Trajectory prediction and conflict resolution for Enroute-to-enroute Seamless Air traffic management – TESA

Wolfgang Schuster[1], Washington Ochieng, Arnab Majumdar
Department of Civil and Environmental Engineering
Imperial College London
London, United Kingdom
[1]w.schuster@imperial.ac.uk

***Abstract*—A key aspect of collaboration and automation under the SESAR concept of operations is the need to guarantee reliable and robust common situational awareness between all stakeholders as a function of time, extrapolated into the future. The aim of TESA is to develop reliable Trajectory Prediction (TP) and Conflict Detection and Resolution (CDR) capabilities, with the specific objectives to address the sources of error and use improved TP to optimise CDR, thereby enhancing capacity, efficiency and safety. TESA will validate the TP and CDR models with real operational aircraft data and undertake sensitivity analyses to characterise performance. A key prerequisite to the development of these Decision Support Tools (DST) is a detailed understanding of the performance requirements for such tools. This paper identifies the functional requirements of TP and CDR tools and develops performance metrics and requirements. These are mapped to the various SESAR concept elements (applications).**

***Foreword* - This paper describes a project that is part of SESAR Workpackage E, which is addressing long-term and innovative research. The project was started early 2011 so this description is limited to an outline of the project objectives augmented by some early findings.**

Keywords-SESAR, trajectory prediction, conflict detection, conflict resolution, uncertainty, performance, metrics

I. INTRODUCTION

Due to the rapid increase in air travel, there is an urgent need to increase enroute-to-enroute airspace capacity and improve safety without negatively impacting the environment. The current tactical approach to Air Traffic Management (ATM) is unable to meet future capacity, safety and environmental demands. Therefore a new strategic, collaborative and automated approach to ATM is required worldwide. Collaboration and automation are at the core of the new approach developed by SESAR [1] . A key aspect within the new concept of operations is the need to guarantee common situational awareness between all stakeholders as a function of time, extrapolated into the future. This is achieved through accurate and reliable Trajectory Prediction (TP), as key objective of TESA. Furthermore, TESA will develop a Conflict Detection and Resolution (CDR) tool focusing on the uncertainty element of TP to optimise CDR without compromising safety.

Key to the achievement of these objectives is a detailed understanding of the SESAR Concept of Operations (ConOps) and the corresponding requirements for Decision Support Tools (DST) with a specific focus on TP and CDR. A detailed review of the relevant literature on the ConOps was carried out to identify the elements that require the support of TP and CDR, and determine functional requirements, performance metrics and performance requirements for each of these elements. This information will help to establish the focus of the remainder of the TESA project and enable a targeted architecture design and development of the TP and CDR tools to address some of the current limitations.

II. NEED FOR TP & CDR

The foundation of the ATM target concept of operation is trajectory-based operations, with pre-determined intentions that the user is required to adhere to, within system constraints. The elements that require TP and/or CDR functionality within the SESAR concept of operations can be divided into the following two high-level categories: *planning* and *monitoring*. The former can further be divided into *advance optimisation* subject to planned constraints, *strategic optimisation* subject to predicted contextual constraints and *tactical optimisation* in reaction to actual contexts (e.g. sudden events). The key SESAR elements requiring the support of TP & CDR and their application domains are identified in the first TESA deliverable [2]. The roles (i.e. functions) of TP and CDR are determined for each of the relevant applications. A distinction is made between the following categories of the ConOps:

- Trajectory Management (TM): new approach to airspace design and management
- Collaborative Strategic Planning (CSP): Networks Operations Plan (NOP)
- Integrated Airport Operations (IAO)

- New Strategic Separation Modes (SSM)
- System-Wide Information Management (SWIM)

The evolution of the ConOps is captured in three primary time-frames:

- Present – 2013: Independent: Separate systems being used at the same time;
- 2013 – 2017: Co-ordinated: Common elements have been identified;
- 2017 – onwards: Integrated
    - Combined: Common elements have been identified and are being integrated (2017 – 2020);
    - Fully integrated: One system incorporating all common elements (2020 – onwards).

The key SESAR elements and applications are divided into the SESAR service levels, to capture the relevant time-frame of the expected implementation of the relevant ConOps strategic areas. For each of these areas, the key elements that require the support of TP and CDR and their link to the high-level categories of the ConOps are identified. The phase of operation for which the support of TP and CDR tools is required, is specified as *"all"*, *"airborne"*, *"climb"*, *"en-route"*, *"TMA"*, *"final approach"* and *"ground"*. The high-level functions that these tools are supporting and the Look-Ahead Times (LAT) required are specified. An extract of the table in [2] is reproduced below.

TABLE I. OVERVIEW OF SESAR CONCEPT ELEMENTS REQUIRING TP AND/OR CDR

Service Levels	**SESAR Concept**			**Phase of Operation**	**TP/CDR high-level function /role (timescale)**	**Implementation**
	Strategic Area	***Key Elements***	***Category***			
Service Level 1 (Short-term: 2008 – 2013)	DCB	AO & CAP	CSP	airborne	TP/CD: advance optimisation (D to M) CR: N/A	Ground
		NCP; DMA/R	CSP	airborne	TP: advance and strategic optimisation (D) CDR: N/A	
		ASC	CSP	airborne	TP: strategic optimisation (H to D) CDR: N/A	
		Traffic load DCM; MSP	TM	airborne	TP/CDR: strategic optimisation (H).	
		ATFCM techniques (e.g. slot swapping)	TM	TMA	TP/CDR: strategic and pre-tactical optimisation (min to H)	

III. STATE-OF-THE-ART TP/CDR REQUIREMENTS

State-of-the-art TP requirements are described in [3], which captures the functional and performance requirements for the modelling of flight behaviour in planned and tactical trajectories. The specifications are derived from requirements of ATC tools specified by the First ATC Systems and Tools Implementation (FASTI) programme [4]. TP is divided into planned trajectory prediction (medium-term view) and tactical trajectory prediction (short-term view). The former is built initially in accordance with the flight intent, as described by the flight plan, and constrained by ATC procedures. The latter is based on the latest tactical clearances given to a flight, without making assumptions on future clearances to be given. The planned trajectory is the basis upon which flight data is nominally distributed to the sectors traversed by a flight, coordination is performed between sectors and between ATC units, sector planning and medium-term conflict detection are performed, and upon which deviation from the planned intent is monitored. The tactical trajectory is used in the detection of conflicts involving aircraft where a further clearance is required in order for the aircraft to return to its own navigation of the planned intent.

The key performance metrics considered in [3] are longitudinal, vertical and lateral accuracy requirements, specified in terms of magnitude of mean and standard deviation per unit-time of prediction. A number of drawbacks can be identified with this approach. Firstly, characterising the tolerable TP performance as a function of LAT leads to a linearly increasing error tolerance. For long flights of e.g. 15 hours, this results in error tolerances that are potentially as large as e.g. 90 nm. Such requirements would prevent accurate gate-to-gate or enroute-to-enroute planning. Secondly, the requirements ignore the time-factor. More important than longitudinal requirements in the assessment of safety requirements are the time-based performance requirements, as time is a key determining factor in potential resolution manoeuvres. Thirdly, [3] does not address the issue of integrity nor of the computational requirements.

TESA has developed a comprehensive list of performance drivers (see next section) that addresses the above limitations. The focus is on quantifying performance requirements from a practical implementation perspective.

IV. TP & CDR FUNCTIONS AND PERFORMANCE METRICS

At the core of future ATM are advanced automation systems, with most requiring sharing of instantaneous and predicted aircraft positions between relevant stakeholders. These positions are provided by navigation systems and TP/CDR tools respectively, in addition to appropriate communication systems. The focus in this document is on TP and CDR, with the former providing forecasts of aircraft trajectories based upon shared (common) flight data and aircraft intent. The latter uses TP outputs to identify conflicts and provide resolution manoeuvres to eliminate these conflicts. The outputs from TP and CDR feed into flight-scripts and the

---

Sponsors: SJU/EUROCONTROL

advisories of automation systems. Therefore, the performance of these automation tools strongly depends on the qualities of TP and CDR (of which TP is a critical component).

This section investigates the characteristics and performance drivers for each of the SESAR elements to determine the role and requirements of TP/CDR. These are then mapped to state-of-the-art TP/CDR (i.e. in the public domain), to identify the current weaknesses (limitations). Each of the SESAR elements is addressed in [2]. This paper provides sample results in the next section. For the sake of clarity, intent is divided into Flight Intent (FI) and Aircraft Intent (AI). FI is defined as the information provided to the Flight-Management-System (FMS). AI is the information provided to the aircraft control system, which takes into consideration environmental and initial state conditions and aircraft performance.

At the highest level, TP/CDR support the following functions:

- Planning (PLAN);
- Flow management (e.g. strategic/local synchronisation); (FLM)
- Traffic control (e.g. active clearances/instructions); (TCTRL)
- Flight control (e.g. FMS); (FLC)
- Monitoring (e.g. surveillance); (MON)
- Conflict avoidance (e.g. minimisation of conflict likelihoods) (CAV) and
- Collision avoidance (COA).

Key performance drivers include:

- Time Between Analysis and Scenario (TBAS);
- Analysis Scenario Volume (ASV);
- Look-Ahead Time (LAT);
- Prediction Accuracy (PA);
- Prediction Integrity (PI);
- Prediction Analysis Time (PAT);
- Detection False Alert (DFA);
- Detection Integrity (DI);
- Detection Analysis Time (DAT);
- Resolution Efficiency (RE);
- Resolution Integrity (RI) and
- Resolution Analysis Time (RAT).

These terms are defined as follows:

TBAS (Time Between Analysis and Scenario) refers to the interval between the time at which the analysis (including TP and/or CD and/or CR) needs to be carried out in support of a scenario and the time at which the actual scenario occurs. It is crucial as it determines the level of contextual uncertainties. ***ASV*** (Analysis Scenario Volume) refers to the physical volume of airspace over which the simulation needs to be carried out. It is divided into local, regional, national and international air volumes. It is tightly linked to the ***LAT*** (Look-Ahead Time), which corresponds to the time-lengths of scenarios to be simulated.

PA (Prediction Accuracy) refers to the measure of the difference between the actual and predicted trajectories sampled over a given flight-segment (the LAT). The prediction accuracy includes longitudinal, lateral, vertical and ***RTO*** (Required Time of Overfly) performance requirements which are specified in terms of ICAO RNP. Currently RNP are only specified for lateral and vertical. Longitudinal and timing requirements have yet to be defined. In this document, required times of overfly requirements are based on the assumption that longitudinal requirements must be at least as stringent as lateral requirements for the respective phases of operation. The required time of overfly for commercial aircraft is then allocated on the basis of typical speeds for each of these phases: 15 seconds (en-route), 2 seconds (TMA), 1 second (precision approaches) and 0.5 seconds (ASM). Larger time between analysis and simulation, and look-ahead times result in larger uncertainties of contextual factors (including environmental conditions) and thereby lead to larger TP uncertainties.

PI (Prediction Integrity) refers to the probability that a given level of accuracy will be met over a certain LAT. It is divided into four main categories, tightly linked to the RNP: low (en-route integrity requirements), medium (TMA integrity requirements), high (precision approach integrity requirements) and very high (ASM integrity requirements). ***PAT*** (Prediction Analysis Time) is the CPU time used in the TP process to simulate a given application requiring the flight path calculation. ***DFA*** (Detection False Alert) is a measure of the probability of identifying the existence of a conflict when none exists, sampled over a given flight segment (LAT). It is divided into safety critical (low), useful (medium) and little impact (high). ***DI*** (Detection Integrity) is a measure of the probability of missed detection sampled over a given flight segment (LAT). ***DAT*** (Detection Analysis Time) is the CPU time used by the CD process to simulate a given application requiring the detection of conflicts.

RE (Resolution Efficiency) is measured in terms of Quality of Service (QoS) metrics including time-delay, additional pollution (e.g. fuel, CO2, NOx) for a given air traffic scenario. It is divided into "high-impact" (high), "medium-impact" (medium) and "low impact" (low). ***RI*** (Resolution Integrity) is the probability that the proposed resolution manoeuvre will (a) resolve the current conflict and (b) not induce any further conflict over the resolution volume. Both detection integrity and resolution integrity are divided into four high-level categories, tightly linked to the ICAO Target Levels of Safety (TLS): low (en-route TLS), medium (TMA TLS), high (precision approach TLS) and very high (ASM TLS). ***RAT***

(Resolution Analysis Time) is the CPU time used by the CR (Conflict Resolution) process to analyse a given application requiring the resolution of conflicts. Note that the TBAS (Time Between Analysis and Scenario) is tightly linked to PAT (Prediction Analysis Time), DAT (Detection Analysis Time) and RAT (Resolution Analysis Time) requirements. Shorter TBAS require shorter PAT, DAT and RAT.

V. MAPPING OF SESAR CONCEPT TO TP & CDR REQUIREMENTS – SAMPLE DISCUSSION

This section discusses the requirements of the first key element associated with the SESAR "Demand and Capacity Balancing" strategic area: AO (Airspace Organisation) & CAP (Collaborative Airspace Planning) (see TABLE I.). A detailed description for all the elements can be found in [2].

Airspace organisation and collaborative airspace planning requires a quantitative analysis of potential airspace changes, the validation of airspace concepts and operational plans, and the definition of potential capacity gains using mathematical simulation models [5]. The core of these simulation models are TP tools, with the key functionality of ***long-term advance planning over regional, national and international air volumes at ground-level, including anticipated controller workload and airspace complexities***. It will also enable the assessment of bottleneck points as a function of available volume in a given airspace. The time between analysis and scenario is of the order of days to months, with significant uncertainties in the flight-intent (in the form of 3D flight plans) and in the contextual factors (including environmental conditions).

The LATs are of the order of the duration of each flight in the respective airspace (i.e. potentially many hours). Prediction accuracy requirements are still to be specified. However they are expected to be at the level of current RNP accuracy requirements for the given phase of operation. Prediction integrity requirements are low at this stage. Computational efficiency is highly relevant given the large number of aircraft that need to be analysed. Conflict detection capabilities would provide added benefit in optimising airspace organisation and planning. The probability of detection false alert and the detection integrity are not critical at this stage, i.e. detection false alert probabilities have a low relevance and detection integrity requirements are low.

While conflict resolution is not required per se for this application, it would benefit from a "replanning tool" based upon conflict resolution. Resolution efficiency and resolution integrity requirements are low, however resolution analysis time requirements are high. The key TP/CD output is a post-processed 4D line. The key challenges are to model the flight intent uncertainties as well as the impact of contextual factors upon the airspace organisation and planning. Key tools to support Airspace Organisation and Collaborative Airspace Planning currently include the "System for Airspace Analysis at Macroscopic Level (SAAM)" for the design, optimisation, visualisation and analysis of airspace structures and route networks; ATC Capacity Analyser (CAPAN) and Re-organised ATC Mathematical Simulator (RAMS) fast time simulation models for the computer simulation of current and future air traffic control operational concepts. It is not known whether these tools have been developed to "safety critical" standards. These tools could benefit from the enhanced ICL HPTP (High Performance Trajectory Prediction) tool [6], which is capable of prediction the en-route phases of flight. It would need to be extended to cover the TMA, for potential implementation into TAM, and the airport surface to provide a true gate-to-gate functionality. Additionally, the ICL HPTP tool could form the basis for the assessment of airspace complexity, controller workload and bottlenecks.

VI. SUMMARY OF TP/CDR REQUIREMENTS

TABLE II. summarises the requirements for TP/CDR for the strategic area "Demand and Capacity Balancing". It is colour-coded, showing those ConOps elements that can already be met with current TP and CDR tools in green, those that can partially be met in yellow and those that cannot be met in red. The table summarising all elements can be found in [2]. It is clear from the table in [2] that the largest fraction of the ConOps elements cannot be met with current tools. The primary limitations that were identified are a lack of understanding of the

- contextual uncertainties
- environmental uncertainties
- aircraft operational uncertainties and
- aircraft performance uncertainties.

VII. TRAJECTORY PREDICTION TOOL

Based upon the identified functional requirements, TESA takes a bottom-up approach in the development of the TP tool, i.e. development of the "best-possible" tool rather than development of a tool meeting specific performance requirements. TESA will then characterise the performance of this tool with respect to the metrics identified in Section IV. The key goal is to address the main challenges that were identified in [2] and summarised for sample elements in Section VI.

The objective of TESA is to develop a TP tool covering all phases of operation, from gate to gate, including airport surface movement. TESA will use ICL's en-route HPTP tool and extend it to the Terminal Manoeuvring Area (TMA) and Airport Surface Movement (ASM). The proposed research will focus on developing a tool enabling TP of complex manoeuvres (e.g. procedure turns) and over time horizons of several hours under nominal conditions (i.e. no uncertainties). The focus is on reducing ambiguity and complexity of aircraft intent representation for these manoeuvres, on accounting for aircraft dynamics and operational limitations, and on modelling

TABLE II. TP/CDR REQUIREMENTS – SAMPLE RESULTS

Application	AO & CAP	INC; DMA/R & ASC	Traffic load DCM, MSP & ATFCM	UDPP	Automatic F/TCM
DST	TP/(CD)	TP	TP/CD/CR	TP/CD	TP
Implementation	G	G	G	A	G
TBAS	D to M	H to D	RT	RT	RT
ASV	I	R	R	I	L/R
LAT	FD	FD	≤ 2 H	FD	min to H
Functions	PLAN	PLAN/FLM	FLM	PLAN/CAV	MON
PA [nm]	5	5	5	1	0.1 to 5
PI	1	HA	HA	1	TLS
DFA	LI	LI	HI	LI	NR
DI	1	1	HA	1	NR
RE	1	1	med	med	NR
RI	1	1	TLS	med	NR
Update rate	D	H	m	m	s
Output	4D-line	4D-line	4D-vol + CDC + CRC	4D-line + CDC	4D-line
Key challenges	FI-U/CF	FI-U (G)/EU	CE/TP-U/CD-U	CC/EU/CE	CE/EU

the impact of wind during such procedures. The performance will be developed on the basis of real-data from flight-data records.

A key issue that needs to be addressed in optimising 4D trajectory prediction is the confidence that can be placed in the predicted trajectories. This confidence is dependent upon how reliably the trajectory prediction uncertainties can be modelled. Up-to-date, there has been a lack of understanding of TP uncertainties, which has lead to a lack of confidence by controllers to adopt these tools in a real operational environment. The second objective of TESA is therefore to study TP uncertainties. TESA will develop software modules to enable the assessment of TP uncertainties and develop a TP tool with the necessary integrity to provide the required confidence to controllers and pilots for their use in a real operational environment. The proposed development in TESA will focus on analysing sources of uncertainty in TP from which uncertainty models for 4D trajectories will emerge in order to allow reliable TP over time horizons of several hours. The models, although applicable for gate-to-gate will focus on the Terminal Manoeuvring Area (TMA), where capacity shortages are most important. The models will be validated with real data obtained from aircraft flight-data records.

VIII. CONFLICT DETECTION AND RESOLUTION TOOL

Safety is a key consideration in the development of any novel technology. A key risk to safety in aviation is the potential collision between aircraft, especially in the high density traffic volumes of the airport environment. Currently, aircraft make use of Aircraft Collision Avoidance Systems (ACAS) [7] to mitigate this risk. However, ACAS such as TCAS (Traffic alert and Collision Avoidance Systems) only provide advisories on the current traffic information and do not fully take into consideration the intent or predicted trajectory evolution of the conflicting traffic. As a result, the resolution manoeuvres are non-optimal, especially in scenarios with multiple conflicts. This risk can be eliminated by sharing position and intent information between all aircraft via ADS-B (out) [8].

In TESA, a strategic self-separation logic, based on cooperative planning using advanced strategic, performance-based and distributed conflict detection and resolution algorithms will be developed. The approach will be to maximise use of aircraft intent information as well as TP uncertainty in the development of conflict resolution tools, taking into consideration operational constraints and environmental factors. This will create a new dimension towards CDR with the necessary confidence that these processes can be automated at either the aircraft- or ATC-levels. TESA proposes to develop a CDR tool which will make use of all available parameters (e.g. speed adjustment, heading, altitude change) to control trajectories.

IX. MODEL VALIDATION

The final stage of TESA is to develop performance evaluation modules for TP and CDR. These modules will be used to validate the performance of the TP and CDR algorithms and carry out a sensitivity analysis of the CDR algorithms with respect to the identified constraints (e.g. TP uncertainty).

TESA will first characterise the performance of the TP tool with respect to real flights. A comparison of the predicted trajectories (including uncertainties) as a function of time with the actual recorded trajectories will be used to characterise the TP accuracy (in terms of Euclidean errors) as a function of the uncertainty models developed and determine their validity.

In a second stage, TESA will characterise the performance of the CDR tool with respect to select simulation scenarios and scenarios from a real ATC environment. The CDR tool effectiveness is verified by means of accurate TP models taking into consideration aircraft performance and environmental conditions. The usability of shared trajectories for conflict mitigation will be analysed and the data to be provided by the airspace user defined.

X. CONCLUSIONS

TESA has identified the SESAR concept elements that require the support of TP and/or CDR. The project has defined the various functions that TP and CDR tools must fulfill for each of these elements, and developed relevant performance metrics. Based upon these, TESA has developed performance requirements in terms of these metrics for each of the SESAR concept elements. A comparison with existing tools suggests that current tools are unable to meet the performance requirements for most SESAR concept elements.

TESA aims at, and is in the process of, developing reliable and robust TP and CDR tools which have the potential to meet the performance requirements of the various SESAR concept elements requiring such tools. To this end, TESA will extend its current HPTP en-route tool to the TMA and ASM. TESA will identify the key parameters contributing to TP uncertainties by carrying out a sensitivity analysis. The identified parameters will be modeled based upon real data and used to generate TP uncertainty predictions. The models will be validated by comparing observed errors with predicted uncertainties. Based upon the TP tool, TESA will develop a CDR tool that accounts for TP uncertainties in the resolution trajectories. This enables a reduction of unnecessary large safety margins that are currently required, thereby enhancing capacity and efficiency, without compromising safety. To close the loop, the TP and CDR tools will be used to identify, with respect to the performance metrics developed in Section IV, the SESAR concept elements that can realistically be met with the developed tools.

XI. ACRONYMS

Acronym	Meaning
A	Airborne
ACAS	Aircraft Collision Avoidance System
ADS-B	Automatic Dependent Surveillance - Broadcast
AO	Airspace Organisation
ASC	ATC Sector Configuration
ASM	Airport Surface Movement
ASV	Analysis Scenario Volume
CAP	Collaborative Airspace Planning
CAV	Conflict AVoidance
CC	Contextual Constraints
CDC	Conflict Detection Capability
CDR	Conflict Detection and Resolution
CE	Computational Efficiency
CF	Contextual Factors
COA	COllision Avoidance
CRC	Conflict Resolution Capability
D	Days
DAT	Detection Analysis Time
DCM	Density and Complexity Management
DFA	Detection False Alert
DI	Detection Integrity
DMA/R	Dynamic Management of Airspace/Routes
ENV	ENVironmental
EPA	Environmental Performance Assessment
EU	Environmental Uncertainties
FD	Flight Durations
FLC	FLight Control
FLM	FLow Management
FR	Free Routing
F/TCM	Flight/Trajectory Conformance Monitoring
G	Ground
H	Hours
HA	High Average
hi	high
HI	High Impact
HP	High Performance
HPTP	High Performance Trajectory Prediction
I	International
ICL	Imperial College London
INC	Interactive Network Capacity
l	low
L	Local
LAT	Look-Ahead Time
LI	Low Impact
M	Months
med	medium
min	minutes
MON	MONitoring
MSP	Multi-Sector Planning
NCP	Network Capacity Planning
NR	Not Relevant
PA	Prediction Accuracy
PAT	Prediction Analysis Time
PI	Prediction Integrity
PLAN	PLANning
R	Regional
RAT	Resolution Analysis Time
RE	Resolution Efficiency
RI	Resolution Integrity
RT	Real-Time
s	seconds
TBAS	Time Between Analysis and Scenario
TCAS	Traffic alert and Collision Avoidance System
TCTRL	Traffic ConTRoL
TP	Trajectory Prediction
U	Uncertainties
UDPP	User-Driven Prioritisation Process

REFERENCES

[1] SESAR The Concept of Operations at a Glance, v1.0, 2008.

[2] W. Schuster, W. Ochieng, "Operational Concepts Definition" TESA Deliverable D1.1, August 2011.

[3] Eurocontrol, "Specification for Trajectory Prediction", v1.0, 15 July 2010.

[4] http://www.eurocontrol.int/fasti/public/subsite_homepage/homepage.html

[5] Eurocontrol, "Airspace Organisation and Management" website, http://www.eurocontrol.int/airspace/public/standard_page/14_Airspace_Organisation_and_Management.html, June 2011.

[6] Schuster W, Porretta M, Ochieng W. "High-accuracy four-dimensional trajectory prediction for civil aircraft", The Aeronautical Journal, v116 (1175), January 2012.

[7] http://www.eurocontrol.int/msa/public/subsite_homepage/homepage.html

[8] http://www.eurocontrol.int/cascade/public/subsite_homepage/homepage.html