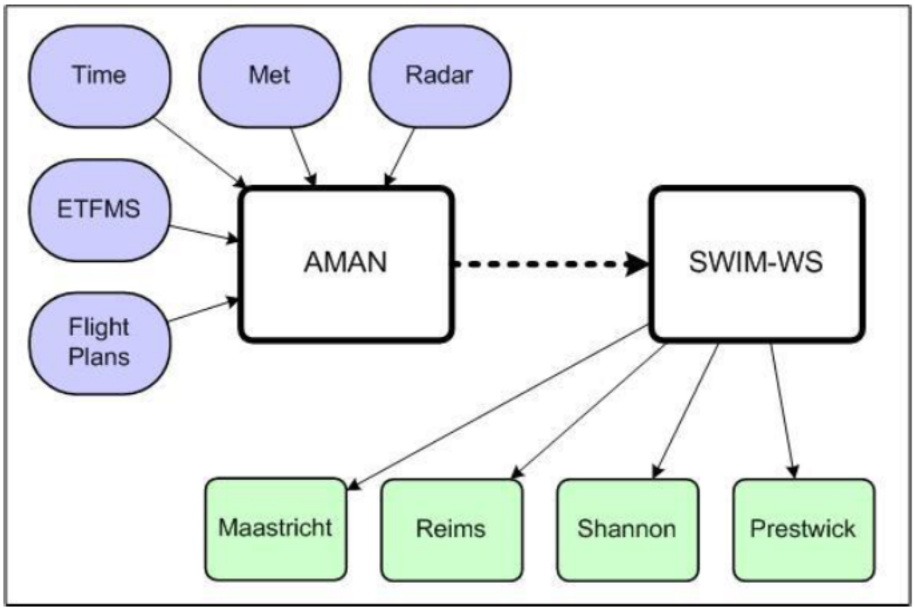


Figure 2: XMAN Trial Architecture (Ops)

The information sources necessary for the measurement of the objectives defined in 5.1 Summary of Exercises Results are collected in Table 7.

Data source	Exercise		
	#1	#2A	#2B
FDR (Flight Data Recorder) files for selected British Airways flights	X		X
SAATS (Shanwick Automated Air Traffic System)	X	X	
GAATS (Gander Automated Air Traffic System)	X		
Flight Plans	X		
Barco Arrival Manager (AMAN)		X	X
Questionnaires to Pilots and Air Traffic Controllers	X	X	X
Radar Replay	X		
ADS-B			X
ETFMS (Enhanced Tactical Flow Management System)		X	
COOPANS (CO-Operation of Air Navigation Service providers) (IAA ATM System)		X	

Table 7: Information sources for exercises measurement

4.2 Exercises Execution

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise start analysis date	Actual Exercise end date	Data sample
Exercise #1	Transatlantic Gate-to-Gate Flight Demonstrations	29/05/2013	17/07/2013	29/05/2013	18/02/2014	100 trial flights
Exercise #2A*	Oceanic Metering Flight Demonstration	06/11/2013	27/11/2013	06/11/2013	27/11/2013	57 trial flights
Exercise #2B*	E-AMAN	01/04/2014	30/04/2014	01/04/2014	30/05/2014	Approximately 20,000 flights
Exercise #3	E-AMAN/DMAN & Oceanic Metering Flight Demonstrations	Defined in the Demonstration Plan [1] as subject to funding from the Boeing FAA NextGen SE2020 Airbridge project which did not become available. Finally performed as a concept study.				

Table 8: Exercises execution/analysis dates

*Exercise #2 divided in #2A and #2B, as explained in 4.3.

4.3 Deviations from the planned activities

The concept of Extended Arrival Management evolved since the beginning of the project and the FABEC XMAN programme emerged. While being the same concept of operations, the preferred wording is XMAN, standing for Cross Border Arrival Management.

One of the main principles agreed by the XMAN partners is that cross border arrival management should be symmetrical and equitable in the application of the delay horizon. The concept of Oceanic Metering defined in the Demonstration Plan therefore became less relevant to the initial demonstration of the concept, however remained an important exercise in determining the capacity of oceanic airspace to absorb delaying a linear manner as part of future symmetrical extensions of the delay horizon. It was therefore decided to split Exercise #2 into two de-coupled exercises, #2A and #2B. These are complementary exercises with no interdependencies and a different assessment methodology. This meant that Exercise #2A could be performed earlier than planned thereby reducing risk to the project. Exercise #2B proceeded as planned. This change was approved by the SJU at the Critical Project Review in August 2013.

Exercise 3 was defined in the Demonstration Plan [1] as being subject to funding from the Boeing FAA NextGen SE2020 Airbridge programme. When the Plan was written the funding was under discussion, however it did finally not come to reality during the life of the project, Exercise #3 was therefore performed as a concept study.

Airbus' contribution to the latter part of the Project was modified to introduce simulation exercises. Accordingly, the contract between Airbus and NATS was amended and signed by December 2013. The remaining work for phase 2 and phase 3 of TOPFLIGHT (WP 5 to 8, and WP0) for Airbus was changed from a review activity only, with limited contributions, to the execution of more significant simulation activities that provided a valuable complimentary input to the XMAN benefits assessment.

5 Exercises Results

5.1 Summary of Exercises Results

The table shown below has been transposed from the original template to allow a better use of space.

Exercise ID	Exercise #1
Demonstration Objective Title	Produce local procedures for the demonstration of the on-board aspects of RNP based Continuous Climb Operations in high density airspace
Demonstration Objective ID	OBJ-02.07-1001
Success Criterion	Produce local procedures for the demonstration of the on-board aspects of RNP based Continuous Climb Operations in both UK and Canadian high density airspace are validated by controllers and aircraft simulators
Exercise Results	One procedure was produced for each domestic airspace in order to facilitate, amongst other operating elements and when possible without penalizing other aircraft, Continuous Climb Operations. In addition to this, standard operating practices for controllers in UK and Canada include the provision of Continuous Climb Operations when separation with interacting aircraft is ensured. In addition to these actions, new RNP-based departure procedures for Heathrow and Gatwick airports were assessed in British Airways and Airbus flight simulators to assess their flyability and operational benefits. The operational concept and supporting enablers were developed and refined, having shown the capability to work coherently together and deliver benefits, meeting the objectives stated in the E-OCVM manual for Phase V3: Pre-industrial development & validation. Approved temporary procedures compliant with all applicable technical/operational specifications and standards were in place for the trials. In terms of E-OCVM, it complies with the requirements specified for Phase 4: Industrialisation.
Demonstration Objective Status	OK
Exercise ID	Exercise #1
Demonstration Objective Title	Produce local procedures for the demonstration of the on-board aspects of RNP-based Continuous Descent Operations in high density airspace
Demonstration Objective ID	OBJ-02.07-1002
Success Criterion	Produce local procedures for the demonstration of the on-board aspects of RNP-based Continuous Descent Operations in both UK and Canadian high density airspace are validated by controllers and aircraft simulators.

Exercise Results	One procedure was produced for Canadian domestic airspace in order to facilitate, amongst other operating elements and when possible without penalizing other aircraft, CDO. There was no procedure in place to affect Eastbound trial aircraft after crossing the OExP, as this phase of the flights will be the subject of a case study in Phase 2 of the project. The operational concept and supporting enablers are developed and refined, having shown the capability to work coherently together and deliver benefits (E-OCVM V3). Approved temporary procedures compliant with all applicable technical/operational specifications and standards were in place for the trials (E-OCVM V3).
Demonstration Objective Status	OK

Exercise ID	Exercise #1
Demonstration Objective Title	Conduct a sufficient number of single aircraft trial flights to allow analysis to be conducted
Demonstration Objective ID	OBJ-02.07-1003
Success Criterion	At least 30 single aircraft trial flights are conducted
Exercise Results	100 trials flights were successfully conducted.
Demonstration Objective Status	OK

Exercise ID	Exercise #1
Demonstration Objective Title	Collect data relating to fuel burn from single aircraft trial flights
Demonstration Objective ID	OBJ-02.07-1004
Success Criterion	Fuel consumption data is collected for all single aircraft trial flights
Exercise Results	97 flight plans and 83 FDR files including fuel consumption information were collected.

Demonstration Objective Status	OK
Exercise ID	Exercise #1
Demonstration Objective Title	Collect data relating to greenhouse gas emissions from single aircraft trial flights
Demonstration Objective ID	OBJ-02.07-1005
Success Criterion	Greenhouse gas emission data is calculated for all single aircraft trial flights.
Exercise Results	Greenhouse gas emission data was calculated based on the results obtained for the objective OBJ-02.07-1004, using a factor of 3,18.
Demonstration Objective Status	OK
Exercise ID	Exercise #1
Demonstration Objective Title	Collect data relating to track mileage from single aircraft trial flights.
Demonstration Objective ID	OBJ-02.07-1006
Success Criterion	The track mileage for all single aircraft flights is recorded
Exercise Results	Actual track mileage information was recorded and collected for 39 trial flights. The 97 full-detailed flight plans collected also include details of track miles between waypoints.
Demonstration Objective Status	OK
Exercise ID	Exercise #1
Demonstration Objective Title	Confirm which actors are required to publish which items of pertinent, timely, accurate and accredited information to enable the successful application of the concept elements.
Demonstration Objective ID	OBJ-02.07-1007

Success Criterion	The project provides a list of actors and data items supported by expert opinion and empirical evidence.
Exercise Results	Actors involved in the publication and the information to be offered have been identified. The details, based on the findings during the flight trials, can be found in the SWIM analysis enclosed in Appendix E of Complementary Results to TOPFLIGHT B1 Demonstration Report [2].
Demonstration Objective Status	OK
Exercise ID	Exercise #1
Demonstration Objective Title	Confirm which actors are required to subscribe to which items of pertinent, timely, accurate and accredited information to enable the successful application of the concept elements.
Demonstration Objective ID	OBJ-02.07-1008
Success Criterion	The project provides a list of actors and data items supported by expert opinion and empirical evidence.
Exercise Results	Actors involved in the publication and the information to be offered have been identified. The details, based on the findings during the flight trials, can be found in the SWIM analysis enclosed in Appendix E of Complementary Results to TOPFLIGHT B1 Demonstration Report [2].
Demonstration Objective Status	OK
Exercise ID	Exercise #1
Demonstration Objective Title	Demonstrate that the oceanic clearance can be successfully issued to the demonstration flight aircraft while it is on the ground at Heathrow.
Demonstration Objective ID	OBJ-02.07-1009
Success Criterion	Over 80% of the westbound single aircraft trial flights receive the oceanic clearance while on the ground at Heathrow.
Exercise Results	The trials have shown sufficient airspace coordination capability to issue an initial oceanic profile whilst the aircraft is on ground at Heathrow, thus improving predictability, according to the information collected regarding the initial oceanic clearance process, analysed in Section 6.1.3.1.2 of this report. The only element affecting the issuing of the clearance was interacting eastbound traffic when requesting a block level of 2000ft and Variable Mach of ±0.02M. The profile was approved for 75% of the cases, being the 25%

	cancelled flights due to affecting traffic. Without the optimised request, the clearance would be delivered for 100% of the flights. The operational concept and supporting enablers are developed and refined, having shown the capability to work coherently together and deliver benefits (E-OCVM V3). Approved procedures compliant with all applicable technical/operational specifications and standards were in place for the trials (E-OCVM V4).
Demonstration Objective Status	OK

Exercise ID	Exercise #1
Demonstration Objective Title	Assess the feasibility and benefits of RNP-based SIDs to allow Continuous Climb Operations in high density airspace without penalising other flights.
Demonstration Objective ID	OBJ-02.07-1010
Success Criterion	Sufficient data is collected from the demonstration flights to assess the feasibility and benefits of RNP-based SIDs to allow Continuous Climb Operations in high density airspace without penalising other flights.
Exercise Results	Initial designs of RNP procedures for London TMA were assessed in cockpit simulator sessions together with the current conventional procedures to allow fuel, time and altitude comparisons. Due to safety regulations, the use of procedures not yet published prevented assessment of RNP-based SIDs in flight. The operational concept and supporting enablers are developed and refined, having shown the capability to work coherently together and deliver benefits (E-OCVM V3). Approved procedures compliant with all applicable technical/operational specifications and standards were in place for the trials (E-OCVM V4) to allow Continuous Climb Operations in RNP-based departure procedures.
Demonstration Objective Status	OK

Exercise ID	Exercise #1
Demonstration Objective Title	Assess the feasibility and benefits of using the RTA functionality on-board to achieve the oceanic clearance entry conditions.
Demonstration Objective ID	OBJ-02.07-1011
Success Criterion	Sufficient data is collected from the demonstration flights to assess the feasibility and benefits of using the RTA functionality on-board to achieve the oceanic clearance entry conditions.

Exercise Results	The use of RTA functionality was assessed. The outcome of this activity is that it is not currently supported by the FMC of British Airways aircraft. Honeywell advised the FMC can support RTA but only as an 'AT OR BEFORE' or 'AT OR AFTER' function. This functionality is not supported by ATC and is of very limited use.
Demonstration Objective Status	OK
Exercise ID	Exercise #1
Demonstration Objective Title	Assess the feasibility and benefits of Continuous Descent Operations enabled by the on-board aspects of RNP-based approaches from Top of Descent.
Demonstration Objective ID	OBJ-02.07-1012
Success Criterion	Sufficient data is collected to assess the feasibility of Continuous Descent Operations enabled by the on-board aspects of RNP approaches from Top of Descent.
Exercise Results	Descent profile information from the flight trials has been collected and analysed. The analysis can be found in Section 6.1.3.1.6. The operational concept and supporting enablers are developed and refined, having shown the capability to work coherently together and deliver benefits (E-OCVM V3). Approved procedures compliant with all applicable technical/operational specifications and standards were in place for the trials (E-OCVM V4).
Demonstration Objective Status	OK
Exercise ID	Exercise #1
Demonstration Objective Title	Assess the feasibility and benefits of using Flexible Use of Airspace to enable Direct routing and therefore to reduce track mileage in domestic en-route airspace.
Demonstration Objective ID	OBJ-02.07-1013
Success Criterion	Sufficient data is collected to assess the feasibility and benefits of using Flexible Use of Airspace to enable Direct routing and therefore to reduce track mileage in domestic en-route airspace.
Exercise Results	It was assessed that AFUA implementation and routing information from the flight trials has been collected and analysed. The analysis can be found in Section 6.1.3.1.4. It was negotiated to achieve extra flexibility to flight plan the

	use of a military area in UK airspace when this area was unavailable to general Commercial Air Traffic (CAT), but it was not finally approved. For this particular element, air traffic units in Canada and UK engaged with military controllers for access permission. Current operating practices were in place for this particular concept, but extra coordination between units was performed.
Demonstration Objective Status	OK

Exercise ID	Exercise #1
Demonstration Objective Title	Assess the feasibility and benefits of optimal step climb profiles and variable Mach flight profiles in oceanic airspace.
Demonstration Objective ID	OBJ-02.07-1014
Success Criterion	Sufficient data is collected to assess the feasibility and benefits of optimal step climb profiles and variable Mach flight profiles in oceanic airspace.
Exercise Results	Oceanic profiles and speed information from the flight trials has been collected and analysed. This information was enhanced with questionnaires completed by pilots and controllers participating in the trials. The analysis can be found in Section 6.1.3.1.5 together with the related implementation issues. The operational concept and supporting enablers are developed and refined, having shown the capability to work coherently together and deliver benefits (E-OCVM V3). Approved temporary procedures compliant with all applicable technical/operational specifications and standards were in place for the trials (E-OCVM V4).
Demonstration Objective Status	OK

Exercise ID	Exercise #1
Demonstration Objective Title	Assess the feasibility and benefits of aircraft conforming to an RTA assigned by AMAN.
Demonstration Objective ID	OBJ-02.07-1015
Success Criterion	Sufficient data is collected to assess the feasibility and benefits of aircraft conforming to an RTA assigned by AMAN.
Exercise Results	The AMAN system delay was used by the en-route controllers to slow the aircraft down in the descent phase of the flight absorbing some potential orbital delay in a linear fashion. Westbound flights were not subject to these instructions but instead provided an ETA for controller planning purposes only.

	In addition questionnaires were filled by pilots involved in the trials to assess the impact of slowing-down on fuel consumption. Expected Holding Fix & Fix ETA predictions from Heathrow AMAN system and the aircraft where compared for the trial flights. The variability range of the time differences has not shown any specific pattern that could lead to meaningful conclusions.
Demonstration Objective Status	OK
Exercise ID	Exercise #1
Demonstration Objective Title	Assess the feasibility and benefits of Reduced Engine Taxi Out and Reduced Engine Taxi In.
Demonstration Objective ID	OBJ-02.07-1016
Success Criterion	Sufficient data is collected to assess the feasibility and benefits of Reduced Engine Taxi Out and Reduced Engine Taxi In.
Exercise Results	The use of reduced engine taxi practices for the flight trials have been collected and analysed. The analysis can be found in Section 6.1.3.1.1.
Demonstration Objective Status	OK
Exercise ID	Exercise #2A and #2B
Demonstration Objective Title	The project will refine the local procedures and execute multi-aircraft demonstration flights, for sustainable day to day operational basis after the conclusion of the project.
Demonstration Objective ID	OBJ-02.07-2001
Success Criterion	Procedures are developed and a roadmap developed for implementation on a day to day basis after the trial. Multi aircraft flight trials are executed.
Exercise Results	Multi-flight trials executed in: • Oceanic Airspace for the Oceanic Metering Assessment; • Maastricht, Shannon, Scottish and Reims FIRs for XMAN. The implemented technology and developed procedures in ATC units at Maastricht, Shannon, Scottish and Reims have been created on a sustainable basis so that their use and application can continue and be enhanced after the trials.

Demonstration Objective Status	OK
Exercise ID	Exercise #2B
Demonstration Objective Title	Assess the feasibility and benefits of using E-AMAN for sequencing and extended metering of Heathrow arrivals from multiple destinations.
Demonstration Objective ID	OBJ-02.07-2002
Success Criterion	Sufficient data is collected to assess the feasibility and benefits of using E-AMAN for sequencing and extended metering of arrivals at EGLL from multiple destinations.
Exercise Results	XMAN trials run for one month. Several data sources were used to collect sufficient data to allow a feasibility and benefits assessment. The qualitative feedback was gathered from partner ANSPs and pilots' feedback forms.
Demonstration Objective Status	OK
Exercise ID	Exercise #2A and #2B
Demonstration Objective Title	Assess whether the extension of the T4 (furthest distance displayed) horizon of E-AMAN to 85 minutes flight time from Heathrow for arriving flights leads to a reduction in aircraft fuel consumption and greenhouse gas emissions, and an increase in predictability.
Demonstration Objective ID	OBJ-02.07-2003
Success Criterion	Sufficient data is collected to assess whether the extension of the T4 horizon of E-AMAN to 85 minutes flight time from Heathrow for arriving flights leads to a reduction in aircraft fuel consumption and greenhouse gas emissions, and an increase in predictability.
Exercise Results	Multi-flight trials executed in: • Oceanic Airspace for the Oceanic Metering Assessment; • Maastricht, Shannon, Scottish and Reims FIRs for XMAN. Demonstrated a positive impact on fuel consumption of Oceanic Metering and the AMAN horizon extension. Use of AMAN system improves aircraft landing time predictions, as shown in Section 6.3.3.1.2
Demonstration Objective Status	OK

Exercise ID	Exercise #2A
Demonstration Objective Title	Assess the feasibility and benefits of using Oceanic Metering for Heathrow arrivals.
Demonstration Objective ID	OBJ-02.07-2004
Success Criterion	Sufficient data is collected to assess the feasibility and benefits of using Oceanic Metering for Heathrow arrivals.
Exercise Results	Results indicate that Oceanic Metering is feasible and the impact on fuel consumption has been assessed.
Demonstration Objective Status	OK
Exercise ID	Exercise #2A and #2B
Demonstration Objective Title	Assess the feasibility and benefits of using E-AMAN and Oceanic Metering to enable Continuous Descent Operations for all Heathrow arrivals.
Demonstration Objective ID	OBJ-02.07-2005
Success Criterion	Sufficient data is collected to assess the feasibility and benefits of using E-AMAN and Oceanic Metering to enable Continuous Descent Operations for all Heathrow Arrivals.
Exercise Results	Results show that E-AMAN and Oceanic Metering are feasible and may allow improved traffic presentation enabling more CDOs at Heathrow from Oceanic Arrivals.
Demonstration Objective Status	OK
Exercise ID	Exercise #2B
Demonstration Objective Title	Assess the feasibility and benefits of aircraft participating in demonstration flights conforming to the CTOs assigned by the E-AMAN.
Demonstration Objective ID	OBJ-02.07-2006
Success Criterion	Sufficient data is collected to assess the feasibility and benefits of aircraft participating in demonstration flights conforming to the CTOs assigned by the E-AMAN

Exercise Results	Flights were assigned a speed instruction based on delay information.
Demonstration Objective Status	OK

Exercise ID	Exercise #2B
Demonstration Objective Title	Assess the feasibility and benefits of the use of a ground-ground delay message for Heathrow arrivals.
Demonstration Objective ID	OBJ-02.07-2007
Success Criterion	Sufficient data is collected to assess the feasibility and benefits of the use of a ground-ground delay message for Heathrow arrivals.
Exercise Results	The trials have shown the feasibility of implementing the linear holding concept, based on slowdown speed instructions according to delay information. The benefits of such concept were analysed by the project.
Demonstration Objective Status	OK

Exercise ID	Exercise #2B
Demonstration Objective Title	Assess whether the use of E-AMAN to improve the traffic sequence for Heathrow arrivals changes the rate of missed approaches.
Demonstration Objective ID	OBJ-02.07-2008
Success Criterion	Sufficient data is collected to assess whether the use of E-AMAN to improve the traffic sequence for Heathrow arrivals changes the rate of missed approaches.
Exercise Results	The number of missed approaches and its evolution over time was assessed and shown no impact from the trials.
Demonstration Objective Status	OK

Exercise ID	Exercise #2A
Demonstration Objective Title	Assess whether the traffic presentation at the Oceanic – Domestic interface could potentially be improved due to the implementation of oceanic metering.

Demonstration Objective ID	OBJ-02.07-2009
Success Criterion	Sufficient data is collected to assess whether the traffic presentation at the Oceanic – Domestic interface could potentially be improved due to the implementation of oceanic metering.
Exercise Results	Results indicate that Oceanic Metering is feasible. Oceanic Metering could therefore potentially improve traffic presentation at the Oceanic-Domestic interface.
Demonstration Objective Status	OK
Exercise ID	Exercise #2B
Demonstration Objective Title	Assess whether the use of E-AMAN allows the application of RNP based Continuous Descent Operations to be conducted without increasing ATCO workload.
Demonstration Objective ID	OBJ-02.07-2010
Success Criterion	Sufficient data is collected to assess whether the use of E-AMAN allows the application of RNP based Continuous Descent Operations to be conducted without increasing ATCO workload.
Exercise Results	XMAN trials have shown that ATCO workload in Terminal Control Area, responsible for the provision of CDO, was not affected.
Demonstration Objective Status	OK
Exercise ID	Exercise #2B
Demonstration Objective Title	Assess whether the use of E-AMAN allows the application of RNP based Continuous Descent Operations to be conducted without increasing delay
Demonstration Objective ID	OBJ-02.07-2011
Success Criterion	Sufficient data is collected to assess whether the use of E-AMAN allows the application of RNP based Continuous Descent Operations to be conducted without increasing delay.
Exercise Results	The application of speed instructions as defined in the XMAN trials had a positive impact on delays over 9 minutes.

Demonstration Objective Status	OK
Exercise ID	Exercise #2B
Demonstration Objective Title	Assess the benefits of E-AMAN in the overall performance of Heathrow Airport.
Demonstration Objective ID	OBJ-02.07-2012
Success Criterion	Sufficient data is collected to assess the benefits of E-AMAN in the overall performance of Heathrow airport.
Exercise Results	It was not possible to identify a valid mechanism to assess the impact of E-AMAN on the overall performance of Heathrow airport
Demonstration Objective Status	NOK
Exercise ID	Exercise #3
Demonstration Objective Title	Various
Demonstration Objective ID	OBJ-02.07-3001 to 3007
Success Criterion	Various
Exercise Results	Exercise 3 was subject to funding from the Boeing FAA NextGen SE2020 Airbridge project. When the Demonstration Plan [1] was written, the exercise was subject of discussion. As the funding was finally not realized, Exercise #3 was performed as a concept study.
Demonstration Objective Status	N/A

Table 9: Summary of Demonstration Exercises Results

5.2 Choice of metrics and indicators

The primary focus of TOPFLIGHT was assessing the sustainability of SESAR concept elements. For this reason, and the fact that several Demonstration Objectives impacted a single concept element, the Objectives, KPAs and Metrics per Concept Element are grouped together in Table 10

Concept element	Objective IDs	KPA	Metrics

Reduced Engine Taxi	OBJ-02.04-1003 OBJ-02.04-1004 OBJ-02.04-1005 OBJ-02.04-1016	Efficiency	Application ratio (%) Fuel savings (Kg, %) CO_2 savings (Kg, %)
Oceanic Clearance Before Departure	OBJ-02.04-1003 OBJ-02.04-1009 OBJ-02.04-1011	Efficiency / Predictability	Application ratio (%)
Continuous Climb Operation	OBJ-02.07-1001 OBJ-02.04-1003 OBJ-02.04-1004 OBJ-02.04-1005 OBJ-02.04-1006 OBJ-02.04-1010	Efficiency	Application ratio (%) Fuel savings (Kg, %) CO_2 savings (Kg, %)
Free Routing and Advanced Flexible Use of Airspace	OBJ-02.04-1003 OBJ-02.04-1004 OBJ-02.04-1005 OBJ-02.04-1006 OBJ-02.04-1013	Efficiency	Application ratio (%) Fuel savings (Kg, %) CO_2 savings (Kg, %) Mileage savings (%)
Optimised Oceanic Profile	OBJ-02.04-1003 OBJ-02.04-1004 OBJ-02.04-1005 OBJ-02.04-1014	Efficiency	Application ratio (%) Fuel savings (Kg, %) CO_2 savings (Kg, %))
Continuous Descent Operation	OBJ-02.07-1002 OBJ-02.04-1003 OBJ-02.04-1004 OBJ-02.04-1005 OBJ-02.04-1006 OBJ-02.04-1012 OBJ-02.04-1015	Efficiency / Predictability	Application ratio (%) Fuel savings (Kg, %) CO_2 savings (Kg, %)
SWIM	OBJ-02.04-1003 OBJ-02.04-1007 OBJ-02.04-1008	N/A	N/A
Oceanic Metering	OBJ-02.07-2001 OBJ-02.07-2003 OBJ-02.07-2004 OBJ-02.07-2005	Efficiency	Fuel consumption (Kg)
	OBJ-02.07-2009	Predictability	Feasibility assessment
E-AMAN	OBJ-02.07-2001 OBJ-02.07-2002 OBJ-02.07-2003 OBJ-02.07-2005 OBJ-02.07-2006 OBJ-02.07-2007 OBJ-02.07-2008 OBJ-02.07-2010 OBJ-02.07-2011 OBJ-02.07-2012	Efficiency / Predictability	Fuel savings (Kg) CO_2 savings (Kg) Feasibility assessment

Table 10: Summary of metrics and indicators

The results against these KPAs can be found in Section 5.3.1.

5.3 Summary of Assumptions

The assumptions detailed in this section relate to the conditions that must exist in order for the Flight Demonstrations and associated analysis to be conducted successfully.

Identifier	ASS-02.07-1001

Title	Normal Operations
Type of Assumption	Demonstration Environment
Description	The demonstrations will take place in a context of normal operations; the air and ground systems in use at the time of the demonstration are available and operating normally and there are no non-nominal situations (such as adverse weather, emergencies etc.). This includes the availability of functionality currently planned or in development in projects external to TOPFLIGHT.
Justification	The development of demonstration procedures to account for non-nominal cases, and the development of special or modified systems are not within the scope of the TOPFLIGHT project.
Flight Phase	All
KPA Impacted	All
Source	Project members
Value(s)	Zero
Owner	NATS
Impact on Assessment	None, mitigated
Identifier	ASS-02.07-1002
Title	Procedure Fidelity
Type of Assumption	Accuracy/relevance of Results
Description	RNP based SIDs and STARs can be demonstrated with sufficient accuracy and fidelity in the project via the use of on-board aspects to allow conclusions to be drawn without the development of fully ratified and approved RNP SIDs and/or STARs
Justification	The development of fully ratified and approved SIDs and/or STARs is not within the scope of the TOPFLIGHT project.
Flight Phase	Departure/Climb and Arrival/Descent
KPA Impacted	All
Source	Project members
Value(s)	Zero
Owner	NATS
Impact on Assessment	None

Identifier	ASS-02.07-2003
Title	British Airways Flight Schedule
Type of Assumption	Demonstration Environment
Description	The British Airways flight schedule is subject to changes in flight times, frequency, destination and aircraft type. The assumption is that flights suitable for demonstrations in terms of flight times, frequency, destination and aircraft type exist within the flight schedule within the planned demonstration period.
Justification	Scheduling flights in order to satisfy the requirements of the demonstrations and the development of demonstration procedures to allow for any possible changes in the schedule is not within the scope of the project.
Flight Phase	All
KPA Impacted	All
Source	Project members
Value(s)	Zero
Owner	NATS
Impact on Assessment	None, mitigated

Identifier	ASS-02.07-2001
Title	Pilot Estimate of Fuel Impact
Type of Assumption	Accuracy/relevance of Results
Description	A positive response from the pilot indicates increased fuel on board at the waypoint and therefore a fuel saving. A response that doesn't indicate positive or negative indicates a fuel penalty for aircraft on Cost Index 0, and a fuel saving for aircraft on a higher Cost Index.
Justification	There was ambiguity in the responses given by pilots. Expert guidance was sought from BA to allow the responses to be interpreted.
Flight Phase	Cruise
KPA Impacted	Efficiency
Source	BA
Value(s)	Zero
Owner	NATS

Impact on Assessment	This assumption has directed interpretation of the fuel impact of Oceanic Metering.

Table 11: Demonstration Assumptions

5.3.1 Results per KPA

5.3.1.1 Efficiency

The fuel savings assessment has taken into account the effect of aircraft weight on fuel consumption. A correction factor was calculated to account for the differences in flight planned and actual TOW. The tool used to perform this assessment was the flight planning tool Jetplanner from Jeppesen. Identical flight plans with same aircraft type were run with two different weight values, for each month of the year with average historical winds. The difference in fuel consumption between them was referred to the difference in weight values. That analysis led to the conclusion that additional fuel consumption equates to 3% of the weight excess per flight hour.

The values obtained from fuel consumption assessment have been represented below in a box and whisker chart. This representation method has been selected due to its capacity to graphically depict groups of numerical data showing density, maximum and minimum values. The blue box shows the range that contains 50% of the sample values. The lines extend up to the maximum and minimum calculated values. In addition to the box and whiskers, also violet diamonds are shown on the chart, representing the median values of the fuel consumption change for each concept.

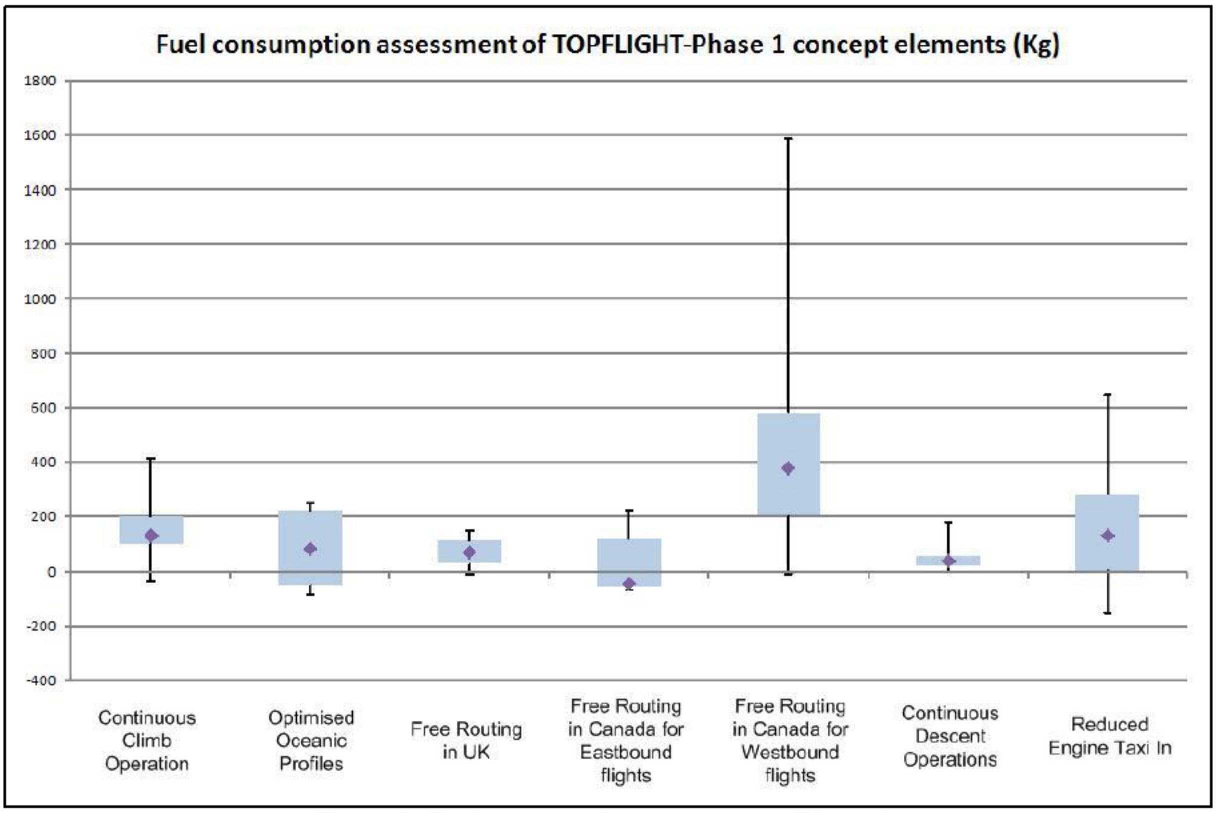


Figure 3: Fuel consumption assessment Phase 1

The assessed concepts are:

- Continuous Climb Operation. 8 valid fuel samples.
- Optimised Oceanic Profile. 9 valid fuel samples.
- Free Routing in the UK. 2 valid fuel samples.
- Free Routing in Canada for Eastbound flights. 3 valid fuel samples.
- Free Routing in Canada for Westbound flights. 13 valid fuel samples.

- Continuous Descent Operations. 7 valid fuel samples.
- Reduced Engine Taxi. 8 valid fuel samples.

The concept elements applicable to the Westbound and Eastbound flights which participated in TOPFLIGHT are shown in the next table, in order to assess the average fuel savings achievable from the gate-to-gate optimisation:

	CCO	Oceanic	FR UK	FR CA EB	FR CA WB	CDO	RETI	Fuel savings
W/B	131	83	70		378	39	133	**Up to 834 Kg**
E/B	131	83		-46			133	**Up to 301 Kg**

Table 12: Fuel savings Phase 1 (Kg)

	CCO	Oceanic	FR UK	FR CA EB	FR CA WB	CDA	RETI	CO_2 savings
W/B	417	264	223		1202	124	423	**Up to 2652 Kg**
E/B	417	264		-146			423	**Up to 957 Kg**

Table 13: CO_2 savings Phase 1 (Kg)

	Taxi	Climb	Domestic	Oceanic	Descent	Entire flight
Fuel reduction per phase of flight	45.9 %	1.5 %	1.2 %	0.4 %	2.6 %	**Up to 1.7 %**

Table 14: Fuel saving proportion per phase of flight

In terms of track mileage, the flight trials data analysis has shown that the use of Free Routing in conjunction with Advanced Flexible Use of Airspace in the route through London and Shannon FIRs could be reduced up to 11NM, which represents 2% of the distance from runway to the Oceanic Entry Point. In Canadian airspace, the 58NM flight distance reduction achieved represents 4% of the Canadian domestic route.

In Exercise #2A the results suggest a potential decrease in fuel consumption if delaying to reach an Oceanic CTO.

The analysis of Flight Data Recorder files for selected British Airways flights that received a speed instruction during Exercise #2B shows the following results:

Date	Callsign	A/T	Orbital holding time saved	Fuel saved due to reduced orbital holding time (Kg)	CO_2 saved due to reduced orbital holding time (Kg)
28/04/2014	BAW811	A321	00:02:33	**84**	**267**
17/04/2014	BAW18A	B772	00:01:56	**147**	**467**
22/04/2014	BAW180	B772	00:00:36	**46**	**146**
12/04/2014	BAW116	B744	00:03:58	**488**	**1552**
02/05/2014	BAW178	B744	00:02:15	**248**	**789**

Table 15: XMAN savings (Data from trial flights)

Complementary activities of Exercise #2B, such as the work in Airbus simulations provide a certain level of cross-validation:

A/T	Orbital holding time saved	Fuel saved (Kg)	CO_2 saved (Kg)
A320	00:01:26	**42**	**134**

A330	00:01:07	**86**	**273**
A380	00:01:06	**152**	**483**

Table 16: XMAN savings (Data from Airbus sims)

The fuel values per holding minute are largely consistent for each aircraft weight category. The variation in time saved by trial flights and simulations is due to the wind factor during cruise phase of flight. To enhance the applicability of the work done at the simulator, zero wind was defined.

The analysed transatlantic flights, connecting London Heathrow with Toronto Pearson and Montreal Trudeau, have an average duration of 6.5 hours. The fuel consumption of carrying extra weight was calculated and resulted 3% of the extra weight per flight hour. The above results, if transferred to lower the fuel on-board, would provide extra benefits: up to 163 Kg for Westbound flights and up to 56 Kg for Eastbound flights.

5.3.1.2 Predictability

It was demonstrated that the oceanic clearance can be successfully issued to aircraft while on the ground at Heathrow. Over 80% of the westbound trial flights in Phase 1 received an oceanic clearance on the ground at Heathrow.

During Phase 1 trials, the AMAN system was used by the en-route controllers to slow the aircraft down in the descent phase of the flight in case of delay, absorbing some potential orbital delay in a linear fashion. Westbound flights were not subject to these instructions but instead provided an ETA for controller planning purposes only from the SASS system. In addition questionnaires were filled by pilots involved in the trials to assess the impact of slowing-down on fuel consumption.

The results of the analysis of Phase #2A support the feasibility of Oceanic traffic meeting a CTO. This will lead to predictability improvements directly and indirectly via an improved presentation of traffic to AMAN.

Expected Holding Fix & Fix ETA predictions from Heathrow AMAN system and the aircraft where compared for the trial flights. The variability range of the time differences has not shown any specific pattern that could lead to meaningful conclusions.

During Phase #2B trials, ETO stability along the aircraft trajectory in the vicinity of 350 NM from Heathrow was assessed. The calculation at these points is based on ETFMS data and predictions, based on flight plan information. ETOs are unstable because actual trajectories differ from predicted trajectories due to direct routeing, winds, etc. The instability window is approximately ± 2 minutes.

5.3.2 Impact on Safety, Capacity and Human Factors

All concept elements demonstrated in the TOPFLIGHT Project were determined to be sustainable, with no prejudice to surrounding flights. Safety was also assessed so that the level of safety was not impacted by the procedures in place. Some concept elements could only be implemented when traffic allowed, such as optimised oceanic profiles. Its implementation without consideration of surrounding traffic would have an impact on average capacity. The exercises definition prevented this from happening.

The procedures in place for the trials in NATS' units went through an ATC Procedures Safety Analysis (APSA) process. APSA is the means by which potential risks are identified, assessed, controlled and documented, satisfying the ATC Procedures aspect of the System Safety Analysis Principle.

The proposed TOPFLIGHT procedures for Exercise #1 did not have a major impact on normal NAV CANADA operations, either in domestic or oceanic airspace. An initial safety analysis concluded that appropriate local controller/supervisor briefings regarding the TOPFLIGHT Project and associated procedures would suffice to address any safety concerns.

In order for British Airways flights to participate in Phase 1 trials, approval was required from the Flight Operations Safety Group (FOSG), which has responsibility for safety oversight within flight operations. The pilot briefing and questionnaires together with the risk mitigation were submitted and accepted with the proviso that the flight crews were also verbally briefed beforehand.

No extra workload was identified for Air Traffic Controllers or Pilots during Exercises #1 and #2A. For the XMAN trials in Exercise #2B, procedures at neighbouring ANSPs were put in place so that ATCOs took into account Heathrow delay for delivering speed instructions to Heathrow inbounds. This increment in ATC workload and R/T was considered acceptable for those units.

The safety case for Oceanic Operations is currently based on planned trajectories. Oceanic Metering would change this by giving aircraft a CTO or amended speed (depending on implementation) however this would not adversely affect conflict protection on planned trajectories. Flights would be required to maintain speed within Mach range agreed with the controller to allow the flight to meet its CTO. Conflict protection would be applied to the entire range of potential speeds.

5.3.3 Description of assessment methodology

All the exercises made use of numerous information sources to calculate the main parameters to be assessed. These information sources are shown in Table 8 Section 4.1. Analysis was through the use of business analysis tools and desktop PC based spread sheet tools developed specifically for the purpose at a local level unless specified below.

For Exercise #1, sustainability was assessed using Business Intelligence and FDR data to determine the number of trial flights that benefited from the optimisation elements.

Fuel savings were assessed using direct comparison between actual fuel consumption from Flight Data Recorder files and fuel estimates from the Flight Plan. Additionally Airbus and BA simulations were conducted to assess the relationship between fuel usage and flight time. The CO_2 reduction was calculated by the application of factor 3,18 to the fuel quantity.

Reduction in flight distance was assessed using direct comparison between actual track miles shown on Flight Data Recorder files compared with the Flight Plan.

Human Factors and Safety impacts were identified from questionnaires completed by ATCOs and Pilots involved in the trials, plus live observation of the trials from ATC Ops Rooms.

For Exercise #2A environment/fuel efficiency was assessed by collecting fuel impact estimates from the Flight Management Systems of multiple British Airways flight of the various aircraft types in transatlantic revenue service. This data was collected via pilots' questionnaires.

Predictability was assessed by comparing ETAs from ground ATM systems listed in 4.1 with each other and to corresponding ETAs from the trial aircraft. Additionally an analysis was made of capacity by measuring the spacing of aircraft flying on the same track when crossing 040W.

For Exercise #2B, FDR files from selected British Airways flights were collected and analysed. The characteristics of the speed, flight level and fuel flow profiles were analysed to assess the impact of the speed instructions and compared with a baseline created by FDR files from flights with no speed instructions experiencing several levels of delay.

In addition to this, an ADS-B data provider was used; aiming to identify the speed profiles for all Heathrow inbounds in the horizon of the speed instructions. ATC Questionnaires were used to identify speed instructions as given to pilots. Business Intelligence data was available for aircraft arriving through Scottish FIR.

Airbus simulations were held to provide complimentary analysis of the effect of speed on fuel consumption. To enable this, the pilot's interaction with the FMS was monitored to allow extrapolation of descend profiles.

5.3.4 Results impacting regulation and standardisation initiatives

The activities conducted during the project have not identified the need for a change in regulation or standardisation.

5.4 Analysis of Exercises Results

The primary objective of the analysis for Exercise #1 activities is to assess the sustainability in a real-world environment of the concepts being demonstrated

Figure 4 summarizes in one graph the application rates of the concepts assessed during the trial flights. It can be observed that the sustainability of the concept elements, without causing any detriment to surrounding aircraft, is quite high; at least 60% for 66% of the concept elements and at least 40% for 100% of the concept elements demonstrated.

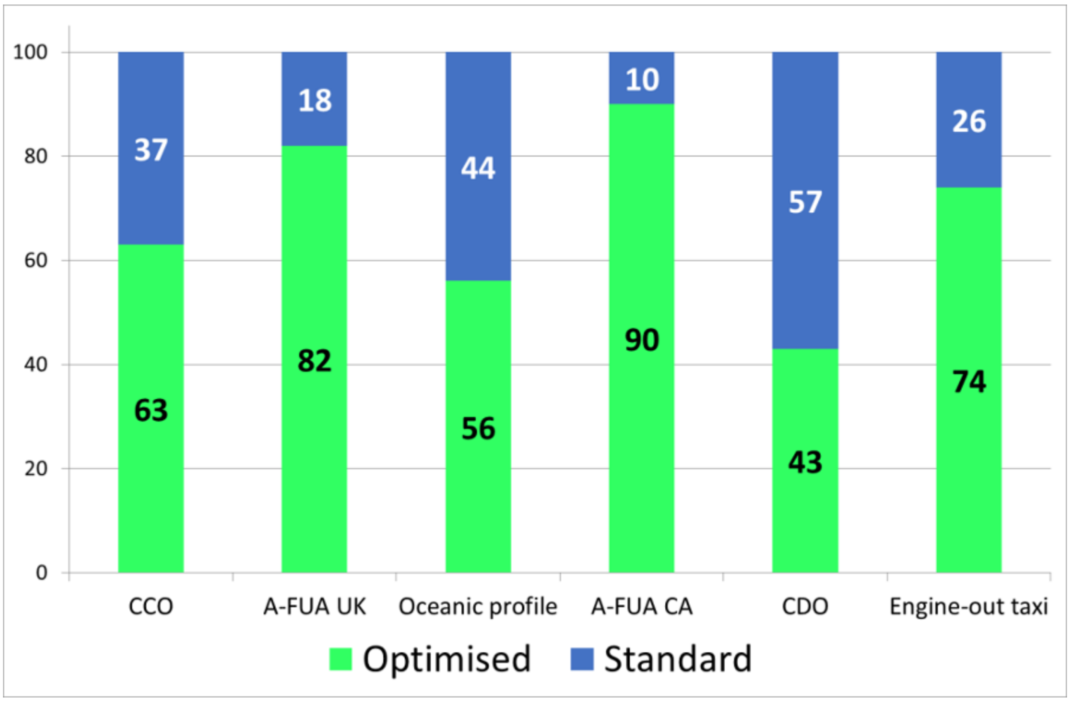


Figure 4: Sustainability by concept element

As described in Section 6.1.3.1, interacting aircraft were in most cases the blocking factors for the optimisation provision. For that reason, time of the day has a big impact in application rates. From this observation, the scalability of the assessed concepts will be greater in less congested airspace.

Figure 5 was produced for the assessment of the gate-to-gate optimisation. In this chart, each radial corresponds to one of the 100 trial flights. The level of optimisation achieved is measured through an index, where 0 represents no optimisation being applied and 1 corresponds to the situation where all concepts elements were used. The line “Confidence” represents the completeness of the data set recovered for each flight, as in some cases, not all the relevant information could be collected.

It is observed in Figure 5 that 25% of the trial flights achieved full gate-to-gate optimisation by the application of every single concept element. For 70% of the demonstration flights, more than 60% of the concepts in place were applied.

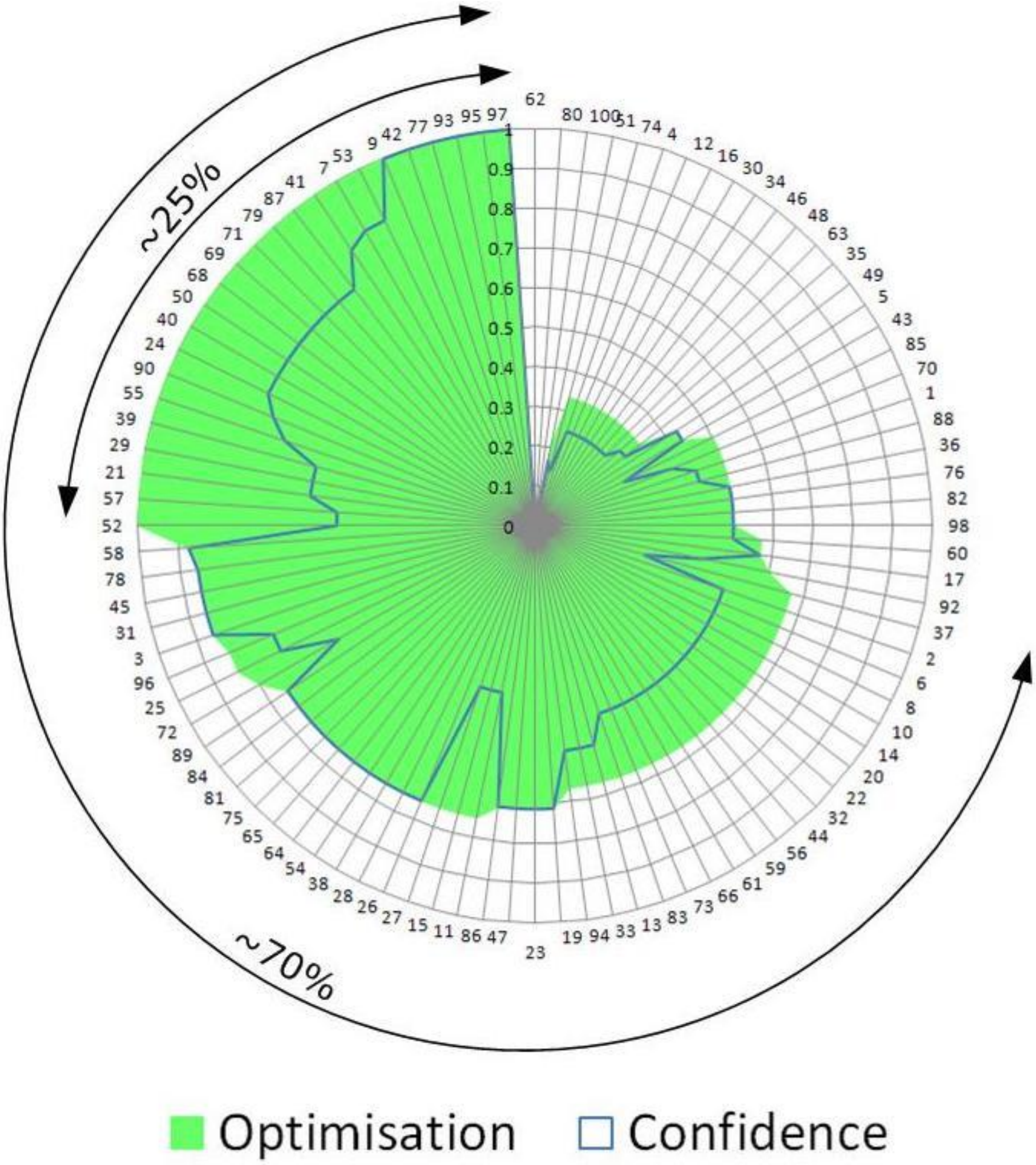


Figure 5: Optimisation achieved per flight

The analysis was limited by several factors: limited set of data, unavailability of updated winds information on-board, take-off weight impact on fuel consumption and coarse data granularity. It is strongly recommended to take these limitations into account when using the provided fuel figures.

Exercise #2A provided system data to measure predictability at the Oceanic-Domestic Interface. Ground ATM system estimates can be accurate depending on phase of flight, and it would be possible to improve the accuracy of system estimates further with better data sharing between systems.

Exercise #2B, consisting of XMAN trials, has proven the feasibility of transferring orbital holding time to linear holding through speed instructions at 350NM. The fuel and CO_2 reduction shown in 5.3.1 represent the initial benefits delivered by the trial, which can be enhanced when this concept achieves a higher maturity level.

5.4.1 Unexpected Behaviours/Results

No Problem Reports were identified during the execution of these Demonstration Exercises.

5.5 Confidence in Results of Demonstration Exercises

5.5.1 Quality of Demonstration Exercises Results

All exercises were performed in live trials. Live trials provide results that are of real world significance, but present numerous uncontrolled variables that can affect the results on the chosen metrics. To overcome this issue, ad-hoc methodology was developed to isolate the effects of the trialled elements and reduce the impact of external influences. Correction factors were developed and used to counteract the effect of parameters which could not be normalised, such as aircraft weight.

For these reasons, TOPFLIGHT is considered to present high quality results, in terms of accuracy and confidence.

5.5.2 Significance of Demonstration Exercises Results

For all exercises a sufficient number of flight trials were executed and sufficient size of data samples collected to make a meaningful assessment of the effect of the trialled concepts with the required confidence.

All exercises in TOPFLIGHT were performed in a live, real-world, non-sterilised environment. As a result, the observations offer as close to a real view of the actual performance when implemented as is possible without actual implementation.

5.5.3 Conclusions and recommendations

The exercises performed in TOPFLIGHT have shown that the SESAR programme is already delivering benefit in European skies via implementation of several elements of the SESAR concept. NATS is at the forefront of this implementation.

The trial flights demonstrated an approach to sustainable gate-to-gate transatlantic flight optimisation, through the application of different SESAR concept elements in all phases of flight, without detriment to other airspace users. The sustainability of those concept elements has been quantified and proven to have high application rates.

The project provided a valuable mechanism for the successful engagement with airspace users with regard to SESAR operating concepts.

For long, complex flights that are optimised on a sustainable basis (rather than a perfect or prioritised basis) quantification of the fuel benefit in the real environment is only achievable through the isolation of the individual concept elements. Furthermore, even when individual concept elements are isolated, variation in key factors can invalidate the baseline data; for example changes in Take-Off Weight, cruise flight level or key waypoints in the route can result in significant changes compared to the flight plan, invalidating direct comparison.

Oceanic Metering is feasible from an airborne and ground system perspective and could result in fuel saving.

XMAN trials have shown that effective queue management can tackle some ATM system inefficiencies which cause unnecessary fuel burn for aircraft subject to holding. This strategy helps the reduction of the fuel burnt by arriving aircraft, by absorbing delay in a more efficient linear phase of flight and thereby minimising the orbital delay experienced. The effectiveness of linear holding can be maximised, and was proven to be feasible, by the use of Cross Border traffic management on a tactical basis which allows earlier response to delay requirements.

6 Demonstration Exercises reports

6.1 Demonstration Exercise #1 Report

6.1.1 Exercise Scope

The purpose of the TOPFLIGHT project was to demonstrate, with multiple aircraft operating revenue transatlantic services, the potential benefits which can be realised from the coordinated introduction of a number of key elements within the SESAR concept.

The project built on the results of previous SESAR & AIRE projects to develop a sustainable and harmonised set of procedures and applications allowing optimum flight operation with the most efficient use of airspace on a coordinated gate to gate basis. This reduced delays, flight time, fuel consumption and emissions.

For Phase 1, 100 gate-to-gate, optimised flights were conducted, one at a time, Eastbound and Westbound between London Heathrow and selected major North American airports.

In addition to demonstrating the integration of several SESAR concept elements to achieve a near perfect optimised gate-to-gate transatlantic flight, this phase of the project provided a baseline for the subsequent phases and further empirical results from revenue aircraft operations on the achievable flight efficiency and predictability.

The same optimised flight concept was used for both eastbound and westbound flights.

6.1.2 Conduct of Demonstration Exercise EXE-02.07-D-101

6.1.2.1 Exercise Preparation

British Airways B747 and B777 flight simulators were used to assess the flyability and operational characteristics of proposed RNP procedures at London Heathrow.

Airbus desktop tool, Performance Engineering Program, was used to evaluate the fuel figures obtained for Continuous Climb Operations and Free Routing from the trials.

6.1.2.2 Exercise execution

100 flights were chosen following the criteria mentioned in 4.1, 50 westbound and 50 eastbound. The airports involved were London Heathrow (EGLL), Toronto Pearson (CYYZ) and Montreal Trudeau (CYUL). The optimised flights were performed one at a time.

Figure 6: London Heathrow, Toronto Pearson and Montreal Trudeau locations

From 29/05/2013 to 25/06/2013		From 26/06/2013 to 17/07/2013	
BA95 (BAW95) Daily	EGLL – CYUL	BA99 (BAW99) Daily	EGLL – CYYZ
	Boeing 777-200		Boeing 747-400
	UTC departure time = 17:15		UTC departure time = 15:20
	UTC arrival time = 00:20		UTC arrival time = 22:55
BA92 (BAW5CA) Daily	CYYZ – EGLL	BA94 (BAW94) Daily	CYUL – EGLL
	Boeing 767-300		Boeing 777-200
	UTC departure time = 22:55		UTC departure time = 02:10
	UTC arrival time = 06:05		UTC arrival time = 08:35

Table 17: Phase 1 trial flights' schedule

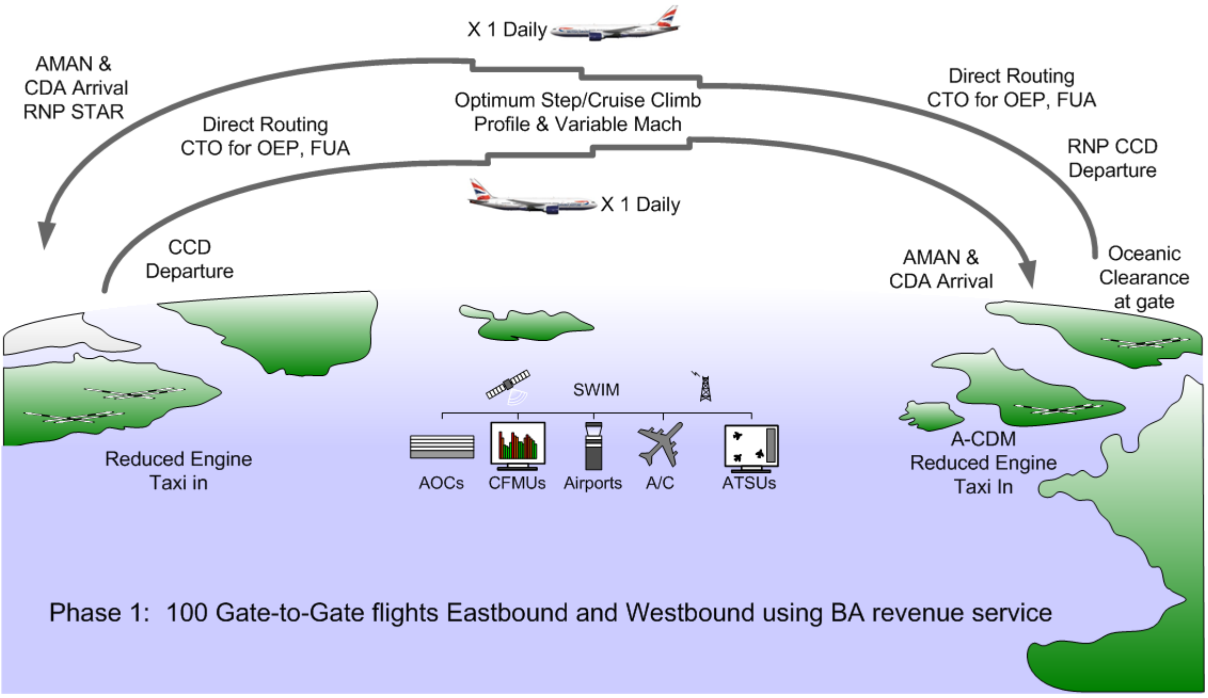


Figure 7: Phase 1 ConOps Overview

The main steps for a westbound flight[2] in Phase 1 were:

- The oceanic clearance was issued on the ground at EGLL and the Target Take-Off Time (TTOT) established via A-CDM,
- The aircraft performed reduced engine taxi if beneficial and appropriate,
- The aircraft flew a Continuous Climb Departure (CCD) using aspects of RNP on-board and was given a direct routing to the Oceanic Entry Point (OEnP). This could be enabled through the Advanced Flexible Use of Airspace (AFUA) concept through the NWMTA. RTA functionality

---

[2] Similar procedures were used for eastbound flights

and other flight techniques and airframe features were used to achieve the Oceanic Clearance entry conditions, where appropriate,

- In oceanic airspace the aircraft executed an optimised series of Step Climbs with a Variable Mach schedule as required allowing the flight to achieve its optimum profile and Controlled Time Over (CTO) for landfall as stated on the destination arrival plan,
- Once in North American en-route radar airspace the aircraft was given a direct routing and arrival sequence derived CTO for the Initial Approach Fix, enabled by AFUA if possible,
- The aircraft performed a Continuous Descent Approach from the Top of Descent using on-board aspects of RNP during approach,
- After touch down the aircraft performs reduced engine taxi, if beneficial and appropriate.
- The concept elements demonstrated by TOPFLIGHT were predicated on the sharing of information between the participants in two continents. In the medium term in both SESAR and NextGen domains this is expected to be via SWIM. Although the project was limited to existing certified equipage and communications, the project confirmed the information flows, priority and timeliness of the shared data items that are required to enable the concept elements of the demonstration flights. This information will inform both SESAR and NextGen SWIM developments.

6.1.2.3 Deviation from the planned activities

No deviations from the Demonstration Plan [1] were identified during Phase 1.

6.1.3 Exercise Results

6.1.3.1 Summary of Exercise Results

6.1.3.1.1 Reduced Engine Taxi

RETI/RETO is a procedure that takes advantage of specific aircraft functionality to reduce the number of engines required to taxi when certain conditions are met. The aim of the procedure is to reduce aviation emissions and fuel burn through unnecessary engine operation for taxi times that are known to be long before the aircraft leaves the gate.

The Captain is responsible for taking the decision to apply the procedure for reduced engine taxi. Weather conditions play an important role in this decision, together with taxi times, workload and the technical status of the aircraft.

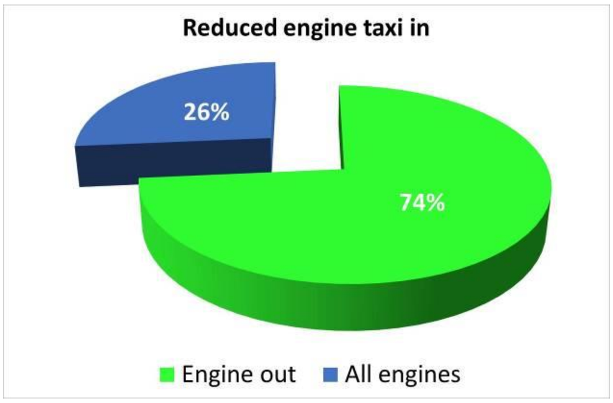


Figure 8: Application ratio of reduced engine taxi in procedure

The use of the RETO procedure was assessed, but the taxi times for the trial flights were in all cases below the application limit: 30 minutes. In all cases, engines must be started following push-back to ensure full operating functionality. Following the procedure involves turning one or two engines off and restarting and warming them up before approaching the runway. The relative long taxi times of London

Heathrow, Toronto Pearson and Montreal Trudeau lead to the conclusion that the application of this procedure at other airports is extremely limited.

On the other hand, Figure 8 shows the high application ratio of RETI procedure. It was observed the increased flexibility offered by the Boeing 744, allowing 1 or 2 engines to be shut down depending on certain criteria, such as taxi route and weather conditions, which may increase the power demanded from the remaining running engines.

The fuel consumption assessment of Reduced Engine Taxi In (also named Engine-Out Taxi) was performed by categorizing each flight according to the runway used to land and the use of the engine-out procedure. The values shown on the next chart represent the median fuel consumption change when the engine-out procedure was applied against the median value for the full engine taxi, when both taxis were performed from landing on the same runway.

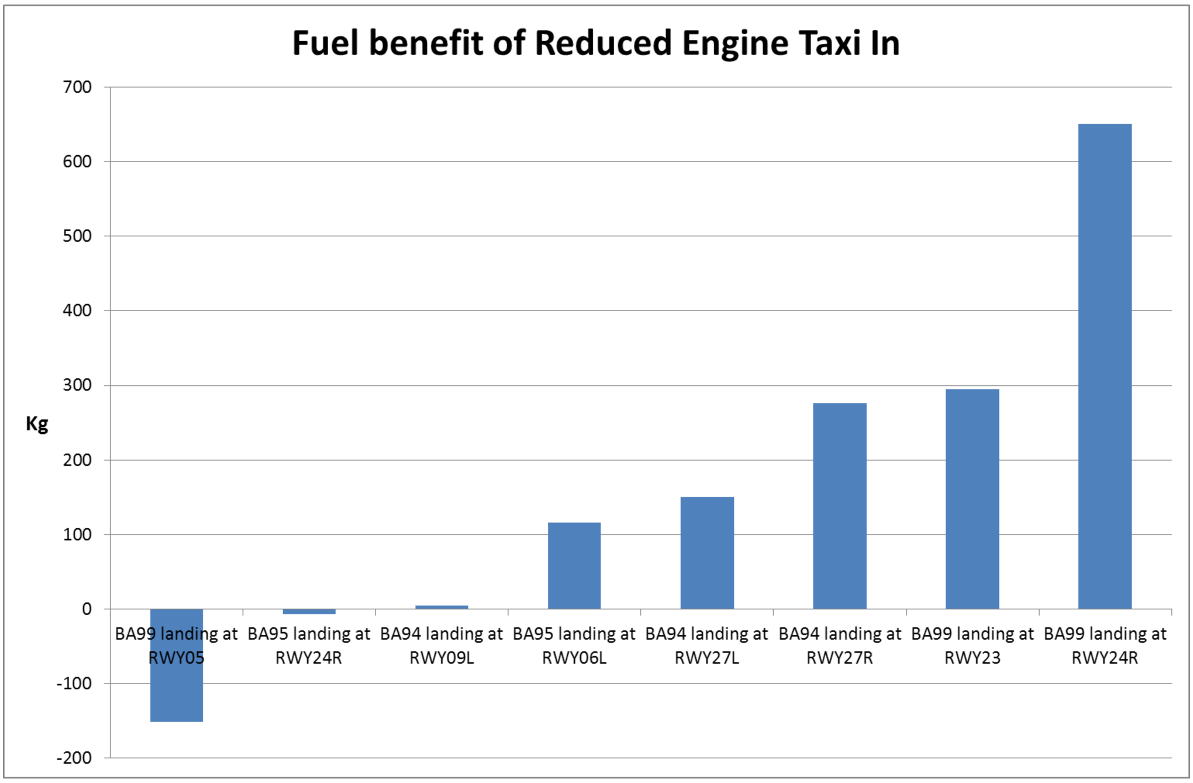


Figure 9: Fuel benefit of Reduced Engine Taxi In

The median[3] of the represented values is 133 Kg fuel savings.

6.1.3.1.2 Oceanic Clearance before departure

The Oceanic Clearance before departure concept element involves managing the departure process with a 'downstream' constraint. The early provision of a CTO at the OEnP increases the likelihood of the flight being allocated its preferred oceanic entry flight level. Furthermore, the oceanic Local Area Supervisor will also use this early provision of accurate intent information to allocate the levels and separations needed to accommodate an appropriate profile for the TOPFLIGHT trial; increasing the chances of this profile being granted compared to the baseline scenario in which the aircraft requests and receives its oceanic clearance on approach to the oceanic boundary.

Due to the long flight distance to the oceanic boundary for eastbound flights, it was decided to assess this element only for westbound trial flights.

A set of procedures were created to assess the predictability and optimization objectives. Their purpose was to achieve to following process:

---

[3] Median denotes the value lying at the midpoint of a frequency distribution of observed values, such that there is an equal probability of falling above or below it.

1. About 3 hours before the flight the BA Flight Dispatcher sent an email to Shanwick supervisor with the requested flight level block and Mach range.
2. About 20-30 minutes before departure the BA Traffic Manager consulted with the BA Turnaround manager to identify a likely departure time. The Traffic Manager then sent another email to the Shanwick Supervisor confirming the oceanic profile request, often including a new entry time for Shanwick. This email included the estimated departure time and was copied to Heathrow Tower.
3. Once the flight pushed back, if the estimated departure time was greater than 3 minutes later than the time the Traffic Manager estimated, the Tower coordinated this with Shanwick. If the estimated departure time was greater than 20 minutes later than the time the Traffic Manager estimated the Tower cancelled the oceanic portion of the trial with Shanwick.
4. Approaching the oceanic boundary the flight either A) requested clearance on VHF and this was a simple matter of confirming the details in the Traffic Manager's email, or B) requested a new oceanic clearance by VHF in the conventional manner (block level, Mach range may still have been possible, depending on traffic).

The provision of an oceanic clearance while the aircraft is at the gate in Heathrow was proven to be feasible. This conclusion was achieved based on the assessment of the information shared by the relevant stakeholders, as shown in Figure 10 and Figure 11.

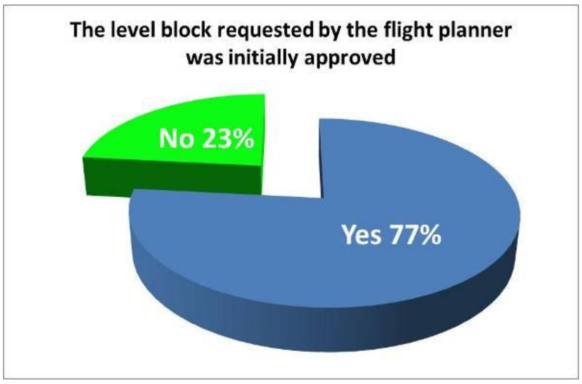


Figure 10: Level block approval ratio

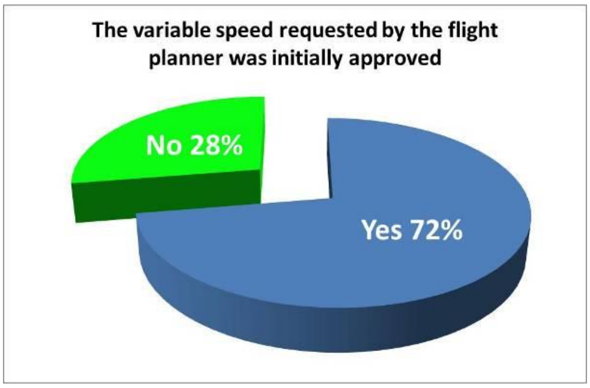


Figure 11: Variable speed approval ratio

In addition to the procedures definition and the feasibility assessment, the trials were successful in identifying the roles involved in sharing information to keep all relevant stakeholders up to date. As Figure 12 and Figure 13 show, the involvement of British Airways Traffic Managers and ATCOs from Heathrow Tower was proven to be crucial in order to update the oceanic boundary estimates.

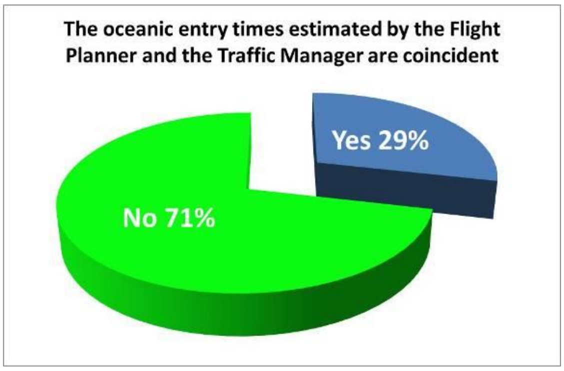


Figure 12: OenP times coincidence

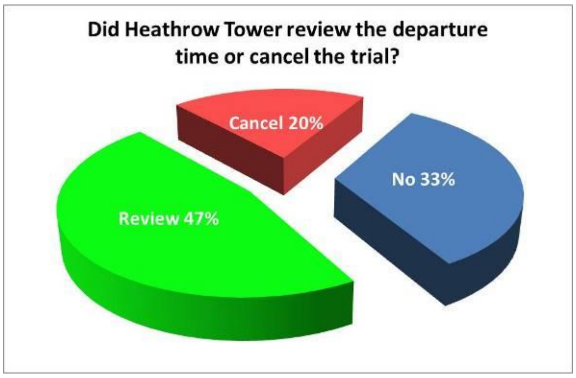


Figure 13: EGLL Tower time revision

Halfway through the flight trials, an A-CDM web portal started live operation in Heathrow, showing a positive contribution to the coordination process, by offering accurate Target Take Off Time (TTOT) estimates and data sharing.

It should be also noted the extra complexity introduced to this procedure by to the inclusion of variable profiles and speeds in the initial clearance.

From the Shanwick OCA perspective, the information shared in advance by British Airways and Heathrow Tower increased the predictability for the trial flights. By broadening this coordination to other flights, more coordination work can be conducted early in the planning phase, which would lead to a positive impact in airspace capacity.

6.1.3.1.3 Continuous Climb Operation

Continuous Climb Operations (CCO) aims at facilitating optimal vertical profiles for departing aircraft. This is enabled by a constant climb at an optimum rate to their desired cruising flight level without spending any time in a level-off at low altitudes.

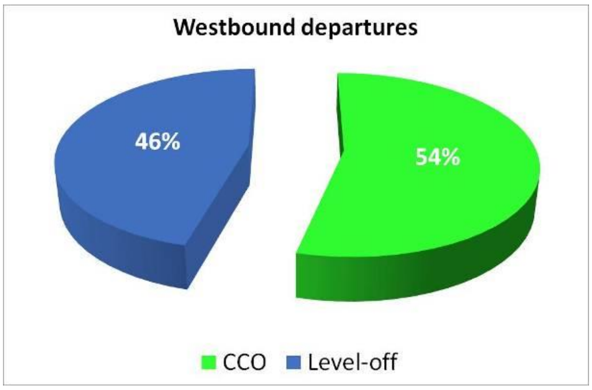


Figure 14: CCO ratio for WB departures

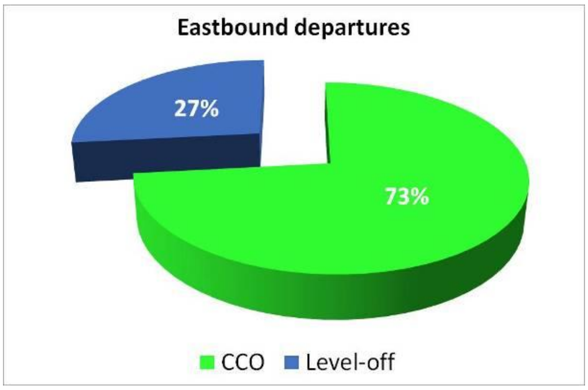


Figure 15: CCO ratio for EB departures

Different air traffic density in London, Toronto and Montreal surroundings is the main reason for different CCO usage rates for Westbound and Eastbound in Figure 14 and Figure 15.

Interacting aircraft were identified as the main blocking factor for constant climb profiles provision. Where airspace is the barrier to CCO in existing operations, airspace modification is the principle means by which CCO can be delivered. This means amending and/or replacing existing conventional Standard Instrument Departure (SID) routes so as to resolve interactions with other (arrival) flows. This is being currently analysed by the London Airspace Management Programme (LAMP) in order to implement new RNP procedures in London TMA.

The departing runway can have a major impact in CCO provision, as it is the case for London Heathrow. This is due to the location of holding stacks with regard to the intended departure route.

It was observed that tactical intervention the ATCOs during the departure phase addressed the compromise between continuous climb operation and direct routing for maintaining separation provision.

The provision of a de-conflicted profile while the aircraft is climbing requires coordination between sectors. Bandboxed[4] sectors resulted in the provision of better climb profiles, due to the reduction of required coordination and the low traffic levels.

The fuel benefits assessment of the Continuous Climb Operation was performed by comparing the fuel burn values of the climb phase in the flight plan against actual values for each flight along the same track distance. In all compared cases, one profile showed a continuous climb whereas the other profile included, at least, one level-off.

The valid samples of fuel consumption variation are represented by columns in the next chart:

---

[4] When traffic is low one controller takes over control of several sectors combined into one. This process is called bandboxing

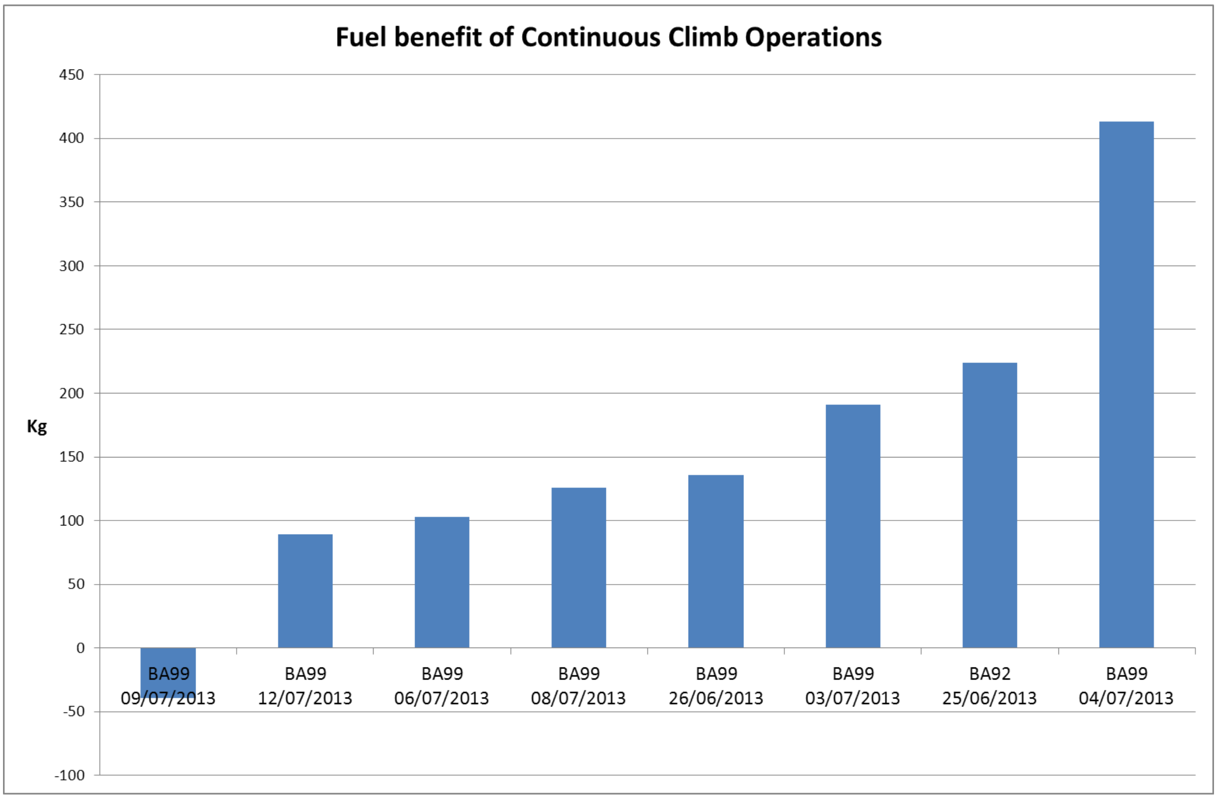


Figure 16: Fuel benefit of Continuous Climb Operations

Negative values represent fuel penalties. The median of the represented values is 131 Kg fuel savings.

The fuel consumption values during the climb phase for flights N74 (BA99, 04/07/2013, 413 Kg) and N84 (BA99, 09/07/2013, -39 Kg) look atypical when compared with the rest of the assessed flights. Unfortunately, it is not possible to assess the winds influence in these cases as Mach and Ground speed, used to calculate winds, are not reflected on the waypoints prior ToC in flight plan. However, even if these values were removed from the assessment, the median value would be kept at 131 Kg.

Four flights were not included in the previous list, as it was not possible to find a fuel consumption correction factor to account for different initial flight levels.

It should also be noted that continuous climb operations reduce turbojet engine wear which can be a significant cost when engines are cycled from cruise to climb power. This associated cost was not quantified.

6.1.3.1.4 Free Routing and Advanced Flexible Use of Airspace

The assessment of free routing for the trial flights was restricted to the portion of the flight within domestic airspace. Two airspace volumes had a key role in the direct routing provision: North Wales Military Training Area (NWMTA) in the London FIR and the Class F restricted airspace associated with 3 Wing Bagotville Military Flying Area in Quebec, Canada. As a result, optimised domestic routes were only possible through successful coordination of civil air traffic control units and Military controllers.

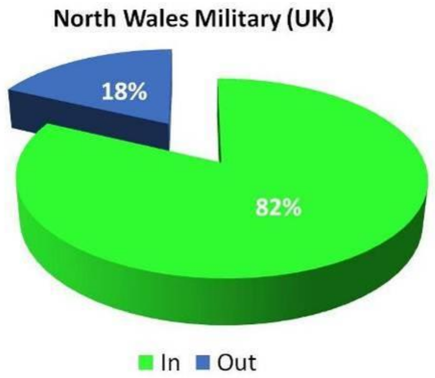


Figure 17: AFUA application ratio in NWMTA

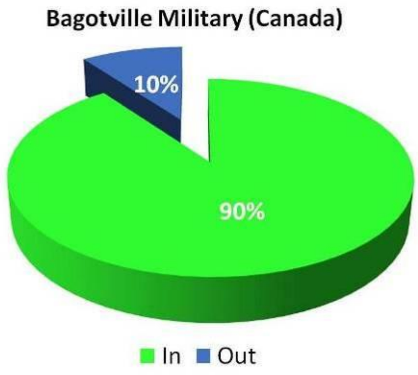


Figure 18: AFUA application ratio in Bagotville

Direct routing provision was based on pilot's request, in order to assess the application of Business Trajectories. On westbound flights, the crew requested a direct routing to their previously coordinated and initially approved Oceanic Entry Point, in order to meet the CTO at the oceanic boundary. It was assessed that the time difference between the best direct route and the baseline would keep the aircraft within the CTO limits (+/- 3 minutes).

Controllers try to avoid direct routing across a FIR corner, causing electronic system issues when the aircraft briefly penetrate another sector. The required coordination can result in a delay to provision of a clearance direct to OEnP. The coordination decision is currently left to controller judgement and the trajectory, from the gate-to-gate perspective, can be penalized. It would be beneficial to provide controllers with a tool to assess best practice in this matter to indicate the penalty to the flight, as this information is currently unavailable.

Coordination between controlling units was shown to be crucial, and depended on the availability of easily accessible communication between the civil and military controllers.

The data analysis of the flight trials showed that the route through London and Shannon FIRs could be reduced up to 11NM, which represents 2% of the distance from runway to the Oceanic Entry Point. In Canadian airspace, the 58NM flight distance reduction achieved represents 4% of the Canadian domestic route.

6.1.3.1.4.1 Free Routing in UK airspace

The Business Trajectory in UK airspace linked the departure point to the OEnP in a CCO. This aspect was taken into account in the fuel consumption assessment, thus the benefits from CCO were deducted from the savings figures.

Fifteen flights crossed the NWMTA from the whole range of analysed samples. However, due to limited information availability, there is neither actual weight nor distance information for nine of them. This information has proven to be crucial for the fuel consumption assessment and the effectiveness of the direct tracks provision. The actual route was in four of them longer than planned, even though they crossed the military area.

Two flights have met the filtering criteria: crossed military area and reduced flown miles. For one of them, the fuel benefit was 169 Kg and the flown distance was reduced by 9 NM. The second flight had a fuel penalty of 9 Kg and a reduction of 11 NM in flown distance. The median of the two values is 70 Kg of fuel savings.

6.1.3.1.4.2 Free Routing in Canadian airspace for Eastbound flights

The location of the Oceanic Entry Points for Eastbound flights regarding the departure airports and restricted areas, allow aircraft to fly very similar routes to the flight planned ones. But even when the flown miles were reduced, tactical intervention from ATCOs did not provide a relevant improvement in fuel consumption, as shown below. This is due to the adverse effect of winds for this particular case.

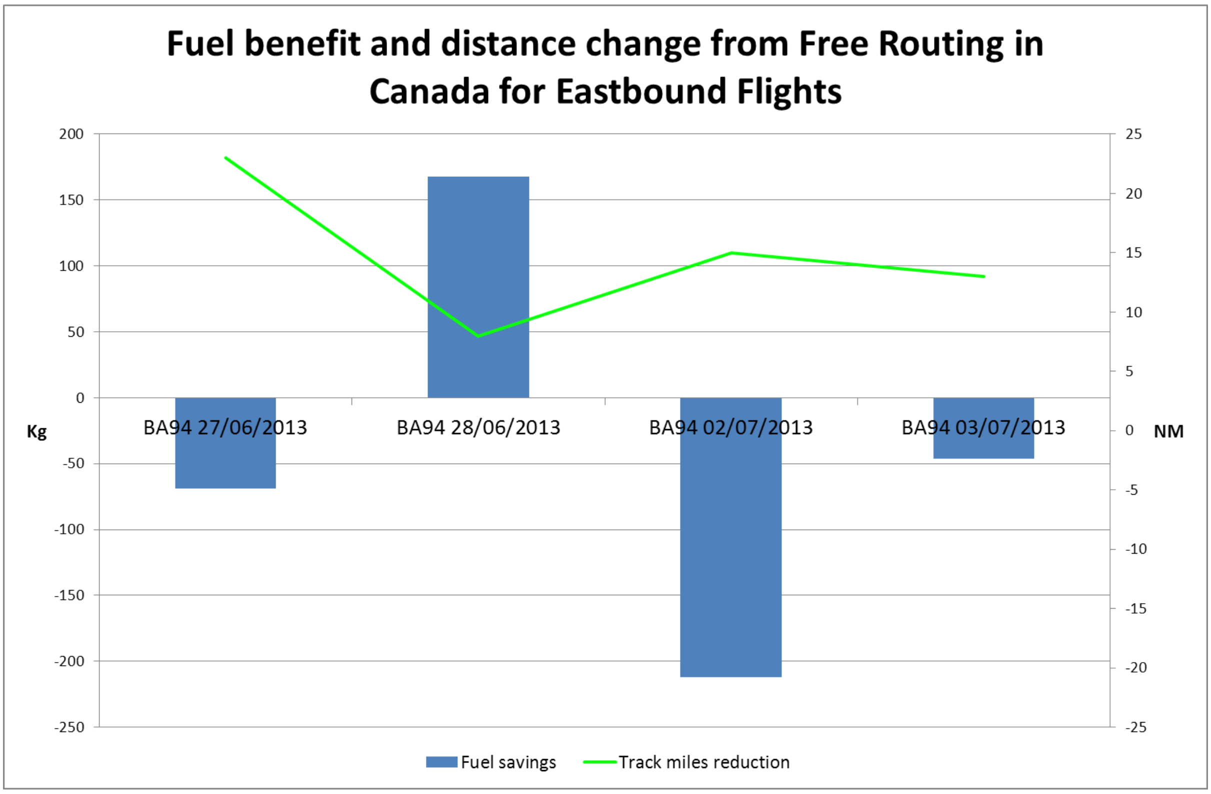


Figure 19: Fuel benefit and distance change from Free Routing in Canada for EB flights

The median value of the fuel consumption changes represented in the chart is 46 Kg of fuel penalty, even though the median flown distance was 14NM shorter.

<u>Flight N69. BA94, 02/07/2013. 212 Kg fuel penalty performing FR in Canada.</u>

A reduction in flown distance of 15 NM was calculated for the en-route Canadian domestic phase of flight. The actual flight does not fly the flight planned waypoints, but when calculating the wind for points at the same longitude, the result is that the tailwind is, at BAREE is 30kts lower than expected.

The conclusion for this particular flight is that a shorter route is penalizing fuel consumption because of adverse winds in the new trajectory.

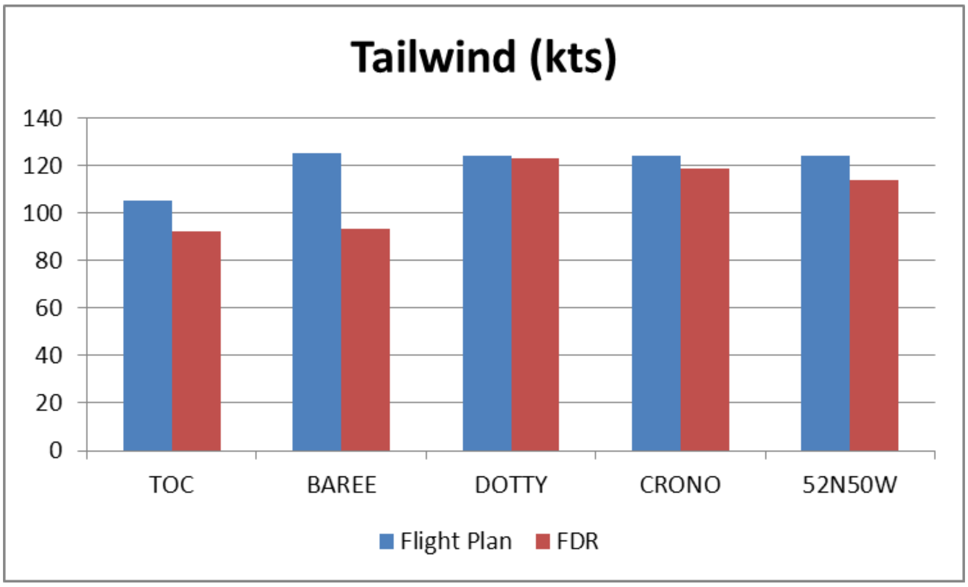


Figure 20: Wind assessment for BA94 02/07/2013

6.1.3.1.4.3 Free Routing in Canadian airspace for Westbound flights

The most direct route towards Toronto airport penetrates Bagotville military area. A significant reduction in track miles and fuel consumption were observed. These values are provided in the chart:

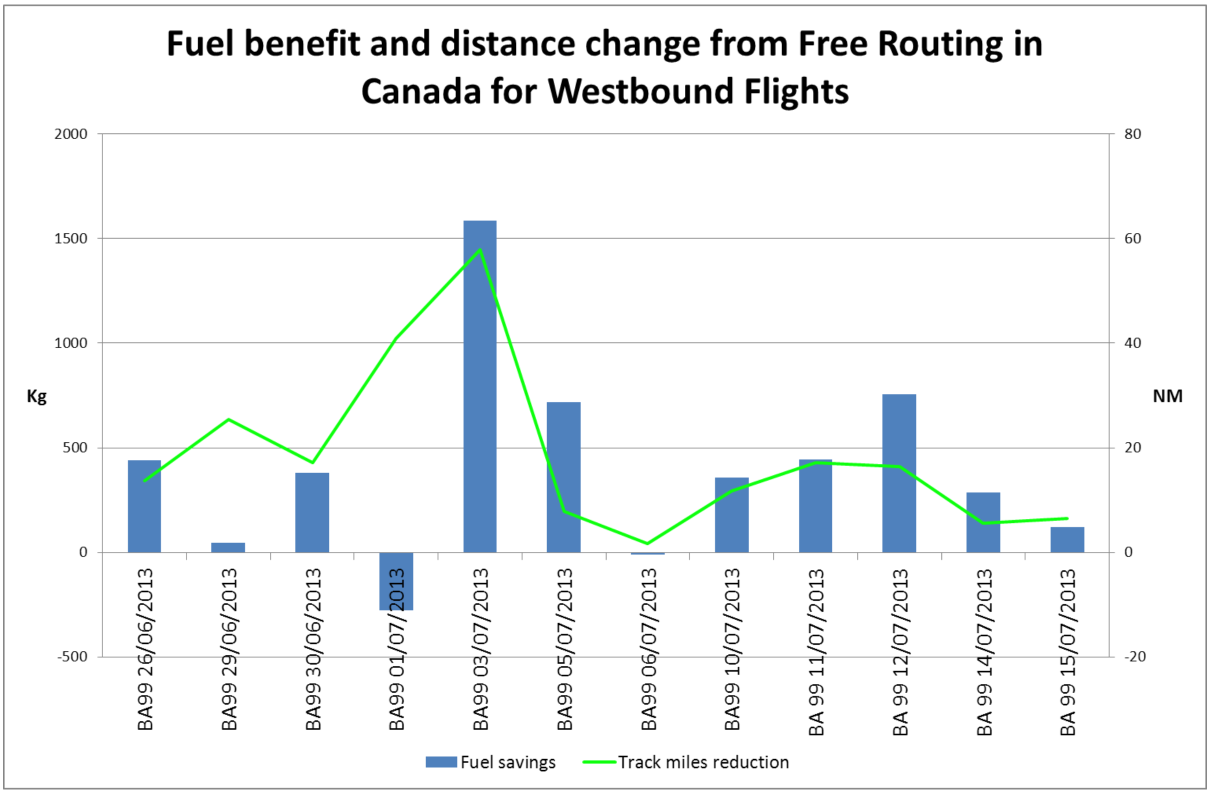


Figure 21: Fuel benefit and distance change from Free Routing in Canada for WB flights

The median value of the fuel consumption changes represented in the chart is 378 Kg of fuel savings, and the distance flown median was reduced in 15 NM.

Flight N68. BA99, 01/07/2013. 277 Kgs fuel penalty performing FR in Canada.

It was calculated that there was a reduction in flown distance of 20 NM during the en-route Canadian domestic phase of flight. The aircraft faced more adverse headwinds when following the shorter trajectory.

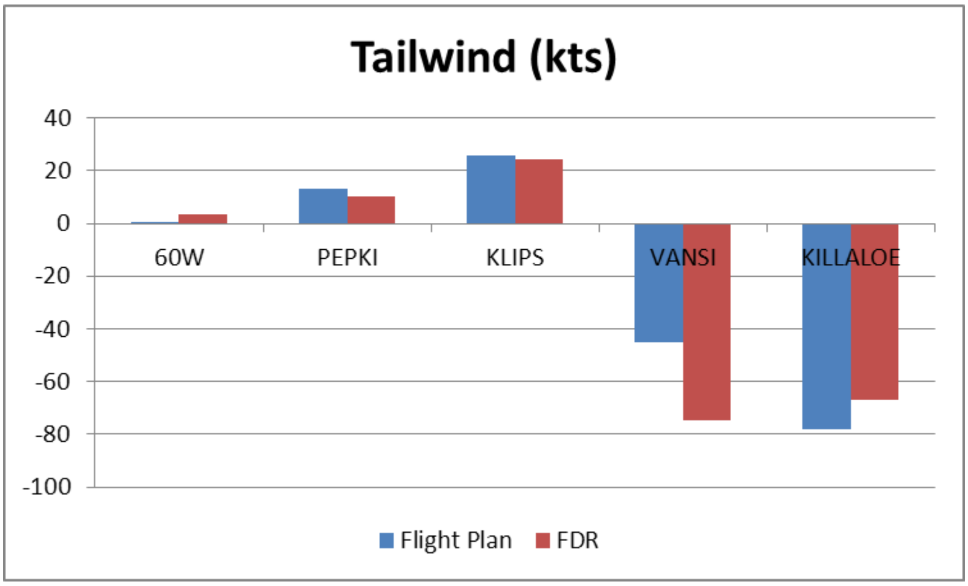
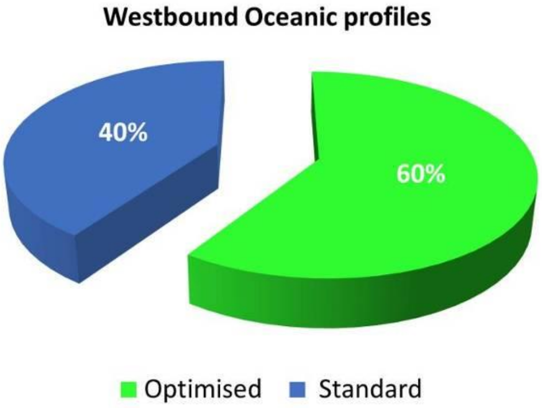


Figure 22: Wind assessment for BA99 01/07/2013

6.1.3.1.5 Optimised oceanic profile

This concept element is built upon the fuel and emissions savings possible from optimised altitude and speeds. As the aircraft burn fuel and get lighter, with the engines at ideal power setting, the thrust weight ratio changes and it is more efficient to fly at higher altitudes. Interesting savings are more significant for long cruise flight, such as North Atlantic crossing. Offering variable speeds also helps aircraft to achieve their desired cost index and meet the CTO at the Oceanic Exit Point.

As shown in Figure 23 and Figure 24, westbound oceanic flights benefited from a less congested airspace and the procedures in place to obtain an initial oceanic profile. On these graphs, any flight being offered Variable Mach or/and Variable Flight Levels was considered to be Optimised.



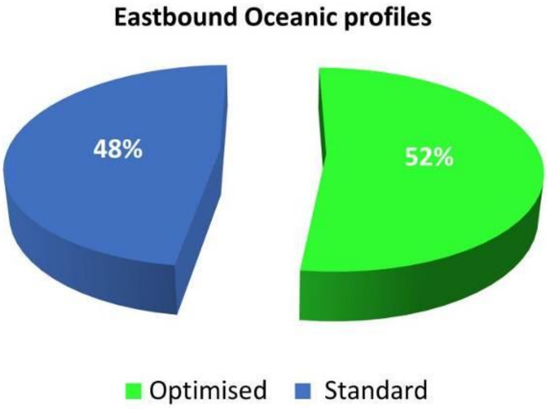


Figure 23: Optimised Oceanic WB flights

Figure 24: Optimised Oceanic EB flights

The top level of optimisation through climb profiles was achieved by 100ft step climbs. As a result of lessons learnt in the TOPFLIGHT trials, British Airways have identified the need to incorporate the ability to perform continuous cruise-climbs without thrust change in the FMC, rather than repeated crew initiated 100ft steps. The current mechanism, subject to application of climb thrust settings, masks the fuel burn benefits coming from flying at optimised levels.

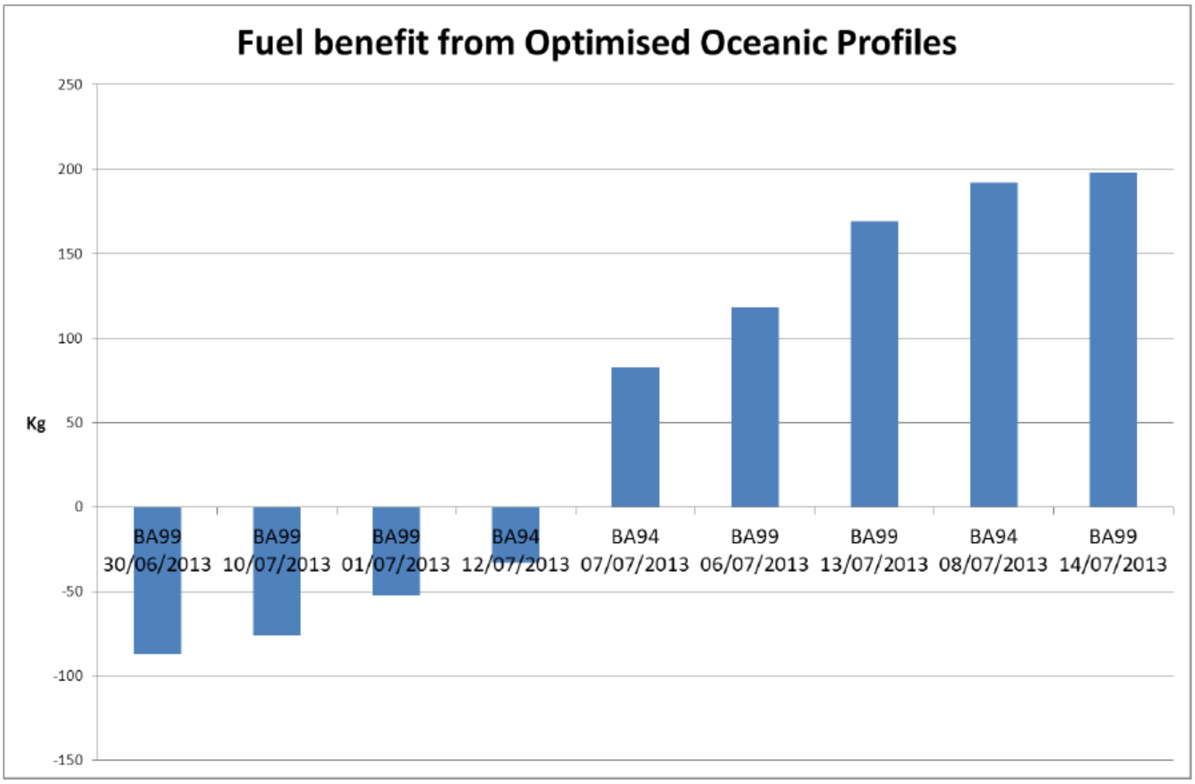


Figure 25: Fuel benefit from Optimised Oceanic Profiles

The median fuel consumption shift that corresponds to flying an optimised oceanic profile is 83 Kg benefit.

Callsign	Date	Fuel change (Kg)	Oceanic profile
BA99	30/06/2013	-87	10 step climbs 100ft each
BA99	10/07/2013	-76	2 step climbs 1000ft each
BA99	01/07/2013	-52	1 step climb 1000ft
BA94	12/07/2013	-33	1 step climb 1000ft
BA94	07/07/2013	83	1 step climb 1000ft
BA99	06/07/2013	118	3 step climbs 500ft each
BA99	13/07/2013	169	1 step climb 2000ft
BA94	08/07/2013	192	2 step climbs 1000ft each
BA99	14/07/2013	198	20 step climbs 100ft each

Table 18: Fuel change and step climbs of optimised oceanic flights.

The above chart does not show the values obtained from 4 particular flights. This is because they were assessed in detail to interpret the fuel penalties shown (506 Kg, 303 Kg, 169 Kg and 133 Kg), reaching the conclusion that for three of them, the calculated values were adversely affected by wind components largely different than planned. For the fourth one, the weight correction could not compensate for the effect of a single step climb.

Flight N71. BA94, 03/07/2013. 506 Kgs fuel penalty during the oceanic phase of flight.

The reason for this fuel penalty is a tailwind 20 knots lower than planned along the oceanic phase of flight. In order to achieve the flight planned time in the ocean, the aircraft must fly at M0.83, instead of M0.81 (flight plan). That leads to an excess of 500 Kg of fuel consumption by the actual flight.

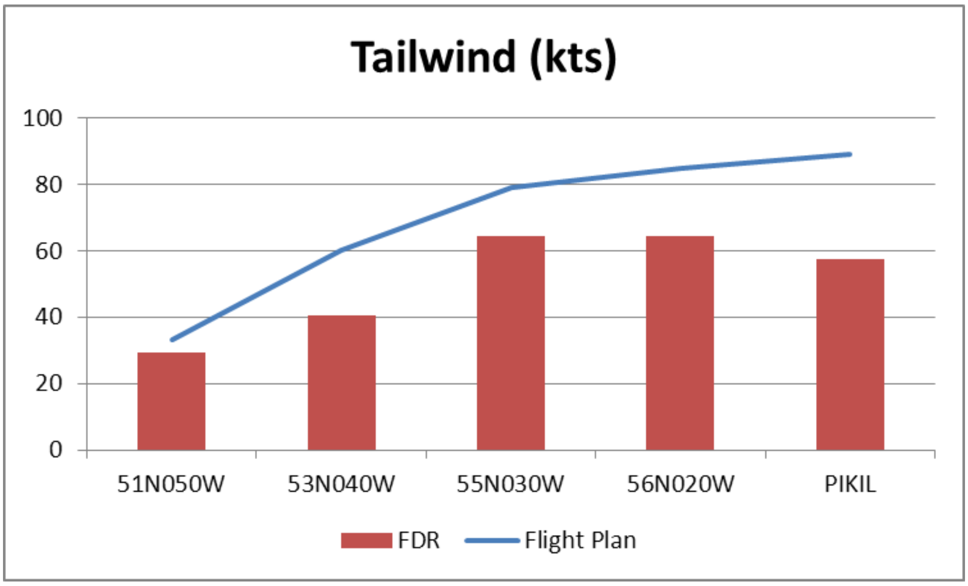


Figure 26: Wind assessment for BA94 03/07/2013

Flight N96. BA99, 15/07/2013. 303 Kg fuel penalty during the oceanic phase of flight.

The flight performs a single step climb of 2000ft at 42,5W. The fuel penalty comes from more severe headwinds at 30W and the single 2000ft step climb.

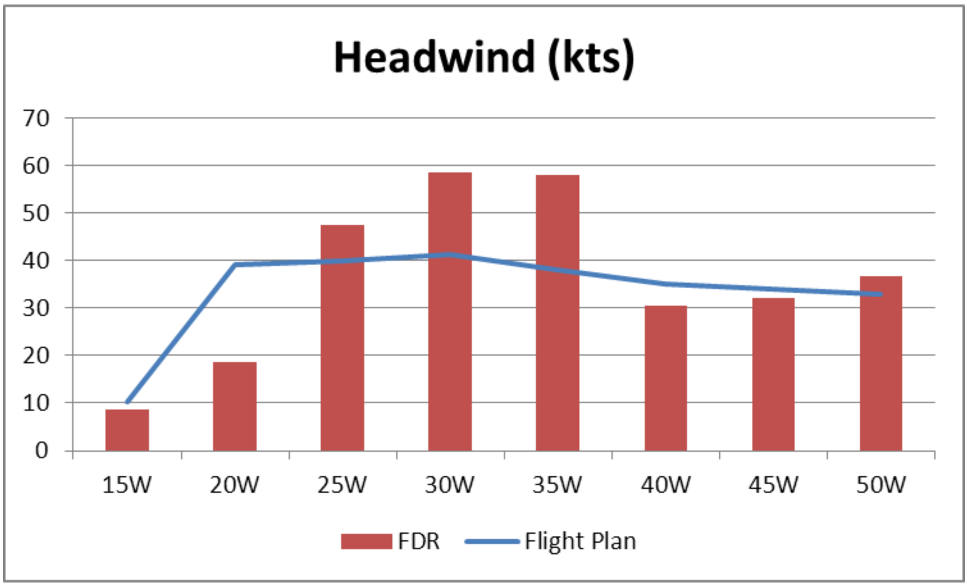


Figure 27: Wind assessment for BA99 15/07/2013

Flight N98. BA99, 16/07/2013. 169 Kg fuel penalty during the oceanic phase of flight.

Flight is 3.4 tonnes lighter than expected. The fuel consumption between 20W and 50W is quite similar to the flight planned, even though the aircraft is lighter and is flying a step climb profile.

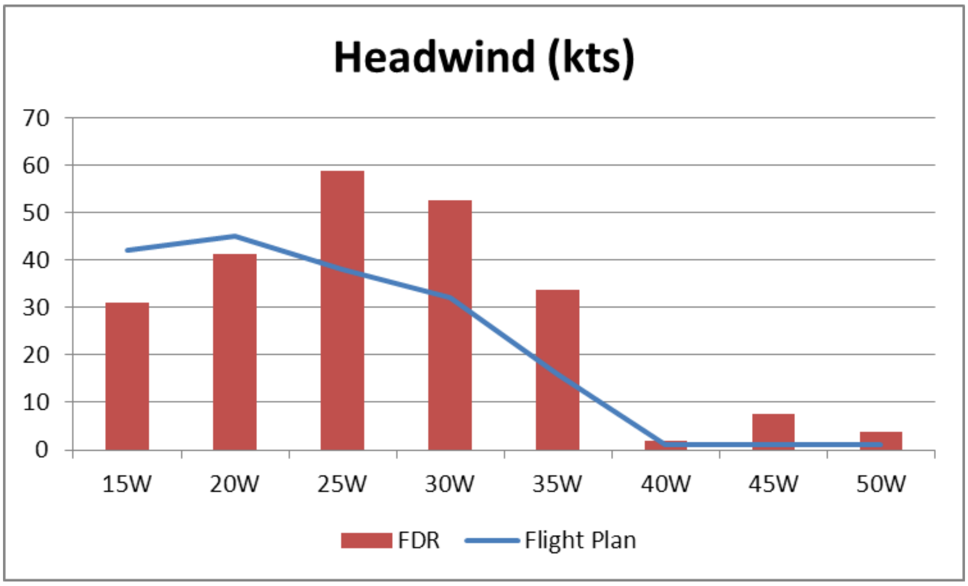


Figure 28: Wind assessment for BA99 16/07/2013

Flight N69. BA94, 02/07/2013. 133 Kg fuel penalty during the oceanic phase of flight.

The actual flight is 2.5 tonnes heavier than planned. The fuel penalty occurs mainly from 30W to 20W and less importantly from 50W to 40W. The flight performs a single step climb of 1000ft at 27W which is the reason for the extra fuel consumption, aggravated by a significant weight difference. As shown in the graph, the planned and actual wind values are fairly similar.

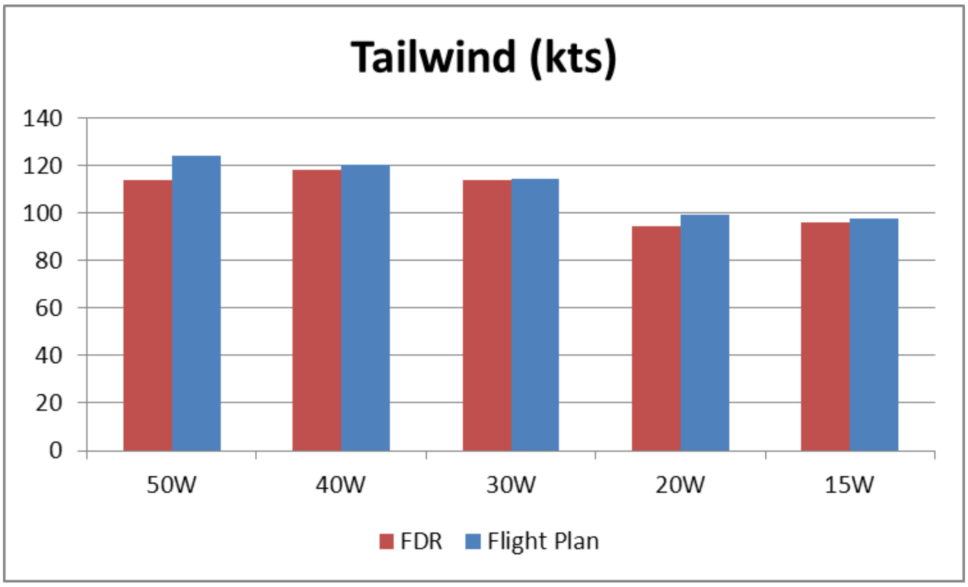


Figure 29: Wind assessment for BA94 02/07/2013

6.1.3.1.6 Continuous Descent Operation

CDO is an aircraft operating technique in which an arriving aircraft descends from an optimal position with minimum thrust and avoids level flight to the extent permitted by the safe operation of the aircraft and compliance with published procedures and ATC instructions. The objective of a CDO is to reduce aircraft noise, fuel burn and emissions by means of a continuous descent, so as to fly the approach glidepath 'clean' only lowering the undercarriage and flap at 4 NM to be stabilized in landing configuration at 2 NM.

The flight trials aimed at providing the gate-to-gate optimum trajectories for the oceanic flights. In descent, this means a Continuous Descent Operation from Top of Descent.

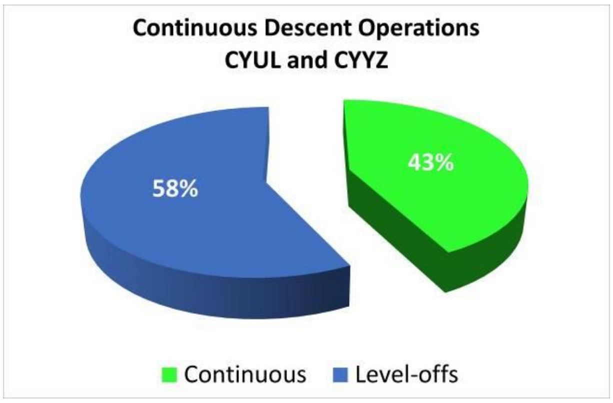


Figure 30: Application ratio for CDO at CYUL and CYYZ

In this particular case, flight plans do not offer appropriate information to compare against the flight data recordings, as flight plans are calculated according to continuous descent approaches from the optimum Top of Descent. The developed methodology to address the benefits of this concept is based on the shift in fuel consumption due to a level flight at non-optimum altitudes instead of flying further at cruise flight level.

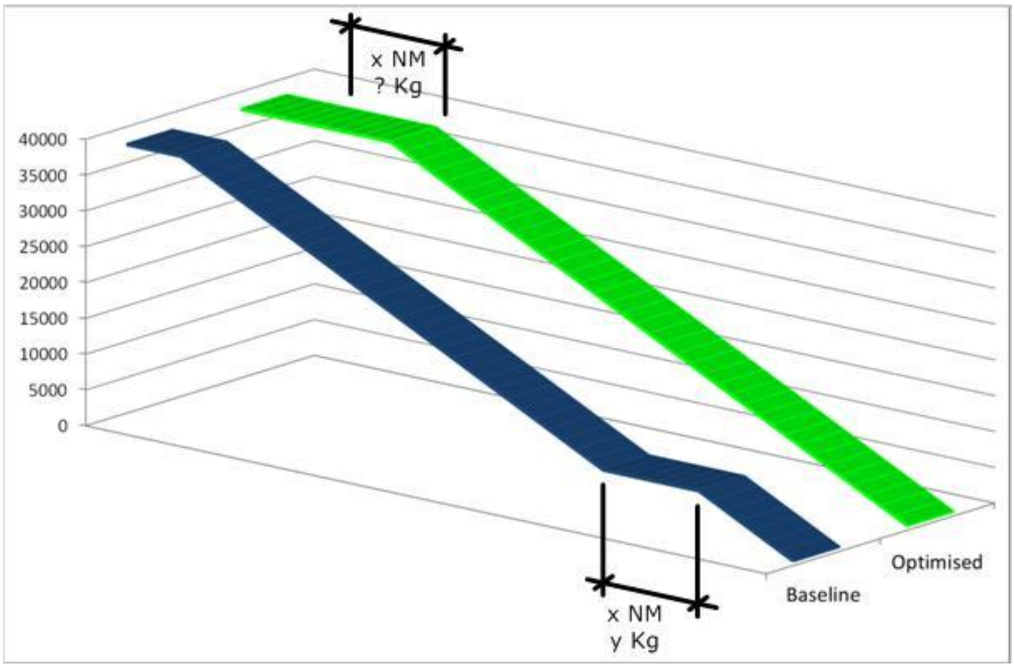


Figure 31: Calculation method of CDO benefits

The fuel consumption and track miles flown during the level-off were calculated in the provided FDR files. That distance was then considered at cruise level flight to see what the fuel consumption of flying those miles at that altitude would be. The difference in fuel consumption is the penalty of having done the level-off.

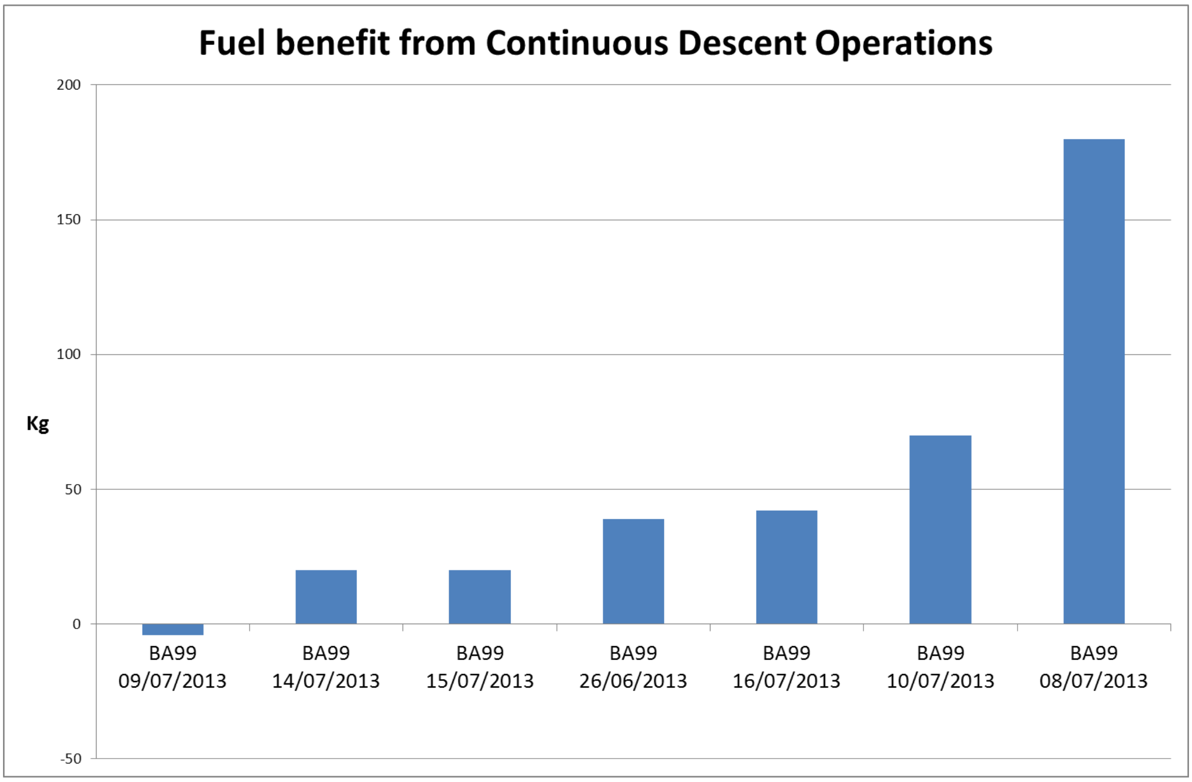


Figure 32: Fuel benefit from Continuous Descent Operations

The median value of the figures shown above is 39 Kg of fuel savings.

6.1.3.1.7 SWIM analysis

There was a significant amount of information supporting the demonstration flights that was sent by email. Some problems arose when it was not received or when there were inaccuracies. This type of supporting information could be published on SWIM automatically as a by-product of other activity such as an update to TTOT. The SWIM protocol for the information would require that it be alerted to those recipients that had subscribed. Use of by-product information and use of syntax and logic check on ‘human’ input of information to SWIM schemas would also reduce errors that appeared in emails.

For any flight, there is a significant amount of information that is currently considered as extraneous to the Flight Object designed to meet current ATM systems and the remarks field is often overloaded with important operational information. This supporting information, unimportant in the current concepts of operation, could nevertheless be extremely useful in future concepts. In particular this would include the assessment of constraints for the ANSPs and aircraft beyond the current sector(s). For example the emails and some phone calls needed in TOPFLIGHT are early instances of trajectory negotiation and the collaborative imposition of constraints and information on failure to meet constraints.

In the SWIM Appendix the information flows are tabulated and those flows that are candidates for SWIM are identified. Simple modified streamflow diagrams are also provided to show information flow of both normal operational messages and the TOPFLIGHT ‘administrative’ messages.

6.1.3.1.8 Results per KPA

6.1.3.1.8.1 Efficiency:

- Westbound flight: up to 834 Kg of fuel savings and 2652 Kg of CO_2 savings (1.5% reduction).
- Eastbound flight; Up to 301 Kg of fuel savings and 957 Kg of CO_2 savings (1.5% reduction).
- 11 NM reduction in London and Shannon FIRs (2% reduction).
- 58 NM reduction in Canadian domestic airspace (4% reduction).

For more detailed information about efficiency values, please see Section 5.3.1.1.

6.1.3.1.8.2 Predictability:

- Demonstrated the issuing of an Oceanic Clearance before departure.
- Demonstrated the use of AMAN system delay to control descent speeds.

6.1.3.1.9 Results impacting regulation and standardisation initiatives

The activities carried out during Exercise #1 have not identified a need for a change in regulation or standardisation.

6.1.3.1.10 Unexpected Behaviours/Results

There were no unexpected behaviours/results.

6.1.3.1.11 Quality of Demonstration Results

The data collected from actual flights was compared against a baseline which was based on the flight plan. The flight plan offered the best baseline of the actual flight. It is run approximately 3 hours before departure and includes estimated winds and weights. This process could have been enhanced by re-running the flight plan with the actual weight and recorded weather parameters. This activity was not performed due to the limited scope of the project.

6.1.3.1.12 Significance of Demonstration Results

The number of trial flights performed during Exercise #1 offers a high level of confidence in the assessment of application ratios. It was agreed in the Demonstration Flight the conduction of 30 to 60 trial flights. To ensure a sufficient number of sample data and guarantee the assessment accomplishment, the trials continued up to 100 flights.

For long, complex flights that are optimised on a sustainable basis (rather than a perfect or prioritised basis) fuel benefit quantification in a real environment is only achievable through the isolation of the individual concept elements. Furthermore, even when individual concept elements have been isolated, variation in key factors can invalidate the baseline data; for example changes in Take-Off Weight, cruise flight level or key waypoints in the route can result in significant changes compared to the flight plan, invalidating direct comparison. Data samples filtered several times to isolate the effect of optimisation elements on fuel values, which led to a highly reliable, but limited, number of valid flights for fuel quantification.

6.1.4 Conclusions and recommendations

6.1.4.1 Conclusions

Analysis of the flight trials in Phase 1 of TOPFLIGHT confirms the success of the Phase 1 trials. These demonstration flights have provided evidence that SESAR is currently delivering benefits in congested airspaces and provides useful tools for potential operational improvements.

The demonstration objectives identified in the Demonstration Plan [1] were met. This was achieved by the assessment shown in Section 5.1, regarding A-CDM, RETO/RETI, CCO, CDO, AFUA, RTA functionality, Optimised oceanic profiles and AMAN. Furthermore, the SWIM analysis, included in Appendix E of Complementary Results to TOPFLIGHT B1 Demonstration Report [2], identifies the actors and information items required to enable the concept elements.

Due to the feasibility assessment performed regarding concept elements, the blocking factors and implementation issues were identified and are reported in this document. This will help SESAR OFA leaders in understanding the challenges faced in live operations with regard the concepts analysed.

Airspace congestion has been identified as the main blocking factor for the provision of optimised trajectories.

The coordination between partners was successful in producing the procedures required to conduct the trials. They also generated a very valuable information exchange between the project partners, which led to a better understanding of the airport, TMA, en-route and oceanic operations, as well as aircraft operations, from different points of view.

The trials enabled British Airways to identify the following FMC enhancements that would deliver immediate benefit in the current ATM environment, while also supporting future ATM concepts:

- The ability to implement true continuous cruise climbs rather than 100’ or 1000' step climbs within an altitude block as the fuel burns off and the aircraft gets lighter,
- The ability to uplink and introduce to the FMC updated wind information as soon as it is available,
- Enhanced RTA functionality to within +/- 10 seconds,
- Common Lat/Long degree format. Currently, discrepancies exist between the waypoints coding format recommended by ICAO and the criteria followed by navigation database providers,
- The ability to display position to the nearest minute on the FMC screen on a clear and intuitive format, essential for RLAT on North Atlantic with 1/2 degree of Longitude tracks,
- CPDLC corruption to the ICAO 24 bit address for the B777 fleet. This is currently preventing BA crews using FANS for CPDLC in UK airspace,
- Implementation of the capability to perform Radius to Fix turns, introduced in new RNP AR & RNP navigation specifications.

The process of providing an initial oceanic clearance while the aircraft is at the departure gate has shown the benefits associated with early information sharing. Those benefits come mainly in terms of moving workload from the tactical phase to the planning phase. The possibility of providing Shanwick with visibility of the departure process, for example via an A-CDM portal, is currently being analysed, based on the project findings.

The assessment of optimised oceanic profiles provision has showcased the feasibility of this concept at the North Atlantic off-peak periods.

In current operations, some of the concept elements are already delivering benefits for the airspace analysed in the trials. RETI, CCO and Free Routing are part of daily operations when traffic permits.

6.1.4.2 Recommendations

The results and conclusions shown in this report should be considered by the SESAR projects involved in the following OFAs:

- OFA 02.01.01 – Optimised 2D/3D routes
- OFA 03.01.03 – Free Routing
- OFA 05.03.01 – Airspace Management & AFUA
- OFA 04.01.02 – Enhanced Arrival & Departure Management in TMA & En-Route

The project has identified airspace congestion as the main blocking factor for trajectory optimisation. Therefore, it is recommended that issues associated with airspace congestion be considered in the preparation for further work on trajectory sharing and prediction.

Some optimisation elements, such as Reduced Engine Taxi, Continuous Climb Operations, Free Routing and Optimised Oceanic Profiles, have shown enough level of maturity and very high application ratios, which suggests their readiness for implementations

6.2 Demonstration Exercise #2A Report

6.2.1 Exercise Scope

This first element of Exercise #2A focuses on conducting an assessment of the impact of oceanic metering via the use of a Controlled Time Over (CTO) for the oceanic exit point for North America originating transatlantic Heathrow inbound flights. In addition an assessment of the feasibility of oceanic metering is made.

This phase builds upon the procedures developed and validated in Phase 1 and further develops those which can be implemented and used in multiple flight scenarios.

This Exercise has targeted E-OCVM level 1.

6.2.2 Conduct of Demonstration Exercise EXE-02.07-D-201 A

6.2.2.1 Exercise Preparation

No V&V platform was required to support this Exercise, as it was solely meant for assessing live data.

6.2.2.2 Exercise execution

Exercise #2A Trials were planned to take place for selected British Airways flights arriving at Heathrow from 6th November to 27th November 2013, for aircraft types B744, B767, B777, B787 and A380. The flights were selected to give a range of aircraft types, oceanic tracks and times of day. Eight different scheduled flights were selected for the trial with data collected from these flights during every day of the trial. These flights are listed in Appendix B of Complementary Results to TOPFLIGHT B1 Demonstration Report [2].

A questionnaire was issued to the pilots of each trial aircraft to collect data on the flight and the impact on fuel consumption of executing a delay in line with the Oceanic Metering concept. Pilots were not requested to execute this delay.

Supporting data was collected from ground ATM systems. These were NATS' SAATS, Barco Orthogon's AMAN, EUROCONTROL's ETFMS, and IAA's COOPANS.

6.2.2.3 Deviation from the planned activities

One of the trial flights selected was operated by a B767 aircraft which did not have the avionics capacity to provide the information required. Therefore no data was collected for flights operated by B767 aircraft. Sufficient flights were selected initially to accommodate the loss of these flights without reducing quality of the analysis.

It was not possible to collect data to support the exercise from FAA's ETMS system. It would have been preferable to collect data directly from ETMS, however as ETFMS is updated by ETMS, some data is indirectly available.

6.2.3 Exercise Results

6.2.3.1 Summary of Exercise Results

The analysis to support this exercise was divided into 3 specific areas:

- Feasibility and impact of Oceanic Metering on Aircraft;
- Assess data supporting Oceanic Metering from aircraft and ground ATM systems
- Assess capacity for Oceanic Metering within Oceanic Airspace.

6.2.3.1.1 Feasibility and Impact

Data was collected for 57 trials flights about the impact on predicted fuel usage of executing a 3 minute delay in arrival time at the Oceanic Exit Point (OExP) as they crossed 040W. 77% of the trial flights estimated a fuel saving most frequently up to 200kg. 33% estimated a fuel penalty of no more than 150kg. Seven flights estimated a saving of more than 300kg. Please note that these fuel estimates come exclusively from flying the same distance at a slower speed.

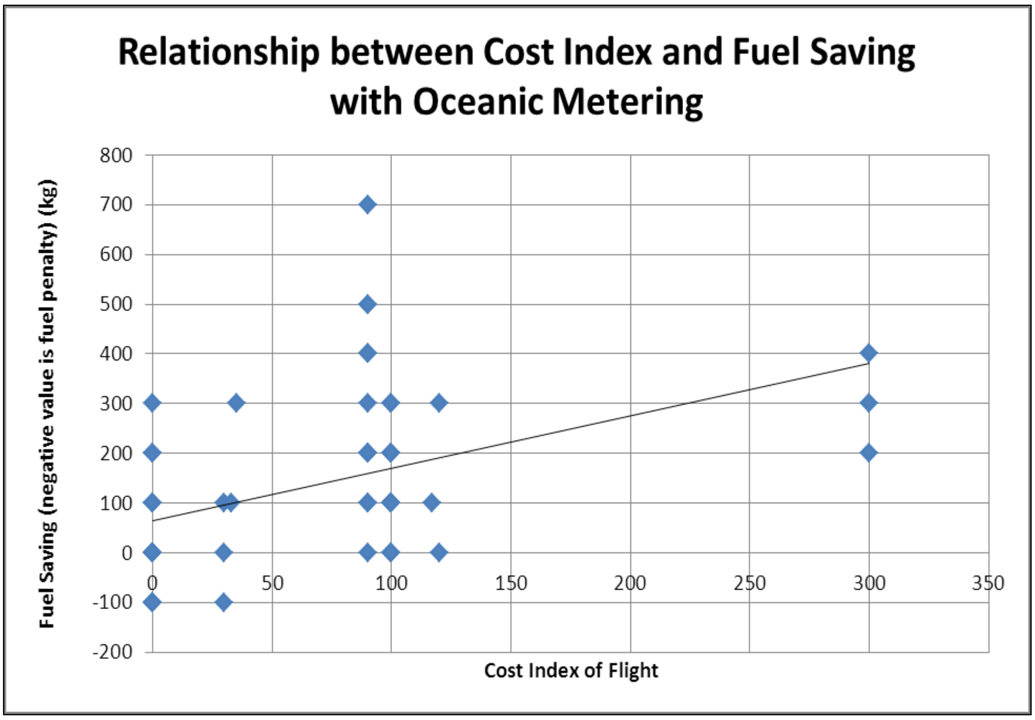


Figure 33: Cost Index Vs. Fuel saving for Oceanic Metering

Figure 33 shows Fuel impact against Cost Index, and demonstrates that the fuel saved during Oceanic Metering increases for flights on a higher cost index. Flights at the highest CI (300) estimated fuel savings of 200 – 400kg, whilst the majority of flights at CI0 estimated fuel consumption increases of up to 100kg. It is proposed this may be because the aircraft slowing to speeds below CI=0 are slowing to the point where fuel consumption increases slowly as speed decreases.

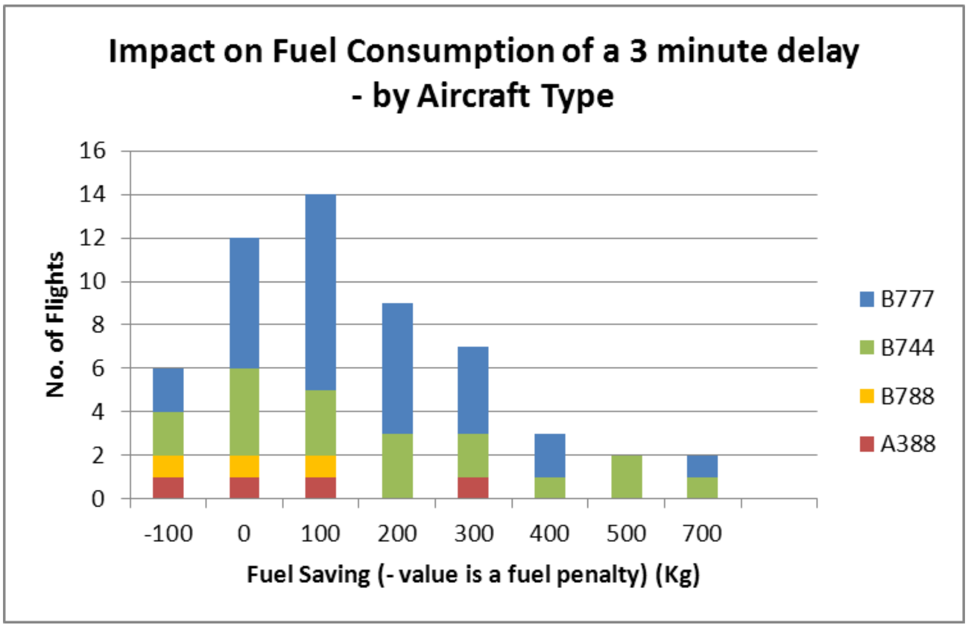


Figure 34: Impact on Fuel consumption by Aircraft Type

Figure 34 above shows the impact on fuel consumption grouped by aircraft type. The A388 and B788 aircraft estimated a low impact on fuel consumption, ranging +/- 100Kg, with an exception at 300Kg fuel savings. The older aircraft types (B744 and B777) estimated impact predominently in the 0-200kg range though there was a wider range of estimates.

56% of pilots indicated no issue with executing the delay. Of the remainder 20% noted that if there were strong turbulence it may prevent the aircraft slowing and 5% raised concerns with procedure (spacing, ATC clearance). One pilot expressed concern that their fuel temperature was nearing freeze point so slowing further was not possible.

6.2.3.1.2 Assessment of Supporting Data

ETAs early in the flight come to AMAN via ETFMS. The ETAs have greatest error in the period following departure until contact with Gander. This could indicate that departure delay is adversely affecting the accuracy of the ETAs, even though aircraft could make up the delay time and return to schedule. With a few exceptions the less accurate system ETAs predict the aircraft to be slower and therefore arrive later than the more accurate estimates predict.

After activation in Gander the ETAs all become generally more accurate as the flight progresses. The accuracy when in Gander varies, but is generally within 5 minutes.

The airborne ETA for the OExP, taken at 040W, is within 2 minutes with one exception when it was nearly 10 minutes ahead of the system estimates.

ATM systems contain ETAs for the OExP with an accuracy of around 5 minutes or less for most of the Oceanic portion of the flight. SAATS provided the most accurate system estimate for the OExP, but only after direct contact has been established with the aircraft via FANS, just before Gander sends a Clearance Request message to Shanwick and approximately 2 hours before reaching the OExP. Prior to this point the ETA is highly inaccurate; more so than even the initial flight plan. All flights in the trial were ADS-C equipped, generating position updates to SAATS every 18 minutes.

The impact of any inaccuracy depends on how Oceanic Metering is implemented. If metering by giving speed instructions for example, a speed change to affect a 3 minute delay, arriving 0603 rather than 0600 according to the ATM system. If the ETA is 5 minutes out the aircraft would have arrived at 0555 but with the speed change now arrives at 0558. If metering by a target time of arrival, the controller would request arrival at the OExP at 0603, and the aircraft may actually need to lose 8 minutes to comply because of the ATM system inaccuracy. If metering by speed, the actual arrival time of the aircraft will remain inaccurate, however if metering by arrival time, the impact on the aircraft may be less predictable, but it's arrival time will be accurate. The costs and benefits of each method would need to be assessed and considered in any implementation of Oceanic Metering. Because of these inaccuracies, Oceanic Metering by target arrival time would enable a more predictable presentation of traffic at the Oceanic boundary.

System ETAs for the COP were available from the ETFMS system and COOPANS only. The COOPANS ETA was provided approximately 10 minutes from arrival at the COP, however at this point the estimate was more accurate than the estimate in ETFMS (or therefore) AMAN.

ETAs for the stack were provided by ETFMS and also AMAN, which generates its own estimates for Stack. Both these estimates were generally accurate to +/- 5 minutes within 70 minutes of arriving at the stack.

There was a high degree of variation in the AMAN ETAs for Stack over time, reflecting the greater parameters used by AMAN to generate its estimates. These include traffic, arrival sequencing and weather, and also ATC intervention such as vectoring to delay or make up time. Conversely the ETAs provided by ETFMS generated from correlated position reports from the UK were less variable. It was noted that the AMAN estimates changed markedly between 20 and 14 minutes before reaching the Stack. This is possibly due to the effect of the descent speed procedure in place at Heathrow. Aircraft with predicted delay are slowed at this point to reduce holding; AMAN immediately updates its ETA for the stack, resulting in a more accurate ETA. It is likely that the aircraft in the trial all experienced arrival delay at Heathrow. However a larger sample of data would be required to prove this connection.

Appendix B of Complementary Results to TOPFLIGHT B1 Demonstration Report [2] contains graphs supporting the results described above.

6.2.3.1.3 Capacity Assessment

An assessment of the capacity available in Oceanic Airspace to accommodate Oceanic Metering was made. Aircraft position reports at 030W were collected from NATS' SAATS system, and the corresponding 030W position reports for aircraft leading and following the trial aircraft. This gave an indication of spacing by providing the time that each aircraft crossed 030W. Note that the comparative speeds of the aircraft were not taken into account.

Standard separation in Oceanic airspace for in-trail aircraft is 10 minutes, which can be reduced to 5 minutes if both aircraft are ADS-C equipped and provide more frequent ADS-C periodic updates. Crossing aircraft need to be separated by 15 minutes.

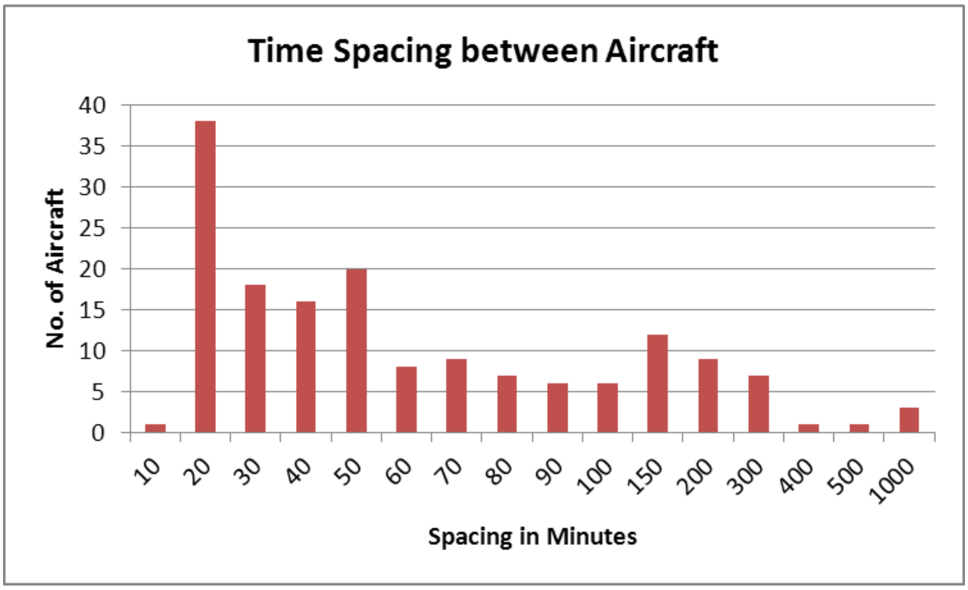


Figure 35: Time Spacing between Aircraft

Figure 35 represents a histogram where each bar represents the number of aircraft with a specific spacing in minutes. The most common spacing is 10 - 20 minutes, however 75% of flights have a greater spacing than 20 minutes between either following or leading aircraft and 30% have a greater than 20 minutes between both leading and following aircraft. This indicates that the majority of flights may have capacity to slow down by a few minutes without impacting the following aircraft, but that surrounding flights need to be considered.

Spacing is generally greater for aircraft on random tracks rather than those using the Organised Track Structure (OTS). 60% of OTS flights are spaced between 20 – 40 minutes. 25% of aircraft on random tracks are spaced at 20 minutes, with the majority of the remainder ranging fairly evenly up to 300 minutes. This concurs with the existing understanding that that OTS tracks are generally more congested than random tracks.

6.2.3.1.4 Results per KPA

Environment / Fuel efficiency – The results demonstrate a decrease in fuel consumption if delaying to reach an Oceanic CTO.

Predictability - Results support the feasibility of Oceanic traffic meeting a CTO. This leads to potential predictability improvements directly and indirectly via an improved presentation of traffic to AMAN.

6.2.3.1.5 Results impacting regulation and standardisation initiatives

If the Oceanic Metering concept is adopted, a future Oceanic Metering procedure should define the procedure and the mechanism by which its suitability is assessed (by pilot and controller) taking into account surrounding traffic and weather.

6.2.3.1.6 Unexpected Behaviours/Results

There were no unexpected behaviours/results.

6.2.3.1.7 Quality of Demonstration Results

The fuel impact estimates are from the aircrafts' Flight Management System (FMS) which rounds fuel usages to the nearest 100kg. This leads to an error of +/- 50kg. Also, interpretation of the data was necessary because of ambiguity in the pilot responses to the questionnaire. This interpretation was based on assumptions provided by BA. It was assumed that if a positive fuel impact was given this was a fuel saving. It was also assumed that if an impact was not positive or negative, the cost index could be used to imply whether the value was a saving or a penalty: a flight at Cost Index 0 would experience a penalty and a flight at higher cost indexes would experience a fuel saving.

Airborne data was collected through pilot questionnaires so may contain an element of human error. To minimise the impact of this the data has been analysed for general trends to avoid over-reliance on the accuracy of every return.

The data was collated into a spreadsheet from the original pilot questionnaires by BA. The system data collected by Barco Orthogon for AMAN and the IAA for COOPANS also required some manual or automated pre-processing before receipt by NATS. NATS pre-processed SAATS data using automated tools from the original logs, and EFTMS data from pre-filtered logs provided by EUROCONTROL.

6.2.3.1.8 Significance of Demonstration Results

This exercise was constrained by time and resource. The results described here are indications, which have not been measured for statistical significance. However to ensure confidence and operational significance in these results, the validity of the results and conclusions have been verified with domain experts.

6.2.4 Conclusions and recommendations

6.2.4.1 Conclusions

The majority of aircraft, particularly those operating at higher cost indices, estimated a fuel saving associated with Oceanic Metering. This fuel saving must be viewed in conjunction with the benefits of reduced holding and delay at Heathrow. The saving is smaller for newer aircraft types and aircraft flying at a lower cost index. Concepts such as Optimised Oceanic Profiles using Step Climbs or Variable

Flight Levels and Variable Mach demonstrated in Phase 1 of TOPFLIGHT could allow the operator to maximise the fuel efficiency of Oceanic Metering.

Oceanic Metering is feasible from an airborne perspective. The concerns raised by pilots regarding turbulence and surrounding traffic can be mitigated by creating new procedures for Oceanic Metering.

SAATS provides the most accurate ETAs for the OExP, approximately 2 hours before reaching the OExP. Sharing this data in other ATM systems such as ETFMS and AMAN would improve ETAs in these systems.

There can be a discrepancy between airborne and ground estimates of ETA at the OExP of around 5 minutes. This difference may be improved by better use of existing SAATS estimates and data sharing between centres, which would facilitate Oceanic Metering. Because of these inaccuracies, Oceanic Metering by target arrival time (Time-Based Flow Management) would enable a more predictable presentation of traffic at the Oceanic boundary.

COOPANS provided most accurate ETAs for the COP. Sharing this data in other ATM systems such as ETFMS and AMAN would improve ETAs in these systems.

This analysis confirms that ETAs change significantly as the aircraft transits between centres, particularly in the early stages of the flight. There is a recurring pattern of all ETAs being more accurate prior to departure, less accurate following departure and then more accurate as the flight progresses. Estimates based on the initial flight plan can be inaccurate as they use weather information up to 6 hours old, and flights travelling West to East over the ocean have a wider window of opportunity to change their oceanic track, impacting ETAs on the East side of the Ocean.

Gander's GAATS is the first system in the flight's progress to estimate ETAs using existing Oceanic metrological conditions. Updates to ETFMS from Gander immediately improve accuracy of the ETA. This demonstrates how more timely sharing of ETA data between centres is therefore an area where it may be possible to improve the accuracy of ETAs across ATM systems.

Following a delay all ETAs are shifted back the duration of the delay, however operators can attempt to maintain original arrival times.

Oceanic Airspace has the capacity to accommodate Oceanic Metering, but this capacity is most constrained at lower flight levels (FL380 and below) and on the OTS. The results indicate there is generally space to slow or speed up some aircraft at all times of day and on all tracks. It should also be noted that there is a seasonal variation to capacity in Oceanic Airspace, where traffic levels are lower in winter than in summer. This trial took place in November when the jet stream is strong, and November 2013 experienced particularly strong winds. It tends to be more use of random tracks during winder whilst in summer the traffic increases on the OTS.

Oceanic Metering is feasible from an airborne and ground system perspective. Ground ATM system estimates can be accurate depending on phase of flight, and it would be possible to improve the accuracy of system estimates further with better data sharing between systems. There is capacity in the airspace even without widespread use of Reduced Longitudinal Separation, though capacity could be constrained on the busiest tracks at the busiest times of day.

The Oceanic Metering flight demonstration has shown how data accuracy changes with each stage of flight and between the different ATM ground systems. It has highlighted examples where data accuracy could be improved if necessary. This information will be used by NATS' Queue Management strategists to develop equitable metering concepts making best use of the available data, and to support the conversations to enable more timely sharing of data between ANSPs to improve estimates over the Ocean and therefore arrival planning accuracy.

Oceanic Metering cannot be implemented in isolation because it would not be equitable to aircraft arriving at Heathrow from all directions. This is a key requirement of NATS' Queue Management strategy. However in conjunction with other metering concepts it may be part of an equitable solution.

6.2.4.2 Recommendations

It would be possible to improve the accuracy of ETAs across ATM systems by timely sharing of ETA data between centres, for example:

- Sharing of Gander-generated ETAs for flights before they enter Gander's airspace.

- Inclusion of ETAs for OExP from SAATS and COP from COOPANS in other ATM systems such as ETFMS and AMAN would improve ETAs in these systems.

It was observed that ETAs adjusted following departure became less accurate due to departure delay which pilots would then seek to recover. It may therefore be more accurate to use the original flight planned times when calculating ETAs for points in UK airspace, (ignoring Flight Departure messages), until updates are available from Gander and Shanwick which will take metrological conditions and flight progress into account. It would be interesting to compare the accuracy of SAATS data for ADS-C flights against non-ADS-C flights which report position every 40 minutes. The sharing of this ETA data could be carried out using SWIM.

A more detailed study of Oceanic Airspace capacity using more aircraft and taking into account aircraft speeds, weather conditions and optimal flight levels for metered aircraft should be part of the development of an Oceanic Metering concept.

Procedures for Oceanic Metering should take into account weather conditions particularly turbulence, and impact on surrounding traffic.

Eastbound track loading figures are notified by Gander at a 2300UTC teleconference. This could be an opportunity to incorporate TOPFLIGHT optimised oceanic profiles and oceanic metering for flights on tracks with capacity and re-file their amended flight plans. Operators may be encouraged to use a less optimal track in return for a more flexible flight profile.

6.3 Demonstration Exercise #2B Report

6.3.1 Exercise Scope

Exercise #2B is aligned with previous Exercises #1 and #2A in TOPFLIGHT, towards a more optimum flight operation with the most efficient use of airspace. Effective Queue Management helps to reduce the fuel burnt by aircraft arriving at Heathrow through the absorption of delay in a more efficient linear phase of flight, thereby minimising the low altitude stack delay currently experienced.

To maximise the effectiveness of linear holding, the use of Cross-Border Arrival Management (XMAN) on a tactical basis is an essential element of current Queue Management techniques for Heathrow inbounds, due to geographical constraints. This requires a close cooperation with neighbouring ANSPs.

Work already carried out within NATS' airspace has descent speeds applied to Heathrow inbounds in relation to AMAN predicted delay. This delivers flows of traffic at reduced speeds giving benefits in reduced fuel burn whilst acting uniformly to preserve the planned arrival sequences.

6.3.2 Conduct of Demonstration Exercise EXE-02.07-D-201 B

6.3.2.1 Exercise Preparation

The Performance Engineering Program software, from Airbus, was used to inform regarding the impact in time and fuel of slowing down aircraft in cruise phase of flight and descent. The results of this assessment can be found in Appendix D of Complementary Results to TOPFLIGHT B1 Demonstration Report [2].

In addition to that, a session in an A320 flight sim at Airbus facilities in Toulouse was held on the 22nd of May. It was meant to analyse the interaction with the FMC to introduce speed instructions, downstream constraints and, in general, descend phase variables. The report of this session can be found in the same Appendix.

6.3.2.2 Exercise execution

Exercise #2B was limited to the application of a simple speed reduction of 0.03 Mach for Heathrow inbounds at 350NM from touchdown when the expected delay at the airport was over 9 minutes. The involvement of all neighbouring ANSP partners was crucial to ensure an equitable as possible application of delay absorption in the cruise phase of flight. The involved ATC units were: Maastricht UAC, DSNA Reims UAC, IAA Shannon ACC, NATS Prestwick Centre and Swanwick Area Control. The arrival delay information was based on BARCO AMAN data transmitted on Web-Service continuously to all partners.

The XMAN trials were executed over a period of 1 month, starting with a limited operation service check on the 31st of March from 15:00 to 17:00 UTC and continued from the 1st April to 30th April 2014, between 06:30 and 22:00 UTC.

6.3.2.3 Deviation from the planned activities

It was initially envisaged that a CTO would be sent to aircraft by NATS, via datalink, which would be achieved with the use of RTA functionality. However as the concept evolved and the FABEX XMAN programme emerged it was agreed that a more sustainable approach that allowed more partners to participate was for neighbouring ANSPs to issue speed instructions allowing aircraft to comply with CTO. It is intended that future evolutions of the XMAN concept will include the use of CTOs issued to aircraft locally.

6.3.3 Exercise Results

6.3.3.1 Summary of Exercise Results

Stack holding for Heathrow alone is estimated to have cost aircraft operators in the vicinity of €72 Million in 2009. In addition to the environmental impact, this congestion in the vicinity of major airfields and groups of airfields has a detrimental impact on safety, with TMA airspace and the holding stacks a regular focus of safety improvement work.

The primary result showed by the trial is the feasibility of the concept and successfully coordination with other ANSP units, by implementing ATC procedures and introducing systems modifications to allow HMIs that show Heathrow delay.

The evolution over time of the average delay values was assessed. Initially figures for March and April 2014 were plotted to identify potential effects on delays after the start of the trials. Secondly, this data was compared against the data from the same period the year before in order to identify any trend.

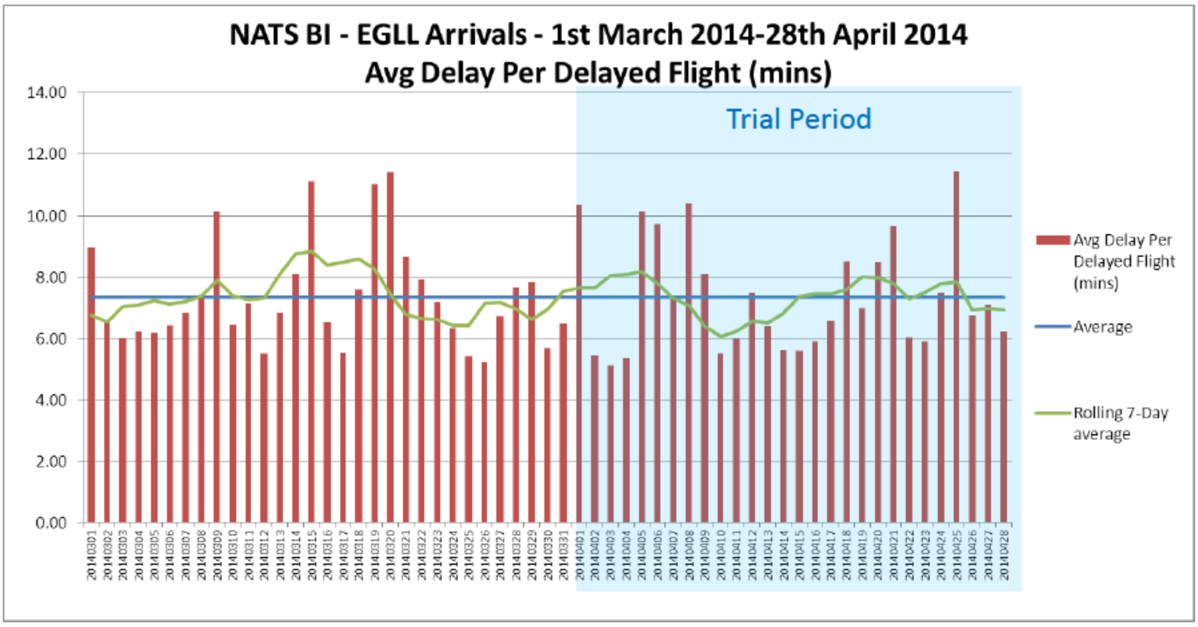


Figure 36: Delay values for March and April 2014

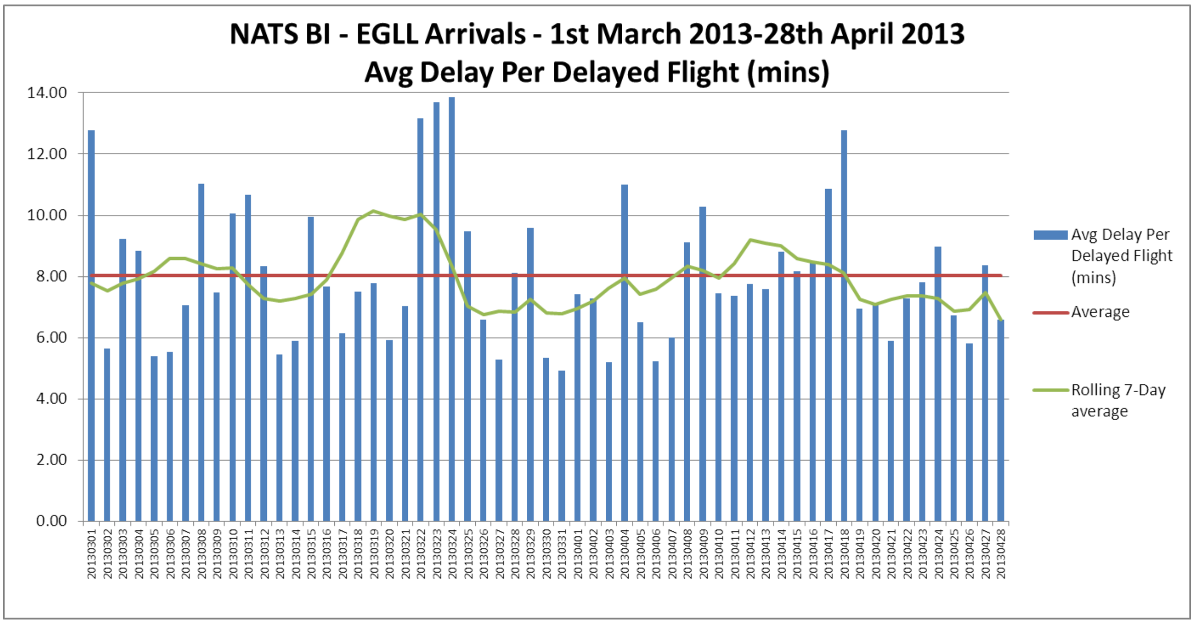


Figure 37: Delay values for March and April 2013

This comparison must be treated with caution as changes can be misleading due to a variety of factors (outside of the trial) that can influence average holding delay on a day to day/year to year basis. Such as weather, runway configuration, operational issues in neighbouring airports, emergency landings, cancelled flights, etc. However, no material change is observed in this data comparison between pre- and in-trial dates for 2014.

Specific methodology to isolate the effect of the speed instructions in the delay time was developed according to Figure 38.

Figure 38: Summary diagram of analysis methodology for delay evolution in Exercise #2B

The model aimed at isolating the effect of the speed instructions in holding times, by comparing the model behaviour with the speed instruction (actual data) and without it (calculated).

This process was repeated for every Heathrow arrival for 3 sample days during the trial. A set of parameters were required to reproduce the model:

- Speed change instructions:
    - Callsign;
    - Aircraft position when the speed instruction is issued;
    - Speed change.
- Actual stack-in time;
- Top of Descent Point per callsign;
- Stack-out rate = Heathrow arrivals rate.

ADS-B data was used to identify speed instructions. This was achieved by a data feed from FlightAware, filtered by Heathrow arrivals. Radar data would be the ideal information source to identify these speed changes. However, the range of NATS surveillance systems does not cover the area where the speed instructions were issued by Maastricht, Shannon and Reims, as shown in Figure 39.

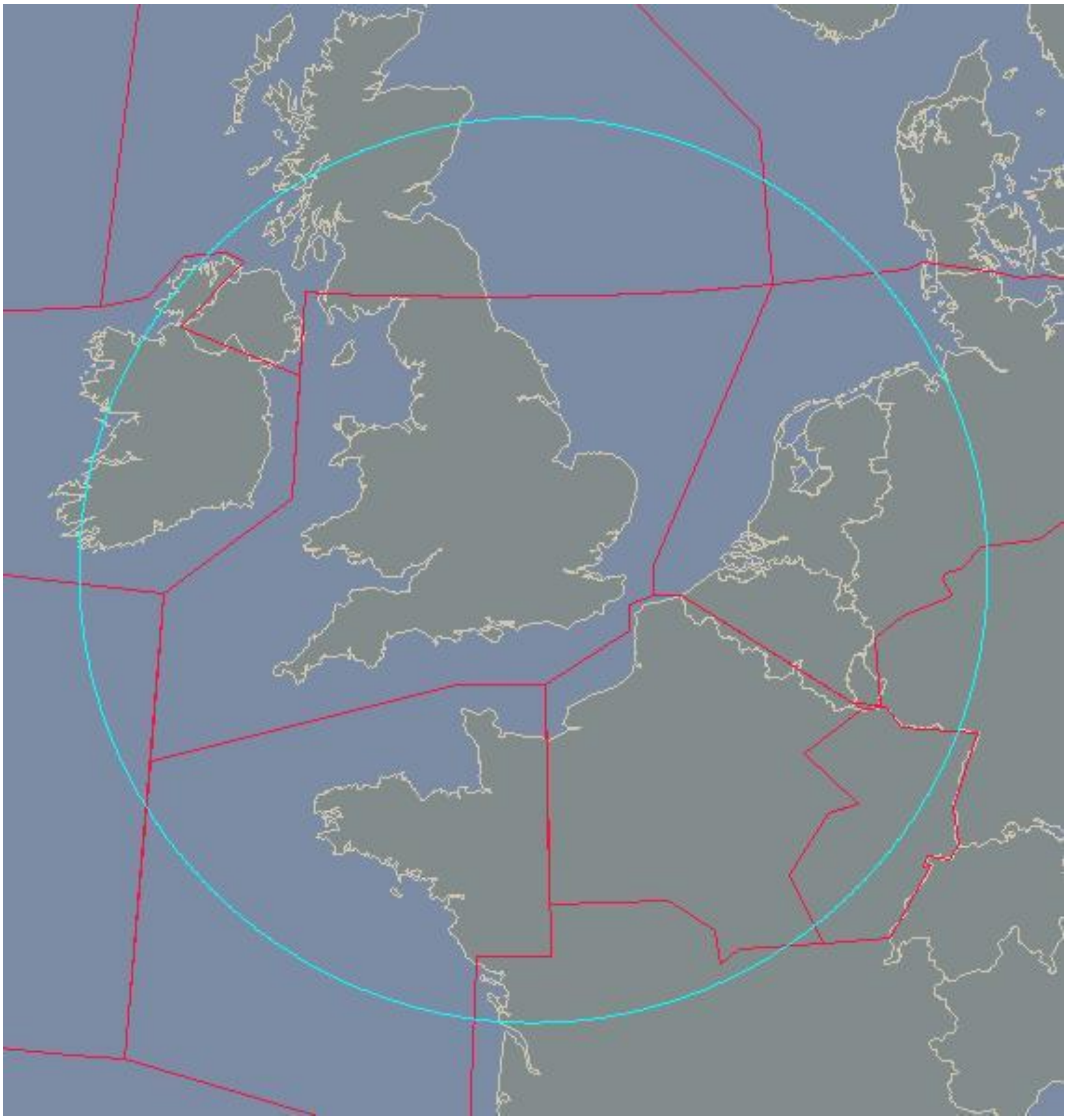


Figure 39: 350NM range from EGLL

Sample days	28th April	29th April	30th April
Number of Heathrow Arrivals on the day	674	674	682
The total holding delay incurred on the day (mins)	2,147	3,946	7,667
The total number of delayed (holding) flights	345	511	576
The average holding delay per delayed flight	6.2 mins	7.7 mins	13.3 mins[5]
The maximum holding delay of all delayed flights	17.8 mins	19.6 mins	39.9 mins
Flights > 500NM from DEP to EGLL[6]	437	437	440
Flights with Delay > 8-mins[7]	92	228	371
Flights > 500NM from DEP to EGLL & Delay > 8 mins	50	138	219
Flights > 500NM & Delay > 8 mins & FlightAware data	35	94	102
Identified speed instructions for: Flights > 500NM from DEP to EGLL & > 8 mins	5	21	43
Proportion of flights that received a speed instruction in relation to the eligible ones (> 500NM from & Delay > 8 mins)	10 %	15 %	20 %
Average calculated flight absorption time achieved	1.3 mins	1.2 mins	1.4 mins
* Max cumulative theoretical in-flight absorption time.	63.7 mins	170.9 mins	307.3 mins
Estimated reduction in average holding delay per delayed flight	10 seconds	19 seconds	31 seconds

Table 19: Analysis of all-day data sample for XMAN trials

Flights were eligible for a speed instruction if they experienced more than 8 minutes delay. It was determined that between 7 and 30% of total inbounds met these criteria. The 30% figure corresponds to a day with very high levels of delay at Heathrow due to fog. From those eligible flights, the ADS-B data feed offered groundspeed information at the desired range (300 to 400 NM) for 50% - 70% of them. With this limiting factor in mind, Table 19 shows that 10% to 20% of the eligible flights were shown to have received a speed instruction.

A qualitative assessment was conducted in order to understand why a greater proportion of eligible flights did not receive a speed instruction. No specific problems were reported during the follow up teleconferences with the involved ANSPs and Airline Operators. The project team engaged directly with EGLL based operators to address common issues such as occasional misunderstanding, purpose of the trial and the concern that aircrew would miss their position in the holding stack. Amongst the reasons for not applying the speed instruction, it has been reported the high controller workload or inability of aircrew to reduce speed as requested.

Finally, FDR data was used to conduct an in depth assessment for a selection of flights that did receive a speed instruction in order to determine the effect on fuel flow and the relationship between groundspeed, airspeed and Mach number. The results of this analysis are shown below.

Date	Or	Callsign	A/T	Delay	Speed instruction		
					At (from EGLL)	Groundspeed before speed instruction	Time lost due to the speed instruction
28/04/2014	CPH	BAW811	A321	00:11:50	380 NM	436 kts	00:02:33
12/04/2014	JFK	BAW116	B744	00:10:28	367 NM	588 kts	00:03:58
22/04/2014	JFK	BAW180	B772	00:07:42	346 NM	485 kts	00:00:36

---

[5] Abnormal delay values due to fog

[6] It is assumed that 150NM are required to end the climb phase and start cruise flight.

[7] A value of 8 minutes was chosen, because at least a minute of delay absorption by candidate flights was assumed.

02/05/2014	JFK	BAW178	B744	00:10:04	370 NM	503 kts	00:02:15
17/04/2014	JFK	BAW18A	B772	00:15:13	352 NM	495 kts	00:01:56

Table 20: Analysis of FDR files for selected BA flights

The variation in the column “Time lost due to the speed instruction” is mainly due to the differences in groundspeed, which at the same time are greatly affected by the wind factor.

The next figures have been marked to easily identify the speed instructions and holding time:

- Circled area 1 shows the speed instruction in Calibrated Airspeed.
- Circled area 2 shows the instantaneous fuel flow reduction to adapt to the new instructed Mach.
- Circled area 3 shows the holding time.

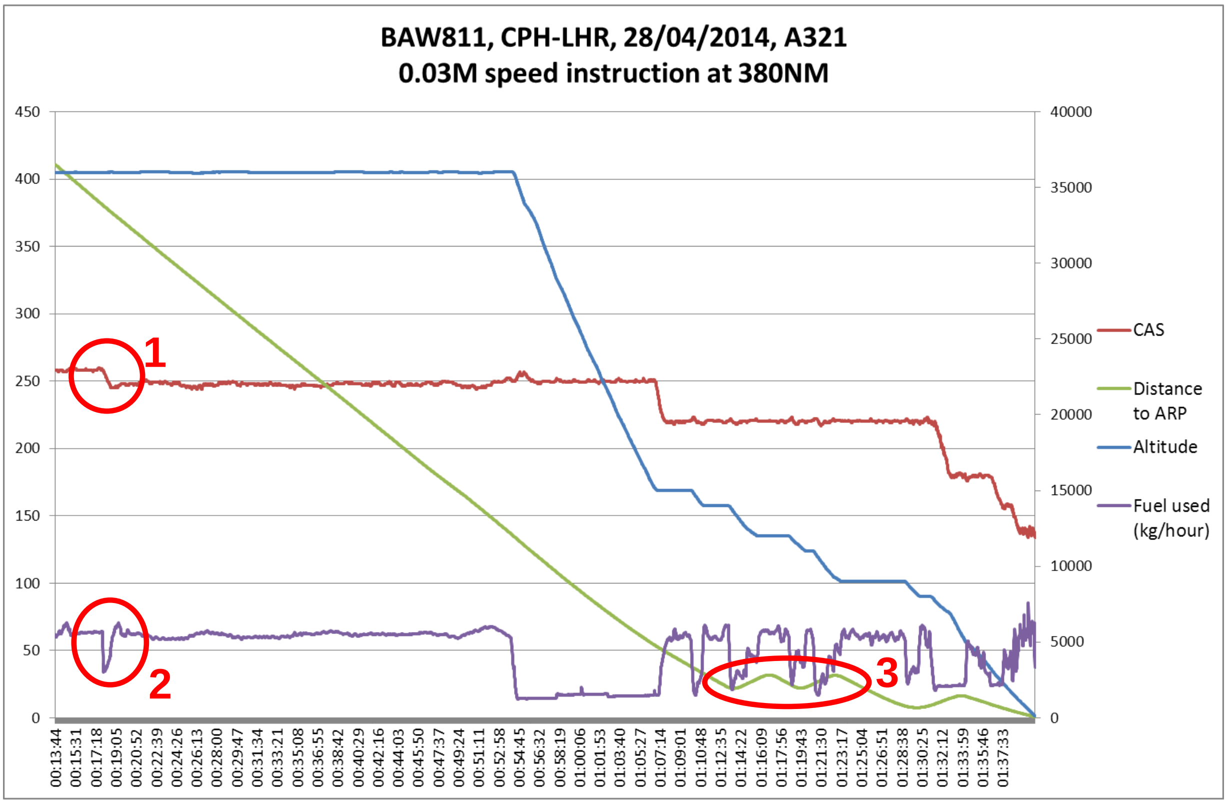


Figure 40: BA811 28/04/2014 speed, distance, altitude and fuel flow representation

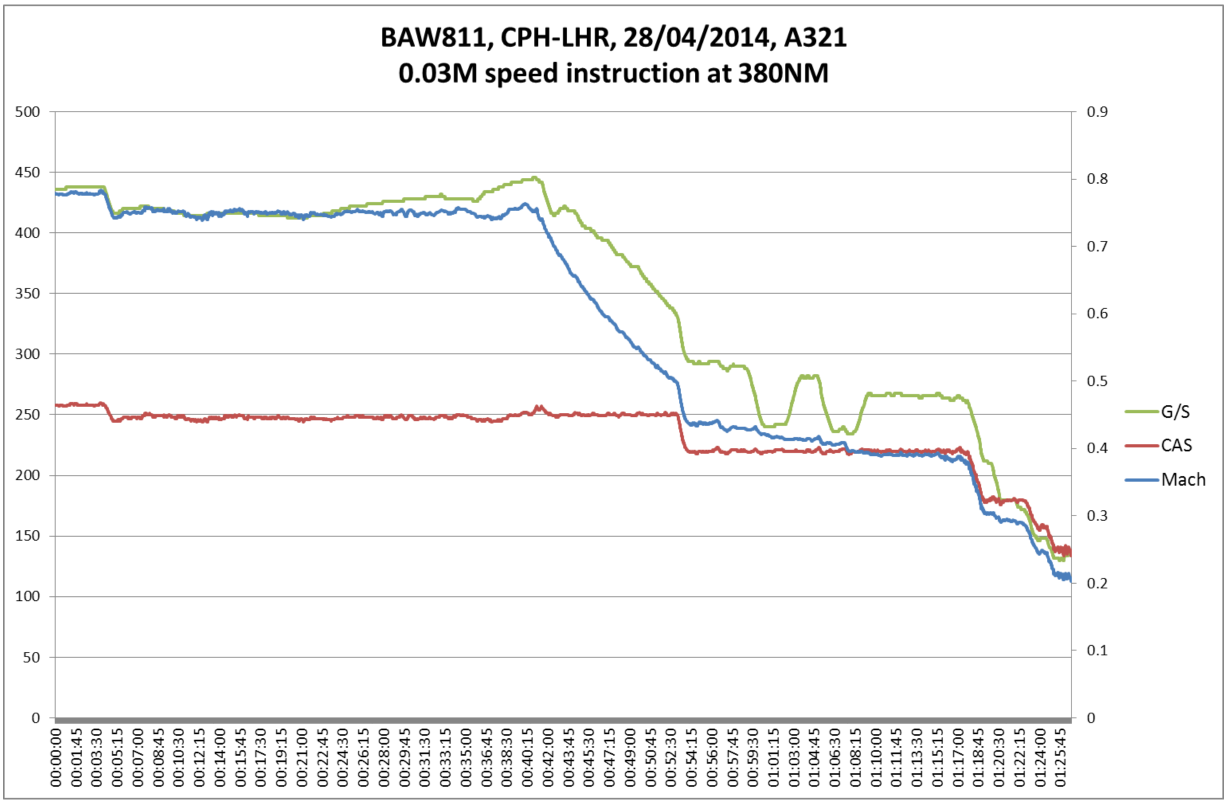


Figure 41: BA811 28/04/2014 speeds assessment

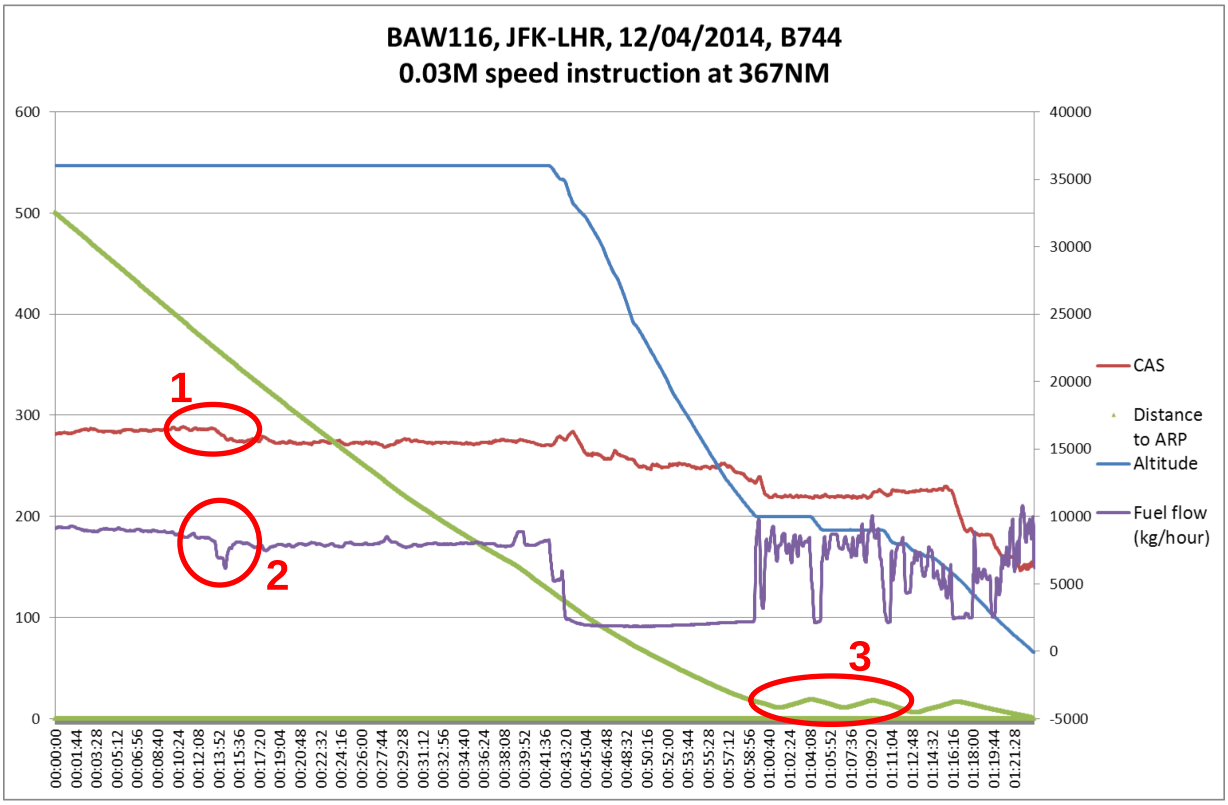


Figure 42: BA116 12/04/2014 speed, distance, altitude and fuel flow representation

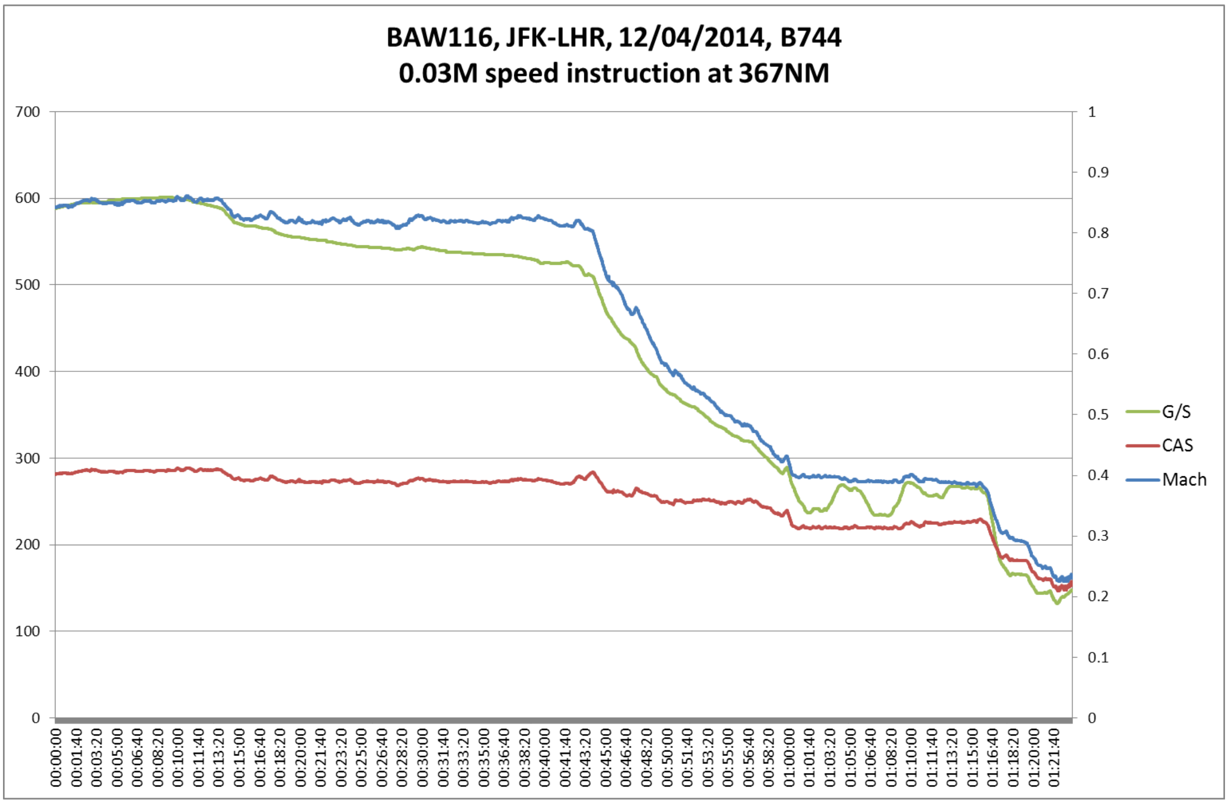


Figure 43: BA116 12/04/2014 speeds assessment

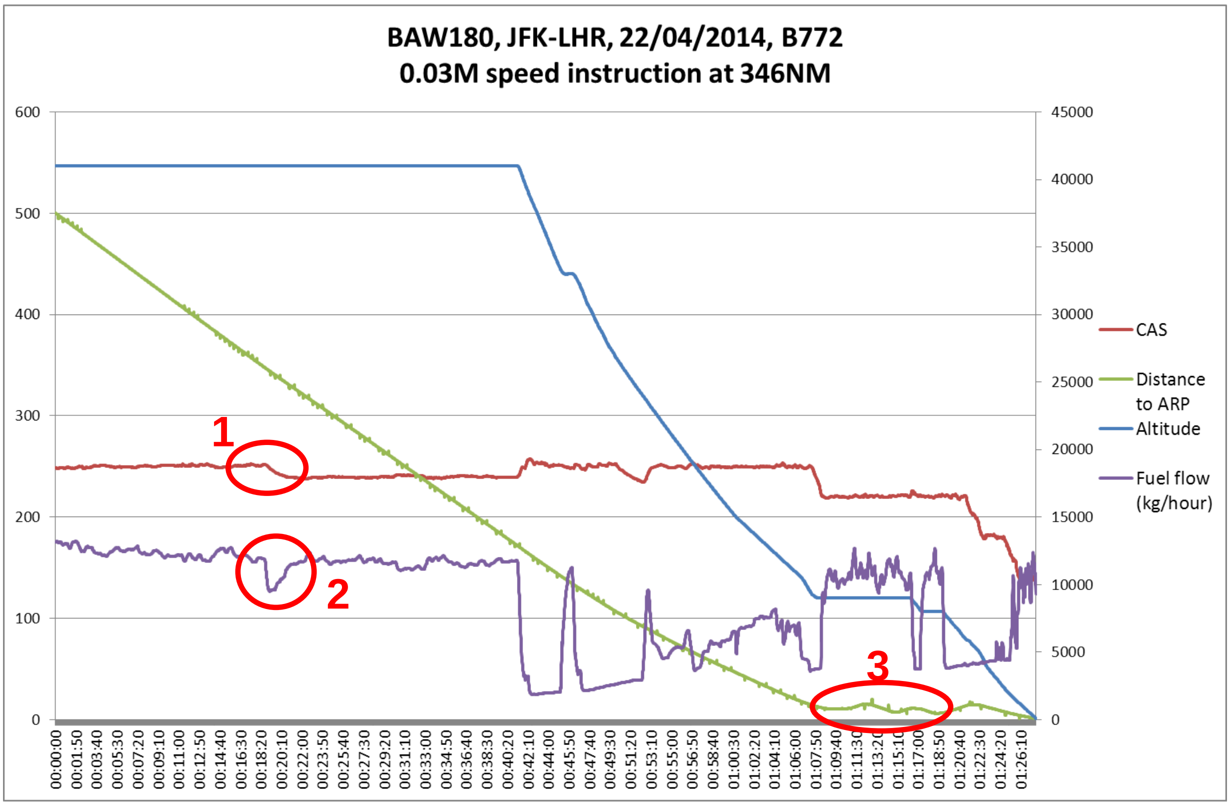


Figure 44: BA180 22/04/2014 speed, distance, altitude and fuel flow representation

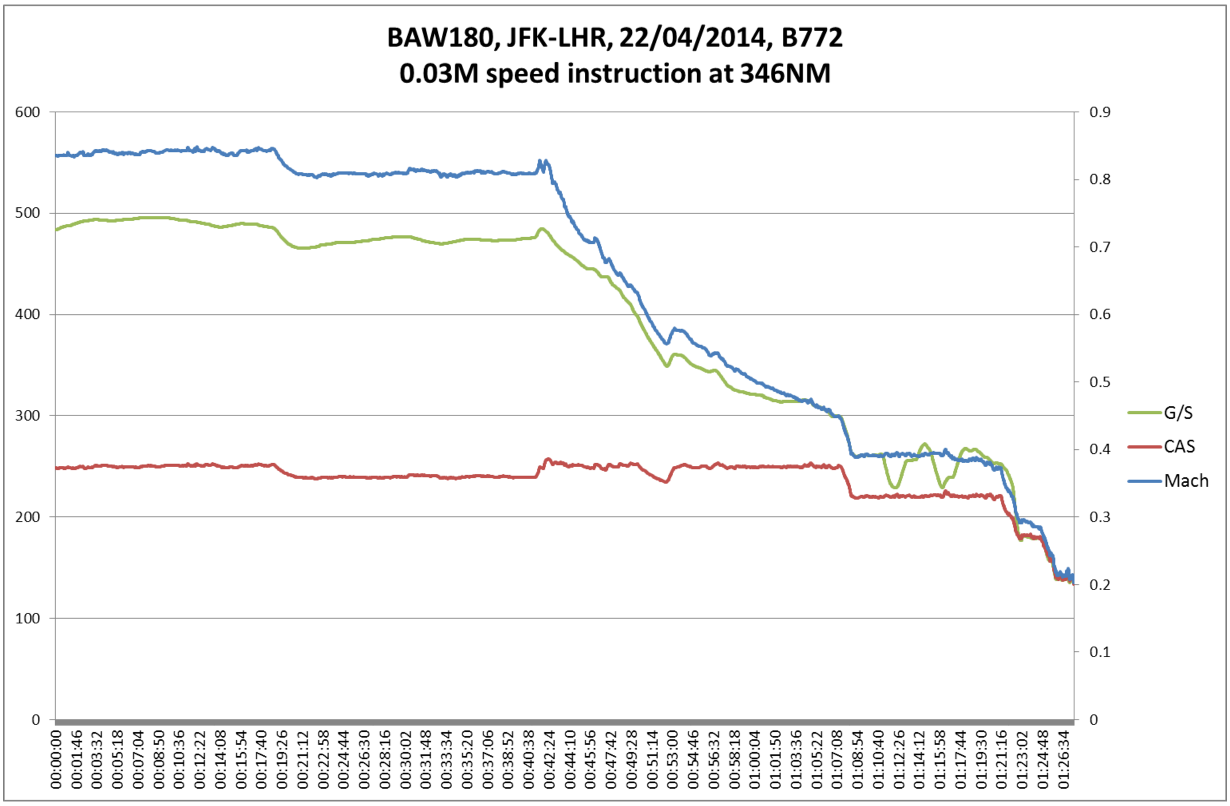


Figure 45: BA180 22/04/2014 speeds assessment

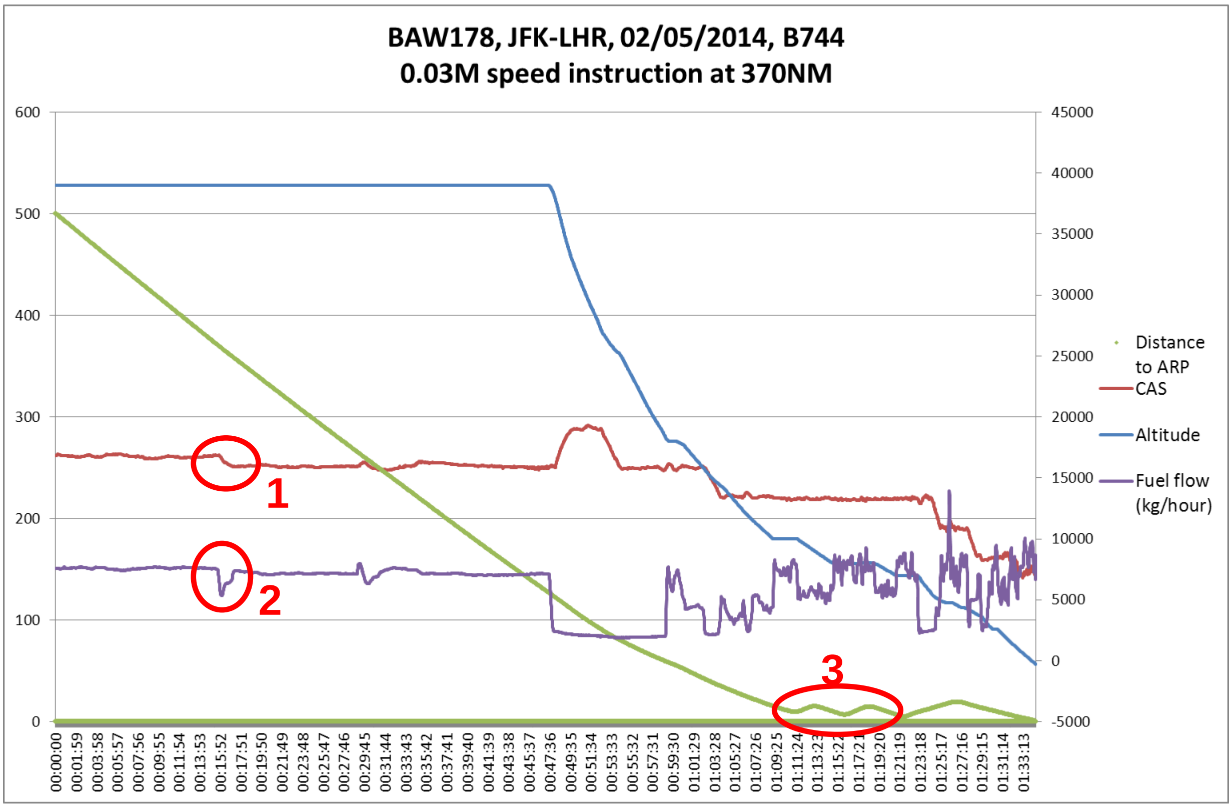


Figure 46: BA178 02/05/2014 speed, distance, altitude and fuel flow representation

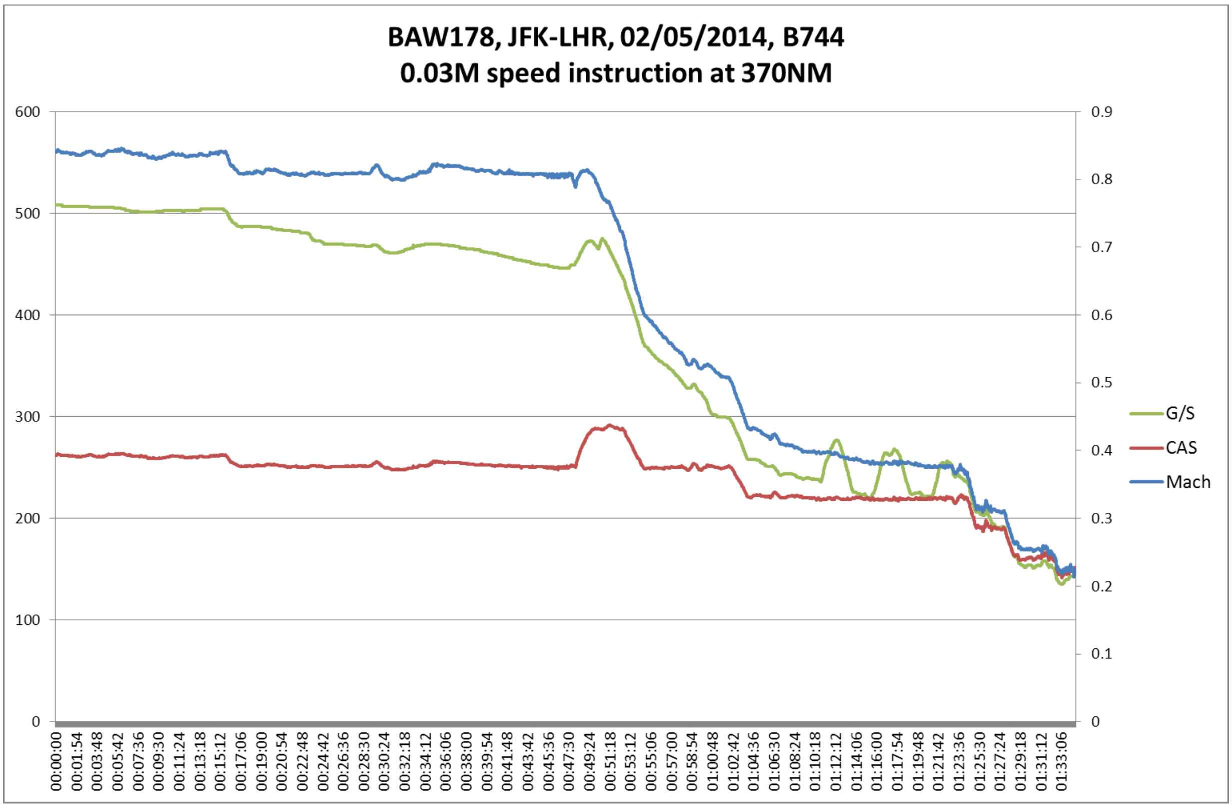


Figure 47: BA178 02/05/2014 speeds assessment

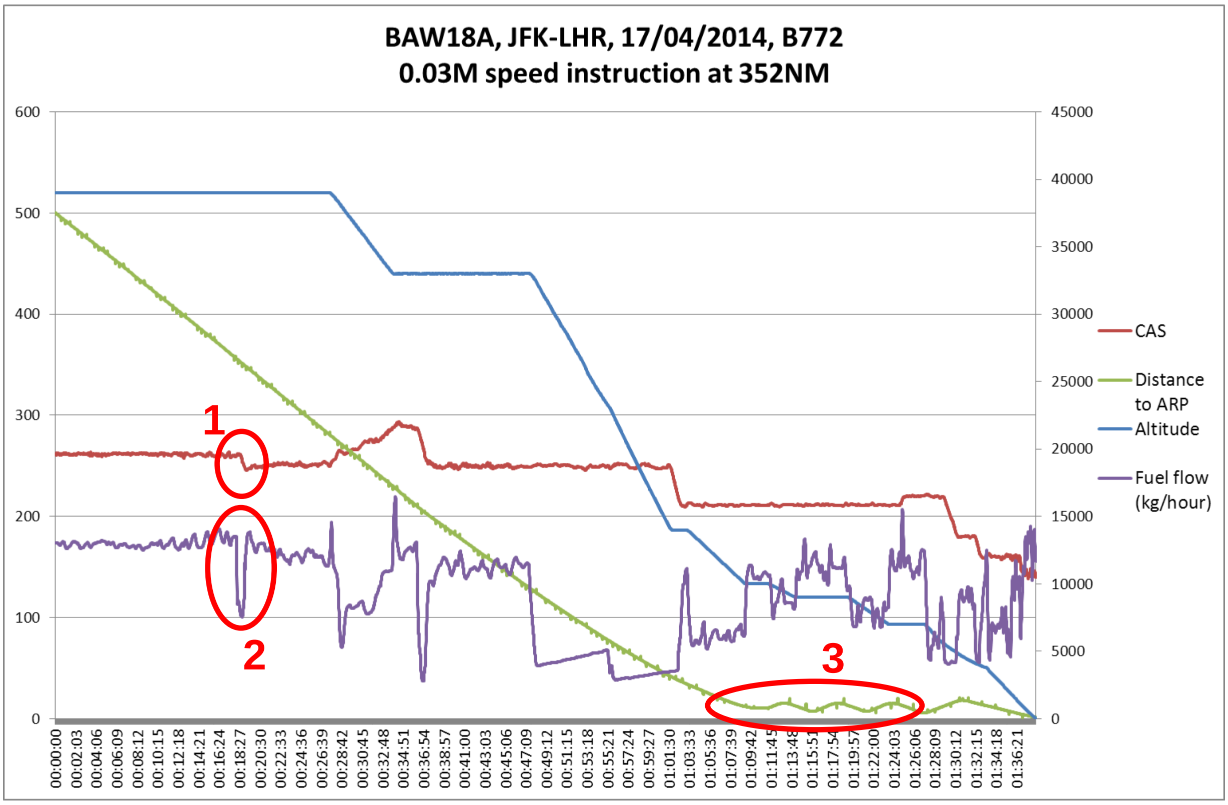


Figure 48: BA18A 17/04/2014 speed, distance, altitude and fuel flow representation

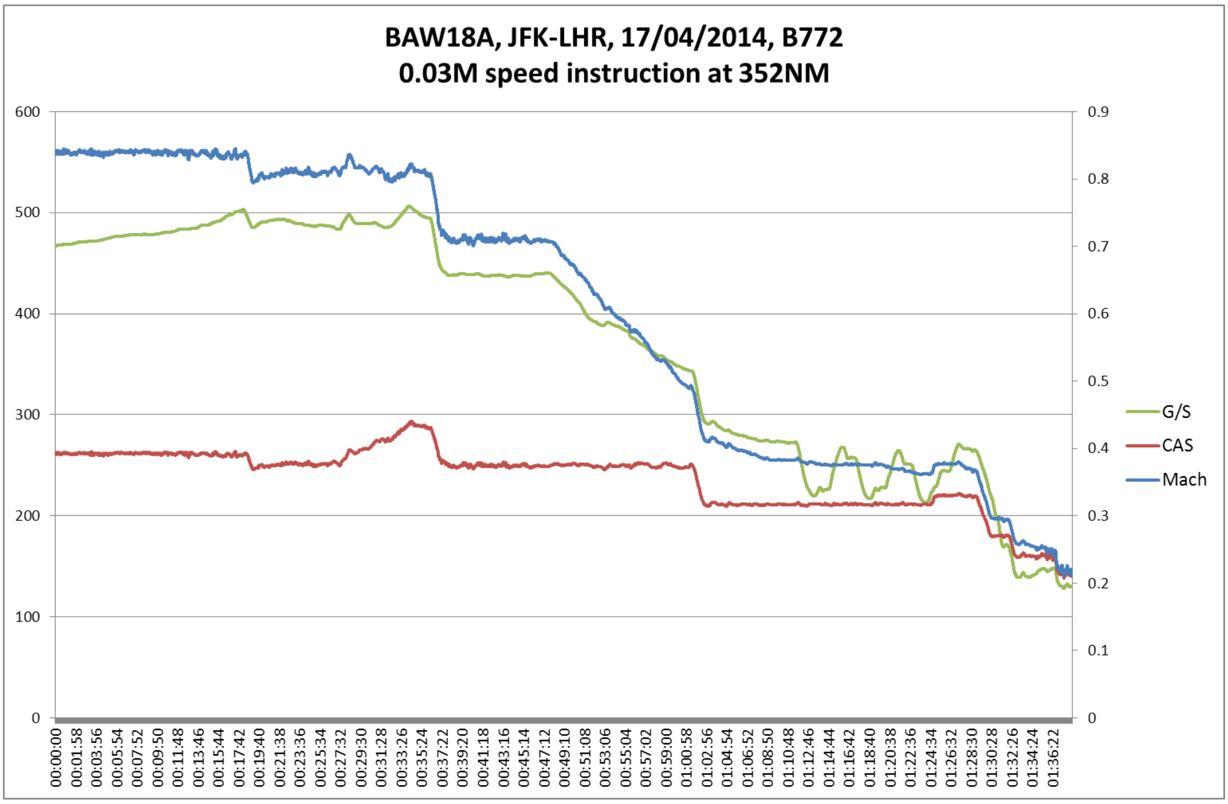


Figure 49: BA18A 17/04/2014 speeds assessment

Figure 40 to Figure 49 show a sudden drop in fuel flow to adapt to the new Mach number, which must be reduced by 0.03. Once the new speed is achieved, the fuel flow returns to similar levels before the instruction. The fuel flow values tend to decrease with time as the flight evolves, a likely result of aircraft getting lighter as fuel is burnt.

6.3.3.1.1 SWIM analysis

SWIM is an essential enabler for the SESAR ConOps. The use of SWIM to provide Heathrow AMAN sequence time constraints to sectors in another domain was a successful demonstration of Cross-border Management (XMAN). The demonstration also shows that long look ahead imposition of 4D constraints and eventual negotiation is successfully enabled by SWIM. From a London point of view there is no extra processing load for provision of the information regardless of the number of SWIM recipients. However, the controller coordination workload is significantly reduced and the long look ahead imposition of linear delay raises aircraft flight efficiency and reduces stack occupancy saving fuel and emissions and increasing safety.

One of the purposes of TOPFLIGHT was to investigate the use of SWIM and identify the information flows in the current system that would be candidates for SWIM. In Phase 1 the information flows during gate to gate transatlantic flight were identified. These showed that SWIM would support a greater richness of up-to-date information without imposing extra workload as the information would be generated as a byproduct of normal operations. Those stakeholders that wish to have information subscribe and will from then on receive the information and any updates automatically.

In Phase 2 the time horizon for Heathrow AMAN was extended in all directions. This would provide little or no difference if the sequence time constraints generated by AMAN were not shared with the aircraft sufficiently early for linear delay to be used rather than increasing stack occupancy with orbital delay close to destination. The adjacent ANSPs were provided with a web service that communicated the predicted Heathrow delay within the UK/Ireland FAB and between the UK/Ireland FAB and the Central Europe FAB.

Figure 50 shows the physical structure of the SWIM link from NATS Heathrow AMAN to the Reims CAUTRA system. Logically the UK NATS system linked to SWIM through a Service Oriented Architecture (SOA) interface. The CAUTRA system linked to SWIM through its own SOA interface. This architecture was based on the AMAN part of the D08 prototype from P10.9.2, XMAN.

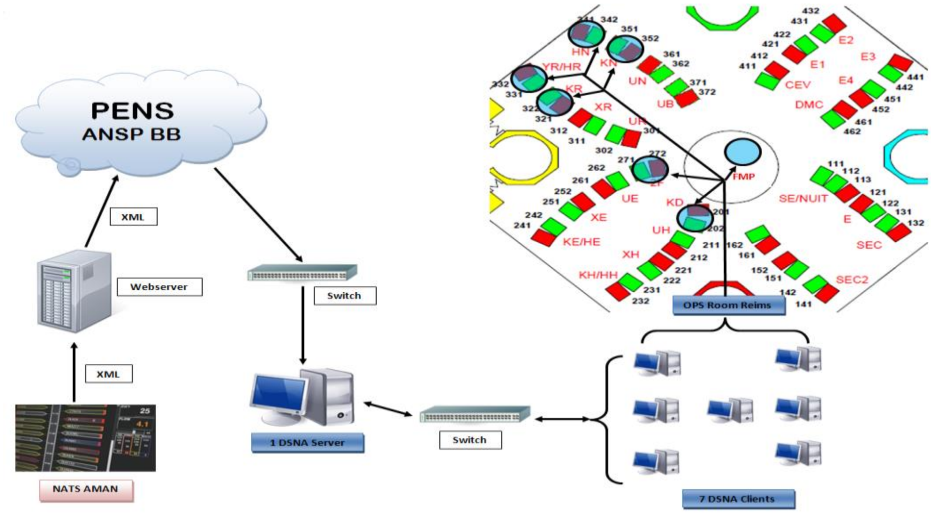


Figure 50: Simple Diagram of Physical Implementation of Heathrow AMAN to the Reims CAUTRA SWIM Link

Adding more recipients to the Phase 2 SWIM system only required the centre to develop its own SOA interface to SWIM without performance or processing impact on the NATS Heathrow systems. The Phase 2 extended AMAN demonstration was only implementing SWIM as means of passing AMAN sequence time information, it has validated a functioning prototype for a complete SWIM system.

6.3.3.1.2 Results per KPA

Assuming that the time lost from the speed instruction to Top of Descent is then reduced from the orbital holding time, the analysis of these flights shows the following results:

Date	Callsign	A/T	Orbital holding time saved	Fuel saved (Kg)	CO_2 saved (Kg)
12/04/2014	BAW116	B744	00:03:58	**488**	**1552**
17/04/2014	BAW18A	B772	00:01:56	**147**	**467**
22/04/2014	BAW180	B772	00:00:36	**46**	**146**
28/04/2014	BAW811	A321	00:02:33	**84**	**267**
02/05/2014	BAW178	B744	00:02:15	**248**	**789**

Table 21: Fuel and CO_2 savings for selected BA flights during XMAN flight trials

The fuel values per holding minute are largely consistent for each aircraft weight category with a complementary activity performed in Airbus simulators, which provide a certain level of cross-validation. The variation in time saved by trial flights and simulation is due to the wind factor during cruise phase of flight. To enhance the applicability of the work done at the simulator, zero wind was defined.

A/T	Orbital holding time saved	Fuel saved (Kg)	CO_2 saved (Kg)
A320	00:01:26	**42**	**134**
A330	00:01:07	**86**	**273**
A380	00:01:06	**152**	**483**

Table 22: Fuel and CO_2 savings from Airbus sims

Predictability of Estimated Landing Times (ELDTs) was improved by extending the AMAN horizon to 85 minutes before landing. Key success factor is the combination of ETFMS data (as provided by the Network Manager) with arrival sequencing and delay prediction capabilities (as provided by AMAN). Further detailed analysis of larger data samples is required to precisely quantify the enabled predictability improvements, but analysis of individual flights (see example below) indicated significant improvements enabled by E-AMAN due to the early prediction and consideration of estimated arrival delays.

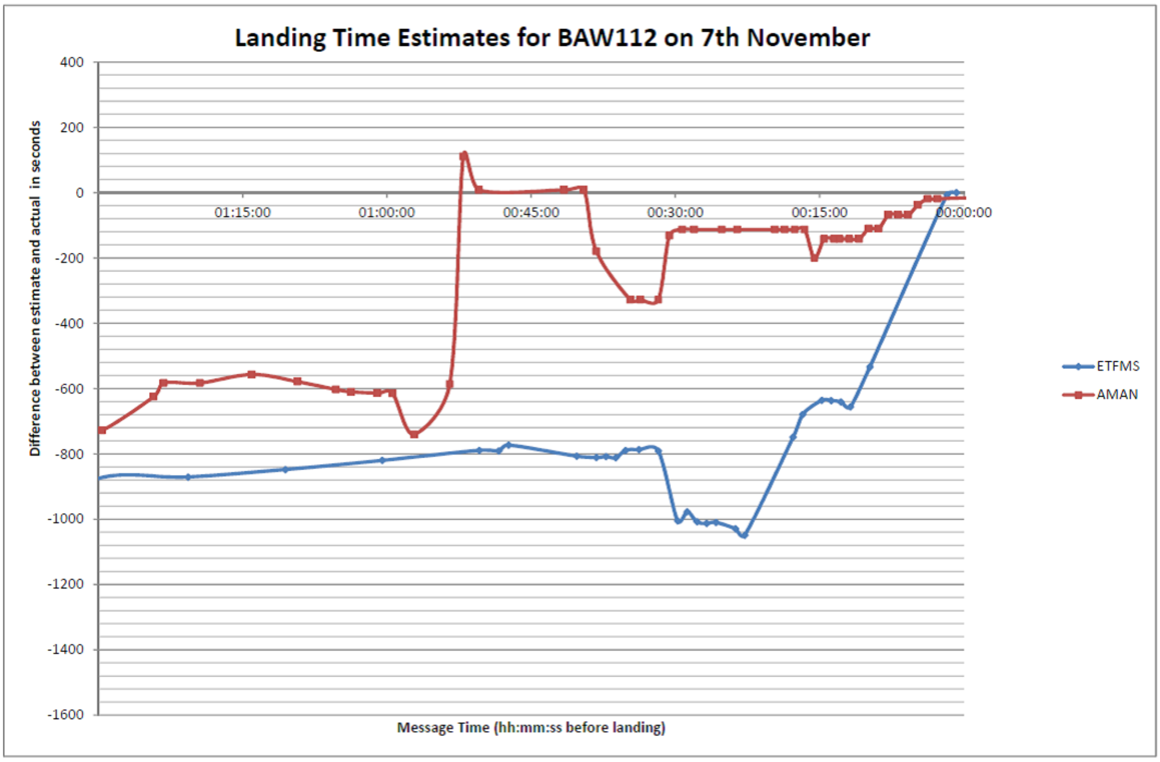


Figure 51: Landing Time Estimates for BA112 07/11/2013

6.3.3.1.3 Results impacting regulation and standardisation initiatives

The activities carried out during Exercise #2B have not identified a need for a change in regulation or standardisation.

The arrival sequence and delay information during the XMAN trials were published using a SWIM WS based on open standards. This service has been designed to comply with SWIM standards.

6.3.3.1.4 Unexpected Behaviours/Results

Several aircraft reported to be speeding up before the XMAN instruction at 350NM, so that the speed increase compensates the reduction.

6.3.3.1.5 Quality of Demonstration Results

The XMAN trials were assessed by taking into account all Heathrow inbounds during 30 days to provide a data sample as large as feasible.

The analysis was constrained by the fact that comparable ATC instruction information from the ANSPs was not available for the same dates as the ADS-B data, so the speed changes could not be confirmed. In addition to this, ADS-B data capture from FlightAware was not complete for all Heathrow in-bounds (estimated as up to ~ 60% for “XMAN potential” arrival traffic). Finally, ADS-B data provides only Ground Speed information as opposed to ideally Indicated Air Speed (IAS); the latter eliminating at source the potential variable impact of prevailing wind conditions within the data. However, the Figures in 6.3.3.1 show that Ground Speed reliably represents the changes in Mach Number.

Data from selected British Airways flights was chosen to represent a range of delays in the baseline situation, which means without speed instructions. The data was then compared with flights likely to have received a speed instruction, due to their actual delay equal or over 9 minutes. The information entails very detailed and accurate data, but constitutes a limited sample.

The direct comparison of delay levels between days in and out of the trials can show a trend, but the amount of factors impacting the delay figures can mask the enabled benefits provided by the concept.

6.3.3.1.6 Significance of Demonstration Results

1 to 2 minutes was the expected amount of time lost by arriving aircraft when they received a speed instruction to slow down 0.03M at 350NM. There were several independent variables potentially affecting the delay evolution: weather, EGLL runway configuration, temporary closures of neighbouring airports, go-arounds, emergency landings, cancelled flights, demand, etc. These factors reduce the confidence in the direct average delay values comparison.

The Demonstration Exercise was performed in live trials under normal operations and for one month. As a consequence, there is absolute confidence in having achieved a high level of operational significance for the trials.

6.3.4 Conclusions and recommendations

6.3.4.1 Conclusions

XMAN trials have shown that effective queue management involving neighbouring ANSPs can tackle some ATM system inefficiencies which cause unnecessary fuel burn for aircraft subject to holding.

The NATS Arrival Sequence Message Web-Service has proven to offer a sustainable and reliable service for this purpose.

The assessment of maximum holding delay absorption benefits in en route, based on an average speed changes calculated, ranges between 10-20 seconds for normal holding delay days.

Of all flights eligible for a speed instruction (flight > 500NM and delay > 8 mins), only 17% flights were issued with one, although confidence in this figure is not high due to an ADS-B data quality issue.

It is considered that the number of flights slowed down within the three day data sample would have a negligible effect on the simulation model used to determine the impact in average delay.

The trials have confirmed the expected amount of time that can be lost before ToD, when a speed instruction of 0.03M is given to a flight at 350NM from arrival. The complimentary simulations performed by Airbus showed a potential of 1 to 2 minutes.

These observations indicate the potential need to assess the ‘optimal’ predicted AMAN delay criterion used to trigger the need for ATC speed intervention.

The main savings in fuel burn and CO_2 emissions come from a reduction in orbital holding time. The observed instantaneous fuel flow for the analysed trial flights after a 0.03 Ma speed reduction does not indicate the existence of a fuel savings trend. As shown in Figure 33, one important factor influencing the change in fuel flow is the selected cost index before the speed change.

6.3.4.2 Recommendations

Delay can be affected by multiple parameters. For this reason, isolating the effect of one of them requires a consistent approach such as the model described in 6.3.3.1. However, the data required to feed this model must be highly reliable and covering all flights involved, in order to identify all speed changes. As a result, it is recommended that a mechanism be developed to perform a more extensive data collection. This would also allow cross-validation between data from ANSPs partners, airlines and Business Intelligence services.

The delay values offered by the AMAN system were reported to be unstable by the units in charge of issuing speed instructions. In addition to that, the delay values were often similar to the trigger value of 9 minutes. The observation of these results suggests the following recommendations:

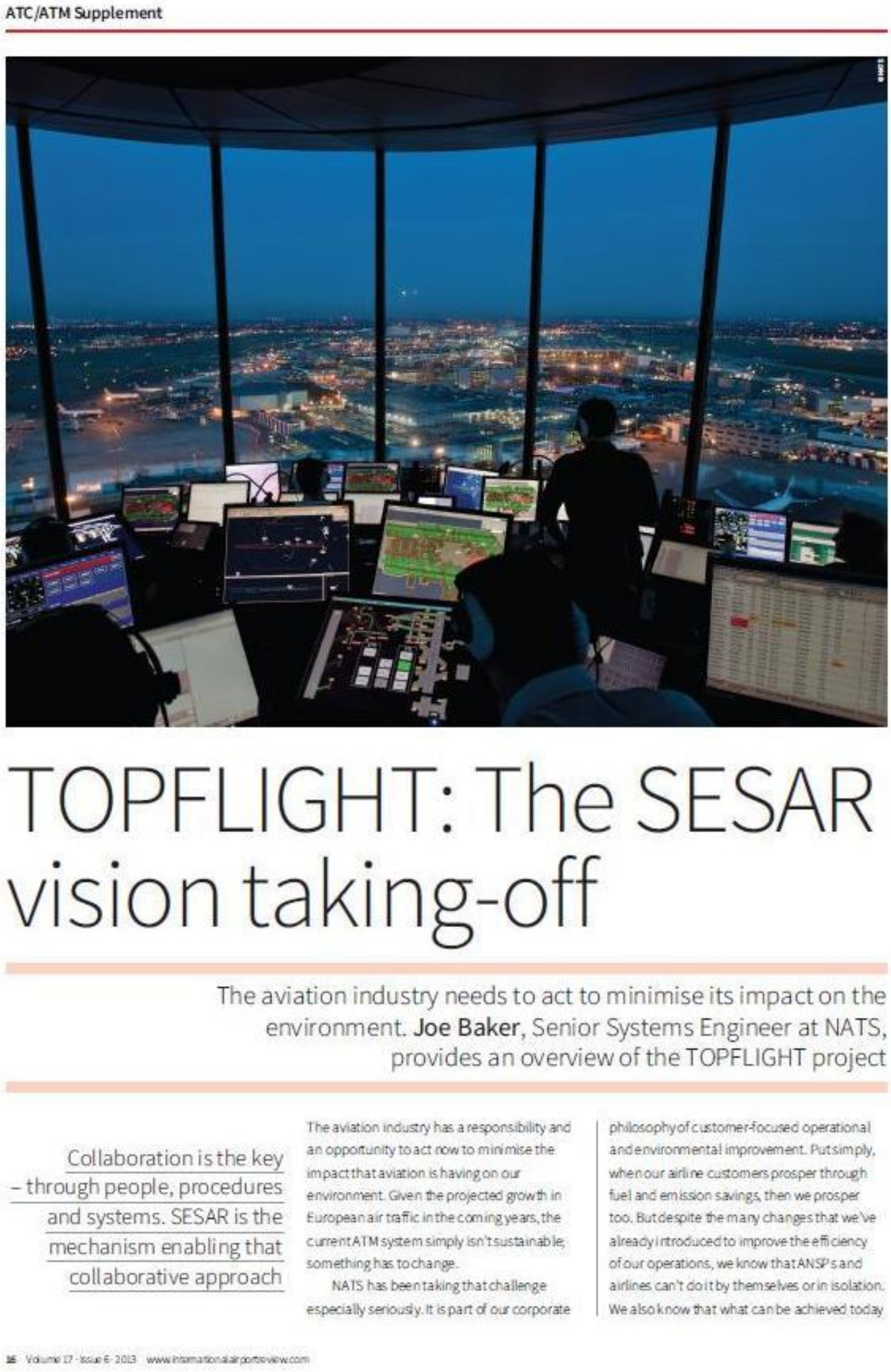
- Further investigation of the delay data stability distributed by AMAN is required.
- Examination of the delay value at which speed instructions are issued is required, so that a higher proportion of delayed aircraft can be affected.

7 Summary of the Communication Activities

7.1 External communication

The following is a summary of the more significant communications activity undertaken in relation to TOPFLIGHT;

- Article in International Airport Review. Issue 6, 2013.



ATC/ATM Supplement

TOPFLIGHT: The SESAR vision taking-off

The aviation industry needs to act to minimise its impact on the environment. **Joe Baker**, Senior Systems Engineer at NATS, provides an overview of the TOPFLIGHT project

> Collaboration is the key – through people, procedures and systems. SESAR is the mechanism enabling that collaborative approach

The aviation industry has a responsibility and an opportunity to act now to minimise the impact that aviation is having on our environment. Given the projected growth in European air traffic in the coming years, the current ATM system simply isn't sustainable; something has to change.

NATS has been taking that challenge especially seriously. It is part of our corporate philosophy of customer-focused operational and environmental improvement. Put simply, when our airline customers prosper through fuel and emission savings, then we prosper too. But despite the many changes that we've already introduced to improve the efficiency of our operations, we know that ANSPs and airlines can't do it by themselves or in isolation. We also know that what can be achieved today

16 Volume 17 · Issue 6 · 2013 www.internationalairportreview.com

Every element of the flight has been designed to reduce emissions, boost efficiency and minimise delays

is limited by the constraints of the current ATM concept and its supporting technologies.

The European ATM concept needs to be overhauled, modernised and updated; this is the purpose of the European Commission's Single European Sky programme, which is driving the defragmentation of Europe's skies to achieve a more efficient service while improving safety, reducing costs for airspace users and minimising the impact on our environment. Underpinning this aim, which NATS fully supports, is the research required to ensure that operating concepts, and the supporting air and ground technologies, evolve together in a way that maximises their future potential. Collaboration is the key – through people, procedures and systems. SESAR is the mechanism enabling that collaborative approach.

SESAR is a large multi-disciplinary research programme that has been in the development phase for over three years, and is now starting to deliver validated and tangible elements of the future ATM concept. Last year the SESAR Joint Undertaking – the European agency appointed to deliver the research – launched a programme to expose and test some of those more mature elements in a real-world operational environment. It is a reflection of NATS' key role within Europe that we are leading one of its most ambitious and far reaching projects within that programme – TOPFLIGHT.

> TOPFLIGHT is an exciting opportunity to prove that operationally and environmentally optimised flights based on the SESAR concept are scalable

In collaboration with our partners in TOPFLIGHT – British Airways, NAV CANADA, Boeing, Airbus Prosky and Barco Orthogon – NATS is developing an optimised transatlantic flight model. This means that every element of the flight – from the pushback time and climb and descent trajectory, to the routing and oceanic flight profile – has been designed to reduce emissions, boost efficiency and minimise delays without adversely impacting other airspace users. The project aims to demonstrate the improvements that we can achieve on an on-going basis and in a multi-flight environment, taking what has previously only been attempted in one-off demonstration flights and bringing it into real world operations. We are testing the future ATM concept for Europe in a live environment, which is a truly exciting proposition.

Not only does this have value in further maturing the concept, but it is also helping us to understand the issues and opportunities we will face when transitioning from current operations to a SESAR-based future. Upon successful completion of TOPFLIGHT, the hope is to introduce the procedures that offer immediate benefit into regular operations for the first time.

Phase one of the project is now complete. Over the course of the summer 100 transatlantic flight trials took place and we are now in the midst of analysing the benefits of the new procedures we introduced. This involves extracting and analysing large volumes of data from both our own ATC systems and from individual aircraft systems. We are also analysing the

TOPFLIGHT BA cockpit simulation

excellent feedback we received from the participating pilots and controllers. From this analysis we will then make a comparison between TOPFLIGHT and current operational procedures. Pre-flight estimates and simulations suggested that potential savings of around 0.5 tonnes of fuel per flight could be possible, but the initial results from the summer trials indicate savings greater than one tonne for some flights, which is very encouraging.

Even relatively simple changes, such as re-routing aircraft through military airspace in the west of Wales when it was available, look likely to have saved around 100kg of fuel per-flight. A meaningful improvement has also come from providing pilots with an oceanic profile before departure. Our early analysis shows that this provided an increased degree of certainty that the flight would follow an optimum oceanic trajectory with minimal air traffic control intervention, while avoiding any negative impact on other airspace users.

The phase one flights this summer took place between London Heathrow and Toronto or Montreal, Canada and the desire now is to expand the programme to include the FAA with flights to Boston and New York JFK, therefore creating a gate-to-gate optimised flight concept between some of the most significant city-pairs on the North Atlantic. More immediately, TOPFLIGHT's next phase will take all that we've learned and add the use of cross border arrival management, or XMAN. This will involve working with our Irish, French and EUROCONTROL colleagues to better coordinate and manage the flow of Heathrow arrivals. We believe this could help reduce average orbital holding for flights that hold before arriving at Heathrow from eight minutes to just three, bringing significant benefits in fuel burn and noise reduction.

TOPFLIGHT is an exciting opportunity to prove that operationally and environmentally optimised flights based on the SESAR concept are scalable, sustainable and can help meet the challenge of increasing air traffic in Europe. The success the project has enjoyed so far suggests that it may have a significant impact on North Atlantic operations, while also representing an important step towards the implementation of a true Single European Sky.

TOPFLIGHT's objectives:

- To develop, demonstrate and transition to operations, an airline-driven concept for the gate-to-gate optimisation of flights between North America and Europe based on multiple elements of the SESAR concept
- To capture data that will enable the delivery of sustainable operational change to both a complex Terminal Manoeuvring Area and a high density oceanic environment
- To identify the requirements the concept would place on future System Wide Information Management (SWIM) infrastructure
- To synchronise concepts and intercontinental operational changes with both the FAA NextGen Programme and with NAV CANADA.

Joe Baker is a Senior Systems Engineer at NATS, the UK's leading air navigation service provider. Joe has been responsible for the technical leadership and project management of collaborative research projects in the field of CNS & ATM since 2007; he has delivered projects funded by NATS, EUROCONTROL and SESAR, including several successful transatlantic flight trial campaigns focusing on innovative ATM concepts or technology. Previously, Joe managed the deployment of new CNS infrastructure.

- Article in Aviation Week. Issue: 1st of July 2013.

AIR TRAFFIC MANAGEMENT

TONY OSBORNE/AW&ST

British Airways flights to and from Canada are being used for the Topflight trials.

Optimizing Atlantic Skies

Air navigation providers on both sides of the Atlantic are leading the way for greater efficiency

Tony Osborne London

Trials have begun on a series of optimized transatlantic flights which will test technologies and ideas destined for use in the next generation of air traffic management systems.

Air traffic control organizations in Canada and the U.K. hope these "perfect" flights will offer fuel savings of up to half a ton per transatlantic sector and help reduce delays without increasing workload for pilots and controllers.

The project, called Topflight, has been a year in planning, with officials from U.K. National Air Traffic Services (NATS), NavCanada and British Airways working together on the program, with NATS leading the project. Data collection started on May 29, using two daily British Airways flights, one westbound from London to Montreal and the second eastbound from Toronto to London, and will go on each day until July 23, collecting data on around 60 sectors in all.

The selected flights are being given an optimized flight plan from gate-to-gate, covering the entire flight process from the continuous ascent departure and direct routings to the Atlantic airways. The scheme follows on from what NATS called its "Perfect Flight" demonstration from London to Edinburgh back in 2010.

"The idea of the project is to show that we can provide more efficient trajectories for transatlantic flights," says Joe Baker, Topflight project leader at NATS. "It was also important to demonstrate that the optimized flight profiles of these flights would not adversely affect the other flights around them," he adds.

The project is highly complex. Each flight will work with 13 air traffic control centers between the U.K. and Canada. The project also required the use of British Airways 777 and 747 simulators, which were used to demonstrate the required navigational performance (RNP) and changed Standard Instrument Departures (SIDS), tests which could not be trialed on a normal day at Heathrow.

The transatlantic flight trial is phase one of the program. Full data analysis will begin in September, but Baker and his team are confident of achieving fuel savings of up to half a ton per sector—roughly 1.6 tons of CO_2—which could equate to significant savings if applied to all transatlantic flights each day.

"One-off trials, such as the Perfect Flight project in 2010, have already proven the level of benefit that can be achieved in isolation," says Baker.

"But these wider trials are an exciting opportunity to look at how we might implement these ideas for multiple flights in a real-life operational environment."

Pilots are aware they are flying on the Topflight trials, but their preparation is little different to others conducting transatlantic flights. The primary difference is that they are given two flight plans—the standard one provided on the ground and a second, optimized plan once the flight is airborne, based on the latest weather data. The Topflight trials aircraft are given continuous ascent departures to their cruising altitudes before being given direct routings to the point where the aircraft will join the Atlantic airways.

Baker points out that such direct routings have then taken flights into the busy military training airspace over North Wales, but that the close cooperation between civil and military air traffic controllers in the U.K. means a flight can save around 100 kg (220 lb.) of fuel with only a slight change in route. A similar issue will arise as the aircraft arrive in Canada, where they normally avoid the military airspace around Bagotville, Quebec. However, the Topflight aircraft will generally be routed through that airspace before making a continuous descent into Montreal. At the end of each flight, the pilots will be asked to provide the ATC agencies feedback on the service they were provided.

Phase 2 of the trials is aimed at reducing holding times for arrivals at London Heathrow Airport. Using a cross-border arrival manager (XMAN), a computer system for handling handoffs, controllers will be able to conduct "linear holding." Rather than aircraft arriving in London airspace and then circling to wait for their slot to land, controllers will be able to see a flight approaching the U.K. from a longer distance and plan its slot entry, slowing aircraft down if necessary, to prevent them from arriving too early for their slots. NATS says this could mean that the frustration of circling for several minutes before embarking on the downwind leg to land could be reduced—if not eliminated—for some flights. A currently unfunded phase three would see a similar scheme carried out by the FAA in the U.S. at a major East Coast airport.

The project comes as NATS pursues an increasing environmental focus for its services. The company is being given financial incentives by its customers to improve its environmental performance in the coming years. NATS could benefit by up to £2.4 million ($3.7 million) in extra payments if it manages to achieve the best possible routings for air traffic through U.K. airspace and from the country's airports, although it also may have to pay back up to £4.6 million to airlines if it performs poorly. ✪

AviationWeek.com/awst

AVIATION WEEK & SPACE TECHNOLOGY/JULY 1, 2013 49

- Article in SJU website: http://www.sesarju.eu/news-press/news/optimised-transatlantic-flight-trial-begins-1274
- Article in NATS website: http://www.nats.aero/news/optimised-transatlantic-flight-trial-begins/
- Article in ADS Advance: http://adsadvance.co.uk/optimised-transatlantic-flight-trial-begins.html
- Article in Business Green: http://www.businessgreen.com/bg/news/2275985/ba-readies-environmentally-optimised-transatlantic-flights
- Article in Green Air Online: http://www.greenaironline.com/news.php?viewStory=1712

- Article in Airport Technology: http://www.airport-technology.com/news/newsuk-nats-lead-perfect-transatlantic-flights-trial-project
- Article in ATC Network: http://www.atc-network.com/atc-showcases/topflight-putting-the-sesar-vision-into-action
- SESAR Demonstration Activities Workshop in December 2013 at Lisbon.
- Demonstration at NATS' stand at the World ATM Congress 2014 in Madrid.
- Project presentation to the British Airports Authority in December 2012.

7.2 Internal communication

- Dedicated webpage in NATS intranet, covering the different elements of the project from several perspectives. It explains the operating implications for the ATC centres involved in managing the traffic in London TMA, London FIR and Shanwick oceanic airspace. TOPFLIGHT relationship with the Queue Management Program, mainly due to project's Phase 2 activities. Connection with the London Airspace Management Program (LAMP) in order to assess the use of newly designed RNP departure procedures in London TMA.
- Article in 'Swanicle' (internal news issue for London FIR and TMA ATCOs).
- TOPFLIGHT stand in NATS Marketplace. This is a 2 weeks long, 3 hours a day event aimed at increasing exposure for projects developed by NATS among NATS operational staff. ATCOs in Swanwick Ops Unit are the intended receivers of this information, as their implication is crucial to achieve a successful implementation. [redacted], from TOPFLIGHT, attended the TOPFLIGHT stand. The event, held in November 2013 was used to exchange information about Phase 1 results and explain the implications of Phase 2 in connection with the Queue Management strategy.
- Briefing provided to NATS ATC Watch Supervisors in Swanwick, a week before the Phase 1 trials started (May 2013).
- Briefing provided to NAV CANADA Shift Managers, Supervisors and Controllers in the ATC units affected: Gander (Oceanic and Domestic), Moncton, Montreal and Toronto ACCs.
- Instruction papers were written for British Airways' pilots, dispatchers and traffic managers. Along with one-to-one instruction.

8 Next Steps

The TOPFLIGHT Project has assessed several concept elements in three different Exercises: Reduced Engine Taxi, Oceanic Clearance (CTO) before Departure, Continuous Climb Operations, Free Routing, Advanced Flexible Use of Airspace, Optimised Oceanic Profiles, PBN procedures, Continuous Descent Approach, SWIM, Oceanic Metering and XMAN. The implementation of such a variety of concept elements presents different possibilities and challenges.

The necessary steps for the implementation of the concept elements demonstrated vary greatly from concept to concept. In baseline operations, some of the concept elements are already delivering benefits for the airspace analysed in the trials. RETI, CCO and Free Routing are part of daily operations for British Airways, NATS and NAV CANADA when weather and traffic permits.

The London Airspace Management Program (LAMP) is working on the implementation of RNAV-1 procedures in London TMA. The new procedures exploit existing and future aircraft capabilities allowing them to fly precise trajectories through use of Performance Based Navigation, by taking advantage of the greater flexibility in airspace design through closely spaced arrival and departure routes independent of ground-based navigation aids.

Oceanic metering is likely to be implemented in the long term when accurate time estimates for Heathrow inbounds en-route from all directions allow the extension of the equitable delay horizon (360°).

The XMAN trials will continue until October 2014, thus complying with one of the recommendations made in this analysis: to achieve greater experience in the application of the concept and allowing time to review the delay threshold. The decision to maintain the procedures as standard operational practices will be based on the final assessment.

All concept elements assessed were proven to be feasible in the high density environments in which they were demonstrated, suggesting they would be feasible in other environments resulting in greater fuel savings and CO_2 reductions.

8.1 Conclusions

The demonstration exercises performed in TOPFLIGHT have provided evidence that the SESAR programme has the potential to deliver sustainable improvement in the current operational environment. NATS is at the forefront of making these SESAR concept elements part of normal operations.

Coordination between ANSP units has proven crucial for the successful implementation of some concepts. Free Routing on Westbound flights from 1000ft to OEnP was only feasible thanks to the coordination between ATCOs in London and Shannon FIRs. The use of variable speeds and step climbs in the oceanic phase of the flights was also only permitted by the collaboration of Gander and Shanwick controllers. Coordination between units is even more evident for the XMAN trials, where the actual speed instructions impacting an airport delay are delivered by a controller from a different ANSP. FABs implementation is improving this coordination.

TOPFLIGHT has proven the relevance of airspace users' engagement and information sharing. This was achieved by explaining the concepts to be demonstrated to airline management, aircrew and ground support personnel, air traffic controllers and airport operators, so that they understand the system optimization and in particular the benefits available to the airlines.

TOPFLIGHT has showcased the benefits associated with early and expeditious information sharing, which mainly stem from moving workload from the tactical phase to the planning phase, using innovative web based technology.

The project has achieved its objectives and as a consequence has successfully provided metrics to assess the concepts demonstrated in terms of: feasibility, sustainability, fuel consumption and CO_2 savings.

The project provided a valuable mechanism for the successful engagement with airspace users with regard to SESAR operating concepts.

8.2 Recommendations

This project aims to inform OFA leaders and additional parties involved in demonstration and validation activities within SESAR, especially those projects with an active contribution to the relevant OFAs. The results and conclusions drawn from the demonstration exercises undertaken in TOPFLIGHT also aim to inform the SESAR Joint Undertaking, broader stakeholders of the SJU and other relevant projects within the Demonstration Programme.

The limitations related to airspace capacity were highlighted in the previous section; the provision of optimised trajectories is dependent on traffic congestion. In order to overcome this constraint and maximize capacity, it is recommended that further research be conducted into trajectory sharing and prediction, so that more coordination work is conducted early in the planning phase. The provision of an Oceanic Clearance before Departure has shown the positive contribution delivered by A-CDM, and any further work conducted on the adjustment of turnaround times would be highly beneficial. The accuracy of ground ATM system estimates can also be improved by enhancing the data sharing processes between them.

The trials enabled British Airways to identify a series of FMC enhancements that would deliver immediate benefit in the current ATM environment, while also supporting future ATM concepts. These recommendations can be found in 6.1.4.1 and would benefit the major aircraft operators.

The XMAN trials have shown that effective queue management can tackle some ATM system inefficiencies which cause unnecessary fuel burn for aircraft subject to holding. With better data sharing and increased data accuracy, the expansion of the current 350NM horizon should be examined while being equitable in terms of delay absorption.

9 References

9.1 Reference Documents

The following documents provide input and further information:

[1] TOPFLIGHT Demonstration Plan [A.1]

[2] Complementary Results to TOPFLIGHT B1 Demonstration Report

-END OF DOCUMENT-