Abstract Review

June 27 - 30, 2005

Track 1 – Metrics and Performance Management (Room- Constellation D)

Economic Contribution and Productivity of ATM

Paula Leal de Matos – Eurocontrol DAS

This paper estimates the economic contributions of ATM to GDP and to employment in selected countries, as well as to provide some measures of ATM-related investment and economic productivity. Its focus, driven in part by availability of data, is on the European and North American economies. Incomplete information and estimates along parallel lines are also provided for small groups of States in Central and South America, South Asia and South Africa. The total impact of ATM (including direct, indirect and induced effects) on North American and European GDP in 2002 was estimated to be of the order of $22 billion, with total direct, indirect and induced employment at approximately 230,000 jobs. In these two regions, ATM capital investment amounted to approximately 20% ($2.6 billion) of revenue in 2002. Considering only direct values, worldwide ATM revenues were estimated to be in the range of $16-20 billion in 2002. Numerous other estimates of a similar nature are provided. Comparisons with other European data, confirm the view of ATM as a sector in which jobs have high skill content. Productivity appears to be comparable to that in other technologically advanced sectors of the economy. The findings of this study should be treated as preliminary, in view of data limitations and the diverse economic characteristics of the countries and regions examined.

Extent and Impact of Future NAS Capacity Shortfalls in the United States: A Socio-Economic Demand Study

Shahab Hasan – LMI

David Ballard – GRA, Inc.

The U.S. aeronautics industry remains one of the undisputed success stories in global competitiveness throughout the latter half of the past century and is currently one of the largest positive industrial contributors to the U.S. balance of trade. Yet experts agree that demand for air transportation will soon outpace National Airspace System (NAS) capacity, and that such capacity shortfalls will impose significant, tangible costs to the nation. Long-term strategic planning is therefore essential to safeguard America's economic prosperity, national security, and quality of life. Such planning requires a broad-based national perspective that considers the needs of the aviation industry and its customers and equips policy makers and planners with the information necessary to effect beneficial change. In response to those requirements, the National Aeronautics and Space Administration (NASA) and the Federal Aviation Administration (FAA) with GRA, Inc., LMI, and the Volpe National Transportation Systems Center undertook a year-long study to assess the potential benefits of transforming the air transportation system to meet future demand. Our research quantified the projected economic loss to the United States over the period 2015-2025 should NAS capacity fail to keep pace with the anticipated growth in demand. The study estimated that the anticipated shortfall in NAS capacity could have significant costs for the nation, ranging between a cumulative $91.6 billion and $229.4 billion from 2015-2025. Our research thus establishes a firm foundation for what must follow—a complete cost-benefit analysis of potential federal investment in a new national initiative to transform the air transportation system.

Flight Efficiency Studies in Europe and the United States

Tarja Kettunen – ISA Software

Dave Knorr – FAA

The paper presents two similar studies carried out in the field of flight efficiency, one by Eurocontrol Experimental Centre, one by the FAA. The studies calculate the excess distances of flights as the difference between the actual flight path length and the direct route length. The results of the EEC study suggest that aircraft fly around 10 percent excess distance compared to direct routes. In the US the inefficiency is around 6 to 8 percent. The cost of flight inefficiency is evaluated. The important division of flight inefficiency between terminal and en route airspaces is explored. 70 percent of the total excess distance flown in the US is found to take place within terminal airspace and the remaining 30 percent in en route airspace. The European study supports this finding based on the results for certain airport pairs. Differences between direct routes and wind optimal routes as well as the impact of weather in flight efficiency are also discussed.

A Preliminary Analysis of the Impact of Mile-In-Trail Restrictions on NAS Flight Operations

Tim Myers – Metron Aviation, Inc.

The National Traffic Management Log (NTML) was deployed nationally on December 17, 2003 to among other objectives record the implementation of various traffic management initiatives (TMIs) including Miles-In-Trail (MIT) restrictions. Using these data we developed an algorithm to identify the flights involved in each MIT restriction. Based on a limited sample of these data, this paper presents a preliminary analysis of the impact of MIT restrictions on National Airspace System (NAS) operations with a focus on airborne delay, actual flight spacing, and arrival compliance during Ground Delay Programs (GDPs). This initial analysis led to the following conclusions: • It does not appear as though MIT restrictions have a significant impact on airborne delay, flight spacing, or GDP arrival compliance based on the limited MIT restriction data evaluated in this study. • 39% of MIT restrictions implemented between May 1-14, 2004 involved 5 or fewer flights, indicating these restrictions potentially may not have been needed. • Further analysis is required to evaluate the potential impact of MIT restrictions on departure delays.

Modeling Delays and Cancellation Probabilities to Support Strategic Simulations

David Lovell – University of Maryland

Modeling delays and cancellation probabilities is important for strategic-level decision support tools in aviation planning. In this paper, we introduce models for average delays and cancellation probabilities that distinguish between carriers but do not rely on proprietary information. The models were developed for a strategic simulation to determine the effects of congestion management schemes at LaGuardia Airport, including government regulations, administrative controls, and congestion prices. We also demonstrate the use of the models to help determine the appropriate number of hourly slots to offer in a hypothetical slot auction.

Estimation of Arrival Capacity and Utilization at Major Airports

Husni Idris – Titan Corporation

Antony Evans – Titan Corporation

Airport arrival capacity has become a primary constraint to air traffic flow in the National Airspace System (NAS). Increased airport capacity may be achieved through Decision support tools (DSTs) designed to increase operations under current runway configurations and air traffic procedures. In order to assess the potential benefits of such DSTs it is important to measure the degree to which arrival capacity is utilized by current operations at an airport. This paper presents an approach to estimate the arrival capacity achievable at an airport and the degree to which it is utilized by current operations. In this approach the degree to which airport arrival throughput saturates under high demand is identified and quantified under specific runway configurations and meteorological conditions. Capacity envelopes representing the maximum achievable airport arrival capacity were estimated conservatively as the 99th percentile of throughput for runway configurations that exhibited throughput saturation, and as the 100th percentile of throughput for those that did not exhibit throughput saturation. The effective arrival capacity for each runway configuration and meteorological conditions was also identified by simulating arrival operations and calibrating the arrival capacity to result in the current observed level of delay under high demand. The ratio of effective to achievable capacity was used as a measure of the underutilization of arrival capacity due to inefficiency in operations under high demand. This ratio reflects the potential benefits of DST application, which may increase utilization through improved operation efficiency. The ratio of arrival throughput to effective arrival capacity was used as a measure of the utilization of the capacity by the current level of demand. This ratio reflects the degree to which the demand at an airport is constrained by capacity. Along with the demand growth rate this ratio can indicate when DST application may be needed in the future at unconstrained airports. This approach was applied to BOS, and the secondary airports in the region: BDL, PVD and MHT. Utilization due to demand at BDL, PVD and MHT was found to be on average 50% of that at BOS, suggesting that demand is well below capacity at these airports. This suggests that metering is not necessary at these airports under current demand levels. Those configurations at BOS that saturate show an average ratio of effective to achievable capacity of 0.83. This indicates the potential throughput benefit from DSTs that increase operation efficiency.

The Feasibility of Measuring Capacity in a Real-Time ATM Simulation Independent of Subjective Controller Workload Measurement

Mick Van Gool – Eurocontrol

Kevin Corker – San Jose State University

We report on the results of an experiment on metric validation with a human-in-the-loop real-time ATM simulation. We then compare the results of this metric validation with a computational human performance model replication of the evaluation to assess the independence of the INTEGRA high level metrics from subjective controller workload measurements.

Track 1 – Airport Management (Room- Constellation D)

An Analysis of Potential Capacity Enhancements Through Wind Dependent Wake Turbulence Procedures

Jeff Tittsworth – MITRE Corp.

The FAA and NASA are jointly embarking on a multi-phased research and development program to develop and implement wake avoidance solutions that can safely reduce separations and improve capacity at airports in the NAS. The mid-term phase of the research focuses on the potential application of wind-dependent procedures for improved departure operations from Closely Spaced Parallel Runways (CSPR) in the U.S. This paper describes the research performed to date by the research team, including the FAA, Lambert St. Louis International Airport operational staff, MIT Lincoln Laboratory and MITRE/CAASD. It describes the operational concept, the wind prediction algorithms being developed to support this concept and an analysis of expected algorithm performance. In addition, this paper addresses the information requirements for a decision support tool to support this procedure and the potential benefits that may be realized by this procedure at several CSPR airports in realistic weather and traffic demand encountered in recent years. NASA is in early stages of extending this wind-dependent solution for other operations such as single runway departures. The paper also describes the thrust of these evolutionary concepts and the directions of research.

Improving Flight Efficiency Through Terminal Area RNAV

Kevin Sprong – MITRE Corp.

Analysis of Area Navigation (RNAV) arrival flights at Las Vegas airport, in the form of operational data analysis and simulation modeling, has shown improvements in flight efficiency. A redesign of flight paths in Las Vegas airspace has confounded a pure RNAV vs. non-RNAV comparison, but statistical analysis has allowed a partitioning of effects. Analysis of metrics such as altitude, flight time variation, arrival interval, and flight time and distance will provide insight into the increase in flight efficiency possible with RNAV. MITRE CAASD performed several analyses concerning benefits of RNAV arrival procedures in the terminal area, incorporating both simulation modeling and data analysis into the project. Initial results for Las Vegas show promise toward the full RNAV vision.

Verification and Validation Results from the Operational A-SMGCS Field Trials of the Project BETA

Joern Jakobi – DLR

A-SMGCS is a modular concept defined in the ICAO Manual on A-SMGCS (Doc9830). A-SMGCS systems are aiming to provide adequate capacity and safety in relation to specific weather conditions, traffic density and aerodrome layout. With the complete concept of an A-SMGCS, ATS providers and flight crews are assisted in terms of surveillance, control, planning and guidance tasks. To facilitate the implementation of A-SMGCS and to mature the necessary technology and operating procedures, the European Commission funded the project BETA (operational Benefit Evaluation by Testing A-SMGCS) within the 5th framework programme. Two sample A-SMGCS systems were installed at the two European mid-size airports Hamburg and Prague using equipment from Industry and R&D labs. The operators were trained in simulation and on-site. The prototype A-SMGCS installations have been used to control the regular airport traffic from a separate BETA controller working position in the Tower. Appropriate testing methodologies concerning functional and operational testing were developed and fed forward to the European MAEVA validation standard. Significant progress was made with the maturation of the technical equipment. Operational issues like proper transponder switching have been tackled. The benefit categories of an A-SMGCS were identified and qualified. The paper presents the BETA approach, the main findings and results as well as the main lessons learnt.

Airline Operational Benefits of Surface Surveillance

Dan Howell – MCR, LLC

Airlines can optimize surface operations using real-time surface surveillance data. The Federal Aviation Administration's Air Traffic Organization (ATO) Technology Development Team (formerly Safe Flight 21 and Surface Technology Assessment) began examining the operational impacts of surface surveillance data sharing in current and future FAA tools. This study examines taxi time and departure rate benefits of surveillance data for airlines using two examples. The first example investigates the operational impact of data provided to Federal Express (FedEx) at Memphis International Airport (MEM) through a joint FAA/ National Aeronautics and Space Administration (NASA) project. We first use an unexpected loss of surface surveillance data as an opportunity to gauge impacts. The analysis measures changes in taxi-out times, queue lengths, and departure rates before, during, and after the surveillance outage. We repeat the analysis using a baseline period and a post-implementation period. Both data sets display a reduction in taxi-out times and indicate an increase in effective departure rates (approximately 3 aircraft per hour greater) during times when surveillance was available. The second example examines the impact of data provided to the Delta Air Lines ramp tower at Dallas-Fort Worth International Airport (DFW). We find a decrease in Delta taxi-out times relative to airport surface queues after implementation and compared with airlines not using surface surveillance.

Outbound Punctuality Sequencing by Collaborative Departure Planning

Eugene Tuinstra – NLR

Most significant delays in ATM are created on the ground during flight preparation before pushback and during ground operations until take-off. Significant benefits can be achieved by improving departure planning. This can be realised by bringing together different actors in ATM and by using their planning data in a flexible, efficient and transparent way. Departure planning can be optimised towards punctuality, towards acceptance of airlines' planning preferences and towards efficient use of available runway capacity. A Departure Management tool (DMAN), the so-called Outbound Punctuality Sequencer (OPS), developed by NLR, is presented in this paper. The tool aims to support the pre-departure planning process in an interactive and co-operative way. Optimisation towards punctuality is achieved by using flight preference functions. The OPS DMAN tool is a planning-support tool based on balanced decision-making. The contributions of different constraint-related flight preferences to an optimised departure planning are made transparent to the user. This paper explains the tools and presents some preliminary evaluation and validation results.

Tactical Departure Management with the Eurocontrol / DLR DMAN

Dietmar Bohme – DLR

The paper deals with tactical departure management when using the Eurocontrol /DLR DMAN. It describes characteristics of that operational prototype reflected on objectives and requirements of the DMAN development. The description comprises explanations of the general approach and the embedded algorithms with respect to the used operational- and constraint models, the planning, and timing. The paper also outlines the DMAN architecture. Particular consideration is given to first results from real-time simulation trials RTS1 with DMAN which took place in the framework of the European Gate-to-Gate project at Malmo in 2004. In this context an explanation of the operational concept for departure management with DMAN is given. The paper not only shows and comments first, partly surprising results, but also gives some statements about lessons learnt.

Linking Existing on Ground, Arrival and Departure Operations

Maria Mas – Isdefe

Patricia Pina – AENA

LEONARDO, Linking Existing On Ground, Arrival and Departure Operations is a research project promoted by the European Commission, with the participation of companies from France (ADP, DNA and Air France), The Netherlands (NLR), Italy (Sicta) and Spain (Aena, Iberia, Indra, Ineco and Isdefe), together with Eurocontrol. The objective of Leonardo is to demonstrate the feasibility of implementing Collaborative Decision Making (CDM) processes supported by the integration of existing tools for arrival (AMAN), departure (DMAN), surface (SMAN), stand allocation and turn-around management. The integration of these decision supporting tools promotes the information sharing among airport stakeholders and makes it possible to provide the airlines, the airports and the air traffic service providers with early and reliable planning updates. In order to achieve these objectives, systems integrating the afore mentioned planning tools were developed and tested at Madrid-Barajas airport and at Paris-Charles de Gaulle airport. The results of Leonardo experiments give evidence of the benefits achievable applying CDM procedures at the airport level. It has been demonstrated that the airport operator and the airlines improve the safety and the efficiency of their ground processes using ATC planning updates and that the ATC improve air traffic management thanks to the information provided by the airport and the airlines. This paper begins with the description of the concept of CDM implemented and tested by Leonardo. Then, the paper reports in detail the results of the experiments carried out, highlighting figures for the benefits achievable and finally, the paper concludes with an overview of what has been developed and achieved.

Benefits Obtained from the Estimation and Distribution of Realistic Taxi Times

Jose Miguel de Pablo Guerrero – AENA

Patricia Pina – AENA

Collaborative Decision Making is seen as an important approach to make best use of available infrastructure and the scarce resources and as an important support for Air Traffic and Airport slot compliance. Several projects and companies in Europe and USA are working in the definition, implementation and validation of CDM processes. In Europe, EUROCONTROL has launched the Airport CDM (Collaborative Decision Making) Project, part of the EATM Airport Operations Program, focused on the development of Airport CDM Applications. This project describes the Operational Concept of the Airport Collaborative Decision Making (CDM) Applications, outlining the necessary steps towards the Collaborative Airport. In order to complement the work being done by EUROCONTROL and in close cooperation with them, the European Commission promoted a research project called LEONARDO, Linking Existing On Ground, Arrival and Departure Operations. Within the Leonardo project, the CDM application called "Variable Taxi Time Calculation", as defined by Eurocontrol, was tested. This application aims at improving airline adherence to scheduling by introducing and distributing realistic taxi times. This paper is focused on the results obtained in Leonardo trials for CDM Variable Taxi Time Calculation. During these experiments, taxi times were not considered as fixed values (default taxi times), but they were calculated taking into account factors such as the runway in use, stand / gate location, aircraft type, operating procedures, taxiway usage, the traffic congestion, the weather, etc. The paper begins with a description of how taxi times were estimated in Leonardo and potential benefits of such approach. Then it reports in detail the results of the experiments carried out, highlighting figures for the benefits achievable and finally, the paper concludes with an overview of what has been developed and what would be the best areas for continuing these research activities.

Track 1 – Air Ground Cooperation (Room- Constellation D)

Joint NASA Ames/Langley Experimental Evaluation of Integrated Air/Ground Operations for En Route Free Maneuvering

Richard Barhydt – NASA Langley Research Center

In order to meet the anticipated future demand for air travel, NASA is investigating a new concept of operations known as Distributed Air-Ground Traffic Management (DAG-TM). Under the En Route Free Maneuvering component of DAG-TM, appropriately equipped "autonomous" aircraft self separate from other autonomous aircraft and from "managed" aircraft that continue to fly under today's Instrument Flight Rules (IFR). Controllers provide separation services between IFR aircraft and assign traffic flow management constraints to all aircraft. To address concept feasibility issues pertaining to integrated air/ground operations at various traffic levels, NASA Ames and Langley Research Centers conducted a joint human-in-the-loop experiment. Professional airline pilots and air traffic controllers flew a total of 16 scenarios under four conditions: mixed autonomous/managed operations at three traffic levels and a baseline all-managed condition at the lowest traffic level. These scenarios included en route flights and descents to a terminal area meter fix in airspace modeled after the Dallas Ft. Worth area. Pilots of autonomous aircraft met controller assigned meter fix constraints with high success. Separation violations by subject pilots did not appear to vary with traffic level and were mainly attributable to software errors and procedural lapses. Controller workload was lower for mixed flight conditions, even at higher traffic levels. Pilot workload was deemed acceptable under all conditions. Controllers raised several safety concerns, most of which pertained to the occurrence of near-term conflicts between autonomous and managed aircraft. These issues are being addressed through better compatibility between air and ground systems and refinements to air and ground procedures.

Design of an Airborne Spacing Director to Minimize Pilot Speed Actions

Eric Hoffman – Eurocontrol EEC

A flight deck tool was designed to assist pilots in acquiring and maintaining a required time delay behind a lead aircraft. A system architecture for manual and automatic 'merge' behind and 'remain' behind modes is proposed with required design and performance criteria. A manual 'remain' guidance mode suggesting calibrated airspeed was developed. The control law minimised pilot speed actions by using lead aircraft history to anticipate large speed changes. This guidance mode was tuned and validated using descent profiles recorded from real-time experiments, and a pilot model in the loop. A sequence of four aircraft was modeled to investigate potential benefits. The number of calibrated airspeed adjustments needed to maintain spacing was found to decrease by at least a factor of three for all trailing aircraft when the lead aircraft history based prediction was used.

Pilot Perspective of ASAS Self-Separation in Challenging Environments

Rob Ruigrok – NLR

This paper describes the results of two Real-Time Simulation experiments (RTS2 and RTS3) on ASAS Self-Separation, conducted on the Research Flight Simulator at NLR in Amsterdam, within the context of the Mediterranean Free Flight (MFF) Program. RTS2 specifically investigated the procedures defined for transitions between Managed Airspace (MAS) and Free Flight Airspace (FFAS). Both Airborne Traffic Situational Awareness (ATSAW) and Airborne Self-Separation Assurance have been addressed in Managed and Free Flight Airspace, respectively. For RTS3 a pilot human factors evaluation was conducted on ASAS Self-Separation, investigating the effects of weather, military activities and failures. Further, training needs for ASAS Self-Separation have been assessed, as well as the need for a vertical navigation display. Based on the results from these experiments it can be concluded that there are no showstoppers found for ASAS Self-Separation in challenging environments. The Human Machine Interface as well as the Conflict Detection & Resolution algorithms appear well accepted by participating subject pilots. Slight adjustments to the ASAS algorithms and procedures were identified based on the experiment results.

Cockpit Display of Traffic Information (CDTI) Assisted Visual Spearation (CAVS): Pilot Acceptability of a Spacing Task During a Visual Approach

Randall Bone – MITRE Corp.

At many busy airports maximum efficiency and minimum delay occur when visual approaches are being conducted by pilots using visual separation from traffic for a portion of the approach. Pilot willingness to accept responsibility for visual separation also affords controllers maximum flexibility in traffic management under conditions of high traffic load. It may be possible to extend that efficiency to lower weather conditions if pilots are able to perform the same separation tasks by reference to a Cockpit Display of Traffic Information (CDTI) in lieu of visual contact out-the-window (OTW). This concept has been developed under the name CDTI Enhanced Flight Rules (CEFR); however, this paper will use the more descriptive and current term of CDTI Assisted Visual Separation (CAVS). Use of CAVS procedures may be applicable during visual or instrument approaches. This paper will mainly discuss the visual approach application since it will be the likely initial implementation. It will also review the maturity of the concept, including pilot objective and subjective results from four simulations. These results indicate positive pilot feedback and good performance.

Air and Ground Simulation of Terminal-Area FMS Arrivals with Airborne Spacing and Merging

Todd Callantine – San Jose State University/NASA Ames Research Center

A combined air and ground simulation of terminal-area arrival operations was conducted at NASA Ames Research Center to evaluate Distributed Air Ground Traffic Management (DAG-TM) project Concept Element 11 (CE 11): Terminal Arrival: Self-Spacing for Merging and In-trail Separation. The simulation was the final DAG-TM study conducted at NASA Ames with

funding from the NASA Airspace Systems Program Advanced Air Transportation Technologies (AATT) project. The study evaluated the feasibility and potential benefits of using pilot and controller decision support tools (DSTs) to support time-based airborne spacing and merging in terminal radar approach control (TRACON) airspace. Sixteen simulation trials were conducted in each treatment combination of a 2x2 repeated measures design. In trials 'with ground tools,' air traffic controller participants managed traffic using sequencing and spacing DSTs. In trials 'with air tools' seventy-five percent of aircraft assigned to the primary landing runway were equipped for airborne spacing and merging, including flight simulators equipped with an enhanced cockpit display of traffic information (CDTI) flown by commercial pilots. In all trials controllers were responsible for separation and issued clearances by voice. All aircraft were equipped with Flight Management Systems (FMSs) and ADS-B and entered TRACON airspace on charted FMS routes. Routes to the primary landing runway merged. Each scenario began with a traffic flow that was well coordinated for merging and spacing and ended with an uncoordinated flow. This paper presents the simulation and results of from an air traffic management (ATM) perspective. The results indicate that airborne spacing improves spacing accuracy and is feasible for FMS operations and mixed spacing equipage. Airborne spacing capabilities and the degree of flow coordination affect clearance selection. Controllers and pilots can manage spacing clearances that contain two callsigns without difficulty. For best effect, both DSTs and spacing guidance should exhibit consistently predictable performance.

Spacing Instructions in Approach: Benefits and Limits from an Air Traffic Controller Perspective
Eric Hoffman – Eurocontrol EEC

A new allocation of tasks between controller and flight crew is envisaged as one possible option to improve the sequencing of arrival flows. It relies on a set of new spacing instructions where the flight crew can be tasked by the controller to maintain a given spacing with respect to a designated aircraft. The investigations initially focussed on upstream sectors (en-route) highlighting positive impact on controller activity and on control effectiveness. In addition, the air experiments conducted in parallel did not reveal any show stopper. However, although promising, the application to downstream sectors (approach) appeared as an issue. An analysis of the specificity of the approach compared to the en-route was conducted. Then, organisation of roles, working methods and airspace design have been adapted to apply the spacing instructions in approach, and gradually refined to optimise their use under a very high traffic load. This paper outlines the main adaptations required and presents the results from the latest approach experiment. Six approach controllers were involved over four weeks. The airspace consisted of two generic approach sectors derived from an existing environment. Overall feedback from controllers was positive. The proposed working method, though implying significant changes as compared to today, seemed easy to use and assimilate. The analysis of instructions and eye-fixations shows a positive impact on controller activity (relief from late vectoring and earlier flow integration). The analysis of inter aircraft spacing on final shows more regular spacing. The next step will consist in investigating interaction between upstream and downstream sectors when using an arrival manager.

Airborne Precision Spacing in Merging Terminal Arrival Routes: A Fast-Time Simulation Study
Karthik Krishnamurthy – Titan Corporation

Researchers at NASA Langley Research Center are investigating airborne technologies and proce-dures to increase runway capacity by precisely spac-ing landing aircraft at the runway threshold. Under the concept, referred to as Airborne Precision Spac-ing (APS), flight crews are cleared by Air Traffic Control to follow speed cues from onboard automa-tion to achieve precision spacing (time- or distance-based) at the threshold, relative to a designated lead aircraft. Prototypes of the onboard automation were previously used to demonstrate precision spacing op-erations in aircraft flying in-trail to the runway, both in simulation and in flight-test. Following those suc-cesses, the research focus has shifted to investigating the feasibility of precision spacing operations on-board aircraft across multiple arrival streams to a common runway. The prototype onboard automation has been modified to enable the new procedures, re-ferred to as Airborne Merging and Spacing for Ter-minal Arrivals (AMSTAR). As part of the testing of the new tool and opera-tional procedures, AMSTAR operations under a range of operational conditions were studied in fast-time simulations. The study investigated AMSTAR performance in long arrival sequences composed of diverse aircraft types ranging from light jets to heavy transports. Three arrival streams with two merge points were modeled, and two different merge fre-quencies were evaluated. Results of the study indi-cate that inter-arrival spacing was achieved to within 10 seconds even with a diverse fleet of aircraft types having dissimilar final approach speeds and unequal spacing assignments. If the entire fleet was composed of a single aircraft type, spacing was achieved to within 5 seconds of the assigned value. The number of additional speed changes required to achieve pre-cision spacing were comparable across the different test conditions. Schedule deviations were stable and did not exceed 30 seconds over the entire one hun-dred aircraft simulated landing sequence.

Ground-Side Perspective on Mixed Operations with Self-Separating and Controller-Managed Aircraft
Paul Lee – San Jose State University / NASA Ames Research Center

An anticipated increase in future traffic demand has propelled an investigation of numerous concepts aimed at improving efficiency and gaining capacity by reducing controller workload. NASA Ames and NASA Langley Research Centers have recently conducted a joint simulation to test the En Route Free Maneuvering concept element of Distributed Air-Ground Traffic Management (DAG-TM), which integrated advanced air and ground decision support tools (DSTs) with Controller-Pilot Data Link Communication (CPDLC). In this concept, controller "managed" aircraft flying under Instrument Flight Rules (IFR) were mixed with self separating "autonomous" aircraft flying under Autonomous Flight Rules (AFR). The overall results showed a significant potential for capacity gains and controller workload reduction, provided that safety concerns raised by the controllers can be addressed. The overall results are summarized in [1]. This paper describes the ground-side automation prototyped for DAG-TM operations and presents results on sector capacity, controller workload, traffic constraint compliance and safety. Controller feedback on the overall concept and the provided DSTs is discussed in detail. Results presented here also indicate that integrated ground-side DSTs can increase capacity even before concepts like airborne self separation are ready for operational implementation. DAG-TM research was funded by the Airspace Systems program as part of the Advanced Air Transportation Technologies project. DAG-TM activities were conducted by NASA Ames, NASA Langley, and NASA Glen Research Center.

Track 2 – Airspace Management (Room- Constellation E)

An Efficient Method for Airspace Analysis and Partitioning Based on Equalized Traffic Mass

Alexander Klein – George Mason University

We present a potential new partitioning mechanism for NAS-scale airspace that utilizes a high-resolution hexagonal grid. We use the Traffic Mass metric: total aircraft position report ("ETMS TZ hit") count in each grid cell or airspace sector/center. Its relationship to Workload metrics is discussed. We describe a fast algorithm that processes large amounts of traffic data and creates potential airspace center boundaries starting from a selected number of seed locations. The airspace partitioning is based on the Equalized Traffic Mass principle: total traffic counts for each center must be about equal, with busy centers being smaller in size than centers with sparser traffic. The same principle can be applied to sector boundary design inside a center. By selecting appropriate seed locations (e.g. around major airports or along major flows), we can control how the algorithm grows the Centers. We discus possible applications and extensions of the algorithm, including TZ hit rate as a metric, "delta-traffic-mass" comparisons, effects severe weather patterns and temporal changes in traffic flows on the "elasticity" of the airspace boundaries generated by the algorithm. Finally, we outline future work, including the use of fast-time simulation tools in conjunction with grid-based air traffic analysis.

Assessment of the 3D-Separation of Air Traffic Flows

David Gianazza – CENA/LOG

This paper is a continuation of [1] and [2], where two algorithms were introduced, allocating optimal separated 3D-trajectories to the main traffic flows. The reader may also refer to [3] (PhD thesis, in french) for more details. In [1], these algorithms -- an algorithm for the sequential strategy, and an evolutionary algorithm for the global optimization -- were tried on a toy problem, and the two strategies were compared. In [2], the algorithms were again briefly introduced and illustrated on the same toy problem, and then applied to real traffic data, using operational aircraft performances, but with only one 3D-trajectory per flow. In this paper, we present more realistic models of 3D-flows, with several trajectories per origin-destination link. The 3D-separation concept is then assessed by comparing the conflicts detected in a traffic of reference, with the conflicts detected when the aircraft belonging to the main traffic flows follow separated 3D-trajectories.

Emergence and Impact of Secondary Airports in the United States

Philippe Bonnefoy – MIT

As major airports in the United States have reached their maximum capacity and became congested, available capacity at surrounding airports has been utilized by the emergence of secondary airports. Airlines have entered service at regional airports in order to capture and stimulate local and peripheral markets, also resulting in the emergence of secondary airports. Given the expectation of a larger number of operations in the National Airspace System (NAS) in the upcoming years, this trend of secondary airport emergence is likely to strengthen. In order to understand the dynamics of regional airport systems, a study of the factors that led to the emergence of secondary airports was performed. The congestion at the core airport and the distribution of population at the regional level, ground access and airport infrastructure were identified as major factors. The nature of the regional airport system, in terms of percentage of connecting passengers at the core airport, was also identified as a contributing factor. Economic factors influenced the entry of a specific carrier -generally a low-cost carrier- at secondary airports. These carriers stimulated local and peripheral markets. The entries of other carriers –both legacy and low-cost- that followed this initial entry consolidated the airport growth at the emerging airport. As a consequence of the emergence of secondary airports and their integration into a region wide multi-airport system, impacts are induced on the NAS structure. Recent consolidations of TRACONs (Terminal Radar Approach Control) were identified as primary impacts. With the increasing pressure of demand on core airports in the upcoming years, the development of additional secondary airports will be required. The transition from a single core airport to region wide multi-airport systems and the emergence of new secondary airports in existing multi-airport systems, impose new constraints that need to be taken into account in the future NAS improvements.

Analysis of Excess Flying Time in the National Airspace System

George Solomos – MITRE Corp

Research on the United States (U.S.) National Airspace System (NAS) has sought answers to the following questions: Is there measurable excess flying time in the NAS? If so, where does it occur? Using aircraft track and flight information for multiple years, we have discovered a significant level of excess flying time when using a "best observed" flying time as a standard. In the en route regime, 4 to 5 minutes per flight, in good weather, can be detected. Drilling down to a fine-grained geographic mesh on a map of the U.S. enables detection of specific locations of significant delay. These locations can be associated with operational sectors. This information has allowed an examination of changes over time, and should aid in focusing the scarce Federal Aviation Administration (FAA) funding for congestion management.

The factors affecting airspace capacity in Europe: A Framework Methodology based on Cross Sectional Time-Series Analysis using Simulated Controller Workload Data

Arnab Majumdar – Imperial College London

Air traffic in Europe is increasing at a rapid rate and traffic patterns no longer display pronounced daily peaks but instead exhibit peak spreading. Airspace capacity planning can no longer be for the peak period but must consider the whole day. En-route airspace capacity in the high density European air traffic network is determined by controller workload. Controller workload is primarily affected by the features of the air traffic and ATC sector and capacity is usually estimated using the simulation model, the Re-organized ATC Mathematical Simulator (RAMS) model of air traffic controller workload. This paper considers the air traffic and ATC sector factors that affect controller workload throughout the whole day and provides a framework using cross-sectional time-series analysis of the RAMS simulation output. Two simulation studies are presented in contrasting regions of European airspace to show the robustness of the method. Controller interviews are used to enhance the analysis. The results indicate that a sub-set of traffic and sector variables and their parameter estimates can be used to predict controller workload in any sector of the two regions simulated in any given hour.

Track 2 – Decision Support (Room- Constellation E)

Improvement on the Acceptance of a Conflict Resolution System by Air Traffic Controllers

Rainer Flicker – Technical University Berlin

New air traffic management concepts for increasing the capacity of the air space use a longerterm planning than with today's systems realized. The temporally and spatially expanded air space exceeds the cognitive capabilities of humans. Therefore air traffic controllers must be supported technically in terms of conflict detection and resolution. Abstractions of specific conflict resolutions are called conflict resolution strategies. These strategies describe the way of generating solutions, and are independent of the actual conflict situation except for conflict describing parameters.
The air traffic controllers' knowledge about conflict solving was investigated in a literature research. This knowledge was then formulated in the form of hypotheses and examined in a questionnairebased investigation with air traffic controllers of the German air navigation service provider 'Deutsche Flugsicherung GmbH' (DFS). All hypotheses could be confirmed and besides further knowledge was gained.
The examined hypotheses were then, for further information-technical processing, transformed into a decision tree. This forms the basis for the model of the conflict resolution assistance, which was then transferred with methods of object-oriented software design into a software model and was implemented as software component. The newly created software component was then integrated in the air traffic simulation system of the Technical University Berlin, in order to be validated in a scenario-based real time simulation with air traffic controllers of the German
air navigation service provider (DFS).
The evaluation investigation showed an increased acceptance of the conflict resolution assistance system with controllers' knowledge, compared to a system without controllers' knowledge.

Impact of Factors, Conditions and Metrics on Trajectory Prediction Accuracy

Stephane Mondoloni – CSSI Inc.

As a central component of decision support tools, trajectory predictors require accuracy levels commensurate with desired DST performance. In this paper we decompose trajectory prediction accuracy as due to a collection of factors influencing trajectories under specific operational conditions. We discuss the use of "error signals" to report the impact of each factor from which multiple accuracy metrics can be derived. We illustrate how the definition of the derived metric will influence the magnitude and potentially the relative ranking of the effects of various factors. The paper shows that the influence of many factors is approximately linear and how the results of a sensitivity study can be used to approximate a scenario under a wider set of conditions. The results of such a sensitivity study can also be applied to investigate interoperability between DSTs using disparate trajectory predictors.

Air Ground Communications Miami Controller Pilot Data Link Communications Summary and Assessment

John Gonda – MITRE-CAASD
William Saumsiegle – MITRE

The Controller-Pilot Data Link Communications (CPDLC) Build 1 system was operational from October 7, 2002 until September 30, 2004. The system was fielded as a limited-use operational capability in the Miami Air Route Traffic Control Center and surrounding airspace, as a cooperative effort among a group of aviation industry stakeholders, including the Federal Aviation Administration (FAA), airlines, avionics manufacturers, and communications service providers. During the two years of operations, four basic services were enabled through the exchange of more than 85,000 digital messages over an International Civil Aviation Organization (ICAO)-compliant Aeronautical Telecommunications Network (ATN). Thirty aircraft participated in these transactions. The system has shown that CPDLC works, and controllers and pilots have responded positively. This paper describes the CPDLC Build 1 system and summarizes the two years of operations, including the expansion of the basic CPDLC Build 1 capabilities through the Value-Added Services initiative. The paper concludes with a compilation of lessons learned and an overall assessment that places the success of the CPDLC Build 1 system in the context of future CPDLC development.

Integration of Downlink Aircraft Parameters in a French En Route ATC HMI

Vincent Kapp – DSNA

The purpose of the Downlink Aircraft Parameters (DAPs) study is to evaluate and compare different implementations of DAPs in terms of access and visualization in an ATC En Route HMI. Although there have been numerous studies on the DAPs, most of them address cost/benefits issues. The originality of our work relies mainly on the following points:
• The DAPs addressed here are directly used by the controllers,
• The study focuses on the En Route context,
• The study aims at giving very practical recommendations (the DAPs will be used in the French operational environment soon).
The study is divided in two principal parts. In the first part we focus on the controller needs. Then, in the second part, we perform comparative evaluations of several propositions of DAP integration in an ATC En Route HMI. The results we have obtained have enabled us to make recommendations to the DNA technical service in charge of the system specifications. We do not point out a "good solution", but rather recommend a mixed implementation.

Managing Sector Congestion Using Airspace Restriction Planner

Parimal Kopardekar – NASA Ames Research Center

This paper describes a capability, called the Airspace Restriction Planner (ARP), which is designed to predict and manage sector congestion problems. The capability allows the Traffic Management Coordinators (TMCs) to identify the sectors that are going to be over-congested, identify the detailed characteristics of incoming traffic, and plan traffic flow management restrictions such as altitude capping, rerouting, departure delays, and time-based metering or miles-in-trail restrictions. The capability also provides immediate feedback on the effectiveness of the planned restrictions prior to their execution. This capability was prototyped using the NASA's Future Air Traffic Management Concept Evaluation Tool. Using Cleveland Air Route Traffic Control Center's (ARTCC's) Ravenna sector airspace, human-in-the-loop simulations were conducted to examine the effectiveness and usability of the ARP. The results indicated that the TMCs were able to plan more accurate traffic flow management restrictions with the ARP. All eight participants indicated that this capability is valuable and needed for more precise ARTCC-level traffic flow management planning.

Quantifying Convective Delay Reduction Benefits for Weather/ATM Systems

James Evans – MIT Lincoln Laboratory

In this paper, we discuss ongoing efforts to quantify convective weather delay reduction benefits for weather/ATM systems and recommend approaches for future assessments. This is particularly important at this time because: 1. convective weather delays have become a dominant factor in the overall National Air System (NAS) delays (figure 1), and 2. Benefits quantification and NAS performance assessment have become very important in an era of significant federal government and airline budget austerity for civil aviation investments Convective weather events are in general not repeatable (unlike many low ceiling and visibility events) and, give rise to highly nonlinear queue driven delays in congested airspace. Hence, seemingly straightforward comparisons of delays cannot be easily carried out. In this paper, we first discuss at some length the mechanisms by which convective weather delay occurs in the NAS and highlight challenges in delay reduction assessment. We consider this to be very important since one needs to understand how the system operates if one is to design an effective, accurate performance assessment system. We then describe practical results from ongoing analysis of delay reduction for both terminal and enroute systems using user interviews, direct observations of ATM decision making in convective weather, and analysis of delay statistics. The paper concludes for recommendations for future convective weather delay reduction quantification studies.

Track 2 – Environmental Impacts and Mitigation (Room- Constellation E)

SOURDINE II Assessment Aspects of Noise Abatement Procedures

Ruud den Boer – NLR

The SOURDINE-II (Study of optimisation procedures for decreasing the impact of noise) project is a 5th framework RTD project of the European Union focused on the development and assessment of Noise Abatement Procedures (NAPs). It started November 2001 and will be finished August 2005. Four parts can be distinguished in the study: 1. Procedure (approach and departure) definition 2. Further development of assessment tools 3. Procedure assessment 4. Procedure implementation In this paper, the project organization and applied methodology, as well as the first two topics mentioned above, are discussed very briefly. However, the main emphasis in this paper is on parts of the procedure assessment work. In the SOURDINE-II project a selection of approach and departure procedure is assessed with respect to safety, environmental impact (noise and emissions), capacity, Costs/Benefits, and acceptance by end-users (pilots and air-traffic controllers). This paper presents an overview of the initial results of the assessment work, with emphasis on the Real-Time simulations which were executed to determine the acceptance by end-users. Also, a brief overview of a part of the safety study is presented. The work on the Procedures implementation plan has just started and is not included in this paper. Both in the real time simulations as well as in the safety analysis bottlenecks for the implementation of the concept are identified. These bottlenecks will help the operational concept developers to find improvements for the operation before a successive assessment is done.

Human Factors Implications of Continuous Descent Approach Procedures for Noise Abatement in Air Traffic Control

Hayley Davison Reynolds – MIT

Continuous Descent Approach (CDA) procedures can be effective at reducing aircraft noise around airports. The human factors implications for the air traffic controller of transitioning from conventional to CDA procedures are addressed in this paper. Different types of CDA procedures are introduced and models are developed of the controller tasks undertaken during current approach operations. The models are used to perform cognitive difference analyses to highlight the implications of using CDA procedures, particularly with respect to differences in intent, controllability and structure-based abstractions in the lateral, vertical and speed domains. An experiment is described to probe the cognitive implications of one of the key differences between the procedures: removal of periods of constant speed. All of the findings are summarized to provide CDA design guidance in order to ease transition and controller acceptance of their use.

Variability of Contrail Formation Conditions and the Implications for Policies to Reduce the Climate Impacts of Aviation

Victoria Williams – Imperial College London

The contribution of air travel to climate change is significant and growing, but emissions and their effects are not yet regulated. One of the major impacts on climate from the aviation sector is the production of contrails (vapour trails) in the atmosphere and their influence on cirrus cloud formation. Potentially, reducing cruise altitude represents one option for controlling the growing climate impact of aviation. In general, this would reduce contrail and cirrus cloud formation but there are associated penalties, including an increase in the rate of fuel consumption and hence in the rate of carbon dioxide emission. Constraining cruise altitudes also raises operational issues, including increases in airspace congestion and in journey time. Atmospheric variability can change the amount of contrail and contrail-cirrus, so contrails may sometimes be more likely to form at lower altitudes. In these cases, reducing cruise altitude could increase rather than reduce the contrail amount. This paper describes an approach to optimise the balance between the benefits of contrail reduction and the penalties incurred for altitude restriction. The calculations use an air traffic sample for western Europe, with NCEP-II reanalysis data for atmospheric temperature and humidity. A maximum cruise altitude is selected for each six-hour period, according to atmospheric conditions. This altitude provides the greatest reduction in contrail for the lowest increase in carbon dioxide emission. This avoids the contrail and carbon dioxide increases associated with ineffective or counter-productive altitude restrictions. Calculated contrail reductions are presented, along with the associated increases in carbon dioxide. These values compare favourably with previous policy designs based on altitude restrictions fixed on a monthly basis. In addition, potential operational issues associated with a varying altitude restriction policy are discussed.

Environmental Tradeoffs Assessment Around Airports

Kenny Martin – ISA Software

Recently, due to the increased rate of growth of air transport and increased environmental concerns, environmental impact of aviation threatens the development of the air transport. Even though there are technological and CNS/ATM improvements to reduce the environmental effect, the increase of flights is much higher than the achieved benefits. In particular aircraft noise is perceived as one of the most important constraints to growth. In fact, ICAO's Committee on Aviation Environmental Protection (CAEP) recommended new noise abatement procedures to reduce the impact on the areas of surrounding airports [1]. While implementing new noise abatement procedures, as the main focus is reducing the noise impact, generally other environmental issues are discarded such as global emissions and local air quality. Research and harmonised tools to understand better the relationship between noise and emissions is needed in order to ensure sustainable and cost-efficient operational decisions. This study highlights the importance to carry out trade-off assessments to understand the interrelation of different environmental impacts of proposed operational decisions and to determine the economic effects of each decision. The trade-off approach consists of: • Specification of operational scenarios • Quantification of environmental effects • Evaluation by converting the quantified values into monetary terms. One illustrative example is developed to assess the feasibility of the trade-off assessment approach. Preferred emissions route (PER) and preferred noise route (PNR) scenarios are used to demonstrate the study feasibility. One of the important aspects of the study is to demonstrate that the combined use of airspace simulation, environmental and economic tools, makes trade-off assessment feasible for any kind of scenarios, and adds value to operational project evaluation.

Track 2 – Traffic Flow Optimization (Room- Constellation E)

Probabilistic Congestion Management

Craig Wanke – MITRE Corp.

A new approach to airspace congestion management is presented, in which uncertainties in predicting traffic levels and airspace capacity are quantified and considered in developing congestion resolutions. Such a "probabilistic" approach has the potential to greatly improve decision-making. Probabilistic models for predicting traffic demand are presented, with results, and an initial model for predicting airspace capacity is outlined. Candidate displays and human factors issues for use of probabilistic information are discussed, and a probabilistic decision-making framework for en route congestion management is presented.

Advance Planning Through Schedule Analysis

Michelle Somerday – Metron Aviation, Inc.

Combining airline schedule data in one central repository would support evaluation of the day of operations impact of the future airline flight schedule. In this paper, three sample analyses are shown that use schedule data to project operational impact. The first simulates expected arrival delay at Chicago O'Hare International Airport (ORD) based on the schedule for July 2003 vs. July 2004. The second demonstrates the impact on arrival delay of a future schedule increase at Atlanta Hartsfield International Airport (ATL). The third shows the impact of single flight rescheduling or insertion on departure delay at Philadelphia International Airport (PHL). The need to account for unscheduled traffic, different scheduling implementations, and different operational scenarios is also addressed. This is not a comprehensive, rigorous study but is intended to demonstrate the types of analyses that can be conducted using schedule data. With this type of work, possible issues on the day of operations can be identified and potentially mitigated well in advance.

On the Feasibility of Traffic Synchronization in Central European Upper Airspace

Lenka Dravecka – CRDS, Budapest

One general hypothesis for future Air Traffic Management (ATM) is that traffic in a flow shall be better organized to increase its performance in terms of capacity and delays savings. This hypothesis suggests a shift from current ATM concept, which is non-synchronized, to a synchronized system with synchronized distance separation between all aircraft evolving in a flow in order to be able to cope with future air traffic demand. This paper presents one first step towards the evaluation of operational feasibility of this concept in Central European Upper Airspace : the improvement of controllers' productivity through adequate task sharing in the traffic synchronization activity. Task sharing is necessary in this case because synchronization time can span over several sectors in Europe. A simple synchronization model is proposed, taking into account (i) the time duration needed to transform the non-synchronized inbound flows into synchronized ones, and (ii) the variations of conflict situations.

Airline Operations Managers: An Introduction to the Third Leg of the National Air Transportation System

Karen Feigh – Georgia Institute of Technology

US airlines play a large role in the efficient operation of the national air transportation system. Little, however has been written about how airline operations management decisions are made. This paper presents the results of contextual inquiries conducted on three Sector Operational Managers at a major flag carrier. Sector Operational Managers were found to play a key role at both minimizing disruptions to the NAS and in speeding the recovery at the airline level of air traffic following the conclusion of disruptions.

Expanding the Use of Time-Based Metering: Multi-Center Traffic Management Advisor

Steven Landry – NASA Ames Research Center

Time-based metering is an efficient air traffic management alternative to the more common practice of distance-based metering (or "miles-in-trail spacing"). Despite having demonstrated significant operational benefit to airspace users and service providers, time-based metering is used in the United States for arrivals to just nine airports and is not used at all for non-arrival traffic flows. The Multi-Center Traffic Management Advisor promises to bring time-based metering into the mainstream of air traffic management techniques. Not constrained to operate solely on arrival traffic, Multi-Center Traffic Management Advisor is flexible enough to work in highly congested or heavily partitioned airspace for any and all traffic flows in a region. This broader and more general application of time-based metering is expected to bring the operational benefits of time-based metering to a much wider pool of beneficiaries than is possible with existing technology. It also promises to facilitate more collaborative traffic management on a regional basis. This paper focuses on the operational concept of the Multi-Center Traffic Management Advisor, touching also on its system architecture, and prospects for near-term deployment to the United States' National Airspace System.

Dynamic Stochastic Optimization Model for Air Traffic Flow Management with En Route and Airport Capacity Constraints

Mark Hansen – University of California at Berkeley

In this paper, we present a linear dynamic stochastic optimization model for Air Traffic Flow Management (ATFM) that accounts for uncertainty in both airport and en route airspace capacity. Rather than analyzing this problem in its full generality, we focus on the case in which there is a single destination airport and a small number of arrival fixes subject to blockage or reduced capacity as a result of weather. This would typically occur when there is weather in the vicinity of the airport that affects capacity of some of the standard arrival fixes of the airport, along with the acceptance rate (or arrival capacity) of the airport itself. The main decisions in the model are pre-departure delay (or ground holding) and local rerouting of inbound flights. We perform experiments by applying the model to manage arrival flow at Dallas Fort-Worth Intl. Airport (DFW). We consider hypothetical cases when weather blocks some of the standard arrival fixes of DFW, and reduces the airport capacity. Such situations commonly arise at DFW when thunderstorms occur in the vicinity of the airport, and effectively block some of the standard routes and/or fixes delivering inbound traffic. In our model, ground delays are dynamically revised based on updated information on capacity forecasts. When weather impacts en route fixes, and the cost ratio between unit airborne and ground delay is low, some flights are rerouted through weather-free regions. When the airport is the only bottleneck, rerouting flights is not necessary. Results from our experiments show that when weather impact on en route fixes is severe and persistent, substantial benefits in terms of delay savings is achieved from dynamically rerouting flights via weather-free arrival fixes compared to cases where ground delays are dynamically readjusted but no airborne delays are allowed.

Evaluating En Route Congestion Management Through Interactive Simulation

Michael Brennan – Metron Aviation, Inc.

This paper describes a newly-developed simulation environment focused on interactive strategic air traffic management in both the en route and arrival domains. It discusses its origins and how it can be used in Human in the Loop tests to evaluate and improve new procedures and technologies for Traffic Flow Management. It then provides an illustration of how it can be used to investigate management initiatives by using the environment to evaluate both the current approach and potential alternatives to dealing with en route traffic in the face of convective weather. The illustration shows that the current methods are both inefficient and ineffective, and that proposed new technologies will greatly reduce the cost of en route disruption. It further shows that in a least some cases a solution that involves multiple initiatives of differing type provides the best solution.

Response Mechanisms for Dynamic Air Traffic Flow Management

Michael Ball – University of Maryland

Dealing with uncertainty and changing conditions represents a major challenge in air traffic flow management (ATFM). We use the newly developed slot credit substitution (SCS) mechanism as a prototypical example to understand how fast-response, dynamic mechanisms can improve ATFM performance. We develop a quantitative model that estimates the difference in impact of a batch-oriented periodic process and a fast-response asynchronous process and describe some key properties of fast-response mechanisms derived from the SCS case.

Track 3 – Safety (Room- Constellation F)

Preliminary Results from a European Safety R&D Program

Barry Kirwan – Eurocontrol EEC

This paper is concerned with safety research and development (R&D) that is necessary to ensure continued safety of air traffic management, given the major changes that will occur in European ATM over the coming years. The program of safety R&D was developed following the two tragic fatal accidents in Europe of the Milan Linate runway collision and the Ueberlingen mid-air collision. Eight high priority safety R&D work areas were defined: organisational (safety) learning; enhanced safety and risk assessment approaches; integration of safety into early ATM system design processes; short term key risk areas; longer term key risk areas; safety culture; development of a safety roadmap towards the European ATM vision of 2012; and enhanced safety R&D coordination. This paper distils key results and achievements from each of these eight areas.

The Link between Operational Performance and Operational Errors in the National Airspace System

Mark Hansen – University of California at Berkeley

We consider the link between the incidence of operational errors (OEs), operations counts, operational conditions, and weather in the US National Airspace System (NAS). Our main aim is to test the hypothesis--suggested by the human factors literature linking cognitive tasks and human error--that adverse operating conditions lead to higher rates of OEs. Poisson regression estimation results support this hypothesis in all three air traffic control domains—en route, tower, and TRACON. Our results also demonstrate that OEs increase supra-linearly with operations volume, that convective weather causes more TRACON and en route operational errors, that low visibility increases tower OEs, and that there are large facility fixed effects for TRACON and tower OEs. One implication of this research is that investments to improve operational performance of the NAS may also improve its safety performance.

Safety Analysis for Advanced Separation Concepts

John Andrews – MIT Lincoln Laboratory

Aviation panels have called for increasing the capacity of the air transportation system by as much as a factor of three over the next 20 years. The inherent spatial capacity of en route airspace appears able to accommodate the resulting traffic densities. But controller workload presents a more formidable obstacle to achieving such goals. New approaches to providing separation assurance are being investigated to allow airspace capacity to be fully utilized. One approach is to develop computer automation as the basis for separation-assurance processes. This would permit traffic densities that exceed the level at which human cognition and decision-making can function. One of the challenges that must be faced involves the ability of such highly automated systems to maintain safety in the presence of inevitable subsystem faults, including the complete failure of supporting computer systems. Traffic density and flow complexity will make it impossible for human service providers to safely reinitiate manual control in the event of computer failure, so the automated system must have inherent fail-soft features. This paper presents a preliminary analysis of the ability of highly automated separation assurance system to tolerate general types of faults such as nonconformance and computer outages. Safety-related design features are postulated using the Advanced Airspace Concept (AAC) as a basis. Special attention is given to the impact of a severe failure in which all computer support is terminated within a defined region. The growth and decay of risk during an outage is evaluated using fault tree methods that integrate risk over time. It is shown that when a conflict-free plan covers the region of the outage, this plan can be used to safely transition aircraft to regions where service can still be provided.

Safety Analysis Methodology for Unmanned Aerial Vehicle (UAV) Collision Avoidance Systems

James Kuchar – MIT Lincoln Laboratory

The integration of Unmanned Aerial Vehicles (UAVs) into civil airspace requires new methods of ensuring collision avoidance. Concerns over command and control latency, vehicle performance, reliability of autonomous functions, and interoperability of sense-and-avoid systems with the Traffic Alert and Collision Avoidance System (TCAS) and Air Traffic Control must be resolved. This paper describes the safety evaluation process that the international community has deemed necessary to certify such systems. The process focuses on a statistically-valid estimate of collision avoidance performance developed through a combination of airspace encounter modeling, fast-time simulation of the collision avoidance system across millions of encounter scenarios, and system failure and event sensitivity analysis. Example simulation results are provided for an implementation of the analysis process currently being used to evaluate TCAS on the Global Hawk UAV.

Applying Qualitative Hazard Analysis to Support Quantitative Safety Analysis for Proposed Reduced Wake Separation Conops

John Shortle – George Mason University

This paper describes a scenario-driven hazard analysis process to identify, eliminate, and control safety-related risks. Within this process, we develop selective criteria to determine the applicability of applying engineering modeling to hypothesized hazard scenarios. This provides a basis for evaluating and prioritizing the scenarios as candidates for further quantitative analysis. We have applied this methodology to proposed concepts of operations for reduced wake separation for closely spaced parallel runways. For arrivals, the process identified 43 core hazard scenarios. Of these, we classified 12 as appropriate for further quantitative modeling, 24 that should be mitigated through controls, recommendations, and / or procedures (that is, scenarios not appropriate for quantitative modeling), and 7 that have the lowest priority for further analysis.

Quantitatively Estimating Wake Vortex Safety Using P2P Model

Yue Xie – George Mason University

This paper describes a scenario-driven hazard analysis process to identify, eliminate, and control safety-related risks. Within this process, we develop selective criteria to determine the applicability of applying engineering modeling to hypothesized hazard scenarios. This provides a basis for evaluating and prioritizing the scenarios as candidates for further quantitative analysis. We have applied this methodology to proposed concepts of operations for reduced wake separation for closely spaced parallel runways. For arrivals, the process identified 43 core hazard scenarios. Of these, we classified 12 as appropriate for further quantitative modeling, 24 that should be mitigated through controls, recommendations, and / or procedures (that is, scenarios not appropriate for quantitative modeling), and 7 that have the lowest priority for further analysis.

A Method for Rating the Severity of Runway Incursions

Kim Cardosi – DOT/Volpe Center

Risk is a function of the probability of an event and the severity of the consequences of that event. Any discussion of issues of risk in surface operations must include a valid and reliable measure of the severity of the outcome of runway incursions. This paper describes an automated method for rating the severity of the outcome of runway incursions. This model was developed using the same criteria and decisions that experts currently use to determine the severity of an incursion. The model assigns a severity rating based on the information contained in the preliminary report of the incident. This includes: the geometry of the situation that resulted in the incursion and the closest proximity (horizontal or vertical), visibility, type aircraft, and whether or not (and characteristics of) the avoidance maneuver. The initial validation was conducted by comparing the model's assessment of 307 runway incursions to the assessment conducted by a panel of subject matter experts in the FAA Runway Safety Office. In 92% of the incidents, the model matched the group's ratings (of three levels of severity). Patterns of discrepancies are well defined and discussed. Ongoing validation efforts are also described. Finally, possible applications to losses of standard separation in the air are explored.

Track 3 – Innovative ATM Concepts (Room- Constellation F)

Statistical Performance Evaluation Between Linear and Nonlinear Designs for Aircraft Relative Guidance

Thierry Miquel – DSNA

Over the last few years, several concepts concerning the delegation to the flight crew of some tasks currently performed by the air traffic controllers have emerged. Among these new ideas, relative guidance has appeared to be capable to contribute to the enhancement of air traffic capacity though it raises difficult technical challenges. Indeed, this kind of maneuver appears difficult to perform manually, and may induce an excessive increase in flight crew workload, thus requiring new on-board automated functions. Some linear and nonlinear techniques have already been applied to design a feedback loop which performs automatically merging maneuvers and maintains station keeping behind a designated aircraft. The main contributions of the paper consist in a new nonlinear design of the feedback control loop and in the comparison between a linear design and the proposed nonlinear design, namely a proportional/derivative design and the proposed backstepping design. The comparison is based on Monte Carlo simulations, and promotes the nonlinear design. Indeed, a touch of complexity in the design process allows for better performances: backstepping fosters quick achievement of merging and station keeping maneuvers.

Estimation of Delay Propagation in the National Aviation System Using Bayesian Networks

Chun-Hung Chen – George Mason University

Flight delay creates major problems in the current aviation system. Methods are needed to analyze the manner in which micro-level causes propagate to create system-level patterns of delay. Traditional statistical methods are inadequate to the task. This paper proposes the use of Bayesian networks (BNs) to investigate and visualize propagation of delays among airports. The BN structure was developed from expert judgment and validated against empirical data. Parameters were estimated using a novel empirical Bayes approach in which regression estimates were used to construct a Dirichlet prior distribution, which was then updated from multinomial samples. Empirical results demonstrate greater predictive accuracy using our empirical Bayes approach than linear regression or Bayesian analysis with non-informative prior distributions. Our results clearly demonstrate the value of Bayesian networks for analyzing and visualizing how system-level effects arise from subsystem-level causes.

Route Charging Policy for a Functional Block of Airspace (CEATS)

Lorenzo Castelli – University of Trieste

The introduction of the CEATS UACC (Central European Air Traffic Services Upper Area Control Centre) controlling the upper airspace of several central European countries opens the doors for assessing different route charging policy scenarios in order to maximise its potential benefits in terms of efficiency, safety and cost-effectiveness, and minimise the drawbacks. In this study, first we compare three charging scenarios by computing the Unit Rate values to be set by each ANSP located in the CEATS area. Then we analyse the impact that such Unit Rate values may have on the Aircraft Operators flying in the CEATS area. We conclude that, without a compensatory mechanism, the policy of considering different Unit Rates for each ANSP in the area would adversely affect the regional carriers and all the airlines based in the CEATS area since the CEATS Unit Rate turns out to be significantly lower than the Unit Rates of the national ANSPs controlling the lower airspaces.

Analyzing Air Traffic Management Systems Using Agent-Based Modeling and Simulation

Amy Pritchett – Georgia Institute of Technology

This paper presents the viewpoint that an air traffic management system is emergent, i.e., exhibiting behaviors at the system-wide level that emerge from the combined actions of individuals within the system. Emergence carries with it the additional implication that these phenomena typically cannot be predicted by examining the individuals' behavior alone. As a result, this paper proposes agent-based simulation as a method of predicting the impact of revolutionary changes to an air transportation system. Agent based simulation can integrate cognitive models of human performance, physical models of technology behavior and description of their operating environment. Simulation of these individual models acting together can predict the result of completely new transformations in procedures and technologies. While agent-based simulations cannot include every aspect of system behavior, they can provide quick, cost-effective insights that can supplement other forms of analysis.

Interactive and Immersive 3D Visualization for ATC

Matt Cooper – Linkopings Universitet

Air traffic control (ATC) is a human-dependent safety critical activity therefore the information that is made available to the human decision-maker - the controller - is of extreme importance. In ATC, the design of human-machine interfaces requires particular attention, especially when a new technology is considered. To support the investigation on the applicability of the new 3D Virtual Reality technology for air traffic control, our strategy has been to establish parallel, mutually beneficial technology-driven design and human-centred evaluation approaches. The technology-driven investigation aims at exploring all features that can be offered by 3D stereoscopic visualisation and multimodal interactions technologies while the ultimate goal of the human-centred investigation is to empirically uncover the main implications derived from the adoption of 3D stereoscopic interface for ATC, with particular attention to controllers' acceptability. This paper describes the implementation, from our technology-driven design approach, of a 3D stereoscopic system for real time visualisation and manipulation of data in air traffic control. We will discuss the modelling and 3D visualisation of specific ATC objects such as aircraft trajectories, convective weather, conflicts, etc. and the multi-modal interaction schemes associated to the controller

working environment. Results of our user-centred, empirical analysis of the applicability of 3D stereoscopic technology for ATC are being published elsewhere, and are not discussed herein.

Shifting the ATM Paradigm: From the Use of System Resources to the Management of Objectives

Laurent Guichard – Eurocontrol EEC

Paradigm Shift project (SHIFT), started in January 2004, proposes a new paradigm for an innovative Air Traffic Management, based around five main interrelated operational concepts: Contract of Objectives, Operational Plan, Target Windows, Decentralized Airspace, and Dual Airspace. The analysis introduces a new way of designing the air navigation infrastructure based on the concept of management by objective instead of by means. It defines the foundation of an ATM system able to cope with traffic demand at the horizon of 2020 and beyond , while maintaining a very high target level of safety and supporting a sustainable air transport business development. Investigations on the acceptability of the Contract of Objectives, and on the impact of the Dual Airspace are presently on going. This paper presents the holistic view of current ATM and describes the concepts suggested by SHIFT for the shift of paradigm, a necessity for future ATM mechanism.

Design for Innovation in ATM

Patrizia Marti – DeepBlue

This paper presents the work carried out in the framework of a study performed under the CARE Innovative Action initiative of Eurocontrol. In particular it accounts for the outcomes of the CREA! project (Creative Research Environment for ATM) both in terms of innovative concepts for Air Traffic Management (ATM) and in relation to design approach developed during the project. Innovation is a topic of great interest in complex safety critical systems like ATM, nevertheless classical design approaches concentrate on problem definition and analysis, articulating solution within the identified problem space. The approach that will be discussed in this paper focuses on problem setting rather then looking for solutions with respect to actual or potential breakdowns.

Co-operative Air Traffic Management: A Technology Enabled Concept for the Next Generation Air Transportation System

Everett Palmer – NASA Ames Research Center

Co-Operative Air Traffic Management (CO-ATM) is a concept under exploration at NASA Ames Research Center for transformation of aircraft and air traffic management operations towards the Next Generation Air Transportation System (NGATS). CO-ATM aims at providing a scalable framework for greatly increasing capacity in a safe and secure environment while giving airspace users increased flexibility in managing their operations. CO-ATM envisions sector controllers controlling conventional aircraft along predictable flight paths and area controllers coordinating trajectory changes with flight crews of equipped aircraft in the same airspace via data link. Area controllers operate with extensive automation support for conflict detection and resolution and traffic flow management. Routine tasks like handoffs and transfer of communication are conducted by the automation. Equipped aircraft operate at different levels of autonomy. Tasks like aircraft-to-aircraft spacing can be delegated to the flight crews. Flight crews of equipped aircraft can coordinate preferred trajectories for traffic flow constraints with the area controller or operate at higher levels of autonomy, if desired and authorized. CO-ATM aims at achieving substantial capacity and efficiency benefits. It builds on lessons learned from distributed air/ground traffic management (DAG-TM) research, and addresses identified safety, coordination, automation and mixed equipage concerns. CO-ATM provides a transition path from the current system to the next generation with gradual shifts in roles and responsibilities and incentives to for aircraft operators to equip. The paper reviews plans and concepts for the Next Generation Air Transportation System (NGATS) and relevant research findings from DAG-TM studies. It presents the CO-ATM concept in detail and presents a possible transition path in line with our ongoing research at NASA Ames addressing the integration of trajectory based operations and airborne separation assistance (ASAS).

Track 3 – Human Factors (Room- Constellation F)

As Rapid as Paper Strips? Evaluation of Vertidigi, a New Control Tool for Terminal Sectors

Railane Benhacene – CENA

VertiDigi is a vertical view of the flights in a terminal sector. The view, on a touch sensitive screen, tries to provide a similar service to controllers as the current paper Strips do: a tool to input control clearances naturally, intuitively and at a speed sufficient to allow the traffic to be efficiently managed. In arrival sectors, an Arrival Manager (AMAN) is often used. The AMAN delays in minutes can also be expressed on the vertical view as a moving target (ball indicating the desired position) for each flight. The resulting ball train is a novel way of representing an arrival sequence in a perceptive, analog way. Experiments conducted with 8 air traffic controllers from Paris ACC tried to establish the following: • Compare VertiDigi vs. Strips input times, • Assess acceptability of the vertical view, • Estimate usability of the ball train The most evident outcome is that input times are in the same order of magnitude as papers Strips, and promising to be even shorter with minimal training. Meanwhile, the vertical view did not affect the controllers' mental view of the traffic. The ball train, in turn, did not yield better usage, performance or acceptance than the current AMAN HMI.

Controller-Pilot Radio Channel Utilization and Cognitive Issues

Jasenka Rakas – NEXTOR

This paper introduces a new metric, termed cognitive utilization, which tries to capture the percentage of time in which controller has to "think" about certain aircraft. In that sense, cognitive utilization sums all the time intervals during which a specific communication "transaction" is underway. Voice-communication messages for fifteen 30-minute sector samples, and related traffic data are analyzed in order to determine whether cognitive utilization affects sector capacity. First, we investigate the relation between physical utilization and sector capacity, and then, whether there is an independent cognitive effect. We find that in most cases cognitive and physical utilization are closely correlated, but that there are a few instances in which the former vastly exceeds the latter. It appears that when this occurs, pilots capacity to conduct voice communications is substantially reduced.

Organizational Issues and Safety Culture in ATM, Part 1: Stability Analysis

Marcus Arvidsson – Lund University

The Swedish Air Navigation Services Provider (LFV ANS) are undergoing major organizational changes in order to adapt to changing demands on efficiency and technical development in air traffic control. In these change processes the foundations of the safety work can be affected and changes in the existing safety culture can be introduced. In a joint research project – Human Factors in Air Navigation Services (HUFA) – between the Swedish Civil Aviation Administration and Lund University the focus is on human and organizational factors and safety in air traffic control. The aim of the project is to study safety culture and related organizational issues in order to monitor these during the change processes. Study locations are the two main air traffic control centers and parts of the LFV ANS head office in Sweden. Using questionnaire assessments, three measurement rounds will be conducted during the course of about three years. Studies 1 and 2 are completed, where the first one has given baseline values. After 20 months, study 2 was completed in order to monitor the effect of spontaneously occurring organizational changes. This paper presents results concerning the stability of the investigated organizational climate, leadership style of team managers, psychosocial work environment, and safety culture.

User Request Evaluation Tool (URET) Adoption and Adaptation; Three Center Case Study

Tatjana Bolic – University of California at Berkeley

The objective of this paper is to present findings of exploratory interviews regarding the air traffic controllers' adoption and adaptation of User Request Evaluation Tool (URET). The importance of this investigation lies in better understanding of changes brought about by the use of Decision Support Tools by sector controller teams and what can be done to avoid some of the unintended consequences. The main purpose of URET is to support sector team strategic planning allowing controllers to concentrate on more user-beneficial control actions. Actual improvements depend on the way controllers use the automation tools in their work. Three things have been noticed about usage of URET: first, different sector teams use it in different ways; second, in many instances URET usage differs from what was intended; and third, the usage varies across centers. We interviewed subject matter experts to explore how controllers have adopted and/or adapted URET in three different Air Route Traffic Control Centers (ARTCC), across mentioned variations. The goal of this research is to draw lessons from the experience with URET that can inform technology deployments in the future.

Simulated Free Routing Operations in the Marseille UIR: Results and Issues from a Human Factors Perspective

Thomas Kircher – DSNA

Human performance considerations are expected to be central to the efficiency and safety of advanced Air Traffic Management (ATM) systems, while increases in traffic and advances in available technologies are projected. Free Flight (FF) and Free Routing (FR) proposals to relax airspace and give greater autonomy to aircraft represent applications of possible new air traffic management paradigms. Relaxing route and part of altitude restrictions within a specific airspace is allowed by Free Routing (FR) operation. In FR airspace, users freely plan their routes between an entry point and an exit point without reference to a route network. This paper exclusively concerns Free Routing, and presents the main results of a study conducted by the DSNA as a participation in the Mediterranean Free Flight (MFF) program. The DSNA carried out an extensive experimentation in the third series of MFF large-scale real-time simulation (RTS3), with the object to acquire results on the Free Route concept in a busy Mediterranean area. The obtained results complement those coming from the

first and second series of MFF real time simulations, as well as the other simulations in the RTS3. The DSNA simulation trials, denominated RTS3/FR in the rest of this document, took place in January and February 2004 in the experimentation facilities of its research center in Toulouse. For the RTS3/FR, controllers were provided with an original set of tools designed to assist them in dealing with Free Route traffic, according to operational requirements specifically defined for FR. Eleven controllers from the Marseille air traffic control centre, two military controllers, and six pseudo-pilots participated in the simulation trials. These trials consisted of eighteen measured exercises. The main lesson of this specific RTS3/FR is that Free Route as simulated is not adapted for high levels of traffic load. In case of sufficiently low traffic, the concept would be usable on condition that sector design is improved, and that controllers' tools can be made perfectly reliable. The paper examines FF and FR cognitive implications, then introduces the experimental set up, gives information on the main aiding tools, and presents the main results of the simulations from a human-factors perspective.

On the Integration of Human Performance and Collision Risk Simulation Models of Runway Operation

Henk Blom – NLR

The integration of a human performance model (Air Man-machine Integration Design and Analysis System, Air MIDAS) and an accident risk assessment methodology (Traffic Organization and Perturbation AnalyZer, TOPAZ) was investigated in order to learn about the similarities and differences of their models, to demonstrate the feasibility of such integration, and the integration impact on accident risk assessment. The application example for this assessment is an airport surface operation in which a taxiing aircraft makes an unintended incursion into a departure runway. This paper describes the process for integrating the simulation based models of human performance for this example, and presents the result of this integration up to the level of risk of collision between two aircraft.

Conflict Perception by ATCS Admits Doubt but not Inconsistency

Philippe Averty – CENA

Though there is considerable agreement among the past studies about the great variability in conflict judgments by Air Traffic Control Specialists (ATCS), this work puts a first step forward in direction of a common core shared by controllers for perceiving conflicts. First, traffic scenarios were built from real traffic recordings, showing two converging aircraft. Three variables characterized these scenarios, respectively quantifying horizontal and vertical separations and the time when the judgment had to be formulated. The conditions created by factorial manipulation of three variables led to the design of short scenarios (about 1 min) upon which 161 controllers gave their opinion about the possible occurrence of separation loss (less than 3 NM and 1000 feet). The data, currently being analyzed, already show an important variability among experts, confirming the results of the past studies. But the way that the median values of responses are spread over the combinatory range of the scenarios appears very coherent and could prefigure a model of conflict perception by ATCS community. Further, values guaranteeing a certain level of security have been found and compared both on the horizontal plane and altitude. It shows (and quantifies) the higher efficiency, or reliability of those obtained on the plane. Considering anticipation in the judgment (variable D°A), it shows how uncertainty varies while anticipation decreases. Moreover, particular variations of uncertainty appear within responses resulting from scenarios with “near minima” separation values. These variations tend to evidence the line of thought of ATCSs dealing with the limits of the margin they have to set for a conflict/non-conflict classification.

Relationship of the Aircraft Mix Index with Performance and Objective Workload Evaluation Research (Power) Measures and Complexity Ratings

Elaine Pfleiderer – FAA

Aircraft mix (i.e., the mix of aircraft with different performance characteristics in a sector) has been repeatedly cited as a complexity factor in en route air traffic control. However, little attention has been focused on examining this relationship statistically. The present study is the third in a series of investigations designed to define, quantify, and assess the validity of aircraft mix as a contributor to traffic complexity. Eighteen 30-minute samples of System Analysis Recording (SAR) data were collected from the Fort Worth and Atlanta en route centers. Performance and Objective Workload Evaluation Research (POWER) measures and the Aircraft Mix Index were computed in 6-minute intervals for each of the 36 samples. Principal Components Analysis (PCA) of the combined data sets produced four components with eigenvalues >1 accounting for approximately 71% of the variance. The Aircraft Mix Index was most closely associated with Component 1, which was composed of variables generally associated with traffic complexity. These variables were used as predictors against a criterion of controllers’ subjective “Complexity” ratings in multiple regression analyses of low- and high-altitude sector samples. The Aircraft Mix Index failed to contribute significantly to the explained variance in the both the low-altitude (R=.69; R2=.47) and high-altitude (R=.57; R2=.33) sector models. In the aggregate, the results suggest that although aircraft mix appears to be associated with traffic complexity, it may not be as influential as other complexity factors in the en route environment.