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Notes

Table of Contents

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Human Factors

Ecological Approach to Train Air Traffic Control Novices in Conflict Detection and Resolution

Clark Borst, Max Mulder and Rene Van Paassen, TU Delft

In the near future, air traffic controllers will need to work with more sophisticated automation to meet higher demands in flight technical performance and operational safety. However, the aviation community fears that more intelligent sup- port systems could diminish the 'hands-on' skills and cognitive expertise of controllers. To overcome this, training will become a critical issue to help them understand the rationale underlying the automation as well as to develop and preserve their expertise. But what if we could design automation in such a way that the emphasis lies on cooperation by making the technical systems share their deep knowledge? Can such 'transparent' systems actually help to develop and maintain the cognitive expertise required for the job? In this paper, an ecological interface for conflict detection and resolution, developed in a previous study, was used as a 'transparent' system that provides a deeper insight into the causal constraints governing traffic situations. It was hypothesized that this interface would expedite novice learning and convergence to 'best practices' when compared to an instructional training method. Results from the experiment, in which 16 students participated, revealed that the overall control performance in the final measurement session, featuring a conventional radar display, was not significantly different between the ecological and the instructional group. However, observations and trends suggested that the ecological group revealed more critical reflection behavior (leading to delayed actions), which occasionally allowed participants to solve 'novel' conflict scenarios. Further research is needed to analyze and map the student's development of cognitive expertise.

Critical Personality Aspects for Human-Machine Interaction in Highly Automated Aviation

Solveig Eschen, Katja Gayraud and Doris Keye-Ehing, DLR

Working safely and successfully with highly automated human-machine interfaces of future aviation is not only a matter of cognitive performance, but also of personality. This study examines which personality aspects correlate with safety-critical performance in human-machine (hybrid) teams. Personality was surveyed with the Hybrid Team Questionnaire HTQ and the Balloon Analogue Risk Task BART which measures risk taking. The Hybrid Interaction Scenario HINT simulates relevant processes in future human-machine team interaction in aviation and was used as performance measure. In an exploratory study with 156 applicants for aviation careers, safety-critical effects of some facets of general personality as well as risk taking were found. Especially personality aspects concerning disinhibiting, spontaneous behaviour and sensation seeking show correlations with poorer performance in the HINT simulation.

Modelling and Analysis of Controller's Taskload in Different Predictability Conditions

Elmira Zohrevandi, Valentin Polishchuk, Jonas Lundberg, Åsa Svensson, Jimmy Johansson, Linköping University and Billy Josefsson, LFV

This study aims to first develop a successful taskload model which is able to relate the controller's interaction with the radar screen to the dynamical changes in air traffic patterns. Secondly, the study aims to examine whether i4D equipage, as a specific notion of automation, contributes to an improvement in quantification of controller's taskload model. Thirdly, in a more specific approach the study intends to analyze to what extent controllers may or may not benefit from predictable situations at dense traffic conditions when exposed to higher automated airspace environment. The

model is applied on 18 data sets featuring different i4D-equipage levels. It compares controllers' taskload for three different scenarios between an en-route and a terminal sector.

Meteo & Environment

Probabilistic Aircraft Conflict Detection Considering Ensemble Weather Forecast
Eulalia Hernández, Alfonso Valenzuela and Damián Rivas, University of Seville

In this paper, the effects of wind uncertainty on the problem of conflict detection are analyzed. The wind components are modeled as random variables; the wind uncertainty is obtained from weather forecasts. The case of two en-route aircraft flying at constant altitude, constant airspeed, constant course, and subject to the same wind is considered. The conflict is characterized by several indicators, such as the minimum distance between aircraft, the time to minimum distance, and the conflict probability. The analysis is based on the transformation of random variables, which evolves the wind probability density functions to obtain the probability density functions of the indicators. Numerical results are presented for a given particular scenario.

Wind-Based Robust Trajectory Optimization using Meteorological Ensemble Probabilistic Forecasts
Daniel González, Manuel Soler and Manuel Sanjurjo , UC3M

A major challenge for Trajectory-Based Operations is the existence of significant uncertainties in the models and systems required for trajectory prediction. In particular, weather uncertainty has been acknowledged as one of the most (it not the most) relevant ones. In the present paper we present preliminary results on robust trajectory planning at pre-tactical level. The main goal is to predict trajectories that are efficient, yet predictable. State of the art Ensemble Probabilistic Forecasts are used as data for wind (assumed to be the unique source of uncertainty). An ad-hoc optimal control methodology has been developed to solve trajectory planning problems considering wind input from EPFs. A set of Pareto Optimal trajectories is obtained, in particular results for the minimum fuel trajectory and the most predictable trajectory are presented and discussed. Trade- off between fuel consumption and time dispersion is obtained and discussed. It is shown how uncertainty can be quantified and reduced by proposing alternative trajectories.

Continuous Climb Operations with Minimum Fuel Burn
Judith Rosenow, Stanley Förster and Hartmut Fricke, TU Dresden

Continuous climb operations are one of several instruments, developed by the Single European Sky ATM Research program SESAR to improve the environmental compatibility of the future air traffic management by designing an air traffic system with minimum environmental impact and minimum direct operational costs at an increased safety level, compared to today. With respect to minimum fuel flow, the optimum continuous climb is defined as a continuously climb profile with a minimum number of level-offs and trust changes to avoid superfluous acceleration forces. This definition results in highly aircraft specific and weather dependent continuous climb profiles which are hardly to predict. In this paper, the optimum climb profiles of four different aircraft types are estimated under real atmospheric conditions by modeling trajectories with an aircraft performance model, which is specialized to unsteady flows. We found, that even in realistic weather conditions, the target function of the aspired true air speed is very similar to the objective of climbing with a maximum climb rate, which corresponds to a minimum fuel climb profile in a standard atmosphere.

The cruising altitude and a corresponding true air speed with respect to a maximum specific range is more important for an optimized continuous climb, than the climb gradient.

Safety and Security

A Safety Impact Quantification Approach for Early Stage Innovative Aviation Concepts
Sybert Stroeve, Bas Van Doorn, NLR and Joan Cahill, Trinity College Dublin

This paper presents a straightforward approach for safety impact quantification of innovative aviation concepts in early development stages. The safety impact quantification approach provides a high-level and broad overview of the accident risk reduction that may be obtained by the novel concept. The approach uses a systematic assessment of change factors for base event probabilities in a total aviation system risk model, consisting of combinations of event sequence diagrams and fault trees. The approach is illustrated in terms of the assessment of an innovative third pilot adaptive automation concept. The results indicate that this concept can effectively reduce the fatal accident risk.

Discussion on Complexity and TCAS Indicators for Coherent Safety Net Transitions
Christian Verdonk and Francisco Sáez, Cranfield University

Transition between Separation Management in ATM and Collision Avoidance constitutes a source of potential risks due to non-coherent detection and resolution clearances between them. To explore an operational integration between these two safety nets, a complexity metric tailored for both Separation Management and Collision Avoidance, based on the intrinsic complexity, is proposed. To establish the framework to compare the complexity metric with current Collision Avoidance detection metrics, a basic pair-wise encounter model has been considered. Then, main indicators for horizontal detection of TCAS, i.e. tau and taumod, have been contrasted with the complexity metric. A simple method for determining the range locus for specific TCAS tau values, depending on relative speeds and encounter angles, was defined. In addition, range values when detection thresholds were infringed have been found to be similar, as well as its sensitivity to relative angles. Further work should be conducted for establishing a framework for the evaluation and validation of this complexity metric. This paper defines basic principles for an extended evaluation, including multi-encounter scenarios and longer look ahead times.

Data Science

Big Data Analytics for a Passenger-Centric Air Traffic Management System
Pedro García, Nommon , José Javier Ramasco, IFISC, Gennady Andrienko, Fraunhofer , Nicole Adler, Israel Hebrew University of Jerusalem, Carla Ciruelos, ISDEFE and Ricardo Herranz, Nommon

BigData4ATM is a SESAR 2020 Exploratory Research project that investigates how new sources of passenger-centric data coming from smart personal devices can be analysed to extract relevant information about passengers' behaviour. In this paper, we introduce the project and present a case study focused on the analysis of door-to-door passenger journeys from mobile phone data. Anonymised call detail records (CDRs) for several million users in Spain are used to infer door-to-door trips for the Madrid-Barcelona corridor and identify the long-distance transportation mode (air,

rail, road) chosen by each user. These door-to-door itineraries are upscaled to the total population using demographic data and used to estimate modal split, airport catchment areas and door-to-door travel times. Estimated modal shares are compared to official statistics to validate the results. We finish by outlining future research directions and discussing how the information extracted from mobile phone records can be exploited to inform decision making in air transport and ATM.

Visual Analytics and Machine Learning for Air Traffic Management Performance Modelling
Rodrigo Marcos, David Toribio, Nommon, Laia Garrigó, Núria Alsina, ALG, Gennady Andrienko, Natalia Andrienko, Fraunhofer, Luca Piovano, UPM, Thomas Blondiau, Transport & Mobility Leuven and Ricardo Herranz, Nommon

INTUIT is a SESAR 2020 Exploratory Research project which aims to explore the potential of visual analytics and machine learning techniques to improve our understanding of the trade-offs between ATM KPAs, identify cause-effect relationships between indicators at different scales, and develop new decision support tools for ATM performance monitoring and management. This paper introduces the project and reports its initial results. We propose a set of research questions on ATM performance identified through a combination of desk research and consultation with ATM stakeholders, we assess the main data sources on ATM performance available at European level, and we map the research questions previously defined to the data sources that are most relevant for each question. To illustrate the role that visual analytics can play in addressing these questions, we present the preliminary results of an ongoing case study focused on analyzing the spatio-temporal patterns of ATFM delays in the European network. We finish by outlining future research directions.

Decision Support Tools

TriControl - A Multimodal Air Traffic Controller Working Position
Oliver Ohneiser, Malte-Levin Jauer, Hejar Gürlük and Maria Uebbing-Rumke, DLR

The TriControl multimodal controller working position (CWP) demonstrates a novel concept for natural human-computer interaction in Air Traffic Control (ATC) by integrating speech recognition, eye tracking and multi-touch sensing. All three parts of a controller command – aircraft identifier, command type and value – are inserted by the controllers via different modalities in parallel. The combination of natural gazes at aircraft radar labels, simple multi-touch gestures, and utterances of equivalent values are sufficient to initiate commands to be sent to pilots. This reduces both controller workload and the time needed to initiate controller commands. The concept promises easy, well-adjusted, and intuitive human-computer interaction.

Probabilistic Runway and Capacity Forecasting using Machine Learning to Support Decision Making
Arjen de Leege, To70 and Ceriel Janssen, KLM

In this paper we present a system that supports airlines to take timely actions to mitigate the impact of runway capacity shortfalls and unforeseen long taxi times on airline performance, and to optimize fuel on board for airborne holding and taxiing. The system makes use of a machine learning technique to provide a 30-hour probabilistic forecast. The system has been validated to ascertain its predictive power and to determine the impact on decision making. The probabilistic forecast matches with the realized use fractions to within 7%. An experiment in using the display indicates

that decisions to cancel flights are made earlier which allows more time to re-route passengers, and better targeting of advices to take extra fuel on board to allow for airborne holding.

CNS Technology

GBAS Interoperability Trials and Multi-Constellation/Multi-Frequency Ground Mockup Evaluation

Thomas Feuerle, Mirko Stanisak, TU Braunschweig, Susumu Saito, Takayuki Yoshihara, ENRI and Andreas Lipp, EUROCONTROL

This paper describes MC/MF GBAS concepts and discusses the provision of a MC/MF ground mockup development and provision for evaluation flight trials which took place in frame of SESAR project 15.3.7 at Toulouse airport in May 2016. TU Braunschweig (TUBS) provided as sub-contractor to EUROCONTROL the ground mockup software to establish a valid MC/MF GBAS signal-in-space (SIS) for the flight trials. In addition TU Braunschweig performed interoperability trials to test the airborne equipment with signals of different GBAS ground stations. This included Multi-Mode-Receiver (MMR) hardware from Thales Avionics as well as software packages from Japan's Electronic Navigation Research Institute (ENRI) and TUBS. The results of these trials will be described and discussed as well. The paper will close with an outlook to planned future activities.

Effect of ADS-B Characteristics on Airborne Conflict Detection and Resolution

Thom Langejan, Emmanuel Sunil, Joost Ellerbroek and Jacco Hoekstra, TU Delft

Most Free-Flight concepts rely on self-separation by means of airborne Conflict Detection and Resolution (CD&R) algorithms. A key enabling technology for airborne CD&R is the Automatic Dependent Surveillance-Broadcast (ADS-B) system, which is used for direct state information exchange between aircraft. Similar to other communication systems, ADS-B is affected by a number of limitations which can be broadly classified as system and situation related deficiencies. This research investigates the impact of these limitations on the viability of using ADS-B for airborne CD&R within the Free-Flight context. Here, `state-based' conflict detection and the modified voltage potential conflict resolution algorithm are used as a case-study. An ADS-B model is developed, and its effect on the aforementioned CD&R method is measured using three fast-time simulation experiments. The experiments studied overall safety with ADS-B, as well as the specific effect of situation related characteristics, i.e., transmission range and interference, on safety. The results indicated that the overall safety with ADS-B was comparable to the case where perfect state information was assumed. Additionally, it was found that increasing ADS-B transmission range also increased signal interference, which in turn lowered safety. This suggests that the degrading effect of ADS-B signal interference should be considered in future airborne CD&R research, particularly for high traffic densities.

Airports

Investigating the Safety-Relevance of Limited Distinctive Features on a Multi Remote Tower-Working Position

Lothar Meyer, LFV and Hartmut Fricke, TU Dresden

The novel concept of controlling multiple airports remotely by just one tower controller at a time promises clear benefits of cost-efficiency and working conditions for aerodrome control services particularly at airports with low traffic density. The increasing amount of information and functionality of input devices places on the other hand new demands on the attention and memory of the tower controller. Helping the controller to distinguish information and to compensate for similarities in the information cues of different sources is of increased importance on a working position with independent operations. Possible confusion and forgetting of safety-relevant information is identified as a possible consequence if the implemented design of the working position offers too little distinctiveness. An experimental study was conducted, using stress test reactions and interviews for verifying the relevance of distinctive features on a multi remote tower-working position. The results reveal that the probability of confusing safety-relevant information cues might increase. In contrast, the test persons demonstrated that the working position does not offer any additional potential of lapses in memory. The final discussion addresses specific means of mitigating the risk involving design issues.

Can LiDAR Point Clouds effectively contribute to Safer Apron Operations?
Johannes Mund, Philipp Latzel and Hartmut Fricke, TU Dresden

The current system of conventional and remote airport ground control still largely relies on the direct visual contact between the ATCO and his objects of interest. Despite supporting video cameras and dedicated radar applications, sudden occurrences in the ATCO`s situational picture may deteriorate safety without further risk mitigating tools or sensors. Especially low visibility conditions and also darkness regularly give rise to capacity backlogs, incidents and accidents. At the same time, LiDAR sensors and computer vision algorithms have made considerable progress in recent years. A combination of both offers the unique capability to allow for the detection of small unknown objects and simultaneously to enable the classification of known objects for distances of up to several hundred meters. This work describes the experimental assessment of the corresponding potential safety benefits for apron operations when using LiDAR sensing to improve the controller`s situational picture. The experiment was designed as a controller-in-the-loop study and was conducted with academic students in an apron control tower simulator. The central metrics gathered were the number of (emerging) hazardous situations that could be recognized by the test person with associated reaction times. Compared to conventional apron control, the hazard recognition rates increased by 18% on average whereas reaction times decreased by 45% for an ideal LiDAR configuration. With regard to individual hazard categories, the contribution to safety was largest for Foreign Object Debris (FOD) scenarios with increased hazard recognition rates of 33%.

Runway Pressure Research
Wouter Vermeersch, Paul Roling, TU Delft and Dragana Mijatovic, LVNL

The Cross-border Arrival Management (XMAN) project, which is part of the Single European Sky program, tries to reduce the negative effects of delay in the proximity of airports. The main idea is to shift the necessary delay from the Terminal Maneuvering Area (TMA) or holding towards the cruise flight phase by reducing the speed of aircraft. Although the shift of delay absorption from the TMA to the en-route phase shows promising results for fuel consumption and reduced emissions, the question rises whether this En-Route Delay Absorption (ERDA) can also have a negative impact on the runway efficiency. If aircraft are delayed too much in an earlier flight phase due to e.g. inaccuracy of the expected arrival times, so called gaps appear in the landing sequence. As a result, the total number of aircraft that actually landed per time period decreases. The idea is that in order to maintain an optimal runway throughput, some expected delay should be left in the TMA for the approach controller to absorb. The approach controller can use this additional time to fine-tune a

tight landing sequence without any gaps that would result in an underused runway when the demand for landings is high. This phenomenon is defined as Runway Pressure. The main goal of this research project is to investigate the effect on the runway throughput when the expected delay is absorbed in the en-route phase. To achieve this goal, different fast time simulations are performed with a model of Amsterdam Airport Schiphol in AirTOp software. Based on the simulation outcomes, it can be concluded that ERDA can sometimes result in a small decrease of runway throughput, with a maximum of one aircraft per rolling hour. By the end of an inbound peak which last two hours, the actual landing time of an aircraft with ERDA is between 30 and 90 s later than the same aircraft with no ERDA. So the inbound peak is enlarged in time and extended with at most one extra landing when ERDA is applied. The benefit is that aircraft spend up to four minutes less in the TMA or holding pattern near the airport.

RPAS

Human and Technical Performance Aspects in RPAS Integration Trials in Controlled Airspace

Jorge Bueno, Carlos Regidor, ISDEFE, David Escribano, CRIDA, María Vega, INTA and Fernando Ferrández, ENAIRE

Flight trials are one important step to assess the viability of RPAS integration in non-segregated and controlled airspace. The DEMORPAS project, with the financing support of the RPAS Demonstrations Programme launched by the SESAR Joint Undertaking, studied the viability of RPAS flying in a controlled airspace shared with manned aircraft by performing two real flight trials where an RPAS and a manned aircraft where provided with air traffic control by different ATC dependencies; ground, tower, approach and en-route. Moreover, specific RPAS aspects such as the need to modify on short notice its initial flight trajectory, emergencies which do not happen in manned aviation or conflicts between an RPAS and a manned aircraft. Our results show that human factors related with the communications between remote pilots and air traffic controllers (ATCOs) need to be improved as well as ATCOs need to be trained to improve the perception of RPAS. Technical aspects such as communications means to enable remote pilots to contact ATC dependencies out of radio line of sight as well as remote pilot situational awareness have to be further studied and validated by future flight trials.

Effects of En-route Wake Vortex on RPAS Operations

Marc Pérez-Batlle, Mònica Marcos and Enric Pastor, UPC

Compared with common airliners, High/Medium Altitude Long Endurance (HALE/MALE) RPAS are lighter and have larger wingspan. Therefore RPAS will be extremely sensitive to vortex interactions with larger airliners, not only during departures and arrivals, but also at medium and high altitudes during the en-route phase. The extent of this sensitivity shall be investigated in order to determine safe levels of separation and come up with feasible maneuvers to avoid the effect of wake vortex under the assumption that the RPAS may become unrecoverable by the autopilot. For this reason, the objective of this paper is to model the generation of en-route vortex and quantify its impact into the airworthiness of a potentially conflicting RPAS. To accomplish this objective, a wake vortex generation and encounter model will be created as a first step to define the airliner-RPAS separation requirements due to the airliner's vortex. Then, vortex separation requirements will be compared to those usually employed for separation assurance. Conclusion will show that some current separation standards are not conservative enough when the RPAS faces an airliner wake vortex.

Human Factors Impact Assessment of RPAS Integration into Non-segregated Airspace
Pablo Sanchez-Escalonilla, David Escribano, Laura Fresno and Leticia Sanchez-Palomo, CRIDA

This study covers one of the most critical operational gaps identified for the integration of Remotely Piloted Aerial Systems (RPAS) into non-segregated airspace, which is the impact on Human Factors. There are relevant aspects of these new actors that may have implications in current ATM environments which have not been investigated yet. The analysis of the results obtained during demonstration flights executed as part of ARIADNA and DEMORPAS projects (both co-funded by SESAR) are presented in this paper. Under the umbrella of those two projects, the first real RPAS flights in European segregated airspace emulating a non-segregated one, took place. The representativeness of the results is ensured by using the SESAR program Human Factor indicators in the assessment of the results. In addition, to provide a truly global overview, the study covers airport, approach and en-route operations, evaluating the impact on air traffic controllers in different operational scenarios, including as notable innovation the assessment of RPAS specific contingency procedures. The results point out the high workload perceived by Air Traffic Controllers (ATCOs) that becomes a limiting factor for the integration of RPAS in ATM environments in the short term. Moreover, this study brings to light the aspects that impact on controllers´ workload for further analysis like RPAS performance, ATC procedures, communication and phraseology between remote pilot-ATCO. Therefore, it is essential to determine necessary steps to move forward towards a safe integration of RPAS into non-segregated airspace.

ATM Operations, Architecture and Performance

Agent-based Modelling and Simulation of Trajectory Based Operations under Very High Traffic Demand
Henk Blom and Bert Bakker, NLR

Thanks to decades of evolutionary development, within conventional air traffic control the collaboration between the planning controller and the tactical controller has been optimized. Under the forthcoming paradigm shift to Trajectory Based Operations (TBO), there is need for a novel optimization of the collaboration of these two layers. Trough agent-based modelling and simulation the authors have recently shown that these two layers can collaborate remarkably well under very high en-route traffic demand. Because this finding applied to a pure airborne self separation TBO concept, the EMERGIA project has applied agent-based modelling and simulation to ground-based versions of this remarkably well performing pure airborne TBO design. The aim of this paper is to present the main EMERGIA results and key findings. One key finding is that through an effective collaboration between TBO and tactical layers ground-based TBO has the potential to safely accommodate high en route traffic demands. The other key finding is that a pure airborne TBO has remarkable advantages over a pure ground-based TBO.

Geometric Separation
Kenneth Barker and Nicholas Korbey, Via Technology

This paper presents a resilient method to manage the combinational complexity of en-route aircraft separation by considering the geometric separation of aircraft routes. Aircraft pairs who's routes are separated are considered separated, whilst the separation of aircraft pairs who's routes are not separated is calculated from the sections of their routes which are not separated.

Improved Flexibility and Equity for Airspace Users during Demand-capacity Imbalance
Nadine Pilon, EUROCONTROL, Sergio Ruiz, Andrada Bujor, ALG, Andrew Cook, University of Westminster and Lorenzo Castelli, University of Trieste

ATFM slot-swapping represents the first step towards the participation of airspace users (AUs) in air traffic management and airport collaborative processes. SESAR is advancing this through development of the user driven prioritisation process (UDPP) to achieve additional flexibility for AUs to adapt their operations in a more cost-efficient manner in the presence of unforeseen demand and capacity imbalances that require the application of delays to flights. The contribution of this paper is twofold: (i) to present the challenges achieved so far with respect to UDPP concepts, in particular regarding fleet delay apportionment and selective flight protection; (ii) to pave the way towards future UDPP concepts through the introduction of enhanced selective flight protection.

Maximizing ATM Cost-efficiency by Flexible Provision of Airspace Capacity
Stefano Starita, Arne Strauss, University of Warwick, Radosav Jovanovic, Nikola Ivanov, University of Belgrade and Frank Fichert, Worms University of Applied Sciences

Inefficient airspace utilization together with an increasing demand make the European airspace network highly congested. This, in turn, generates significant delays and consequent cost increments. We propose to address this demand-capacity imbalance by introducing an optimization model which jointly decides on sector charges and capacities. This has to be embedded into a larger framework where we envisage a change in the Network Manager's (NM) role, from a passive mediator between Aircraft Operators (AOs) and Air Navigation Service Providers (ANSPs) to an active actor which purchases airspace capacity and sells trajectories. A case-study analysis is provided to highlight potential benefits of this approach.

Airspace Management

Dynamic Airspace Sectorisation using Controller Task Load
Ingrid Gerdes, Annette Temme and Michael Schultz, DLR

Within this paper a new approach for a dynamic airspace sectorization based on controller task load is presented. We combine fuzzy clustering, Voronoi diagrams and evolutionary algorithms to create an adaptive and time dependent sectorization regarding to a harmonized controller task load. Our optimization strategy considers a predefined set of evaluation parameters and interim sectorizations are implemented for a smooth transition between the evolutionary adaptations of the sector structure. Furthermore, we developed a method to adapt Voronoi diagrams to a non-convex border. A short overview about the used methods is given and several tests of different evaluation functions are performed. The last part of this paper concentrates on the creation and evaluation of the interim sectorizations.

Towards an Operational Sectorisation based on Deterministic and Stochastic Partitioning Algorithms
Judicaël Bedouet, Thomas Dubot and Luis Basora, ONERA

This paper describes a method combining operational deterministic and stochastic approaches to generate optimised and smooth sector configuration plans. First, sector configurations commonly used within an Area Control Centre (ACC) are sorted according to a set of objectives for each time

period. From these Pareto-optimal solutions, we determine through a stochastic method new sector configurations, mainly unstructured, to improve criteria such as the workload distribution. Then these optimized configurations are remodelled with another stochastic function to compute a set of final configurations acceptable by air traffic controllers. Secondly, we integrate these "good" solutions throughout the day to build the smoothest sector configuration plan possible, using the minimization of a dedicated distance function between successive configurations. Results of the SESAR 07.05.04 VP-755 experiments demonstrate that such methods could improve several criteria at the level of an ACC, such as the French Reims ACC, and pave the way for the development of an automated decision support tool integrating such algorithms.

Integrated Optimization of Terminal Manoeuvring Area and Airport

Ji Ma, Daniel Delahaye, Mohammed Sbihi, ENAC and Marcel Mongeau, Université Paul Sabatier - Toulouse 3

Airports and surrounding airspaces are limited in terms of capacity and represent the major bottleneck in the air traffic management system. This paper addresses the problems of airspace conflicts and airport congestion at a macroscopic level through the integrated control of arrivals and departures. Conflict detection and resolution methods are applied to a predefined terminal route structure. Different airside components are modeled using network abstraction. Speed, time and runway changes are managed via an optimization methodology. An adapted simulated annealing heuristic combined with a time decomposition approach is proposed to solve the corresponding problem. Computational experiments performed on real-world case studies of Paris Charles De-Gaulle airport, show the benefits of this macroscopic level approach.

Hot Spot Identification and Mitigation at Strategic Level by Subliminal Changes in Aircraft Time of Arrival at Junction

Dany Gatsinzi, Francisco Javier Saez Nieto and Irfan Madani, Cranfield University

This paper presents some results obtained when applying a different criterion in Air Traffic Flow and Capacity Management (ATFCM) measures. The approach is based on reducing the probability of controller's reactive interventions by "hot spot" identification and mitigation at strategic level, by applying subliminal changes on the aircraft's Times of Arrival (TOA) at the crossing or merging points (junctions). The concept of this strategy is fully aligned with the Trajectory Based Operation (TBO) principles. It is assumed that the changes on the times of arrival only demand very small speed changes to the involved aircraft (A/C). In this assessment, hot spots are established by identifying groups of closely spaced A/C arriving at a junction. A hot spot isolates the set of A/C involved in multiple conflicts, close in their times of arrival at the junction, violating the minimum required "safe" time separation at the junction. The minimum safe time separation is established based on a chosen threshold for the probability of collision obtained by considering the different sources of uncertainties in the aircraft's time of arrival at junction. Some exercises are proposed and solved by applying this method. The obtained results show its ability to remove the conflicts by applying simple linear optimization programming tool. The effect of this method on the aircraft's operating costs is also analyzed. This approach also seeks to change the current capacity-limiting factor, established by the number of aircraft occupying simultaneously each sector, to another parameter where the level of traffic complexity, flowing towards junctions, will be identified and mitigated at strategic level.

Economics

Hub Operations Delay Recovery based on Cost Optimisation
Luis Delgado, University of Westminster, Jorge Martin, Alberto Blanch and Samuel Cristobal, Innaxis

This paper provides the conclusions after applying Agent Based Modelling to solve different hub airline delay situations. The airlines are provided with different strategies to act when delay is encountered in the different stages. Cost optimisation strategies show that delay is transferred from connecting passengers to non-connecting passengers to reduce the amount of missing connections. The optimisation of costs reaches 0.7% in nominal delay conditions. Scenarios with higher fuel costs show aircraft flying slower to reduce fuel costs, increasing delay costs.

Introducing More Competition into ATM: Possible Institutional Designs
Eef Delhaye and Thomas Blondiau, Transport & Mobility Leuven

This article is based on work done within the H2020 SESAR project COMPAIR. We developed a list of new institutional approaches for air traffic control. The idea being that performance of ATM could be improved if more competitive elements are brought into the system. These concepts are fine-tuned and qualitatively assessed based on a literature review, discussions with the COMPAIR advisory board, interviews and an online survey.

Quantifying Resilience in ATM – Contrasting the Impacts of Four Mechanisms during Disturbance
Luis Delgado, Andrew Cook, Graham Tanner, University of Westminster and Samuel Cristóbal, Innaxis

Using traffic and passenger itinerary data for the European network, the cost resilience of four mechanisms, with phased stakeholder uptake, has been assessed under explicit, local and disperse disturbance: industrial action and weather. A novel cost resilience metric has demonstrated logical properties and captured cost impacts sensitively. Of these mechanisms, only A-CDM has been cost-benefit analysed in SESAR, yet the other three each demonstrate particular utility. Flight-, passenger- and cost-centric metrics are deployed to assess the mechanisms, with fully costed results presented, based on extensive industry consultation. Initial work on assessing mechanism payback periods has begun.

The Economic Value of Adding Capacity at Airports
Gérald Gurtner, Andrew Cook, Anne Graham, University of Westminster, Samuel Cristóbal and Denis Huet, EUROCONTROL

This article presents a model for the economic value of airports. More specifically, it focuses on the mechanisms leading to financial gains and losses coming from an increase of capacity. The model is a simple functional model, but highly data-driven. Indeed, many different sources of data have been collected in this study, and combined to produce insight into the air transport system and quantitative values for the calibration of the model. To our knowledge, it is the first time that such a wide range of financial, operational and quality of service data has been synthesised in one database and used to characterise airport performance. This study presents in detail some of the data

analyses performed in support of the modelling process, as well as the model itself and some preliminary results.

Posters

R-Wake project: Wake Vortex Simulation and Analysis to Enhance En-Route Separation Management *Sergio Ruiz, UPC*

Developing Aircraft Performance Models Using Data Mining *Junzi Sun, TU Delft*

Trajectory Prediction *Julia Rudnyk, TU Delft*

An Empirical Analysis of Airspace Structure and Capacity for Decentralized Separation *Emmanuel Sunil, TU Delft*

ATC Advisory System for the Prevention of Bird Strikes *Isabel Metz, TU Delft*

How learning effect of scenarios in human-in-the-loop studies can influence validation results *Åsa Svensson, Linköping University*

Analyzing behaviour of air traffic controllers: An exploratory visual sequence mining approach *Prithiviraj Muthumanickam, Linköping University*

BEST project *Roland Guraly, Slot Consulting*

Participatory Architectural Change MAnagement in ATM Systems (PACAS): preliminary results *Martina Ragosta, Deep Blue*

COPTRA: Combining Probable Trajectories *Andrea Simonetto, Université Catholique de Louvain*

Behavioural Measurements Comparing Conventional and Remote Tower ATC Operations *Tanja Bos, NLR*

Vista - Market forces trade-offs impacting European ATM performance *Graham Tanner, University of Westminster*

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Augmented and Virtual Reality in the Airport Control Tower: the RETINA concept *Sara Bagassi, University of Bologna*

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Agent-Based Simulation of Decentralized Control for Taxiing Aircraft *Heiko Udluft, TU Delft*

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Coordinated capacity ordering and trajectory pricing for better-performing ATM *Nikola Ivanov, University of Belgrade*

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