E.02.03-D10-STREAM-Final Project Report WP-E

Document information	
Project Title	STREAM - Strategic Trajectory de-confliction to Enable seamless Aircraft conflict Management
Project Number	E.02.03
Project Manager	Advanced Logistics Group
Deliverable Name	STREAM-Final Project Report
Deliverable ID	D10 (contract D0.7)
Edition	01.00.00
Template Version	03.00.00
Task contributors	
Advanced Logistics Group	

Abstract

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

Authoring & Approval

Prepared by - *Authors of the document.*		
Name & Company	Position & Title	Date
[redacted] ALG	[redacted]	30/04/2013
[redacted] ALG		30/04/2013
[redacted] ALG		30/04/2013

Reviewed by - *Reviewers internal to the project.*		
Name & Company	Position & Title	Date
[redacted] ALG	[redacted]	30/04/2013
[redacted] ALG		30/04/2013
[redacted] ALG		30/04/2013

Approved for submission to the SJU by - *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
[redacted] ALG	[redacted]	30/04/2013

Document History

Edition	Date	Status	Author	Justification
00.01.00	14/03/2013		[redacted]	First version submitted
00.02.00	30/04/2013			Version including amendments after document revision.

Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground.

Table of Contents

PUBLISHABLE SUMMARY **4**

1 INTRODUCTION **6**

1.1 PURPOSE OF THE DOCUMENT 6
1.2 INTENDED READERSHIP 6
1.3 INPUTS FROM OTHER PROJECTS 6
1.4 GLOSSARY OF TERMS 7

2 TECHNICAL PROJECT DELIVERABLES **9**

3 DISSEMINATION ACTIVITIES **10**

3.1 PRESENTATIONS/PUBLICATIONS AT ATM CONFERENCES/JOURNALS 10
3.2 PRESENTATIONS/PUBLICATIONS AT OTHER CONFERENCES/JOURNALS 11
3.3 DEMONSTRATIONS 11
3.4 EXPLOITATION PLANS 11

4 TOTAL ELIGIBLE COSTS **13**

5 PROJECT LESSONS LEARNT **14**

6 REFERENCES **15**

List of tables

Table 1 - List of Project Deliverables 9
Table 2 - Overview of Billing 13
Table 3 - Overview of Effort and Costs per project participant 13
Table 4 - Project Lessons Learnt 14

List of figures

Figure 1: CD&R Algorithms architecture 4
Figure 2: Assessment Methodology & Metrics 5

Publishable Summary

The main achievement of STREAM has been to explore innovative trajectory de-confliction algorithms supporting the concept of a rolling conflict management process that seamlessly bridges the gap between strategic pre-departure flow management and conflict detection and resolution during flight execution. The STREAM concept of operations considers pre-departure and dynamic Conflict Management as part of a future, hypothetical, enhanced Network Management function. It assumes a seamless, periodic Conflict Detection and Resolution (CD&R) process in effect from pre-departure phase, being the Conflict Management part of the collaborative design process of the Network Operations Plan (NOP), up to the execution of the flight, when conflicts are tactically resolved by controllers.

The STREAM strategic trajectory de-confliction algorithms exploit the information available in the Shared Business Trajectory (SBT) and the Reference Business Trajectory (RBT), depending on the time of computation relative to the trajectory execution. By applying early de-confliction measures during the SBT negotiation phase, trajectories can potentially be adjusted so that some of the conflicts that would appear during flight execution may not actually materialize, thereby reducing the number of tactical interventions by air traffic controllers and hence the deviations from the agreed RBT. STREAM concept also provides with the possibility to dynamically deal with the de-confliction with a fast response when the RBT is updated, which is of great importance in specific environments highly affected by uncertainty and trajectory prediction error. The outputs of the STREAM algorithms are amendments to some of the input trajectories with an effect in a detected conflict, resulting in amended RBTs

Since these pre-departure de-confliction actions need to consider simultaneously a very large number of flights over wide regions of airspace to ensure their effectiveness, the CD&R algorithms incorporate computational achievements that permit them being run in linear time with respect to the number of trajectories being considered for de-confliction. The STREAM advanced CD&R solution has been successfully implemented as a proof-of-concept prototype demonstrating the ability of supporting the whole 4D state space of the ATM system. The tool is excellent from the computational efficiency point of view, being able to perform in few seconds the CD&R process in an ECAC-wide scenario provided a 650MIPS (relatively slow CPU).

Module	Runtime
Conflict Detection (CD)	8 s
Resolution Trajectory Generator + CD [Generating resolutions to conflicts and re-checking CD]	41 s
Clustering [Dividing the problem in manageable sub-problems]	9 s
Interaction Causal Solver (ICS) [analysing network interactions and proposing positive domino effect resolution scenarios]	20 s
Overall process	**78 s**

Table 1. Algorithm modules runtimes

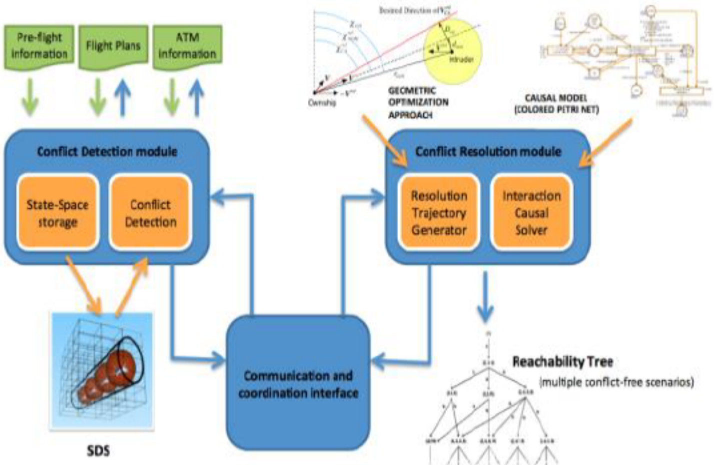

Figure 1: CD&R Algorithms architecture

The effectiveness of the algorithms is strongly dependent on the accuracy and robustness of the trajectory prediction capability they rely upon. Trajectory prediction enables the algorithms to detect potential conflicts and to ensure at the maximum extent possible that the proposed trajectory amendments will result in conflict-free trajectories. On this prototype version of STREAM only simple strategies to tackle uncertainty were tested (i.e. increasing the minimum safety distances in both the CD and the CR modules), and only the metric of minimum delay was considered online during the resolution process to determine the optimality of the conflict-free scenarios provided by the system. Nevertheless, STREAM CD&R algorithms were designed with an expansion and modular perspective in order to potentially integrate in future versions new n-dimensional state-space variables and online metrics. This approach would further consider overall network performance could be of inestimable help for the future ATM system envisaged by SESAR.

As part of the STREAM project, a performance assessment framework, a methodology and a set of metrics were developed to evaluate the potential impact of the operational implementation of the STREAM algorithms on airspace users and on the ATM system as a whole. A fast-time simulation environment was applied, which served as a test bed for the algorithms and allowed synthesizing high fidelity representations of the trajectories that aircraft would fly in response to the amendments proposed by the STREAM algorithms.

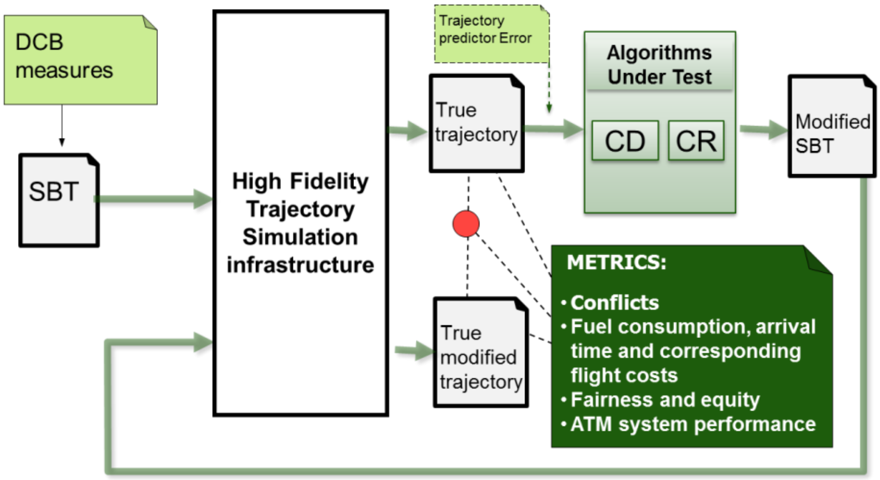

Figure 2: Assessment Methodology & Metrics

The simulation results obtained serve to provide a quantitative assessment of the potential impact of the STREAM algorithms on a broad range of performance metrics in a representative scenario. More in detail, the assessment results show how the 7 NM version of the STREAM algorithms performs slightly better than the 10 NM one in the ATM System Performance Metrics while the 10 NM version outperforms the 7 NM one in the Operational Efficiency and Fairness and Equity Metrics. The assessment highlighted the potential positive impact on performance of the use of level changes to resolve conflicts.

The performance assessment methodology also allowed studying the sensitivity of the metrics to trajectory prediction performance. An analysis was performed in order to evaluate the robustness of the STREAM solution in terms of conflict resolution success with respect to the trajectory prediction error. Two types of perturbations were introduced to model the Estimated Time of Departure Error and Along Track Error, with realistic distributions. The results obtained in this sense a demonstration of the capability to perform a thorough sensitivity analysis and provide insight into the potential value of the STREAM solution not only for individual conflict management but also to enable efficient flow management strategies.

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

This document may be of interest to researchers on Air Traffic Flow Management, conflict detection and resolution and ATM performance assessment. In addition, those involved in the SESAR Work Packages working on related topics may also find it relevant, as the solutions proposed may be applicable to their work.

1.3 Inputs from other projects

STREAM project initially identified a list of SESAR mainstream projects which could be subject to provide relevant inputs to STREAM activities. Those projects were identified within SESAR WPs 4, 7 and 10:

- WP4
  - 04.05: Traffic management framework in En-Route
  - 04.07.02: Separation task in en-route trajectory based environment
- WP 7
  - 07.06.01: Collaborative NOP
  - 07.06.02: Business/Mission Trajectory Management
  - 07.06.05: Dynamic DCB
- WP10
  - 10.02.01: ATC Trajectory Management Design
  - 10.02.02: Trajectory Management Exchange Formats Definition
  - 10.02.03: ATC System support to RBT/MT Revision
  - 10.04.01: Enhanced Tools for Conflict Detection and Resolution
  - 10.08.01: Complexity Assessment and Resolution

During STREAM project development main links with SESAR mainstream projects was established with projects from WP7.

On the other hand, in the framework of WPE, STREAM project established a good coordination with the following projects:

- NEWO: explores the potential of innovative modelling techniques applied to the study of the Air Transport network interactions
- UTOPIA: study communication mechanisms needed for trajectory synchronization, its associated uncertainty, and advanced trajectory management
- TESA: Trajectory prediction and conflict resolution for en-route to en-route seamless air traffic management
- ONBOARD: improving the performances of the ATM system in the short term planning phase to enable the Network Manager to better manage the ATFM delay in Europe

1.4 Glossary of terms

Term	Definition
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATM	Air Traffic Management
BT	Business Trajectory
CD	Conflict Detection
CD&R	Conflict Detection and Resolution
CFMU	Central Flow Management Unit
CI	Cost Index
CR	Conflict Resolution
DCB	Demand Capacity Balancing
E-ATMS	European Air Traffic Management System
ECAC	European Civil aviation Conference
FAA	Federal Aviation Administration
FMS	Flight Management System
KPA	Key Performance Area
KPI	Key Performance Indicator

Term	Definition
NOP	Network Operations Plan
RBT	Reference Business Trajectory
RVSM	Reduced Vertical separation Minima
SBT	Shared Business Trajectory
SES	Single European Sky
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SJU	SESAR Joint Undertaking (Agency of the European Commission)
STREAM	Strategic Trajectory de-confliction to Enable seamless Aircraft conflict Management
TP	Trajectory Predictor
UP4DT	User Preferred 4D Trajectory

2 Technical Project Deliverables

Number	Title	Short Description	Approval status
D1.1	Description of the Concept of Operation	Description of the concept of operation	Approved
D2.1	Preliminary technical description of the tool	Preliminary description and modelling of the strategic trajectory de-confliction tool to enable a seamless aircraft conflict management	Approved
D3.1	Preliminary metrics and methodology	Preliminary metrics and methodology for the assessment of the performance of the strategic trajectory deconfliction tool	Approved
D4.1	Preliminary performance assessment	Performance assessment of the preliminary strategic trajectory de-confliction tool to enable seamless aircraft conflict management	Approved
D2.2	Final technical description of the tool	Final description and modelling of the strategic trajectory de-confliction tool to enable seamless aircraft conflict management	Approved
D3.2	Final metrics and methodology	Final metrics and methodology in order to assess the performance of automated tools, analyse their impact and benefits for the ATM community	Approved
D4.2	Final performance assessment	Performance assessment of developed strategic trajectory de-confliction tool to enable seamless aircraft conflict management	Submitted

Table 2 - List of Project Deliverables

3 Dissemination Activities

3.1 Presentations/publications at ATM conferences/journals

1. **1st WPE Annual Joint Event – SESAR Innovation Days 2011. ENAC, Toulouse (France). From 29/11/2011 to 01/12/2011.** Two presentations were performed by the STREAM team members covering project preliminary results, including concept of operations, algorithms and metrics as well as baseline assumptions adopted. Associated papers: *STREAM – Concept, methodology and tools* (authors: Andrea Ranieri and Ruben Martinez from ALG, Miquel Angel Piera from UAB and Javier Lopez and Miguel Vilaplana from BRTE); *and Relational Time-Space Data Structure To Speed Up Conflict Detection Under Heavy Traffic Conditions* (authors Sergio Ruiz, Miquel Angel Piera and Catya A. Zuñiga from UAB). STREAM presentations were well received, obtaining positive feedbacks from the scientific Community, EUROCONTROL and the European Commission. Evaluators of the STREAM technical paper suggested to better focus the scope of the exercises planned in the project, this suggestion was fully considered during the activities of the project, in particular when giving specification on the validation strategy.

2. **5th International Conference on Research on Air Transportation – ICRAT 2012. University of California, Berkeley (USA). From 22/05/2012 to 25/05/2012.** Project results obtained so far were presented. Associated paper: *Computational Efficient Conflict Detection and Resolution through Spatial Data Structures* (authors: Sergio Ruiz, Catya Zuñiga and Miquel Angel Piera from UAB and Andrea Ranieri and Ruben Martinez from ALG). Paper presentation was well received; general positive feedback was provided by the audience.

3. **2nd International Conference on Application and Theory of Automation in Command and Control Systems – HALA! ATACCS 2012. Imperial College, London (UK). From 29/05/2012 to 31/05/2012.** STREAM members from UAB (Catya Zuñiga and Miquel Angel Piera) presented a PhD descriptive paper on the topic Pre-tactical Trajectory De-Confliction algorithm for Air Traffic Management. Andrea Ranieri from ALG participated to the PhD panel session on 4D Trajectory Management. The research directions of PhD in HALA! confirmed their coherency with STREAM methodology and results.

4. **Info day of the WPE 2nd call for projects. SESAR JU, Brussels (Belgium). 12/06/2012.** Andrea Ranieri from ALG gave an executive presentation on the STREAM project objectives and scope.

5. **2nd WPE Annual Joint Event – SESAR Innovation Days 2012. Technische Universitaet of Braunschweig and DLR, Braunschweig (Germany). From 27/11/2012 to 29/11/2012.** The STREAM team performed a presentation of the project results in 2012. Associated paper: *Causal Decision Support Tools for Strategic Trajectory De-confliction to Enable Seamless Aircraft Conflict Management (STREAM)* (authors: Jenaro Nosedal, Sergio Ruiz and Miquel Angel Piera from UAB and Andrea Ranieri, Ruben Martinez and Alex Corbacho from ALG). Paper and Presentation were well received by the audience, receiving specific feedbacks very positive from the attendants. The Young Scientist Award 2012 was assigned to Sergio Ruiz from UAB, member of the STREAM project team.

3.2 Presentations/publications at other conferences/journals

1. **Elsevier Transportation Research Part C.** In February 2013, the paper *Strategic de-confliction in presence of large number of 4D trajectories using causal modelling approach* (authors Sergio Ruiz, Jenaro Nosedal and Miquel Angel Piera form UAB and Andrea Ranieri from ALG) was sent to Elsevier for its evaluation, feedback not received yet.

3.3 Demonstrations

No demonstrations have been performed apart from the verification and validation exercises performed in the context of 4.1 and 4.2 project activities.

3.4 Exploitation plans

The European dimension of STREAM will ensure cross-fertilization of innovative know-how at a European level, and the potential for exploitation and dissemination of the project results will be strengthened thanks to different capabilities and business threads of the members of the STREAM consortium.

ALG will benefit in the future from the knowledge acquired through the definition and validation of the STREAM concept. Different extended scopes of the STREAM concept would be studied by ALG for applying STREAM solutions in the long term planning phase and in Dynamic Airspace Configuration contexts. Additionally Indra, ALG's parent company, would consider STREAM developments as elements possibly being part of their future ATM IT systems and products.

Thanks to the STREAM project, BR&TE has developed and tested major enhancements to its air traffic simulation and analysis infrastructure to fulfil the challenges posed by the project. The ability to simulate thousands of trajectories with a high degree of fidelity to recreate an innovative operational concept and asses the performance impact on the airspace users and the ATM system as a whole is a great asset of the tool, which we plan to exploit in future projects, both for internal R&D purposes and working with external partners. We believe that the simulation and analysis capabilities that result from STREAM have the potential to facilitate the early evaluation of new trajectory-based concepts, such as those proposed in SESAR. In particular, the ability to model trajectories with a high degree of fidelity to evaluate metrics such as fuel consumption, environmental impact and impact of operating costs can provide valuable insight before conducting more expensive and complex validation exercises such as real time simulations. We plan to pursue further initiatives using our simulation and analysis infrastructure in relation with SESAR Validation Activities and ANSP's environmental impact assessment projects.

UAB has been able to develop a new tool to support the state space of the ATM system. This tool is excellent from the computational efficiency point of view, and it opens the opportunity to develop state space analysis tools to test new SESAR paradigm under a causal analysis. Thus STREAM project has contributed to a better understanding of practical ATM problems, opening research opportunities related to practical aspects such as the need of new approaches to tackle uncertainties while considering capacity constraints, and also the robustness and sensitivity of the RBT's to ETD delays. Considering the research and technology transfer capacity of UAB, STREAM project will allow us to improve the quality of our research and we hope it will foster new collaborations with the different ATM stakeholders in relation with SESAR Validation Activities.

A specific application of the developments performed in STREAM project is found in FIREMANIA (TIN2011-29494-C03-01), which is a research project supported by the Science and Innovation Spanish Ministry to provide greater flexibility and more agile capabilities in terms of fire management. Among the different technologies and research approaches, the use of Unmanned Aeronautical Vehicles (UAV's) is under study to provide the right information obtained at the right time and place at very low cost to the operational decision making unit. The SDS developed can be used to guarantee safety distances between cooperative aircraft.

Additionally, there are other potential applications through ASLOGIC, which is a spin-off company of Universitat Autònoma de Barcelona participating in several projects at Palma the Mallorca International Airport. There is a potential interest to use the SDS approach to support the ABT's in order to improve the ramp handling operations.

4 Total Eligible Costs

Date	Deliverables on Bill	Contribution for Effort	Contribution for Other Costs (specify)	Status
15/12/2011	D0.0, D0.1, D1.0	43.571,26 €	750,00 € (travel costs)	Paid
07/06/2012	D0.2, D2.1, D3.1, D4.1	107.038,52 €	3.511,05 € (travel costs)	Paid
18/12/2012	D0.3, D0.4, D0.5, D2.2, D3.2	68.125,045 €	2.869,025 € (travel costs)	Paid
TBD	D0.6, D0.7, D4.2	48.046,88 €	1.425,00 € (travel costs)	To be billed
GRAND TOTAL		266.781,71 €	8.555,08 € (travel costs)	

Table 3 - Overview of Billing

Company	Planned man-days	Actual man-days	Total Cost	Total Contribution	Reason for Deviation
ALG (coordinator)	223	248	208.352,56 €	104.176,28 €	ALG has been allocated with 19,5 additional man-days coming from BRTE in the context of D4.1, D2.2 and D3.2. In addition, 5,5 extra man-days have been necessary during the execution of the project.
BRTE	227,5	208	153.115,98 €	76.557,99 €	BRTE has transferred 19,5 man-days to ALG in the context of D4.1, D2.2 and D3.2
UAB	399,5	407	94.602,51 €	94.602,51 €	UAB needed 7,5 extra man-days during the execution of the project, mainly regarding D2.2 activities.
GRAND TOTAL	850	863	456.071,05 €	275.336,78 €	

Table 4 - Overview of Effort and Costs per project participant

5 Project Lessons Learnt

What worked well?
Great team spirit and mutual trust and respect. Friendly and relaxed relationships among the partners. Excellent collaboration between team members properly coordinated under a mutual-learning approach.
Strong R&D focus balanced with solid project management practices and a pragmatic approach to obtaining tangible results.
Excellent feedback from EUROCONTROL reviewers, contributing to focus the research and technological development in the right track.
The two phases approach evolution of STREAM developments has been proven to guarantee the achievement of the initially planned scope and objectives.
The project consortium has been able to demonstrate that the STREAM concept envisages a solution capable of dealing with complex traffic scenarios and being applied at ECAC level in a dynamic environment thanks to algorithm short run times.
What should be improved?
More frequent and detailed communication of project progress to project officer.
Enhanced coordination and collaboration with SESAR related WPs and with other SESAR WP-E projects.
Lack of efficiency regarding accessibility to some EUROCONTROL tools (i.e. EDEP) and other data.
Lack of direct contact with potential end-users of the technology that has been developed in STREAM.
With STREAM project it has been possible to demonstrate and assess an advanced solution of the concept being simulated (fast time simulation) in a particular ECAC environment. However, the consortium has encountered many further ways of potential investigation and development which would be very constructive for building a more consolidated version of the tool as well as a wider scope of applications in the context of trajectory optimisation accounting for network effects. Many of these aspects have not been exploited due to effort and schedule constrains related to the existing contract. Many topics that STREAM project closure leaves open could be explored in the future with additional support.

Table 5 - Project Lessons Learnt

6 References

[1] STREAM Concept of Operations. Deliverable D 1.0. STREAM (Strategic Trajectory de-confliction to Enable seamless Aircraft conflict Management), Project E.02.03. SESAR WP-E.

[2] Ranieri, A., Martínez, R., Piera, M.A., López, J., Vilaplana, M., "STREAM - Strategic Trajectory de-confliction to Enable seamless Aircraft conflict Management: Concept, methodology and tools". 1st SESAR Innovation Days, Toulouse, 29th November to 1st December 2011.

[3] SESAR Consortium, "The ATM target concept, milestone deliverable 3", Version 1.0, 2007.

[4] STREAM Preliminary Metrics and Methodology. Deliverable D3.1. STREAM (Strategic Trajectory de-confliction to Enable seamless Aircraft conflict Management), Project No E.02.03. SESAR WP-E.

[5] STREAM Preliminary Performance Assessment. Deliverable D4.1. STREAM (Strategic Trajectory de-confliction to Enable seamless Aircraft conflict Management), Project No E.02.03. SESAR WP-E.

[6] Performance Scheme for Air Navigation Services and Network Functions in Europe. Commission Regulation (EU) No 691/2010 of 29 July 2010. Official Journal of the European Union. 3-8-2010, L 201, pp 1-21.

[7] PRR 2010 - Performance Review Report: An Assessment of Air Traffic Management in Europe during the Calendar Year 2010. Performance Review Commission, May 2010. http://www.eurocontrol.int/prc.

[8] Schmidt, D. "On Modeling ATC Work Load and Sector Capacity", Journal of Aircraft, Vol. 13, No.7, July 1976.Purdue University, West Lafayette, Ind.

[9] Majumdar, A. & Ochieng, W.Y. "The factors affecting air traffic controller workload: a multivariate analysis based upon simulation modelling of controller workload". Centre for Transport Studies, Imperial College, London. 2000.

[10] Christien, R., Benkouar, A., Chaboud, T. & Loubieres, P. "Air traffic complexity indicators & ATC sectors classification". Presented at ATM 2003.Budapest, 23-27 June, 2003.

[11] EUROCONTROL, Standard Inputs for EUROCONTROL Cost Benefit Analysis. Edition Number: 4.0, Edition Date: October 2009, Publications Reference 07/04/03-18, 2009, http://www.eurocontrol.int/ecosoc/public/standard_page/cba.html

[12] Airbus Customer Services, Flight Operations Support & Line Assistance, "Getting to Grips with the Cost Index", STL 945.2369/96, Issue II- May 1998

[13] Roberson, Bill, "Fuel Conservation Strategies", Boeing Commercial Airlines, Aeromagazine, Aero Quarterly QTR_02/07.

[14] Cook, Andrew J. and Tanner, Graham and Williams, Victoria and Meise, Gerhard "Dynamic cost indexing: cost estimations and building the prototype". 7th EUROCONTROL Innovative Research Workshop & Exhibition, 2 - 4 Dec 2008, EUROCONTROL Experimental Centre. (Unpublished)

[15] Del Pozo de Poza, I., Vilaplana, M. Goodchild, C. "Assessing Fairness and Equity in Trajectory Based Operations", 9th AIAA Aviation Technology, Integration, and Operations Conference (ATIO), September 2009, Hilton Head, South Carolina (US), AIAA 2009-6973.

[16] EUROCONTROL, "EUROCONTROL Medium-Term Forecast: IFR Flight Movements 2011-2017", Edition v1.0, STATFOR Doc442. October 2011. http://www.eurocontrol.int/statfor/gallery/content/public/forecasts/Doc442-MT-Flights-Sep11-v1.0.pdf

[17] EUROCONTROL, Base of Aircraft Data (BADA). http://www.eurocontrol.int/eec/public/standard_page/proj_BADA.html

[18] PRR 2011 - Performance Review Report: An Assessment of Air Traffic Management in Europe during the Calendar Year 2011. Performance Review Commission, May 2012. http://www.eurocontrol.int/prc.

[19] López-Leonés, Javier, 2008, "Definition of an Aircraft Intent Description Language for ATM", PhD Thesis. University of Glasgow, UK

[20] Javier López-Leonés, Miguel A. Vilaplana, Eduardo Gallo, Francisco A. Navarro, Carlos Querejeta . "The Aircraft Intent Description Language: A Key Enabler For Air-Ground Synchronization In Trajectory-Based Operations" 26th Digital Avionics Systems Conference. October 2007

[21] ASIS Consortium (BR&TE, GE Aviation, Airservices Australia, Indra Sistemas, Barco-Orthogon)., "Towards an Open Test bed for the Study of Trajectory Synchronization in the Future ATM System: The ASIS Initiative", ICNS conference, Washington, May, 2009.