Final Project Report WP-E

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Abstract

The final report of the ONBOARD project provides a publishable summary of the results. In addition it lists all deliverables, dissemination activities, eligible costs, deviations, bills and lessons learned.

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Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground.

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Publishable Summary

One of the difficulties in improving the performance of ATFM through optimization is the presence of uncertainty. Future capacity state predictions are inherently uncertain due to factors such as weather effects and unscheduled demand but neither in current practice nor the SESAR concept of operations information that could be available on the uncertainty associated with the system is used. The goal of the ONBOARD project has been to see if improvements can be made in ATFM performance by explicitly incorporating information about uncertainty within the optimization in the Network Management planning and execution phases.

Furthermore, the ONBOARD project has also focused on addressing the two factors that jointly account nowadays for two thirds of the total ATFM delay in Europe: weather and knock-on effects.

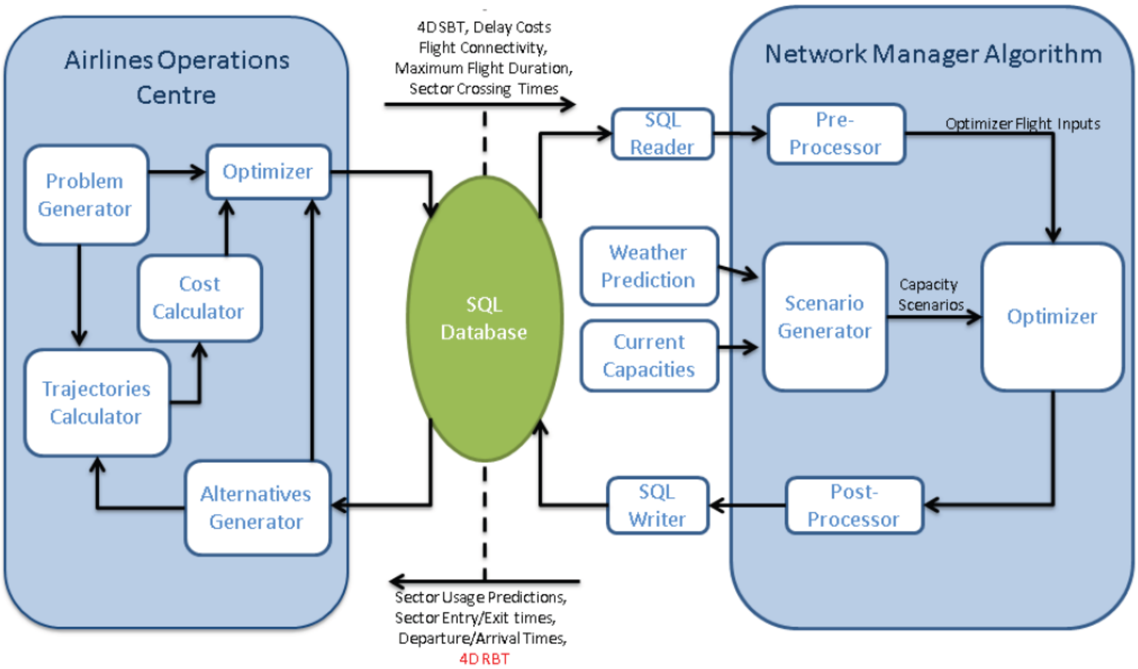
The approach followed in the project to research on these key issues (uncertainty due to weather and unscheduled demand, on the one hand, and knock-off effects, on the other) has consisted of developing two interacting algorithms, one acting as the Airline Operations Centre (AOC) and the other as the Network Manager (NM), being in charge of managing the knock-on effects and the weather and unscheduled demand uncertainty, respectively.

The concept of disturbance feedback from control research (MPC) is applied within the NM to handle uncertainty information on unscheduled demand and weather forecast. The formulation developed introduce, in the control optimization, the notion that one can have a fundamental plan based on the idea that feedback is present in the control implementation, meaning that the resulting action will take into account the effects of possible future disturbances. The solutions produced via this methodology within the NM are then iterated with the AOC providing alternative recovery plans for further iterations.

To that end the AOC models in a realistic way the knock-on effects caused by the rotational reactionary delays introduced in the system by late aircraft arrivals: in particular, it solves in the event of disruptions (e.g. due to the time constraints imposed by the Network Manager) the integrated problem of airline operations and control, i.e. to determine simultaneously the optimum aircraft rotation plan and the optimum set of flight plans (i.e. trip fuel and 4D trajectory) for each flight leg of the airline schedule, that minimizes the airline operations costs, including the costs of disruption recovery (e.g. passengers compensation due to departure delay).

To be able to obtain realistic results out of the project, those two brand new algorithms have been integrated into a simulation platform developed ad hoc, consisting of a set of databases to exchange data, several HMIs to control the different processes and a Radar HMI that allows the researcher to follow the simulation from the perspective of an eventual sub-regional Network Manager.

The platform consists of two main components, the Network Manager (NM) and the Airline Operations Centre (AOC). The figure below depicts the high level system architecture. The Network Management algorithm is the core research goal of the project as this is where the uncertainty will be incorporated. The Airline Operation Centre algorithm is necessary in the project to interact with the Network Management algorithm and pursuits its own research challenges.



The main role of the Airline Operations Centre (AOC) algorithm is to calculate the necessary airspace user recovery plans to cope with adverse scenarios (e.g. significant traffic congestion at an airport or at an airspace volume), by updating the aircraft rotation plan (e.g. delaying, re-routing or cancelling flights; swapping slots) and retiming part of the flights schedule until the original flight schedule can be resumed.

The basic architecture of the AOC algorithm is shown on the left hand side of Figure. The AOC gives an initial desired plan to the Network Manager and then generates alternatives taking into account the Network Manager restrictions in an iterative process.

The Problem Generator module provides feasible problem cases for each set of flights. This module loads the problem information from the Evaluations Scenario Tool and distributes aircraft through the network in order to assure that the problem is feasible, i.e. there are enough aircraft to fly the schedule.

The Trajectories Calculator module performs a two-step process. In the initial iteration, it calculates the optimal desired trajectory for each flight as a function of direct operating costs. Once the Network Manager has imposed constraints, this module calculates new trajectories for affected flights which take into account the restrictions.

The Cost Calculator module calculates the cost of flying all the trajectories generated before and after restrictions, considering direct costs (i.e. fuel cost, time related costs).

The Integer Program Optimizer module calculates optimal fleet assignment plans for several scenarios, taking into account the planned flight legs and associated costs by modeling the problem as an Integer Program (IP).

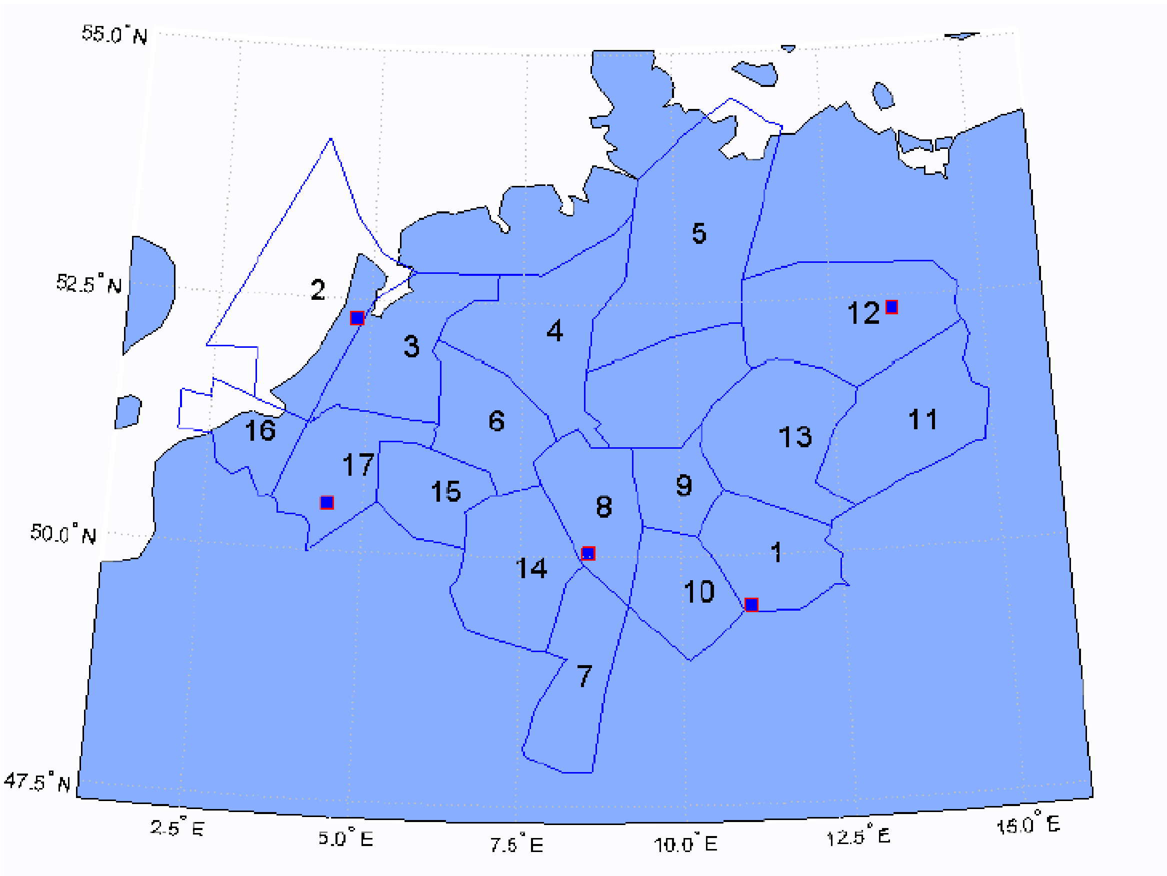
The Alternatives Generator module calculates alternative plans and their associated costs, taking into account the Network Manager restrictions. It generates sets of alternative flight plans to operate affected flights by re-routing, re-timing and updating trajectories.

The focus of the Network Manager (NM) is on the subset of ATM which deals with allocating airspace resources such that the balance between capacity and demand is maintained in the presence of both enroute and airport capacity constraints. This is known as Air Traffic Flow Management (ATFM) and many studies have applied optimization to the problem to find the best solution (subject to some objective).

The scope of the system considered covers airport departure and arrival capacity limits at airports as well as enroute sector capacity limits. Control actions available are delays to the arrival, departure, and sector crossing times. Modelling of ATFM problems can broadly be divided into three categories: discrete decision models (sometimes referred to as Lagrangian models) which consider the individual plan of each aircraft in the problem (Flight-by-flight); aggregate flow models (sometimes referred to as Eulerian models) which consider the flow rates and densities in control volumes but do not track individual aircraft plans; and hybrids of the two (Eulerian-Lagrangian), which augment aggregate models to include some knowledge of individual flights. The NM adopts an Eulerian-Lagrangian or primarily flowbased ATFM viewpoint, meaning that a separate optimization stage is required to disaggregate the solution.

The baseline flow based optimization model implemented is a slight reformulation of the model presented in Sun and Bayen which was inspired by the Lighthill-Whitham-Richards theory and by the Daganzo cell transmission model commonly used in highway traffic.

One of the integration example problem presented in this project consists of a set of 30 flights between 5 airports with ICAO codes: EBCI, EDDB, EDDF, EDDN and EHAM. The flights are distributed through a day of operations between 6:00 to 16:00 hours. Each flight has an associated optimal nominal trajectory and plan. All airspace sectors involved in the problem are considered to have a 5 aircraft capacity in any given 5-minute time window. The figure below shows the area where the problem is considered.



The table below summarizes the results obtained with the Network Manager:

	Scenario	No. Sector Capacity Breaches	Ground Delay
AOC Ideal Plan Solve Time: 4.6 s	c_1	13	0
	c_2	13	0
	c_3	13	0
	c_4	15	0
Nominal Solve Time: 4.9 s	c_1	0	18
	c_2	0	18
	c_3	0	18
	c_4	2	18
Robust Solve Time: 14.5 s	c_1	0	20
	c_2	0	20
	c_3	0	20
	c_4	0	20
Disturbance Feedback Solve Time: 130.3 s	c_1	0	18
	c_2	0	18
	c_3	0	18
	c_4	0	20

1) AOC Ideal: If the AOC ideal flight plans are accepted demand-capacity-imbalances were found to occur in between 13 and 15 sector-times depending of the scenario enacted. As would be expected in this case there is no ground or airborne delay.

2) Nominal: If only the “nominal” scenario, c1, is considered in the optimization, as would be expected delays have been introduced in order that no demand-capacity-imbalances occur when this scenario is enacted. As the problem case explored here has a relatively sparse population of flights, this solution is also adequate for two further scenarios, c2 and c3. However, in the final scenario, c4, demand-capacity imbalances were found to occur in 2 sector-times.

3) Robust: In the robust case one plan is made to satisfy all scenarios. As a result no demand-capacity-imbalances occur. However the price paid for this is that in all scenarios are subject to the most conservative level of delay required in any one scenario. As previously mentioned in more dense problem cases it is also highly likely that a robust solution is infeasible.

4) Disturbance Feedback: The disturbance feedback case also incurs no demand-capacity-imbalances. However, as tailored feedback solutions are developed, the minimum amount of delay needed for each scenario can be applied.

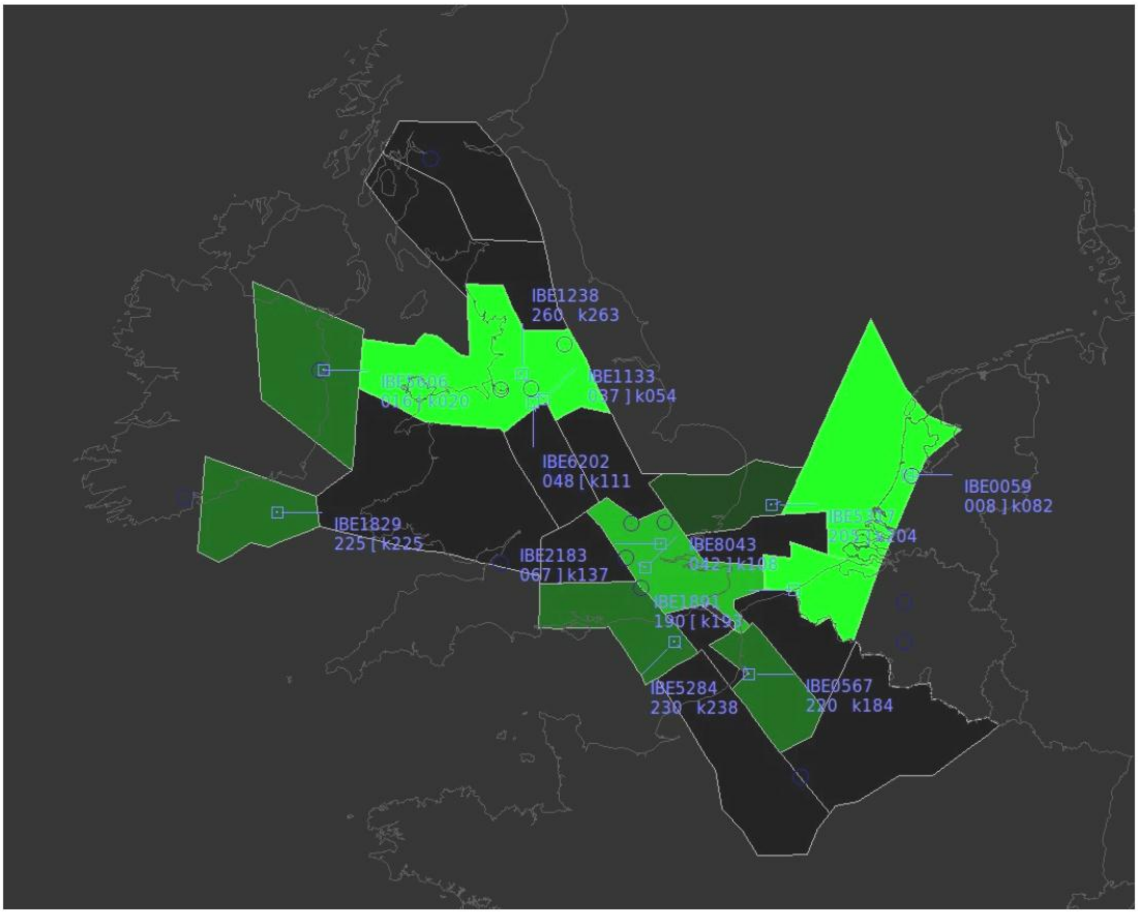
The Network Manager proposed for this particular case and using Disturbance Feedback the following changes:

Flight Id	Resource Id	OTA (mins)	TTA (mins)
16852	EDUUFULL	503.6	513.6
	EDUUFFMML	512.0	522.0
	EDYYMNHI	514.7	524.7
	EDYYFLELO	534.4	544.4
	EDYYZEELO	548.6	558.6
	EHAM	550.7	560.7
1227	EDYYMNHI	564.9	574.9
	EDYYFLELO	582.1	592.2
	EDYYZEELO	596.2	606.2
	EHAM	598.3	608.3
2223	EDYYFLELO	635.9	645.9
	EDYYRHHI	643.6	653.7
	EDUUNTMML	656.2	666.2
	EDUUFFMML	660.8	670.7
	EDUUSLNH	663.3	673.3
	EDDF	666.6	676.6
2224	EDUUFFMML	718.7	743.7
	EDUUSLNH	721.3	746.3
	EDDF	724.6	749.6
1229	EDYYMNHI	680.9	690.9
	EDYYFLELO	698.1	708.2
	EDYYZEELO	712.2	722.2
	EHAM	714.3	724.3
16854	EDUUFULL	911.6	916.6
	EDUUFFMML	920.1	925.1
	EDYYMNHI	922.7	927.7
	EDYYFLELO	942.4	962.4
	EDYYZEELO	956.6	976.6
	EHAM	958.7	978.7
1233	EDYYMNHI	912.9	917.9
	EDYYFLELO	930.1	945.2
	EDYYZEELO	944.2	959.2
	EHAM	946.3	961.3

The AOC computes the following alternatives to take into account the NM delays:

Flight Id	Alternative
16852	On Ground Delay (600)
1227	On Ground Delay (600)
2223	Modified Trajectory (0.95)
2224	On Ground Delay (1500)
1229	Modified Trajectory (0.95)
16854	On Ground Delay (300)
1233	Modified Trajectory (0.95)

Finally all those data can be presented in a Radar display using the Albatross solution by Skysoft ATM:



An extensive validation has been carried out in the project, in particular to characterize the maximum size of the traffic problem that can be addressed with the algorithmic framework developed (e.g. 20 en-route sectors, 350 flights, 15 uncertainty scenarios) applying a rolling planning window approach to address a full day of operations (e.g. with a 30 minutes planning step)

1 Introduction

1.1 Purpose of the document

The purpose of this document is to:

- Summarise the technical results and conclusions of the project (Publishable Summary);
- Provide a complete overview of all deliverables;
- Provide a complete overview of all dissemination activities (past and in progress). Where appropriate, provide feedback from presentations. Describe exploitation plans.
- Provide a complete overview of the billing status, eligible costs, planned and actual effort (incl. an explanation of the discrepancies).
- Analyse the lessons learnt at project level.

1.2 Intended readership

The intended readership is the personnel at EUROCONTROL and SESAR JU who are concerned with final acceptance of the ONBOARD project results. For those readers, this document gives an overview of the project activities performed regarding the ONBOARD project and final conclusions and/or lessons learned based on the results obtained.

1.3 Inputs from other projects

No inputs from other projects.

1.4 Glossary of terms

Concept / Term	Definition
AOC	Airline Operations Centre
NM	Network Manager

2 Technical Project Deliverables

Number	Title	Short Description	Approval status
D7.2	Evaluation Exercises Report	Description of the results of the evaluation exercises and conclusions.	Submitted
S5.4	Integrated AOC+NM demonstrator	Integrated platform software deliverable.	Submitted
D5.4	AOC+NM demonstrator user manual	Description of the final version of the AOC and NM platform integration and its user manual.	Submitted
S5.3	Evaluation Platform Prototype	Evaluation Platform prototype software including source code, compilation scripts and test data.	Submitted
D5.3	Evaluation Platform User Manual	User manual describing installation, configuration and operation of the Evaluation Platform.	Submitted
D6.7	Evaluation Scenario Plan	Description of the test cases and procedures to verify ONBOARD module and platform performances.	Submitted
S6.5	Draft integrated AOC+NM demonstrator	Description of the draft version of the AOC and NM platform integration.	Submitted
S7.1	Evaluation Scenario Tool	EST prototype software deliverable including source code, compilation scripts and test data.	Submitted
D7.1	Evaluation Scenarios Tool User Manual	User manual describing installation, configuration and operation of the tool to generate data to run the Evaluation exercises.	Submitted
S5.2	NM Prototype	NM prototype software deliverable including source code, compilation scripts and test data.	Submitted
S5.1	AOC Prototype	AOC prototype software deliverable including source code, compilation scripts and test data.	Submitted
D6.2	NM Algorithm Definition	Description of the mathematical model and algorithm representing the air traffic management algorithm.	Submitted
D6.1	AOC Algorithm Definition	Description of the mathematical model and algorithm representing the air users planning and recovery algorithm.	Submitted

Number	Title	Short Description	Approval status
D4.1	Evaluation Platform Concept	Description of the requirements, validation and evaluation methodology, architecture and integration approach of the Evaluation Platform	Submitted
D3.1	Algorithmic Framework Definition	Description of the scope of the air users and network manager algorithms and justification of the selection of the modelling approach to deal with uncertainty.	Submitted
D2.1	State-of-the-art Review	Presentation of the findings of the review of the research literature and assessment of the alternative modelling approaches that could be used in the project.	Submitted
D1.1	Concept of Operations	Description of the concept of operations to be explored in the project.	Submitted

Table 1 - List of Project Deliverables

3 Dissemination Activities

3.1 Presentations/publications at ATM conferences/journals

Network Management under Uncertainty [15]

First SESAR Innovation Days, 29th November – 1st December 2011, Toulouse, France

The ONBOARD project aims at improving the performances of the ATM system (e.g. predictability) in the planning and execution phases by developing new models and algorithms to enable the Network Manager to better manage the two factors that account for two thirds of the ATFM delay in Europe (weather and knock-on effects), in particular by addressing the key sources of uncertainty (weather forecast, unscheduled demand, and the airspace users response to disruptions). This paper describes the specific research objectives, expected results and the status of the project.

Air Traffic Flow Management Under Uncertainty: Application of Chance Constraints [16]

2nd International Conference on Application and Theory of Automation in Command and Control Systems (ATACCS), 29th – 31st May 2012, London, UK

This paper presents a novel application of chance constrained optimization techniques for uncertainty management in Air Traffic Flow Management (ATFM) problems. A deterministic discrete-decision Mixed-Integer Linear Programming (MILP) optimization model of ATFM is augmented to include constraints on the chance of sector capacity violations occurring given probabilistic information about the future capacity states. Two initial formulations of chance constraints are considered: those formulated on probabilities within individual sectors; and those formulated on the joint probabilities between sectors. Results are presented demonstrating the effects of incorporating both forms of the chance constraints on the problem solutions. The directions of the on-going research are discussed.

ONBOARD Project Presentation [17]

SESAR Information Day, 12th June 2012, Brussels, Belgium

As a part of a more general presentation given by SESAR Joint Undertaking regarding WP-E objectives and activities, the presentation briefly describes the ONBOARD project goal, expected outcome, status of the project (at the time) and lessons learned.

Air Traffic Flow Management under Uncertainty [18]

Second SESAR Innovation Days, 27th November – 29th November 2012, Braunschweig, Germany

The goal of the ONBOARD project is to investigate the incorporation of information about the levels of uncertainty in Air Traffic Flow Management (ATFM). The efficiency of ATFM optimizations in preventing local demand-capacity imbalances is reliant on accurate predictions of future capacity states which are inherently uncertain due to factors such as weather effects and unscheduled demand. This paper describes the integration between two elements, the Airline Operations Centre (AOC) which calculates the necessary airspace user recovery plans to cope with adverse scenarios; and the Network Manager (NM) which solves the demand capacity balance problem incorporating uncertainty. The core research aspects are in the introduction of disturbance feedback within the Network Manager optimization, in order to produce tailored solutions for all scenarios. The paper outlines the structure of the system and details of the AOC and NM algorithms. Results are presented demonstrating their interaction as well as the benefits of the disturbance feedback methodology.

Interaction between the Network Manager and the Airline Operations Centre under Uncertainty, The ONBOARD Project: First Results [19]

Tenth USA/Europe Air Traffic Management Research and Development Seminar, 10th – 13th June 2013, Chicago, USA

A technical paper titled "*Interaction between the Network Manager and the Airline Operations Centre under Uncertainty, The ONBOARD Project: First Results*" has been submitted to be presented at the Tenth USA/Europe Air Traffic Management Research and Development Seminar that will take place in Chicago from 10th June to 13th June 2013. This paper outlines the structure of the ONBOARD system and details the AOC and NM algorithms and their integration into a common platform. Also, first results are presented while demonstrating their interaction and the benefits of the disturbance feedback methodology. However, this paper was not accepted.

3.2 Presentations/publications at other conferences/journals

Disturbance Feedback for Handling Uncertainty in Air Traffic Flow Management [20]

European Control Conference 2013 (ECC), 17th – 19th July 2013, Zurich, Switzerland

This paper presents the novel application of disturbance feedback optimization techniques for uncertainty management in Air Traffic Flow Management (ATFM) problems. A pre-existing ATFM flow based model is augmented to include feedback on the disturbances which perturb the weather scenario away from the nominal. Two formulations for modelling the feedback disturbance signal are explored. Results are presented demonstrating the benefits, in terms of reduced delays, of incorporating feedback on the problem solutions over. Some initial studies of the relative computational scaling properties are also presented, demonstrating that taking advantage, within the formulation, of linearly related scenarios can yield computational advantages. Directions for further computational improvement are also discussed.

Bristol is also in discussions with researchers at MITRE Corporation on proposing a special edition of the IEEE Transactions on Intelligent Transportation Systems on the topic of air traffic flow management. This would include contributions from researchers around the world in this area. Bristol expects to submit a journal paper on this topic later in 2013.

3.3 Demonstrations

No demonstrations have been performed, excluding the proper validation exercises or acceptance tests.

3.4 Exploitation plans

Based on the results obtained and the work done along the project, the exploitation plan for the ONBOARD project consists of two main elements:

- Technical dissemination: presentation of the results to potential partners that could be interested in the project-related field and establish relationships of collaboration in order to further improve the current performance of the system.

- Further R&D work: analyse the potential evolution of the tools developed based on the current performance of the system. It is suggested the development of features that could not be implemented in the ONBOARD project, e.g. 3D airspace sectors and / or multiple types of aircrafts. Also, implementation of the Evaluation platform into a simulation product is also suggested in order to be used as an operation assessment or research studies tool.

4 Total Eligible Costs

The following tables present a preliminary summary of the effort (man-days), effort cost and other costs, and SESAR JU contribution. The results are preliminary because this document has been produced prior to the submission to Eurocontrol of the last invoice of the project, which is due by April 5th 2013. Thus, the figures that appear in these tables in red are our best estimation of the final figures.

Note that Bristol's invoices differed from the amounts originally envisaged for the following reasons:

- Bristol's involvement with deliverables did not always align with invoicing, so we were sometimes half way through six months of work on a deliverable when an invoice was due. We chose to postpone invoicing to the later date rather than attribute three months effort to a progress report!
- A meeting originally scheduled for Bristol was held at EEC due to unavailability of EUROCONTROL staff, causing us to incur higher travel costs than anticipated.
- The mismatch between invoicing cycles and Bristol's monthly assessment of staff overheads meant that the staff rates varied between invoices (although the total remains the same as proposed).

Date	Deliverables on Bill	Contribution for Effort	Contribution for Other Costs (specify)	Status
19/12/2011	• D0 Project Management Plan • D0.1 Progress Report 1 • D0.2 Progress Report 2 • D0.3 Progress Report 3 • D1.1 Concept of Operations • D2.1 State of the Art review • D3.1 Algorithmic Framework Definition • D8.2a Presentation at joint network event	28.410,00 €	1.015,31 € (Travels to the meetings of the project, including SID 2011)	Paid
30/11/2012	• D4.1 Evaluation Platform Concept • D6.1 AOC Algorithm Definition	131.662,13 €	5.495,59 €	Paid

Date	Deliverables on Bill	Contribution for Effort	Contribution for Other Costs (specify)	Status
	• D6.2 NM Algorithm Definition • D0.4 Gate Progress Report 4 • S5.1 AOC Prototype • S5.2 NM Prototype • D0.5 Progress Report 5 • D7.1 Evaluation Scenarios Tool User Manual • S7.1 Evaluation Scenarios Tool • S6.5 Draft Integrated AOC+NM Demonstrator • D0.6 Progress Report 6		(Travels to the meetings of the project)	
31/12/2012	• D6.7 Evaluation Scenario Plan • D0.7 Progress Report nº 7 • D8.2b Contribution to SESAR innovation days	9.550,69 €	830,67 € (Travels to the meetings of the project, including SID 2012)	Billed
05/04/2013	• D5.4 AOC+NM demonstrator user manual • S5.3 Evaluation platform prototype • D5.3 Evaluation platform user manual • S6.6 Integrated AOC+NM demonstrator • D0.8 Final Report • D7.2 Evaluation Exercises Report • D8.1 Exploitation Plan	120.075,18 €	2.225,43 € (Travels to the meetings of the project, including SID 2012)	To be Billed
GRAND TOTAL		289.698,00 €	9.567.00 €	

Table 2 Overview of Billing

Company	Planned man-days	Actual man-days	Total Cost	Total Contribution (% contribution)	Reason for Deviation
GMV	535	659	205.311 €	89.086 € (43.4 %)	The effort required to carry out the activities of the project was underestimated in the order of 20%
BRISTOL	287	287	144.175 €	144.175 € (100 %)	No significant deviation
SKYSOFT	77	77	75.249 €	56.437 € (75 %)	No significant deviation
GRAND TOTAL	899	1023	424.735 €	289.698 € (68.2 %)	

Table 3 Overview of Effort and Costs per project participant

5 Project Lessons Learnt

What worked well?
The AOC prototype shows clear benefits in terms of operation cost optimization and demonstrates that recovery costs are reduced significantly if airborne alternatives are considered. The disturbance feedback approach implemented in the NM presents important benefits compared to the alternatives studied in terms of less delay without capacity breaks.
Independent development of AOC and NM in terms of code and platform by means of a set of databases that allowed exchanging information between both systems. Key points such as critical shared information between systems were clearly identified and implemented.
EST, AOC and NM systems have been developed successfully in terms of functionalities and passed all the evaluation exercises. They have also been integrated into a platform in order to run simulations and tests.
Fluent and direct communication and collaboration between EC and consortium members along the project in order to clarify and follow project development. Strict control over tasks with respect to project plan.
Constant dissemination activities in order to present results obtained with the execution of the project. In particular, multiple papers have been submitted in order to present ONBOARD results.
What should be improved?
Further development is suggested in order to implement the platform under a rolling window operation mode, industrialize the NM and/or operate it in a more powerful system to be able to cover larger problems and scenarios.
It is suggested that dissemination activities continue in the future in order to distribute the results of the project and gain visibility on the work done expecting further developments could arise.

Table 4 - Project Lessons Learnt

6 References

[1] **ONBOARD** Concept of Operations E.02.04-ONBOARD-D1.1-Conops V1.2 16/12/11

[2] **ONBOARD** State of the Art Review E.02.04-ONBOARD-D2.1-Sotar V1.1 16/12/11

[3] **ONBOARD** Algorithmic Framework Document. E.02.04-ONBOARD-D3.1-AFD V1.1 16/12/11

[4] **ONBOARD** Evaluation Platform Concept E.02.04-ONBOARD-D4.1-EPC V1.1 07/02/12

[5] **ONBOARD** AOC Algorithm Definition E.02.04-ONBOARD-D6.1-AOCAD V1.1 10/04/12

[6] **ONBOARD** NM Algorithm Definition E.02.04-ONBOARD-D6.2-NMAD V1.1 23/05/12

[7] **ONBOARD** AOC Prototype E.02.04-ONBOARD-S5.1-AOCP V1.0 30/03/12

[8] **ONBOARD** NM Prototype E.02.04-ONBOARD-S5.2-NMP V1.0 30/03/12

[9] **ONBOARD** Evaluation Scenarios Tool User Manual E.02.04-ONBOARD-D7.1-ESTUM V1.1 02/07/12

[10] **ONBOARD** Draft integrated AOC+NM demonstrator E.02.04-ONBOARD-S6.5-DID V1.0 01/08/12

[11] **ONBOARD** Evaluation Scenario Plan E.02.04-ONBOARD-D6.7 - ESP V1.1 01/10/12

[12] **ONBOARD** Evaluation Platform User Manual E.02.04-ONBOARD-D5.3 - EPUM V1.1 15/12/12

[13] **ONBOARD** AOC+NM demonstrator User Manual E.02.04-ONBOARD-D5.4 – DUM V1.1 15/12/12

[14] **ONBOARD** Evaluation Exercises Report E.02.04-ONBOARD-D7.2-EXR V1.0 15/03/2013

[15] L.J. Álvarez, J. Cegarra, and A.G. Richards, “Network Management under uncertainty, The ONBOARD project: research objectives and current status”; in *First SESAR Innovation Day*, no. December 2011, pp.1-7.

[16] Gilian Clare, A. Richards, “Air Traffic Flow Management Under Uncertainty: Application of Chance Constraints” in Second International Conference ATACCS, no. May, 2012, pp. 20-26.

[17] Presentation on “ONBOARD”. GMV. SESAR Joint Undertaking WP-E Information Day. 12/06/2012.

[18] G. Clare, A.G. Richards, J. Escartín, D. Martínez, J. Cegarra, L. J. Álvarez, “Air Traffic Flow Management under Uncertainty: Interactions Between Network Manager and Airline Operations Centre” in *Second SESAR Innovation Day*, no. November, 2012, pp. 1-8

[19] G. Clare, A.G. Richards, J. Escartín, D. Martínez, J. Cegarra, L. J. Álvarez, “Interactions between the Network Manager and the Airline Operations Centre under uncertainty, The ONBOARD project: first results”, submitted for publication, 2013.

[20] G. Clare, A.G. Richards, “Disturbance Feedback for Handling Uncertainty in Air Traffic Flow Management”, submitted for publication, 2013.