7th USA – EUROPE ATM R&D Seminar

July 02-05,2007
Barcelona
Spain

BOOK OF ABSTRACTS

Sessions

Innovative ATM Concepts

COULD ERASMUS SPEED ADJUSTMENTS BE IDENTIFIABLE BY AIR TRAFFIC CONTROLLERS?

[Paper N° 164]

Averty Philippe, DSNA, Toulouse, France
Johansson Björn, Linköpings Universitet, Sweden
Wise John, Honeywell International, Phoenix, Arizona, USA
Capsie Corinne, Sofreavia, Toulouse, France

The interest of using low magnitude speed adjustments as a means of resolving conflicts have recently risen. When implemented early, such changes could be not perceived by Air Traffic Controllers (ATCOs). Thus a significant cognitive resources release can be expected, entailing some benefits for the ATM system (esp. a global capacity improvement). The following work investigates controllers' perception of aircraft speed modifications (ASM). These appeared to be neither easily identified nor clearly differentiable from spontaneous variations (caused by wind, etc.) or pure sensorial impressions by ATCOs. This result is even accentuated for lower magnitudes and better earliness of ASM, and also when a non-conflict diagnosis prevails upon the considered aircraft. On the other hand workload level is not shown having an effect on the perception of ASM.

UNMANNED AIRCRAFT COLLISION AVOIDANCE – TECHNOLOGY ASSESSMENT AND EVALUATION METHODS

[Paper N° 89]

Andrew R. Lacher, David R. Maroney, Dr. Andrew D. Zeitlin
The MITRE Corporation, McLean, VA, USA

Collision avoidance is emerging as a key issue for UAS access to civil airspace. Numerous technologies are being explored in the community to develop a solution for collision avoidance. The problem is multi-dimensional and needs to be addressed at the system level. Requirements for collision avoidance capabilities are complex and vary with the intended airspace of operation and the corresponding potential hazards. The appropriate mitigations are likely to be equally complex. A suite of several sensor technologies is likely to be required in order to address the full set of collision hazards.

The intent of this paper is to present a perspective on the challenges associated with UAS collision avoidance from a civil aviation perspective and to present results from some of MITRE's research addressing collision avoidance technologies and systems performance analysis.

AIR-TRAFFIC COMPLEXITY RESOLUTION IN MULTI-SECTOR PLANNING USING CONSTRAINT PROGRAMMING

[Paper N° 23]

Pierre Flener, Justin Pearson, and Magnus Agren
Uppsala University, Sweden

Carlos Garcia-Avello, Mete Celiktin, and Søren Dissing
EUROCONTROL, Belgium

Using constraint programming, we effectively model and efficiently solve the problem of balancing and minimising the traffic complexities of an airspace of adjacent sectors. The traffic complexity of a sector is here defined in terms of the numbers of flights within it, near its border, and on non-level segments within it. The allowed forms of complexity resolution are the changing of the take-off times of not yet airborne flights, the changing of the remaining approach times into the chosen airspace of already airborne flights by slowing down and speeding up within the two layers of feeder sectors around that airspace, as well as the changing of the levels of passage over way-points in that airspace. Experiments with actual European flight profiles obtained from the Central Flow Management Unit (CFMU) show that these forms of complexity resolution can lead to significant complexity reductions and rebalancing.

SYSTEMATIC AIR TRAFFIC MANAGEMENT IN A REGULAR LATTICE

[Paper N° 115]

Richard Irvine, Horst Hering,
EUROCONTROL Experimental Centre, France

A regular lattice combines two ideas: a repeating (or regular) airspace structure and layers of parallel tracks. A repeating or regular airspace structure has several advantages over an irregular structure. The skills or methods used to control traffic in one part of the structure are applicable throughout the structure. Regularity gives rise to multiple routes between two points with similar distances flown in each direction and at each flight level. Flow management can select routes which distribute traffic over a region. The same mechanism could be used to choose routes which avoid reserved areas. Since the possible routes between two points have similar properties, the selection of an alternative route has a small impact on flight time, contributing to the predictability of airline operations. Properties which apply to an element of the airspace apply wherever that element is repeated, so that reasoning about a small region of the airspace can immediately be scaled up to apply to a much larger region. Layers of parallel tracks eliminate crossing conflicts between aircraft which are flying straight and level. Together with measures to preserve the stability of traffic flows (sufficient spacing, speed regulation, or ASAS sequencing procedures), traffic may be separated into two easily identifiable populations: a "stable" population of cruising aircraft, which require low controller monitoring per aircraft, since there are no crossing conflicts between cruising aircraft, and a population of aircraft in "transition" to or from the stable state, which require greater monitoring. Some preliminary results from fast-time simulations are reported.

NEW AIR TRAFFIC MANAGEMENT CONCEPTS ANALYSIS METHODOLOGY: APPLICATION TO A MULTI-SECTOR PLANNER IN US AIRSPACE

[Paper N° 170]

Kevin Corker, San Jose State University, San Jose, Ca.
Diana Liang, Federal Aviation Administration, Washington, DC
Paul Lee, San Jose State University, San Jose, Ca.
Tom Prevot San Jose State University, San Jose, Ca.

Several developments in the technologies supporting air traffic management (ATM) such as digital communication and improved positioning accuracy for aircraft, have enabled consideration of new organizational and functional operations. One such consideration is a modification of the standard air traffic control team to include a mutli-sector planner (MSP) position. This MSP is being investigated in several research and field studies both in Europe and in the U.S. The feasibility and effectiveness of two of these concept variations was investigated in the current study. The experiment consisted of a pair of one-week human-in-the-loop studies in which the two concepts (Multi-D, in which multiple R-sides are supported by a single D side, and Area Flow, in which the MSP manages flow through their target sector by coordinating with adjacent MSPs., were tested separately with two different 5-person teams, A baseline condition which assumed traditional radar-data roles but with access to advanced decision support tools was also run. Overall, the data suggest feasibility of both variations in the MSP. Workload was manageable for the MSP operations. Area flow operations were found to coordinated with advanced air traffic operations concepts and were shown to be acceptable to the controllers (both R and D side).

IMPROVING ATC EFFICIENCY THROUGH AN IMPLEMENTATION OF A MULTI SECTOR PLANNER POSITION

[Paper N° 130]

Almira Williams, Mark D. Rodgers, Stephane Mondoloni
CSSI, Inc., Washington, DC, USA
Diana Liang
FAA, Washington, DC, USA

This research investigates the introduction of a Multi Sector Planner (MSP) position relative to its potential to provide improvements in the efficiency of using limited ATC resources. The study uses sector Monitor Alert Parameter (MAP) as a simple approximation of workload and traffic complexity, and parametric analysis to determine the range of efficiency improvements that would become possible through the introduction of an MSP position. The research focused on the centers within the contiguous US (regardless of their altitude coverage); however current center area configurations were only considered for the Atlanta ARTCC. The improvement in efficiency of the ATC resource utilization was determined as the percent difference in ATC resources (controller positions) needed to safely monitor and control traffic in the current ATC and in the MSP scenarios. The findings suggest that in the context of current staffing levels, the introduction of the MSP position demonstrates a significant potential to improve the efficiency of ATC resource utilization. It should be noted that the potential improvement depends on the levels of percent MAP utilized at which D-side or MSP controllers would be introduced to support the R-side controllers.

A PSYCHOSOCIAL APPROACH TO UNDERSTANDING PILOT AND CONTROLLER ACCEPTANCE OF CHANGE IN ATM, BASED ON THREE CDA CASE STUDIES

[Paper N° 56]

Andrew Cook, Graham Tanner, University of Westminster, London, UK
Nadine Pilon, Tony Joyce, EUROCONTROL Experimental Centre, Brétigny s/Orge, France

Next generation ATM systems cannot be implemented in a technological vacuum. The further ahead we look, the greater the likely impact of societal factors on such changes, and how they are prioritised and promoted. The equitable sustainability of travel behaviour is rising on the political agenda in Europe in an unprecedented manner.

This paper examines pilot and controller attitudes towards Continuous Descent Approaches (CDAs). It aims to promote a better understanding of acceptance of change in ATM. The focus is on the psychosocial context and the relationships between perceived societal and system benefits. Behavioural change appeared more correlated with such benefit perceptions in the case of the pilots.

For the first time in the study of ATM implementation and acceptance of change, this paper incorporates the Seven Stages of Change model, based on the constructs of the Theory of Planned Behaviour. It employs a principal components (factor) analysis and further explores the intercorrelations of benefit perceptions, known in psychology as the 'halo effect'. Disbenefit perceptions may break down this effect, it appears.

For implementers of change, this evidence suggests an approach in terms of reinforcing the dominant benefit(s) perceived, for sub-groups within which a halo effect is evident. In the absence of such an effect, perceived disbenefits, such as with respect to workload and capacity, should be off-set against specific, perceived benefits of the change, as far as possible.

This methodology could be equally applied to other stakeholders, from strategic planners to the public. The set of three case studies will be extended beyond CDA trials. A set of concise guidelines will be published with a strong focus on practical advice, in addition to continued work enabling a better understanding of the expected, increasing psychosocial contributions to successful and unsuccessful efforts at ATM innovation and change.

COORDINATED ARRIVAL DEPARTURE MANAGEMENT

[Paper N° 102]

Richard Irvine, Horst Hering,
EUROCONTROL Experimental Centre, France

The paper deals with a new concept for the coordination of arrival and departure management when applying mixed mode operations at an airport. It is based on an appropriate tailoring of arrival gaps by automatic introduction of so-called arrival free intervals (AFI) and a corresponding path stretching for the respective arrivals. Thereby the coordination system takes into account both the departure traffic situation on ground and the arrival situation in the TMA, which is contained implicitly in state and planning information coming from controller decision support tools for the arrival and departure management (AMAN and DMAN).

The paper describes the coordination concept with particular consideration of operational and implementation issues. It outlines the required features for AMAN and DMAN and explains the communication between the connected systems. The paper explains in detail the coordination algorithm, which is based on fuzzy rules expressing expertise.

Particular consideration is given to the concept evaluation. The evaluation was done on the example of a traffic scenario which was modified by stochastic disturbances. A large number of simulations were run to enable a comparison of the coordinated and the uncoordinated case. The calculated statistics shows the potential benefits of this coordination concept. The results indicate not only an enhancement of total throughput but also an increase of efficiency, punctuality and predictability of the departure operations on ground.

THROUGHPUT, RISK, AND ECONOMIC OPTIMALITY OF RUNWAY LANDING OPERATIONS

[Paper N° 162]

Babak G. Jeddi, John F. Shortle, Department of Systems Engineering and Operations Research, George Mason University, Fairfax, Virginia

This paper analyzes the optimal level of operations on a single runway used only for arrivals. Two risks associated with landing procedures are the risk of a wake vortex encounter and the risk of simultaneous runway occupancy. We develop optimization models to maximize successful landing operations while mitigating these risk factors. The risks are mitigated by enforcing *go-around* procedures when separation distances are too small. In our capacity optimization, we assume that the go-around procedures are strictly enforced (making the operations risk-free) and their execution is absolutely safe. We develop two models as decision support tools which mimic the system dynamics and provide new insights into the landing process. One model maximizes the risk-free throughput (number of successful landings per unit of time) with and without wake-vortex effects. The second model accounts for dollar benefits and go-around costs in optimizing the system operations' level. This model maximizes expected net economic outcome (total dollar benefits minus total go-around costs) by adjusting the rate of landing attempts. Through these models, we calculate the maximum (risk-free) achievable throughput in the system. This provides a new definition of the *landing capacity* of the runway taking into account the probabilistic behaviour of operations. Several numerical examples are given.

EFFICIENT AND EQUITABLE DEPARTURE SCHEDULING IN REAL-TIME: NEW APPROACHES TO OLD PROBLEMS

[Paper N° 66]

Hamsa Balakrishnan, Massachusetts Institute of Technology, Cambridge, MA. hamsa@mit.edu
Bala Chandran, University of California, Berkeley, CA. chandran@ieor.berkeley.edu

The efficient scheduling of departure runways is an important part of surface operations planning, with the goal of increasing the throughput of airports. Departure scheduling is a complex problem that needs to address the needs of diverse stakeholders including the airport operators, air traffic control and the airlines. The challenge lies in optimizing different objective functions such as maximizing departure throughput, minimizing average delay, and ensuring fairness among the airlines, while simultaneously enforcing wake-vortex separation minima, safely accommodating active runway crossings by arrival aircraft, and complying with downstream flow constraints imposed by the terminal airspace, in a dynamic and uncertain environment.

This paper presents a new class of techniques based on dynamic programming that can determine, in real-time, efficient departure schedules that satisfy the various upstream and downstream constraints imposed on the departure runway system, thereby providing a valuable asset to departure management.

Active ATM Performance Management

FIVE YEARS EXPERIENCE IN ATM COST BENCHMARKING

[Paper N° 94]

Giovanni Nero, Sébastien Portet
EUROCONTROL Performance Review Unit
Brussels, Belgium

Since 2003 the PRC releases annual ATM/CNS cost-effectiveness (ACE) benchmarking reports. These reports are based on mandatory information disclosure provided by the European Air Navigation Services Providers (ANSPs) to the PRC. They comprise factual data and analysis on cost-effectiveness and productivity, including historic and forward-looking trend analysis. The scope of the ACE reports is both en-route and terminal navigation services (i.e. gate-to-gate). The main focus is on the ATM/CNS provision costs as these costs are under the direct control and responsibility of the ANSP. Costs borne by airspace users for less than optimal quality of service are also considered. The report describes a performance framework for the analysis of cost-effectiveness. The framework highlights three key performance drivers contributing to cost-effectiveness (productivity, employment costs and support costs). In 2006, the Performance Review Unit (PRU) commissioned NERA to carry out an econometric analysis of ANSPs costs using ACE data for the period (2001-2004) to examine ANSPs relative cost efficiencies. This more normative analysis sets out a methodological framework based on sound economic theory. Stochastic Frontier Analysis (SFA) is used to attempt to identify cost inefficiencies. However, the model estimation is affected by several problems, including the too small size of the sample, multicollinearity and, the fact that potential exogenous factors are not identified.

ESTIMATING CAPACITY REQUIREMENTS FOR AIR TRANSPORTATION SYSTEM DESIGN

[Paper N° 62]

Shannon Zelinski and Tom Romer
NASA Ames Research Center, Moffett Field, California, 94035, USA

This paper discusses a method for estimating minimum air transportation system capacity requirements using proposed future operational demand cases. Demand profiles are generated by simulating a zero-delay day in the National Airspace System. These demand profiles are then used to estimate the minimum required capacities to satisfy the demand with reasonable delay. The necessary capacity for a given demand case is defined by maximum hourly airport operating rates and en-route sector loadings. Demand cases may vary by operation growth, business model shifts, and route structures. Several demand models and their implications for future air transportation system design are discussed.

EVALUATING THE PERFORMANCE OF NEXTGEN USING THE ADVANCED CONCEPTS EVALUATION SYSTEM

[Paper N° 145]

Frederick Wieland, Greg Carr, George Hunter, Alex Huang, Kris Ramamoorthy
Sensis Corporation, Seagull Technology Division, Campbell, California USA

This paper describes a delay analysis of the Next Generation Air Transportation System (NextGen), as it was envisioned in the summer of 2006, using the Advanced Concepts Evaluation System (ACES). The operational concepts underlying NextGen are described, followed by the modeling techniques and assumptions used. The resulting performance analysis utilizes both good and bad weather days, and accounts for both terminal-area weather effects and time-varying enroute convective weather. The NextGen performance is evaluted using flight delay metrics, and is analyzed in terms of the overall mean as well as the distribution of the delay, which is found to fit a leptokurtic Power Law curve. Results suggest substantial delay savings of the order of tens of millions of dollars per day system-wide with the implementation of end-state NextGen concepts.

EXAMINING THE TEMPORAL EVOLUTION OF PROPAGATED DELAYS AT INDIVIDUAL AIRPORTS: CASE STUDIES

[Paper N° 111]

Andrew M. Churchill, Department of Civil and Environment Engineering, University of Maryland, College Park, MD, churchil@umd.edu
David J. Lovell, Department of Civil and Environmental Engineering and Institute for Systems Research, University of Maryland, College Park, MD, lovell@eng.umd.edu
Michael O. Ball, Robert H. Smith School of Business and Institute for Systems Research, University of Maryland, College Park, MD, mball@rhsmith.umd.edu

Delay propagation is a well-known phenomenon within the global air transportation system. Specifically, because of equipment and crew connectivity, a flight delayed early in the day can induce delays to multiple flights later in the day. In this paper we investigate this phenomenon by developing a statistical model that predicts the average flight delay after a given breakpoint time *b*, based on the average delay before *b*. We then vary *b* and are able to quantify the extent of delay propagation and understand its temporal evolution. We estimate this model for several U. S. airports and are able to compare these airports with respect to their delay propagation characteristics.

DEVELOPMENT OF AN ALGORITHM TO MODEL THE LANDING OPERATIONS, BASED ON STATISTICAL ANALYSIS OF ACTUAL DATA SURVEY (PROESTOP)

[Paper N° 27]

Carlos Barbas, Javier Vázquez, Pablo López.
INECO S.A., Avda. Partenón 4 28042 - Campo de las Naciones, Madrid, Spain

This paper presents the overall method followed to develop the stochastic algorithm based on Montecarlo simulations used by PROESTOP, a tool that estimates the runway occupancy time for arrivals (ROTA) and provides new exit taxiways optimum allocation on a given scenario. The tool, developed by INECO, is currently in use in different projects, namely the development and revision of Spanish airports master plans, the SPADE project within the VI EU Framework Programme and more recently, after the acquisition of a license, in support to studies carried out by EUROCONTROL. This paper describes the whole process from the review of existing methods to the final validation of the model: Reasons for actual data need, and existing models deficiencies are mentioned and illustrated. Data survey design, execution and post-process is presented, including estimation of errors, outliers identification and fitting regression models. Discussion of most influence variables on ROTA, based on statistical analysis, is summarised. An alternative clustering of aircraft models attending their performances is introduced. An Estimated Logistic regression model is described to estimate the exit taxiway probability. Different alternative speed functions along the runway are presented and compared with actual landing data. The steps required to deal with a stochastic model based on Montecarlo simulations are described. The use of standard (Normal, Erlang, etc.) and non-standard (Johnson curves) probability distribution for fitting the input variables was introduced. Description and outcomes of the validation process are presented. And, finally, the current applications of the tool are mentioned.

CALIBRATING AGGREGATE MODELS OF FLIGHT DELAYS AND CANCELLATION PROBABILITIES AT INDIVIDUAL AIRPORTS

[Paper N° 121]

David J. Lovell and Andrew M. Churchill, Department of Civil and Environmental Engineering and Institute for Systems Research, University of Maryland, College Park, MD,
Amedeo R. Odoni, Operations Research Center, Massachusetts Institute of Technology, Cambridge, MA,
Avijit Mukherjee, University Affiliated Research Center, University of California (Santa Cruz), Moffett Field, CA,
Michael O. Ball, Robert H. Smith School of Business and Institute for Systems Research, University of Maryland, College Park, MD

This paper describes methods to calibrate aggregate models of internal delays and cancellations at a single airport. Internal delays are those specifically related to queuing effects at the arrival airport; i.e., they are induced because of a local imbalance between demand and capacity. Together with cancellations, these delays reflect important measures of system performance that are directly affected by carrier scheduling policies, as well as airport and FAA decisions about operating policies that affect capacity. We are concerned with models that might be able to produce outputs that are specific to carriers, but in any event cannot be calibrated with proprietary information, because the issues concern multiple carriers or are approached from the public perspective. Such models are appropriate, for example, when considering operational impacts of demand or capacity changes resulting from changes in

infrastructure, resource allocation, or landing fees.

Thus, the ground truth calibration data must come from publicly available aggregate data bases. The models themselves are unaware of some of the true drivers for cancellations and delays, and rely more on empirical correlations between these performance measures and public supply and demand information. The paper describes our experiences and recommendations about calibrating such models, including data filtering methods. Specific examples from our own efforts at model development are included, but the calibration methods described herein should be applicable to alternative model forms as well.

AIRSPACE COMPLEXITY MEASUREMENT: AN AIR TRAFFIC CONTROL SIMULATION ANALYSIS

[Paper N° 52]

Parimal Kopardekar, NASA Ames Research Center, Moffett Field, CA, USA
Albert Schwartz, Sherri Magyarits, and Jessica Rhodes, Federal Aviation Administration, Atlantic City, NJ, USA

This paper describes results of a dynamic density (DD) human-in-the-loop simulation and DD model development activity that was designed to examine the complexity measures. DD measures that were presented at the US/Europe ATM 2003 Seminar were used in the analysis. This study differed from the previous one in three aspects: first, the simulation included Reduced Vertical Separation Minima procedures, second, the study focused on the Cleveland Air Route Traffic Control Center's airspace where previous study results showed the weakest correlation, and third, the traffic was actively controlled during the simulation, whereas in the previous study, audio/video replays were shown. The results indicated that the DD metric performed better than aircraft count, which is the basis of the presently used complexity gauge, and that the new DD model performed better than the previous model for Cleveland Center.

VALIDATION OF REQUIRED SURVEILLANCE PERFORMANCE (RSP) ACCURACY

[Paper N° 61]

John W. Andrews, Steven D. Thompson
M.I.T. Lincoln Laboratory, Lexington, MA 02420-9185

Required Surveillance Performance (RSP) offers a framework in which new surveillance systems can be approved for use when they meet operationally relevant performance standards without regard to the particular technologies employed by the system.

This paper is concerned with the problem of validating that a proposed system meets RSP measurement accuracy standards. An established form for an accuracy test is the Close Approach Probability (CAP) criterion. When an absolute level-of-safety metric is employed, the CAP test requires determining the probability density that lies far into the tails of the separation error distribution. This paper demonstrates that the inability to know with certainty the form of the error distribution is a formidable obstacle to validating such a criterion. However, when a relative safety approach is employed, validation is less demanding. In this case we show that a simple alternative formulation known as the variance ratio test is equivalent to the CAP test.

WEATHER INDEX WITH QUEUING COMPONENT FOR NATIONAL AIRSPACE SYSTEM PERFORMANCE ASSESSMENT

[Paper N° 24]

Dr. Alexander Klein , Air Traffic Analysis, Inc, Fairfax, VA
Richard Jehlen , Diana Liang , The U.S. Federal Aviation Administration, Washington, DC

The impact of inclement weather – especially convective weather – on the National Airspace System (NAS) is a significant factor affecting NAS operational outcomes such as delays and user costs. It is important to develop objective measures of the combined impact of traffic demand and weather on the air traffic system. Previous efforts have led to the development of Weather Impacted Traffic Index (WITI) metric, a weighted sum of the en-route and terminal weather impact, which we have enhanced further by adding a queuing delay component. The three components are computed for OEP-35 airports on an hourly basis, allowing for a more in-depth analysis of operational impacts. This includes apportioning the impact of en-route convective weather to the affected airports (just as delays manifest themselves at airports). The new metric, the NAS Weather Index (NWX), has higher correlation with the ASPM Delay metric than earlier WITI versions. We have applied this methodology to the analysis of 2004-2006 NAS performance vis-à-vis operational impacts. The NWX metric can be produced on an hourly, daily or monthly basis, NAS-wide or regionalized. It is planned to be used for the FAA's morning briefings, long-term post-season reviews, and future-NAS analyses. Future work includes developing methods for NAS outcome prediction based on weather forecast.

WEATHER NORMALIZATION FOR EVALUATING NATIONAL AIRSPACE SYSTEM (NAS) PERFORMANCE

[Paper N° 163]

Mark Hansen, Jing Xiong, University of California at Berkeley, NEXTOR, Berkeley, CA, USA

The need to benchmark air traffic management performance, predict future performance, and improve our understanding of air traffic operations has created a growing literature on the statistical modeling of delays in the National Airspace System (NAS). This paper contributes to that literature in three distinct ways. First we introduce an innovative delay metric that avoids the distortions created by schedule padding and can be decomposed into different flight phase components. Second, we examine closely how daily variation in weather-impacted traffic affects operational performance. Third, we consider the impacts of weather forecast errors as well as realized weather. Our results demonstrate the value of the new delay metric, show that simple daily averaging adequately captures the effect of weather-impacted traffic, and reveal that false-positive weather forecast errors are a significant source of delay in the NAS.

Safety in ATM

OPERATIONAL RISK ASSESSMENT FOR AIRSPACE PLANNING

[Paper N° 107]

Karim Mehadhebi
Direction des Services de la Navigation Aérienne
Toulouse, France

ICAO policy requires that States maintain an *acceptable level of safety* in the provision of air traffic services (ATS). As a consequence, airspace planners have to adapt this high level safety requirement in the context of their specific operational environment, whenever they implement a new procedure. The main difficulty lies in the nature of the risk, which, over the years, has gradually switched from a *technical risk* (due to either a failure or a poor performance of technical equipment) to an *operational risk.* In other terms, although the performance of navigation and surveillance has drastically improved over the years, the level of safety (expressed in terms of fatal accidents per flying hours) has not followed the same evolution. One of the reasons is that, for some scenarios of operational errors, the accuracy of navigation contributes to increase the risk of collision, as we show in the sequel of this paper.

In this paper we span the current methodologies used for quantitative risk assessment, and we explain their limitations for modeling scenarios of operational errors. Then, we introduce a new methodology, supported by an analytical collision risk modeling together with a software implementation, and we present two applications of this methodology, one involving the assessment of the operational risk in a given part of the airspace, and another one for the detection of "hot spots".

SAFETY ANALYSIS METHODOLOGY FOR ADS-B BASED SURVEILLANCE APPLICATIONS

[Paper N° 58]

Jonathan Hammer, The MITRE Corporation
Gilles Caligaris, EUROCONTROL
Marta Llobet, Sofréavia

The introduction of ADS-B as a surveillance source for both air-to-air and air-to-ground operational use presents many new challenges. While it is possible to use ADS-B for a variety of surveillance applications, development of requirements for these applications requires safety assurance. With the potential disparate uses of ADS-B, a common framework for safety analysis is of paramount importance, both for reducing the time needed for acceptance of new applications, and for providing a common basis for key safety requirements.

This paper describes a method of safety analysis of ADS-B applications that has been agreed to internationally by United States' and European standards bodies. The analysis is structured in two parts: an operational hazard identification and assessment (OHA), followed by an allocation of safety objectives and requirements (ASOR). The OHA identifies hazards and classifies their severity while the ASOR allocates safety

requirements to both ground and airborne functions. The safety analysis methodology includes an analysis of hazard causes, likelihoods, internal and external mitigation means, and the potential effects of hazards on safety, known as operational effects.

Although the analysis techniques themselves have a firm standing in government and industry, what is novel is the application of the techniques to the unique problems of ADS-B, and the framework surrounding the analysis that allows for continued development of ADS-B applications. An example of the analysis is presented for a specific ADS-B application, known as the "Enhanced Air Traffic Service in Non-Radar Areas using ADS-B surveillance (ADS-B-NRA)." This application is important because of its expected near-term use in multiple countries and because the analysis represents the first internationally agreed safety analysis for ADS-B.

A QUANTITATIVE MODEL FOR EN ROUTE ERROR RATE ANALYSIS

[Paper N° 20]

Daniel Murphy, Federal Aviation Administration, Washington, DC
Gerald Shapiro, The CNA Corporation, Alexandria, Virginia

In this paper we demonstrate that the rate of en-route operational errors increases faster than the increase in traffic. We propose a model that explains this relationship, which allows us to compare operational error rates for periods with different traffic levels. We use this model to show that URET, a controller decision support tool recently deployed by the FAA, has significantly reduced the rate of operational errors. These results have important implications for analyzing the safety and capacity impact of new en-route automation systems being proposed as part the next generation air transportation systems for the United States and Europe.

SAFETY RISK ANALYSIS OF RUNWAY INCURSION ALERT SYSTEMS IN THE TOWER AND COCKPIT BY MULTI-AGENT SYSTEMIC ACCIDENT MODELLING

[Paper N° 51]

Sybert H. Stroeve, G.J. (Bert) Bakker, Henk A.P. Blom
National Aerospace Laboratory NLR, Amsterdam, The Netherlands

Runway incursion alert systems in air traffic control towers and cockpits are intended to reduce runway incursion risk. Analysis of the effectiveness of such systems is challenging, because of the context-dependent distributed and dynamic interactions of multiple human operators and technical systems in a runway incursion scenario. Recent views in the safety literature indicate that for risk assessment of such complex scenarios, we need systemic accident modelling, which considers accidents as emergent phenomena from the performance variability of a system. This paper uses multi-agent situation awareness as a prime concept for systemic accident modelling of a runway incursion scenario. Accident risk results are provided for the effectiveness of alert systems in the tower and cockpit for various contextual conditions.

AN ANALYSIS OF OPERATIONAL ERRORS AND THE INTERACTION WITH TCAS RAS

[Paper N° 131]

Garcia-Chico, José L. & Corker, Kevin M., PhD, San José State University, CA

This research evaluated operational errors (OEs) in Air Traffic Control (ATC). It consisted of two exploratory studies. The first one was a classification of OEs and contextual factors. The second one was an in-depth look at OEs that co-occurred with a Traffic Alert Collision Avoidance System (TCAS) Resolution Advisory (RA) onboard. The results provided a systematic characterization of OEs, with potential use to prioritize future research and interventions. Patterns of error in en route and terminal airspace were found to be slightly different. The absence of D-side controllers and the presence of developmental controllers were associated with higher proximity between aircraft. The second study found evidence of deficient pilot-controller communications during TCAS RA events in the OE reports. The results suggest that, the likelihood of receiving vertical clearances in opposite direction to the RA is higher when the information from the pilot to the controller regarding the RA is incomplete. These findings suggest the need to revisit the concept of down linking RA information to ATC.

OPERATIONAL IMPACT OF RA DOWNLINK: RESULTS OF A REAL-TIME SIMULATION

[Paper N° 84]

Stanislaw Drozdowski & Doris M. Dehn, EUROCONTROL, Brussels, Belgium
Jürgen Teutsch – National Aerospace Laboratory of the Netherlands (NLR)
Bernd Lorenz – EUROCONTROL, Budapest, Hungary

If the Airborne Collision Avoidance System (ACAS) identifies an imminent collision, it issues a Resolution Advisory (RA). The RA takes precedence of Air Traffic Control (ATC) instructions and the air traffic controller should not interfere with the according collision avoidance manoeuvre. To date, the only source of information for the controller to know about the RA is the pilot report. However, pilot reports of RAs are often incomplete, delayed, incorrect or even missing. This introduces ambiguity about tasks and responsibilities of pilots and controllers. One option to address this problem consists in downlinking RAs for display at the controller working position (CWP). The present paper gives an overview of EUROCONTROL's Feasibility of RA Downlink Study (FARADS) and describes the results of one of the experiments that have been conducted to determine the impact of RA downlink on the controller's performance, situational awareness and workload. The results of the experiment point to operational benefits of RA downlink. Contradictory clearances to aircraft involved in an RA were exclusively observed in the absence of RA downlink. Controllers' recollection of RA events caused by pilot or controller error was superior if RA downlink was provided. Furthermore, there was no evidence for negative effects of RA downlink, such as cognitive tunnelling on the RA event and a lower ability to separate other traffic in the sector.

SO IT'S RELIABLE BUT IS IT SAFE? A MORE BALANCED APPROACH TO ATM SAFETY ASSESSMENT

[Paper N° 41]

Derek Fowler, Gilles Le Galo, Eric Perrin, EUROCONTROL, Brussels, Belgium
Stephen Thomas, Entity Systems Ltd, UK

There is a view, reflected in some safety-critical software research in the USA and in experience of safety assessments in Air Traffic Management in Europe, that safety stems largely from reliability of systems.

Whilst that view may be appropriate for systems that are simply inherently dangerous (nuclear power plants for example), it would be far too narrow for the more general case of systems that have a specific safety-related purpose to fulfil – for example, car airbags, flight control systems and ATM – since it would exclude consideration of the positive contribution that such systems are required to make to the safety of their operational environment, host system etc.

The paper discusses the implications of this issue for ATM and, whilst acknowledging that this limitation may not have been a major problem in the past (because of the hitherto gradual evolution of ATM systems) it explains why a pre-occupation with system failure (at the expense of functionality and performance) cannot be sustained in the face of more radical changes being considered for ATM over the next 20 years or so.

The paper then presents a new framework, for a broader approach to ATM safety assessment, in the form of a high-level safety argument. It covers what are known as success and failure approaches: the former is concerned with ensuring that ATM systems / services actually deliver the necessary reduction in aviation risk (ie contribute to the prevention of aircraft accidents) when functioning as required; whilst the latter is concerned with ensuring that there would be no significant increase in risk (ie cause, or fail to prevent, accidents) in the event of system malfunction.

The description of the framework is illustrated with examples from recent and current EUROCONTROL work on ATM operational concepts.

A SYSTEMIC MODEL OF ATM SAFETY: THE INTEGRATED RISK PICTURE

[Paper N° 167]

Eric PERRIN, Barry KIRWAN, EUROCONTROL, France, Ron STROUP, FAA, US

There are many new concepts being developed for future ATM, e.g. conflict detection and resolution systems, new traffic management and airport throughput systems, etc. Each can have its own safety assessment and assurance programme. But the future vision of e.g. 2020, may involve a number of such new tools or systems or concepts. This raises a number of questions:

- What is the safety assessment of the overall system?
- How might these new elements interact?
- Are there negative interactions that can be avoided, or even positive interactions, as yet unplanned into the system design concept, which could yield extra safety?
- Where are the strong and weak safety areas in the overall system?
- Is the resultant system risk sensitive to the sequence and timing of implementation?

These are not easy questions, but deserve an answer. Therefore an Integrated

Risk Picture (IRP) is being developed within EUROCONTROL which has as its scope gate-to-gate operations. This development is closely co-ordinated with the FAA within the scope of the FAA/EUROCONTROL Action Plan 15 on Safety. What is being achieved in this paper is the description of the baseline risk picture for 2005 and the risk picture for 2012 (predictive mode for the Single European Sky implementation). Lessons learnt related to practical techniques for risk analysis are provided as well.

IDENTIFICATION AND ANALYSIS OF PROXIMATE EVENTS IN HIGH DENSITY ENROUTE AIRSPACES

[Paper N° 63]

Eduardo José García González, INECO, Madrid, Spain
Francisco Javier Sáez Nieto, Polytechnic University of Madrid, Madrid, Spain
Maria Isabel Izquierdo, EUROCONTROL, Bruselas, Bélgica

A 3D Collision Risk Model (CRM) is being developed by EUROCONTROL as a method of assessing the European en-route risk, due to all causes and across all dimensions within the airspace. This model is expected to be able to provide an estimation of the current risk in a suitable metric, providing measurements of the peak risks in terms of time, geographical location or traffic density. For the moment, current activities are focused in the en-route part with view to extend the work in the near future to the terminal area.

The first part of this paper describes a CRM software prototype designed to handle large volumes of flight data in an efficient way with a high level of automation to identify and analyze proximate events.

The second part of the paper presents a new method based on track segmentation to overcome the current limitations of the model.

Finally, both methods are tested and compared using a one-day traffic data sample provided by MADAP (Maastricht Automatic Data Processing and Display System) servers.

MODELLING AND ESTIMATION OF SEPARATION CRITERIA FOR AIRBORNE TIME-BASED SPACING OPERATION

[Paper N° 137]

Ítalo R. de Oliveira, Paulo S. Cugnasca, University of São Paulo, Brazil
Henk A.P. Blom, Bert (G.J.) Bakker, National Aerospace Laboratory NLR, The Netherlands

Airborne Spacing procedures are amongst the several ATM innovations that aim to delegate part of the aircraft separation responsibility to the flight crew. In particular, airborne time-based spacing (TBS) has been developed and tested with success in many experiments in the recent years. However, there is still little knowledge about hazardous events probabilities in this application, such as the ones related with separation loss.

This paper presents a study formulating the risk evaluation problem as the estimation of the probability of occurring separation loss events for a large scale stochastic hybrid system. The large size of the system state space poses challenges to the Monte Carlo simulation of these rare events. This paper applies a recently developed novel method for speeding up rare event Monte Carlo simulations to the TBS concept of operations.

Integrated Airport Management

PREDICTION OF OPERATIONAL FAILURE STATES AT AIRPORTS BY MEANS OF STOCHASTIC TRANSITION MATRICES

[Paper N° 11]

Daniel Schaad, German Aerospace Center DLR, Braunschweig, Germany

Airports are complex multivariate systems where large numbers of interdependent parameters contribute to the overall operational performance. Consisting of many structurally different subsystems, airports tend to lack functional transparency and thereby impede proper situational awareness for operational management. This is specifically critical in conditions where system malfunctions cause operational irregularities which require ad-hoc recovery action.

Transition matrices are a mathematical description of dynamic changes between system states. They can be generated from a given set of state observations to reflect the dynamic behaviour of complex multivariate systems. In connection with airside process monitoring initiatives as part of the CDM (Collaborative Decision Making) concept, transition matrices can provide decision support to assess and predict critical failure states at airports. A decision support tool based on transition matrices may then be imbedded into other applications used for the operational management at airports.

The transition matrix methodology clearly represents a holistic approach to airport systems as it measures the status of global airport parameters and detects deviations from nominal states as failures. By constantly monitoring these system states, transition matrices are generated to statistically reflect functional dependencies and failure propagation within the system. After a certain “learning” phase, these matrices can then be used to predict failure states on the basis of a given status quo. This provides a basis to assess the criticality of a situation and to develop reactive strategies in a timely manner. Moreover, forecasts can be used to perform a “what-if probing” to analyze the expected outcome of planned corrective measures.

The transition matrix methodology has been described and applied to several test scenarios in order to demonstrate the matrix learning effect and its derived forecasting capability. The key elements of this methodology, its motivation and first results will be presented in this paper.

PREVENTING SELFISH BEHAVIOUR IN DISTRIBUTED TACTICAL AIRPORT PLANNING

[Paper N° 109]

Geert Jonker, Frank Dignum and John-Jules Meyer, Utrecht University, The Netherlands
Henk Hesselink , National Aerospace Laboratory NLR, The Netherlands

In this paper, we sketch a future scenario in which arrival, gate and departure planning is done distributedly by airlines, airports, aircraft and other parties involved. Decision responsibility is shared among multiple parties instead of one. When disruptions occur, plan repair schemes are collaboratively constructed and selected. This results in a plan repair mechanism that takes into account the preferences of all participants. Often in distributed planning research, a cooperative attitude of the participants is assumed. However, it is possible that participants will show a competitive rather than a cooperative attitude. Competitive behaviour can lead to suboptimal performance, as participants care more about their own preferences than those of others. Thus, incentives for cooperative behaviour are needed. We propose the use of money as a means of providing incentives to collaborate, to ensure equitability and to find optimal solutions. We identify a problem that occurs with the use of ordinary money. We introduce a monetary system based on spender-signed money that solves the problem of selfish behaviour.

VALIDATION RESULTS OF AIRPORT TOTAL OPERATIONS PLANNER PROTOTYPE CLOU

[Paper N° 75]

Andreas Pick, German Aerospace Center DLR, Braunschweig, Germany

The air transport traffic will grow. The airports have to handle this traffic with their facilities that have limited resources, especially runways, taxiways and stands. Air traffic control has to handle this traffic in the same limited airspace. Airlines have to ensure the punctuality of their flights for the passengers. The only way to get along with the future traffic without building new facilities and under valid safety regulations is to use the existing resources in a more efficient way. Holistic planning systems and information sharing has become a major field of research for the ATM research community. First concepts and prototypes have been developed to understand and handle the complexity. Of course, there are expectations in such systems, and they have to be evaluated and validated: does a holistic planning system improve punctuality and resource use at airports?

This paper will answer this question for the cooperative local resource planner CLOU, a prototype of a total operations planner that was designed and implemented as a decision support tool. CLOU generates target times for each arriving and departing aircraft within the next hours and uses target functions, given by the stakeholders airline, ATC and airport to meet their wishes.

To understand the presented results, the planning process is outlined; the validation scenarios described and special validation results are discussed.

A-SMGCS VERIFICATION AND VALIDATION RESULTS FROM THE PROJECT EMMA (LEVEL 1&2)

[Paper N° 55]

Jörn Jakobi, DLR, Braunschweig, Germany
Jürgen Teutsch, NLR, Amsterdam, The Netherlands

A-SMGCS is a modular system defined in the ICAO Manual on Advanced Surface Movement Guidance and Control Systems (A-SMGCS) [8]. Such systems aim to "*maintain the declared surface movement rate under all weather conditions within the aerodrome visibility operational level (AVOL) while maintaining the required level of safety*". With the complete concept of an A-SMGCS, air traffic controllers (ATCO), flight crews, and vehicle drivers are assisted with surface operations in terms of surveillance, control, routing/planning and guidance tasks. To harmonise the implementation of the first two levels of A-SMGCS, which focus on surveillance and conflict monitoring, and to further mature the necessary technology and operating procedures, the European Commission funded the project EMMA (European airport Movement Management by A-SMGCS) within the sixth framework programme. Within EMMA, A-SMGCS level 1&2 systems were installed at three European mid-size airports: Milan-Malpensa, Prague-Ruzyně, and Toulouse-Blagnac. Technical and operational trials were conducted at all three sites to verify the technical performance against the requirements and to prove operational feasibility. Additionally, realtime simulations were performed in order to tune parameters of the monitoring and alerting function and to also assess operational improvements under experimental conditions. This paper presents the EMMA validation approach, the main findings and results as well as lessons learnt of the first project phase (2004-2006).

Dynamic Airspace Management

PREDICTING SECTOR CAPACITY FOR TFM

[Paper N° 38]

Lixia Song, Craig Wanke, Daniel Greenbaum, The MITRE Corporation, McLean, VA

A novel approach to sector capacity prediction for airspace congestion management is presented, in which traffic complexity is captured with traffic flow patterns. Predictability of flow features are quantified and considered in describing the traffic flow patterns. Quantifying sector capacity as a function of traffic flow pattern provides a good approximation of the amount of traffic that can be effectively handled in the sector. The sector capacity for each traffic flow pattern is established based on observed system performance to avoid direct measurement of controller's workload and predefining workload threshold. Such a "predictable" sector capacity metric also provides a basis for capturing weather impact on sector capacity.

AIRSPACE CONFIGURATION USING AIR TRAFFIC COMPLEXITY METRICS

[Paper N° 108]

David Gianazza, DSNA, Toulouse, France

Flow regulation is a critical process in air traffic management, ensuring that the incoming traffic does not exceed the ability of air traffic controllers to handle it safely and efficiently. Currently, the European Flow Management Positions (FMP) use flight counts and sector capacities to assess the traffic load and build predicted opening schemes. These schemes, made of predefined airspace configurations, are used to detect potential overloads. Some past research undertaken at the Global Optimization Laboratory led to think that this process was not grounded on solid scientific notions, as concerns the quantification of the controllers workload. Consequently, it is proposed to stop using flight counts and sector capacities to predict this workload, and to use relevant air traffic complexity metrics instead. Another proposal is to explore all the possible combinations of elementary sectors, instead of the small subset of pre-defined configurations currently being used, so as to offer the maximum capacity to the incoming traffic.

In previous works, we assessed the relevance of complexity metrics by comparing their relative influence on the sector status prediction (merged, manned, or split) made by a neural network. Real sector statuses issued from filed configurations were used to train the neural network. A fairly simple relationship between the relevant metrics and the sector status was found. The main contribution of this paper is to use the relevant metrics and the sector status prediction to build realistic airspace configurations. The computed configurations are compared to the actual configurations archived by the ATC centers, and to the FMP opening schemes.

NEW PROCESS FOR "CLEAN SHEET" AIRSPACE DESIGN AND EVALUATION

[Paper N° 91]

Robert S. Conker, Debra A. Moch-Mooney, William P. Niedringhaus, Brian T. Simmons,
The MITRE Corporation, McLean, Virginia

The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) has developed a semi-automated capability to conduct large-scale airspace design. The process is intended to replace traditional methods of developing alternative airspace designs with an approach that is not only more efficient, but also more objective, transparent, and repeatable. The approach outlined in this paper includes the use of automated design tools, fast-time simulation, and application of operational expertise applied in an objective framework.

A TOOL TO DESIGN FUNCTIONAL AIRSPACE BLOCKS

[Paper N° 169]

Charles-Edmond Bichot, Nicolas Durand
LOG (Laboratoire d'Optimisation Globale)
DSNA —ENAC, Toulouse, France

This paper focuses on the selection of a technical tool for the establishment of functional airspace blocks in Europe. This paper shows that the creation of functional airspace blocks is a partitioning problem. Some state-of the- art partitioning libraries and two metaheuristics are applied to this problem. Comparisons have been made between these libraries and metaheuristics. Results show that the Fusion Fission metaheuristic performs better. The purpose of this paper is not to give the best partition of Europe into functional airspace blocks. It only presents a study which compares and suggests different tools for the establishment of functional airspace blocks in Europe.

Human Factors in ATM

THE COMPUTATION OF COMMUNICATION COMPLEXITY IN AIR TRAFFIC CONTROL MESSAGES

[Paper N° 1]

O. Veronika Prinzo, FAA Civil Aerospace Medical Institute, Oklahoma City, OK
Al Hendrix and Ruby Hendrix, Hendrix Consulting Services, Roswell, NM

Over 10 years have passed since a comprehensive analysis quantified the types and frequency of readback errors and communication problems that occur in the air traffic control (ATC) environment. Hence, a content analysis was performed on approximately 50 hrs of pilot and controller messages that were transmitted from five of the busiest US terminal radar approach control (TRACON) facilities between Oct 2003 and Feb 2004. This report describes the computation of ATC message complexity. Furthermore the effects of ATC message complexity and message length on pilot readback performance are presented. The findings show that pilots experienced more difficulty reading back ATC high complexity messages while performing approach tasks as compared with departure tasks. The effects of message length on readback performance were apparent only for approach tasks. Also, non-standard phraseology associated with a lack of English language proficiency and international communications were present. With increases in international travel, areas of concern related to English language proficiency and language production need to be addressed.

ANALYSIS OF MULTIPLE OPEN MESSAGE TRANSACTIONS AND CONTROLLER-PILOT MISCOMMUNICATIONS

[Paper N° 174]

Jasenka Rakas and Suseon Yang
University of California at Berkeley, Berkeley, CA, USA

This study addresses an important and common problem to both voice-based and data link systems: multiple open message transactions and delayed responses in controller-pilot communications. The analyzed database includes 42 thirty-minute controller-pilot voice-recording samples, derived from 33 sectors, positioned in five Air Route Traffic Control Centers (ARTCCs). The database is used in modeling four Logit and Probit regression models.

Study findings indicate that increased multiple open message transactions cause miscommunications and delayed responses by controllers. Because the message transfer time in a data link environment appears to be longer than in the voice-based environment, any further delays in message transactions with data link should be avoided because such transaction delays could make the data link system less efficient and productive.

TACKLING THE PROBLEM OF FLIGHT INTEGRATION

[Paper N° 110]

Benhacene Raïlane, Hurter Christophe, Marion Anthony, DSNA R&D, Toulouse, France
Merlin Bruno, Intuilab, Toulouse, France
Rousselle Marie-Pierre, Protectic, Toulouse, France
Ribet Philippe, Steria, Toulouse, France

The work described here is an attempt to improve an electronic stripping for terminal sectors, VertiDigi, in order to design a version dedicated to the Planning Controller (PC). A brief description of the existing tool is done, as well as its design principles. Past experiments are then evoked. They confirm the good acceptability of the tool for clearance input, but also show the emergence of a specific issue: the Flight Integration Process (FIP). This process includes all the mental, physical and manipulation processes that take place between the announcement of a flight and the actual call from the pilot on the radio frequency.

A field observation survey was conducted in summer 2006 in the three Paris Terminal Area centers (Orly, Roissy, and Athis-Mons). The method and tool used to conduct this survey are explained. The data gathered permits a better understanding of this FIP.

From there, an iterative design is started, to redesign the tool specifically to meet this FIP issue. The method involves operators as early as possible, and uses paper or low-fidelity mock-ups to capture their needs. The different steps are listed, and the convergence towards a final new design.

After a brief description of the new design functionalities, the advantages of this design method are discussed, and future experiments are envisaged to validate the HMI.

EVALUATING TRANSFORMATIONS OF THE AIR TRANSPORTATION SYSTEM THROUGH AGENT-BASED MODELING AND SIMULATION

[Paper N° 175]

Seung Man Lee and Amy R. Pritchett, Georgia Institute of Technology
Kevin M. Corker, San Jose State University, San Jose, CA

To increase the capacity, safety, efficiency, quality, and affordability of air transportation systems require potentially revolutionary transformations. These transformations may involve system-wide changes and innovations as well as changes to individual components within the system. All of these changes require a robust modeling and simulation tool that can evaluate overall collective emergent system performance arising from individual components' behavior as proposed in innovative ATM concepts.

This paper proposes agent-based modelling and simulation (ABMS), including computational human performance models, as a conceptual framework and a simulation platform for a priori computational analysis method of predicting the impact of innovative ATM concepts. A specific test case of analyzing aircraft arrivals into LAX using a variety of spacing techniques was examined throughout as a demonstration, and as an opportunity to compare simulation predictions about current system behavior to available measures. The results indicate that ABMS has the capability to reveal unexpected emergent behaviours and can be used to investigate the causes of and potential solutions to them.

Air-Ground Integration

FAST-TIME SIMULATION EVALUATION OF A CONFLICT RESOLUTION ALGORITHM UNDER HIGH AIR TRAFFIC DEMAND

[Paper N° 173]

Todd Farley, NASA Ames Research Center, Moffett Field, California
Heinz Erzberger, Adjunct Professor, University of California, Santa Cruz, California

In this paper, an automated conflict resolution algorithm is evaluated based on fast-time simulations of nominal and heavily increased air traffic demand in the Cleveland Air Route Traffic Control Centre airspace. The algorithm under study is designed to support an automated separation assurance capability for next-generation air traffic management systems. It resolves detected conflicts that are projected to be between one and twenty minutes from first loss of separation. Rule bases are used to determine which aircraft to manoeuvre and which types of manoeuvre to consider: climb/descent, path stretch, or speed change. The algorithm uses high-fidelity trajectory modelling to identify a four-dimensional resolution trajectory that begins at the aircraft's current position and altitude, is conflict-free for a specified period of time, and ends at a position and altitude on the aircraft's original trajectory. Two case studies are presented to illustrate the operation of the subject algorithm: a typical vertical conflict involving traffic descending through busy flight levels, and an arrival conflict with arrival-fix crossing restrictions and sequencing constraints. The simulation environment is a medium-fidelity, fast-time simulation of departure, en-route, and arrival traffic based on recorded FAA data, and it assumes that all flights adhere to their four-dimensional trajectories precisely. Within the limitations of the simulation, the results indicate that the conflict resolution algorithm is capable of resolving conflicts safely and efficiently at traffic levels significantly higher than today. Safety and efficiency metrics are offered as benchmarks for comparison with alternative algorithms.

PERFORMANCE-BASED AIR TRAFFIC MANAGEMENT: EVALUATING OPERATIONAL ACCEPTABILITY

[Paper N° 116]

Joseph C. Celio, The MITRE Corporation, McLean, Virginia
Elida C. Smith, The MITRE Corporation, McLean, Virginia

The Joint Planning and Development Office (JPDO) has released its vision and integrated plan for the Next Generation (NextGen) air traffic control system. NextGen represents a quantum leap forward in air traffic management, integrating aircraft, automation and humans into a net-centric and collaborative environment based on precise operation of aircraft and common information sharing.

The Federal Aviation Administration (FAA) needs to develop strategies and plans to evolve the present day Air Traffic Management (ATM) system into tomorrow's NextGen system in an affordable and harmonious manner. By 2015, air traffic is expected to increase by 25-30 percent overall and more than that in certain areas of the country. There is also an increased need to hire new air traffic controllers

due to pending retirements that will put stress on workforce management during the next 10 years.

MITRE's Center for Advanced Aviation System Development (CAASD) in partnership with the FAA developed an approach to address this mid-term challenge called Performance-Based Air Traffic Management (P-ATM). P-ATM is a set of capabilities and an operational concept that is firmly aligned with the NextGen vision and represents an affordable and realistic path.

Through 2006, CAASD has engaged a group of Front Line Managers from en route and terminal Air Traffic Control (ATC) facilities in evaluating the operational acceptability of the concept and in estimating its productivity benefits by analyses and Human-In-The-Loop (HITL) evaluations. This document summarizes the evaluation results and outlines the P-ATM capabilities and concepts.

ARRIVAL MANAGEMENT WITH REQUIRED NAVIGATION PERFORMANCE AND 3D PATHS

[Paper N° 147]

Aslaug Haraldsdottir, Julien Scharl, Matthew E. Berge, Ewald G. Schoemig, Michael L. Coats
Boeing Commercial Airplanes, Seattle, Washington

This paper describes an operational concept that enables increased airport and airspace capacity and efficiency through the integration of Flight Management System (FMS) Required Navigation Performance (RNP) capabilities and ground based air traffic management (ATM) automation tools. The concept applies to en route and terminal area operations and uses voice or data link for air/ground communication. This concept is technically feasible for implementation in the 2008-2012 timeframe in a voice environment, assuming that advanced automation tools currently under development are deployed by Air Traffic Service Providers. This near-term step is a key element in the transition to trajectory-based operations in the Next Generation Air Transportation System (NextGen).

The paper describes the operational concept in detail for arrival management, and provides an analysis of several key performance parameters that influence the arrival management process. The concept is applied to arrival operations in Houston airspace. Arrivals into Houston Bush Intercontinental Airport (IAH) are modelled using a fast-time performance modelling approach. The results illustrate the influence of path and speed discretization, wind, trajectory prediction and navigation performance on delivery accuracy and delay in the arrival process.

MERGING ARRIVAL FLOWS WITHOUT HEADING INSTRUCTIONS

[Paper N° 112]

Ludovic Boursier, Direction des Services de la Navigation Aérienne, Paris Orly, France
Aymeric Trzmiel, Steria Transport Division, Issy-les-Moulineaux, France François Vergne, Karim Zeghal, Bruno Favennec, Eric Hoffman,
European organisation for the safety of air navigation
EUROCONTROL Experimental Centre, Bretigny-sur-Orge, France

This paper presents a method to merge arrival flows of aircraft without using heading instructions. The principle is to achieve the aircraft sequence on a point with conventional direct-to instructions, using predefined legs at iso-distance to this point for path shortening or stretching. A series of smallscale experiments was conducted with air traffic controllers to assess benefits and limits of the method. The method was found comfortable, safe and accurate, even under high traffic load, although less flexible than today with heading instructions. Predictability was increased, workload and communications were reduced. Even under high traffic load, the inter-aircraft spacing on final was as accurate as today (runway throughput maintained), while descent profiles were improved (continuous descent from flight level 100). As heading instructions were no longer used, aircraft remained on lateral navigation. The flow of traffic was more orderly with a contained and predefined dispersion of trajectories. All these elements should contribute to improving safety.

AIR/GROUND SIMULATION OF TRAJECTORY-ORIENTED OPERATIONS WITH LIMITED DELEGATION

[Paper N° 158]

Thomas Prevot, Todd Callantine, Jeff Homola, Paul Lee, Joey Mercer,
San Jose State University/NASA Ames Research Center, Moffett Field, CA
Everett Palmer, Nancy Smith, NASA Ames Research Center, Moffett Field, CA

An air/ground simulation of Trajectory-Oriented Operations with Limited Delegation (TOOWiLD) was conducted at NASA Ames Research Center in September 2006. Four radar-certified air traffic control (ATC) specialists in the Airspace Operations Laboratory (AOL), eight glass cockpit pilots in the Flight Deck Display Research Laboratory (FDDRL), and additional "ghost" pilots and controllers operated a heavy eastbound arrival push into Louisville's Standiford airport (SDF) with high density crossing traffic. An arrival management system scheduled aircraft along Continuous Descent Approaches (CDAs) and data linked arrival information to participating aircraft automatically throughout the simulation.

The 2x3 test matrix varied two flight deck conditions: *(1) with and (2) without airborne spacing*, over three ATC workstation conditions: *(1) current day, (2) advanced ATC scheduling and spacing tools, and (3) the same tools integrated with controller pilot data link communication*.

The process of automatically data linking arrival messages to participating aircraft based on a runway schedule proved to be very effective in all conditions. Flight deck-initiated speed changes to meet the CDA speed schedule and lead aircraft assignments were acceptable to pilots and controllers. Airborne spacing reduced the mean and the variance of the inter-arrival spacing on final approach, consistent with prior research. Controller scheduling and spacing tools improved handling of non-participating aircraft which did not receive the arrival information.

The research is sponsored by the Super Density Operations element of NASA's NGATS Airspace program and coordinated with the US merging and spacing team, with participation by the FAA, UPS, MITRE, and NASA.

PROPAGATION OF AIRBORNE SPACING ERRORS IN MERGING TRAFFIC STREAMS

[Paper N° 105]

Dan Ivanescu, Steria, Transport Division, Issy les Moulineaux, France
Chris Shaw, Karim Zeghal, Eric Hoffman
European organisation for the safety of air navigation
EUROCONTROL Experimental Centre, Bretigny sur Orge, France

Research results from domains such as road highway traffic and military vehicle platoons conclude that string stability cannot be obtained when vehicles use only relative spacing information to maintain constant distance behind a predecessor. Air traffic studies confirm these results but such instability has not been shown for constant time delay based airborne spacing. Unlike constant distance based, constant time delay based spacing has the potential to enhance stability by anticipating changes in spacing using the preceding aircraft's history. This simulation based study analysed the merging of aircraft by constant time delay based spacing over the period of the order of an hour to observe any build up of error propagation effects. Aircraft descended from 12,000 feet to 4,000 feet, each trying to achieve ninety seconds spacing with respect to its predecessor. The spacing anticipation time for each trailing aircraft to react to the preceding aircraft's time history was varied from 0 to 20s. Without anticipation, a time spacing error was observed to propagate at about 20 knots groundspeed in a forwards direction (towards runway) growing to about -3.5s (trail aircraft too early and too close). This compression wave was avoided by increasing spacing anticipation to 10s. Values larger than 10s reversed the error and moved it upstream. A tuned scenario was repeated for 5,400 random values of initial time spacing error and top of descent with automatic and manual airborne spacing modes. Time spacing accuracy and pilot activity were measured to be within required values previously derived for a pair of aircraft but the corresponding cost in speed variation was higher.

EVALUATION OF A FLIGHT DECK-BASED MERGING AND SPACING CONCEPT ON EN-ROUTE AIR TRAFFIC CONTROL OPERATIONS

[Paper N° 153]

William J. Penhallegon and Randall S. Bone
MITRE Corporation's Center for Advanced Aviation System Development, McLean, VA

In an effort to reduce aircraft maneuvering, noise, fuel burn, and controller workload, the Federal Aviation Administration (FAA) is developing, and UPS plans to implement, an Automatic Dependent Surveillance-Broadcast (ADS-B) concept termed Merging and Spacing (M&S). M&S has two phases: a strategic set-up by a ground operator followed by tactical Flight Deck-Based Merging and Spacing (FDMS). This paper focuses on FDMS and presents the subjective and objective results of a MITRE human-in-the-loop simulation that examined FDMS from an air traffic controller perspective. The simulation is part of a development and maturation process that is underway for FDMS. The simulation was designed to examine the impact of FDMS on the following en route controller topics: traffic efficiency, voice communications load, safety, workload, and situation awareness. The simulation has been termed FDMS 1 and was conducted in May and June of 2006. Results indicated general acceptability and improvements over current-day operations under normal and non-normal conditions. In comparison to current-day operations, FDMS showed a reduction in: the number of controller-issued maneuvers, the number of communications, and workload. A reduction of situation awareness was not observed. These results will be used to further refine the concept and to focus future simulations as the application moves toward operational approval.

APPLICATION OF KEY PERFORMANCE INDICATORS FOR TRAJECTORY PREDICTION ACCURACY

[Paper N° 127]

Stéphane Mondoloni, CSSI Inc., Washington, DC

Key Performance Indicators (KPI) for trajectory prediction accuracy were applied to flights operating with a meet-time function enabled during climb. Comparison to flights operating open-loop reveals that the meet-time function alters the correlation between typical prediction accuracy metrics. Despite this, the same two KPI measures can be linearly combined in both the open- and closed-loop case to estimate the complete set of metrics with good rank correlation. The performance of a conflict detection function was evaluated as a function of these KPI to determine if these are predictive of conflict detection performance. In both open- and closed-loop cases, improvements in KPI led to improvements in CD performance across the System Operating Characteristics (SOC) curves. Similar SOC curves were obtained in both cases when the average KPIs were set to the same level, indicating that the TP accuracy KPI are predictive of CD performance.

Network and Traffic Flow Optimisation

INCREMENTAL, PROBABILISTIC DECISION MAKING FOR EN ROUTE TRAFFIC MANAGEMENT

[Paper N° 35]

Craig Wanke and Daniel Greenbaum, The MITRE Corporation, McLean, VA

En route airspace congestion, often due to convective weather, causes system-wide delays and disruption in the U.S. National Airspace System (NAS). Today's methods for managing congestion are mostly manual, based on uncertain forecasts of weather and traffic demand, and often involve rerouting or delaying entire flows of aircraft. A new, incremental decision-making approach is proposed, in which prediction uncertainty is explicitly used to develop effective and efficient congestion resolution actions. Decisions are made based on a quantitative evaluation of the expected delay cost distribution, and resolution actions are targeted at specific flights, rather than flows. A massively-parallel simulation of the proposed method has been developed, and results for an operational-scale congestion problem are presented.

A PRE-TACTICAL GENERALISED AIR TRAFFIC FLOW MANAGEMENT PROBLEM

[Paper N° 77]

Rainer Kaufhold, Deutsche Flugsicherung GmbH, Department Research and Development, Research Campus Langen, Germany
Steffen Marx, Carla Müller-Berthel, Karl Nachtigall,
Technical University of Dresden, Faculty of Transport and Traffic Sciences, Chair Traffic Flow Science, Germany

In this paper we present a new model for solving Generalised Air Traffic Flow Management Problem (GATFM), which combines a ground-holding problem with en-route air traffic flow management and, moreover, contains a runway assignment problem. This approach shall help to close the existing planning gap between the Europe-wide air pretactical traffic flow managment process of CFMU and the fine tuned, short term and airport focussed planning tools used in tactical planning.. The main contributions of this paper is novel, network based capacity management model. Based on this approach an integer linear programming problem formulation for the GATFM problem and a dedicated new solution approach, based column generation, is deduced and discussed. The theoretical concept is generic and can be applied to a lot of similar problems in ATFM, especially to combine slot allocation and optimal re-routing First results for real world data of the airport Frankfurt/ Main are presented and look very promising.

RATION-BY-DISTANCE WITH EQUITY GUARANTEES: A NEW APPROACH TO GROUND DELAY PROGRAM PLANNING AND CONTROL

[Paper N° 122]

Robert Hoffman, Metron Aviation, Inc., Herndon, VA,
Michael O. Ball, Robert H. Smith School of Business and Institute for Systems Research, University of Maryland, College Park, MD,
Avijit Mukherjee, University Affiliated Research Center, University of California (Santa Cruz), Moffett Field, CA,

In this paper we describe ration-by-distance (RBD), a new allocation method to be used in ground delay program (GDP) planning. We show that RBD minimizes total expected delay, under certain assumptions related to the manner in which GDP's are dynamically controlled that. On the other hand, RBD has poor characteristics with respect to the equity of the allocation it produces. To address this issue, we define a constrained version of RBD as a practical alternative to allocation procedures used in operations today, and we show that it has superior overall performance.

SCENARIO-FREE SEQUENTIAL DECISION MODEL FOR THE SINGLE AIRPORT GROUND HOLDING PROBLEM

[Paper N° 154]

Pei-chen Barry Liu, Mark Hansen, University of California, Berkeley, CA

This paper aims to advance the support of decision-making in air traffic flow management under uncertainty with a focus on the single airport ground holding problem (SAGHP). Learning from the shortcomings of the scenario-based models for SAGHP that address uncertainty using probabilistic capacity scenarios, we develop a sequential decision model that is not limited by a small set of scenarios. We present computational strategies and demonstrate the computational feasibility of the model.

MACROSCOPIC WORKLOAD MODEL FOR ESTIMATING EN ROUTE SECTOR CAPACITY

[Paper N° 37]

Jerry D. Welch, John W. Andrews, and Brian D. Martin
M.I.T. Lincoln Laboratory, Lexington, MA
Banavar Sridhar , NASA Ames Research Center, Moffett Field, CA

Under ideal weather conditions, each en route sector in an air traffic management (ATM) system has a certain maximum operational traffic density that its controller team can safely handle with nominal traffic flow. We call this the *design* capacity of the sector. Bad weather and altered flow often reduce sector capacity by increasing controller workload. We refer to sector capacity that is reduced by such conditions as *dynamic* capacity.

When operational conditions cause workload to exceed the capability of a sector's controllers, air traffic managers can respond either by reducing demand or by increasing design capacity. Reducing demand can increase aircraft operating costs

and impose delays. Increasing design capacity is usually accomplished by assigning more control resources to the airspace. This increases the cost of ATM.

To ensure full utilization of the dynamic capacity and efficient use of the workforce, it is important to accurately characterize the capacity of each sector. Airspace designers often estimate sector capacity using microscopic workload simulations that model each task imposed by each aircraft. However, the complexities of those detailed models limit their real-time operational use, particularly in situations in which sector volumes or flow directions must adapt to changing conditions.

To represent design capacity operationally in the United States, traffic flow managers define an acceptable peak traffic count for each sector based on practical experience. These subjective thresholds—while usable in decision-making—do not always reflect the complexity and geometry of the sectors, nor the direction of the traffic flow.

We have developed a general macroscopic workload model to quantify the workload impact of traffic density, sector geometry, flow direction, and air-to-air conflict rates. This model provides an objective basis for estimating design capacity. Unlike simulation models, this analytical approach easily extrapolates to new conditions and allows parameter validation by fitting to observed sector traffic counts. The model quantifies coordination and conflict workload as well as observed relationships between sector volume and controller efficiency.

The model can support real-time prediction of changes in design capacity when traffic is diverted from nominal routes. It can be used to estimate residual airspace capacity when weather partially blocks a sector. Its ability to identify dominant manual workload factors can also help define the benefits and effectiveness of alternative concepts for automating labor-intensive tasks.

AIR TRAFFIC COMPLEXITY: AN INPUT-OUTPUT APPROACH

[Paper N° 64]

Keumjin Lee, Eric Feron, Amy Pritchett
School of Aerospace Engineering, Georgia Institute of Technology, Atlanta, GA

This paper addresses a new method for describing the air traffic complexity of a given traffic situation. Air traffic complexity is defined as “how difficult” a given traffic situation is, in terms of the control activity required to resolve it, in response to an additional aircraft entering the airspace. For this, we describe an input-output framework, and present a “complexity map” that clearly provides the effective complexity for a given traffic situation. This complexity map can address airspace with an arbitrary number of aircraft. We also discuss how to extract a scalar measure of air traffic complexity from the complexity map. We illustrate our methodology with a few examples relevant to dynamic airspace management.

ALGORITHMS FOR MANAGING SECTOR CONGESTION USING THE AIRSPACE RESTRICTION PLANNER

[Paper N° 53]

Ray Jakobovits, Metron Aviation, Herndon, VA
Parimal Kopardekar, NASA Ames Research Center, Moffett Field, CA
Jason Burke and Robert Hoffman, Metron Aviation, Herndon, VA

This paper describes automated algorithms for applying restrictions to air traffic to prevent one or more sectors of airspace from becoming overloaded. We evaluate the merits of both heuristic and classical optimization approaches, and we identify tradeoff issues that affect the selection of a particular algorithm for the airspace problem. Our initial results show that a hybrid algorithm combining both classical and heuristic approaches works best.

BENEFITS OF COLLABORATIVE FLOW MANAGEMENT DURING CONVECTIVE WEATHER DISRUPTIONS

[Paper N° 69]

Matthew E. Berge, Michael L. Carter, Aslaug Haraldsdottir, Bruno W. Repetto
The Boeing Company, Seattle, Washington

This paper presents a flexible modelling methodology that is designed to assess a range of operational concepts for collaborative flow management. The particular focus is on the problem of airline schedule recovery in conditions where airspace sectors are capacity limited due to convective weather events. This model is embedded in a dynamic simulation environment, the Boeing National Flow Model (NFM), representing the US National Airspace System (NAS). The airline schedule recovery model is based on an optimization formulation that allows a representation of adaptive airline behaviour in current and future operations. The schedule recovery options considered include ground delay, pre-departure re-routing and flight cancellation. Included is a NAS-wide benefits analysis of convective weather operations enabled by increased automation capability and exploring the benefits of improved forecasting capabilities. The modelling effort also included, for comparative purposes, the development of a baseline representation of current convective weather system response in the NFM, using delay data obtained from the Airline Service Quality Performance (ASQP) database. The results indicate a significant benefits potential for increased automation support and improved convective weather forecasts for the future NAS operation.

Finance, Deployment and Implementation Issues

AIR NAVIGATION SERVICE CHARGES IN EUROPE

[Paper N° 47]

Lorenzo Castelli, Andrea Ranieri
DEEI – University of Trieste, Trieste, Italy

This paper analyzes benefits and pitfalls of the current European charging scheme from the perspective of Air Navigation Service Providers, airspace users and passengers following the introduction of the European Commission Regulation 1794/2006 laying down a common charging scheme for air navigation services.

THE DYNAMICS OF AIR TRANSPORTATION SYSTEM TRANSITION

[Paper N° 118]

Aleksandra Mozdzanowska, Roland Weibel, Edward Lester, and R. John Hansman
Massachusetts Institute of Technology, Cambridge, MA

Both U.S. and European Air Transportation Systems face substantial challenges in transforming to meet future demand. This paper uses a feedback model to identify and describe key issues in the dynamics of system transition, with particular emphasis on stakeholder cost-benefit dynamics and processes for reviewing and implementing new system capabilities. Understanding of these dynamics is further reinforced through discussion of ADS-B and new runway construction examples. To implement the significant changes currently envisioned for ATM systems, it will be critical to structure system changes to anticipate and overcome stakeholder disagreements and improve the efficiency of the approval and implementation processes.

Environmental Considerations in ATM System Design

ENVIRONMENTAL IMPACT OF AIR TRAFFIC FLOW MANAGEMENT DELAYS

[Paper N° 101]

Sandrine Carlie, Ivan de Lépinay , ENVISA, Paris, France
Jean-Claude Hustache, Frank Jelinek, EUROCONTROL Experimental Centre, France

The regulation of European air traffic, as currently done by the CFMU and the regional ATFCM cells, essentially consists in delaying on the ground all flights that may encounter congestion at some stage of their trip. This preventive strategy is based on the assumption that avoiding en-route traffic overload contributes to safety and that ground delays should, in theory, be cheaper than their en-route equivalent from the airspace users' viewpoint. This study aims at performing a comparative environmental analysis of ground and en-route delays, along with assessing the corresponding costs.

ADVANCED NOISE ABATEMENT APPROACH ACTIVITIES AT NOTTINGHAM EAST MIDLANDS AIRPORT, UK

[Paper N° 119]

Tom G. Reynolds, University of Cambridge, Cambridge, UK
Liling Ren & John-Paul B. Clarke, Georgia Institute of Technology, Atlanta, GA, USA

Advanced noise abatement approach procedures incorporating Continuous Descent Approach, Precision Area Navigation and Low Power/Low Drag elements have been developed for a regional UK airport in partnership between academia and key stakeholders. The procedures were designed for a wide variety of aircraft types and equipages using a combination of advanced academic research tools, industry simulators and stakeholder input. Interactions between airspace constraints and procedure design were found to be critical. Flight trials of the procedures have demonstrated significant environmental benefits compared to non-trial flights: 3-6 dBA peak noise reductions and 10-20% fuel burn/emissions reductions have been observed. However, the importance of aircraft automation level, air traffic control coordination and the need for effective environmental performance metrics have been highlighted.

FLIGHT DEMONSTRATION OF THE SEPARATION ANALYSIS METHODOLOGY FOR CONTINUOUS DESCENT ARRIVAL

[Paper N° 178]

Liling Ren & John-Paul B. Clarke, Georgia Institute of Technology, Atlanta, GA, USA

The Tool for the Analysis of Separation And Throughput (TASAT) has been developed to predict the trajectories of different aircraft performing a given continuous descent arrival (CDA) and thereby determine the minimum spacing at a metering point such that there is a high probability of no separation violations during the remainder of the procedure. The resulting reduced need for controller intervention is expected to facilitate the implementation of CDA. This tool includes a fast-time Monte Carlo aircraft trajectory simulation environment and a theoretically rigorous separation analysis methodology based on probabilistic characteristics of aircraft trajectory variations. The tool was used to determine the target spacing between aircraft at the metering point for the Area Navigation based Continuous Descent Arrival flight test project conducted in September 2004 at Louisville International Airport. The flight test results indicated that the determined 15 nm target spacing yielded conditional probabilities of 69.6% for CDA to runway 35L, which is very close to the predicted value of 68.6%. The flight test also indicated an overall total probability of 81.7%, which is between the predicted overall total probabilities of 79.6% and 85.0% for the CDA to runway 35L and 17R respectively. The flight test demonstrated that with the tool developed, Continuous Descent Arrival can be efficiently implemented under moderate to moderately high traffic conditions to achieve environmental and economical benefits.

DETERMINING THE ENVIRONMENTAL BENEFITS OF IMPLEMENTING CONTINUOUS DESCENT APPROACH PROCEDURES

[Paper N° 17]

Eric Dinges, ATAC Corporation, Sunnyvale, CA

Several research efforts to date have been aimed at demonstrating that Continuous Descent Approach (CDA) procedures have the potential for significant environmental benefits including reductions in noise, emissions, and fuel burn. These efforts typically involve evaluating small numbers of CDA flights under idealized flight test conditions. This paper focuses on the development and application of methods for quantifying potential airport-wide environmental benefits of implementing CDAs. These efforts are being performed as part of the demonstration of a CDA modeling capability within the U.S. Federal Aviation Administration's Aviation Environmental Design Tool (AEDT). Existing internationally accepted modeling methods and data are used, where appropriate, including methods described in the Third Edition of European Civil Aviation Conference (ECAC) Doc 29 and data from EUROCONTROL's Aircraft Noise and Performance (ANP) database. These are used in conjunction with real-world operational and flight procedure data to look at the noise, emissions and fuel burn benefits of CDAs. The benefits are evaluated based on potential future levels of CDA implementation as a function of traffic flow density. This type of analysis may help support Air Traffic Management (ATM) decisions on CDA implementation based on tradeoffs between the efforts required to implement CDAs versus the predicted environmental benefits.

AEDT GLOBAL NOX DEMONSTRATION

[Paper N° 16]

Ted Thrasher, Alex Nguyen, Clifford Hall, CSSI, Inc., Washington D.C.
Gregg Fleming, Chris Roof, Sathya Balasubramanian, DOT Volpe Center, Cambridge, MA
Fabio Grandi, Scott Usdrowski, Wyle Laboratories, Inc., Arlington, VA
Eric Dinges, ATAC Corporation, Sunnyvale, CA
Carl Burleson, Lourdes Maurice, Ralph Iovinelli, FAA, Washington, D.C.

The Global NOx (Oxides of Nitrogen) demonstration is the first Capability Demonstrator (CD) sample problem of the Aviation Environmental Design Tool (AEDT). AEDT is intended to facilitate the analysis of tradeoffs between noise and emissions and make the evaluation of air quality and noise impact seamless between the local and global domains. This CD marks an initial step toward creating a harmonized air quality module suitable for local and global analyses by leveraging the work already invested in developing the Emissions and Dispersion Modeling System (EDMS), the System for assessing Aviation's Global Emissions (SAGE), the Integrated Noise Model (INM), and the Model for Assessing Global Exposure from Noise of Transport Airplanes (MAGENTA). This initial CD focused on building a tool that assesses the impacts of different NOx stringencies to support the development of NOx emissions standards and highlights improvements over the previous modeling capabilities in many ways. AEDT implements Boeing Fuel Flow Method 2 (BFFM2) which allows for the use of thrustspecific emission indices corrected for atmospheric conditions, instead of relying on the sea level static certification data collected in the ICAO Aircraft Engine Exhaust Emissions Databank. BFFM2 is implemented in conjunction with a new, gate-to-gate, dynamic aircraft performance module based on the Society of Automotive Engineers' Aerospace Information Report 1845 (SAE-AIR-1845) and EUROCONTROL's Base of Aircraft Data (BADA). AEDT also implements input data processing enhancements to enable a more detailed fleet mix to be modeled. AEDT combines the International Official Airline Guide (IOAG) and FAA's Enhanced Traffic Management System (ETMS) data with the CAEP-developed fleet forecast from their Forecasting and Economics Support Group (FESG) to produce a comprehensive global operations forecast. The resultant aircraft-typespecific route information, allows the results to be aggregated in multiple ways, as opposed to being limited to only assessing global performance. The methodologies used in this demonstration of AEDT capabilities are described in the paper.

QUANTIFYING THE RELATIONSHIP BETWEEN AIR TRAFFIC MANAGEMENT INEFFICIENCY, FUEL BURN AND AIR POLLUTANT EMISSIONS

[Paper N° 65]

Melissa Ohsfeldt, Ted Thrasher, CSSI, Inc., Washington D.C.
Ian Waitz, Gayle Ratliff, Chris Sequeira, Massachusetts Institute of Technology, Cambridge, MA
Terry Thompson, Mike Graham, Rebecca Cointin, Metron Aviation, Inc., Herndon, VA
Warren Gillette, Mohan Gupta, Federal Aviation Administration, Washington, DC

Worldwide air travel demand has increased significantly over the past 30 years, leading to an increased number of flights, associated delays, fuel consumption, and aircraft air pollutant emissions. Demand for aviation is expected to grow three-fold over the next two decades and could potentially lead to an increase in aviation related emissions of air pollutants. This study quantifies the contribution of aircraft emissions at 148 airports that lie within the air quality non-attainment or maintenance areas to the county-level emissions inventories. We also quantify how inefficiency in air traffic management contributes to increased aircraft-related fuel burn and emissions. A baseline fuel burn and emission inventory is presented, consisting of realistic aircraft operations and including delays due to air traffic management inefficiencies. At most of the evaluated airports (~52%), aircraft emissions are a relatively small contributor (<1%) to county level emissions of the criteria pollutants considered in this analysis. Reducing ground delays can significantly impact those airports with high taxi times, leading to potential airport reductions of between 10% and 25% in fuel burn and emissions. A sample efficiency initiative is used to demonstrate the potential reduction in delays, and hence, in fuel burn and emissions.