Shaping the Future of Aerospace

EUROCONTROL

12th USA/EUROPE
Air Traffic Management R&D Seminar

27 - 30 June 2017
Seattle, Washington, USA

A Kenmore Air Seaplane soars over Puget Sound with majestic Mount Rainier in the distance.

Contents

Fresh seafood overflows from the market stalls at Seattle's historic Pike Place market.

Program-at-a-Glance

The Seattle Great Wheel, located at the Waterfront, extends over Elliott Bay.

Monday • 26 June 2017

18:30 - 20:30 — **Registration:** *Prefunction - Great Room 1*

Tuesday • 27 June 2017

07:00 — **Registration:** *Prefunction - Great Room 1*

Plenary Opening Session: *Great Room 1*

08:00 — **Welcome to Seattle:** **David C. Suomi**, FAA Acting Regional Administrator, Northwest Mountain Region

08:15 — **Welcome to ATM2017: Introduction, Program & Logistics**
Colin Meckiff (EUROCONTROL) and **Eric Neiderman** (FAA), ATM2017 Chairs

08:30 — **Opening Keynote (Europe):** **Bo Redeborn**, Former Principal Director ATM and R&D, EUROCONTROL
"Opportunities taken, opportunities missed and opportunities ahead"

09:15 — **Opening Keynote (U.S.):** **Kourosh Hadi**, Senior Director of Airplane Product Development, Boeing Commercial Airplanes
"Challenges in Aviation Innovation"

10:00 — **Coffee:** *Prefunction - Great Room 1*

	Track 1: *Studio 1/2*	Track 2: *Studio 4/5*	Track 3: *Great Room 2A/B*
	Performance Measurement and Management *Session Chair: Jose Miguel de Pablo*	**Integrated Airport/ Airside Operations** *Session Chair: Miquel Angel Piera*	**Terminal Area Operations** *Session Chair: Eric Hoffman*
10:30	**110** Koelle	**3** Huet, Pickup	**61** Vanwelsenaere, Ellerbroek et al.
11:15	**123** Balakrishman,Gopalakrishnan	**105** Sanz, Comendador, et al.	**43** Lascara, Weitz, Monson, Mount
12:00	**128** Estes, Ball, Lovell	**107** Herrema, Treve, Desart, et al.	**30** Priess, Weitz, Bowman, Levitt

12:45 — **Lunch:** *Great Room 1*

	Performance Measurement and Management *Session Chair: Joseph Post*	**Integrated Airport/ Airside Operations** *Session Chair: Hamsa Balakrishnan*	**Terminal Area Operations** *Session Chair: Hartmut Fricke*
14:00	**50** Shah	**23** Papenfuss, Carstengerdes, et al.	**57** Bronsvoort, Hochwarth, et al.
14:45	**130** Liu, Hansen, Lovell, Chuang, et al.	**116** Schultz	**103** Christien, Hoffman, et al.

15:30 — **Coffee:** *Prefunction - Great Room 1*

	Complexity and Big Data *Session Chair: Michael Ball*	**Human Factors** *Session Chair: Sandy Lozito*	**Surveillance and Navigation** *Session Chair: Dirk Kuegler*
16:00	**52** Yang, Yin, Hu, Xu	**20** Kopald, Chen, Chong, et al.	**27** Schaad
16:45	**129** Wang, Xu, Hu, Zhan	**22** Helmke, Ohneiser, Buxbaum, et al.	**118** Trenevska, De Smedt, Moek

Wednesday • 28 June 2017

06:00 — **5K Fun Run**

07:00 — **Registration Desk Open:** *Prefunction - Great Room 1*

	Track 1: *Studio 1/2*	Track 2: *Studio 4/5*	Track 3: *Great Room 2A/B*
	Complexity and Big Data *Session Chair: Michael Ball*	**Human Factors** *Session Chair: Billy Josefsson*	**Separation** *Session Chair: John Robinson*
07:45	**66** Sun, Ellerbroek, Hoekstra	**33** Svensson, Forsell, et al.	**134** Ramos, Schefers, Radanovic, et al.
08:30	**83** Ellerbroek, Verbraak, Sun, Hoekstra	**37** Gianazza	**75** Zhao, Meng, Xu, Geng
09:15	**67** Sunil, Ellerbroek, Hoekstra, Maas	**74** Idris, Burke, Wing, Enea	**31** Wang, Allignol, Durand, et al.
10:00	**97** Radanovic, Eroles, Koca, Nieto	**84** Pelchen-Medwed, Biede	**9** Wei, Li, Fei Liu, Wei Liu

10:45	**Coffee:** ***Prefunction - Great Room 1***		
	Trajectory Prediction ***Session Chair: Craig Wanke***	**Network and Strategic Flow** ***Session Chair: Nicolas Durand***	**Safety and Resilience** ***Session Chair: Dirk Schaefer***
11:15	**25** Sun, Ellerbroek, Hoekstra	**15** Schmidt, Granberg, et al.	**46** Moss, Londner
12:00	**94** Chati, Balakrishnan	**80** Fomeni, Zografos, Lulli	**68** Tra, Sunil, Ellerbroek, Hoekstra
12:45	**121** Vandermeersch, Marmont	**139** Pratts, Xu	**13** Kuhn
13:30	**Lunch:** ***Great Room 1***		

Thursday • 29 June 2017

07:00	**Registration:** ***Prefunction - Great Room 1***		
	Track 1: ***Studio 1/2***	**Track 2:** ***Studio 4/5***	**Track 3:** ***Great Room 2A/B***
	Environment and Energy ***Session Chair: Tom Reynolds***	**Network and Strategic Flow** ***Session Chair: Guglielmo Lulli***	**Safety and Resilience** ***Session Chair: Natesh Manikoth***
08:00	**98** Enea, Bronsvoort, Fricke, et al.	**55** Alam, Chaimatanan, et al.	**136** Roy, Xue, Sridhar
08:45	**138** Kang, Hansen	**60** Conze, Simonetto, Huens, et al.	**104** Blom, Bakker
09:30	**17** Howell, Dean	**125** Balakrishnan, Chandran	**59** Palumbo, Filippone
10:15	**Coffee:** ***Prefunction Great Room 1***		
	Environment and Energy ***Session Chair: Tom Reynolds***	**Network and Strategic Flow** ***Session Chair: Midori Tanino***	**Weather In ATM** ***Session Chair: Mark Weber***
10:45	**135** Jensen, Thomas, Brooks, et al.	**51** Moehlenbrink, Parke, Yoo, et al.	**8** Matthews, Veillette, Venuti, et al.
11:30	**113** Rosenow, Förster, Lindner, Fricke	**101** Taylor, Liu, Wanke, Stewart	**137** Liu, Hansen, Zhang, Li, et al.
12:15	**Lunch:** ***Great Room 1***		
	Environment and Energy ***Session Chair: Karen Marais***	**UAS and RPAS** ***Session Chair: Peter Hecker***	**Finance and Policy** ***Session Chair: Mark Hansen***
13:30	**108** Finck, Martins, Stelkens-Kobsch	**16** Balachandran, Narkawicz, et al.	**89** Jacquillat, Vaze
14:15	**124** Prats, Dalmau, Verhoeven, Bussink	**64** Allignol, Barnier, Durand, et al.	**111** Vaze, Harder
15:00	**119** Reynolds, Clemons, et al.	**140** Rodriguez, Balampanis, et al.	**70** Schmidt, Polishchuk, et al.
15:30	**Coffee:** ***Prefunction - Great Room 1***		
	Weather In ATM ***Session Chair: Mark Weber***	**UAS and RPAS** ***Session Chair: Kenneth Allendoerfer***	**Finance and Policy** ***Session Chair: Michael Standar***
16:15	**99** Dhief, Dougui, Delahaye, Hamdi	**54** Thipphavong, Cone, Lee.	**91** Kirby, Pilon
17:00	**72** Jones, Delaura, Pawlak, et al.	**76** Johnson, Jung, Rios, Mercer, et al.	**132** Ball, Swaroop, Barnhart, et al.
19:00	**Dinner - Guest Speaker:** ***Great Room 1*** **Gregory J. Bowles**, Vice President, Global Innovation and Policy, General Aviation Manufacturers Association (GAMA)		

Friday • 30 June 2017: *Great Room 1*

08:00	**Perspectives from NextGen and SESAR** **FAA Speaker: James T. Eck**, Assistant Administrator for NextGen **SESAR Speaker: Michael Standar**, Chief Strategy & External Affairs, SJU **Joint Question and Answer Session**
09:30	**Coffee:** ***Prefunction - Great Room 1***
10:00	**Panel Session - Innovation, New Entrants, and ATM** *(see page **21** for Moderator & Panel Members)*
11:30	**Best Paper Awards and Closing** **Colin Meckiff** (EUROCONTROL) and **Eric Neiderman** (FAA), ATM2017 Chairs

Full Program

Monday 22 June

18:30 - 20:30 **Early registration:** ***Prefunction - Great Room 1***

Tuesday • 27 June - Opening Session: *Great Room 1*

07:00	**Registration Desk Open:** ***Prefunction - Great Room 1***
08:00	**Welcome to Seattle: David C. Suomi,** FAA Acting Regional Administrator, Northwest Mountain Region
08:15	**Welcome to ATM 2017: Colin Meckiff** (EUROCONTROL) and **Eric Neiderman** (FAA), ATM2017 Chairs
08:30	**Opening Keynote (Europe): Bo Redeborn**, Former Principal Director ATM and R&D, EUROCONTROL *"Opportunities taken, opportunities missed and opportunities ahead"*
09:15	**Opening Keynote (U.S.): Kourosh Hadi**, Sr. Director of Airplane Product Development, Boeing Commercial Airplanes *"Challenges in Aviation Innovation"*
10:00	**Coffee:** ***Prefunction - Great Room 1***

Tuesday • 27 June - Tracks

Track 1: Performance Measurement and Management: *Studio 1/2*

Session Chair: ***Jose Miguel de Pablo (CRIDA)***

Time	Paper	Title	Authors (presenter in ***bold***)
10:30	**110**	Open source software and crowd sourced data for operational performance analysis	***Rainer Koelle*** *(EUROCONTROL)*
11:15	**123**	A Comparative Analysis of Models for Predicting Delays in Air Traffic Networks	***Hamsa Balakrishnan****, Karthik Gopalakrishnan (MIT)*
12:00	**128**	Predicting Performance of Ground Delay Programs	***Alexander Estes,*** *Michael Ball, David Lovell (University of Maryland)*

Track 2: Integrated Airport/Airside Operations: *Studio 4/5*

Session Chair: ***Miquel Angel Piera (Universitat Autònome de Barcelona)***

Time	Paper	Title	Authors (presenter in ***bold***)
10:30	**3**	Local and network impact assessment of Airport Collaborative Decision Making (A-CDM)	***Denis Huet*** *(EUROCONTROL), Simon Pickup (Atlas Chase)*
11:15	**105**	Analysis of Saturation at the Airport-Airspace Integrated Operations	***Alvaro Rodriguez-Sanz****, Fernando Gomez Comendador, Rosa Arnaldo Valdes (Technical University of Madrid), Jose Manuel Cordero Garcia and Lucia Meler Garcia (CRIDA)*
12:00	**107**	A novel machine learning model to predict abnormal Runway Occupancy Times and observe related precursors	***Floris Herrema*** *(EUROCONTROL AND TUDelft), Vincent Treve and Bruno Desart (EUROCONTROL), Ricky Curran, Dries Visser (TUDelft)*

Track 3: Terminal Area Operations: *Studio 2 A/B*

Session Chair: ***Eric Hoffman (EUROCONTROL)***

Time	Paper	Title	Authors (presenter in ***bold***)
10:30	**61**	Analysis on the Impact of Pop-Up Flight Occurrence when Extending the Arrival Management Horizon	***Alexander Vanwelsenaere****, Joost Ellerbroek, Jacco M. Hoekstra (Delft University of Technology), Evert Westerveld (Air Traffic Control the Netherlands)*

Tuesday • 27 June - Tracks (continued)

11:15	**43**	Measuring Performance of Initial Ground-based Interval Management - Spacing (GIM-S) Operations	***Brock Lascara,*** *Lesley Weitz, Thomas Monson (MITRE), Robert Mount (FAA)*
12:00	**30**	Analysis of the Use of Estimated Time of Arrival Broadcast for Interval Management	***Stephanie Priess,*** *Lesley Weitz, Stuart Bowman (MITRE), Ian Levitt (FAA)*

12:45 **Lunch:** ***Great Room 1***

Track 1: Performance Measurement and Management (continued): *Studio 1/2*

Session Chair: ***Joseph Post (FAA)***

Time	Paper	Title	Authors (presenter in ***bold***)
14:00	**50**	Causal Inference for ATM Counterfactual Estimation	***Akhil Shah*** *(RAND Corporation)*
14:45	**130**	Causal Analysis of En Route Flight Inefficiency – the US Experience	***Yulin Liu,*** *Mark Hansen (University of California, Berkeley), David Lovell, Cara Chuang, Michael Ball (University of Maryland), John Gulding (FAA)*

Track 2: Integrated Airport/Airside Operations (continued): *Studio 4/5*

Session Chair: ***Hamsa Balakrishnan (MIT)***

Time	Paper	Title	Authors (presenter in ***bold***)
14:00	**23**	What to say when: Guidelines to Decision Making	***Anne Papenfuss****, Nils Carstengerdes, Sebastian Schier and Yves Günther (DLR)*
14:45	**116**	Aircraft Boarding – Data, Validation, Analysis	***Michael Schultz*** *(DLR e.V.)*

Track 3: Terminal Area Operations (continued): *Studio 2 A/B*

Session Chair: ***Hartmut Fricke (TU Dresden)***

Time	Paper	Title	Authors (presenter in ***bold***)
14:00	**57**	Design Considerations of Vertically-Constrained PBN Procedures for Trajectory Management	***Jesper Bronsvoort*** *(Airservices Australia),* ***Joachim Hochwarth*** *(GE Aviation),* **Christina Young** *(FAA) Greg McDonald (Independent), Jean Boucquey (EUROCONTROL), Sergio Torres (Leidos), Mike Paglione (FAA)*
14:45	**103**	Toward the characterisation of sequencing arrivals	***Raphael Christien****, Eric Hoffman, Aymeric Trzmiel, Karim Zeghal (EUROCONTROL)*

15:30 **Coffee:** ***Prefunction - Great Room 1***

Track 1: Complexity and Big Data: *Studio 1/2*

Session Chair: ***Michael Ball (University of Maryland)***

Time	Paper	Title	Authors (presenter in ***bold***)
16:00	**52**	A case study of non-linear dynamics of "human-flow" behavior in terminal airspace	***Lei Yang****, Suwan Yin, Minghua Hu (NUAA), Yan Xu (Technical University of Catalonia)*

Tuesday • 27 June - Tracks (continued)			
16:45	**129**	The Structure and Dynamics of the Multilayer Air Transport System	***Yanjun Wang**, Xinhua Xu, Minghua Hu (Nanjing University of Aeronautics and Astronautics, Jianming Zhan (Air Traffic Management Bureau, Civil Aviation Administration of China)*

Track 2: Human Factors: *Studio 4/5*			
Session Chair: *Sandy Lozito (NASA Ames)*			
Time	**Paper**	**Title**	**Authors (presenter in *bold*)**
16:00	**20**	Read Back Error Detection using Automatic Speech Recognition	***Hunter Kopald**, Shuo Chen, Ronald Chong, Yuan-Jun Wei and Zachary Levonian (MITRE)*
16:45	**22**	Increasing ATM Efficiency with Assistant Based Speech Recognition	***Hartmut Helmke,** Oliver Ohneiser (German Aerospace Center, DLR), Jörg Buxbaum (DFS Deutsche Flugsicherung GmbH), Christian Kern (Austro Control GmbH)*

Track 3: Surveillance and Navigation: *Studio 2 A/B*			
Session Chair: *Dirk Kuegler (DLR)*			
Time	**Paper**	**Title**	**Authors (presenter in *bold*)**
16:00	**27**	PBN Hybrid Procedures as an Enabler for Airport Accessibility in Challenging Terrain	***Philipp Daniel Schaad** (Austro Control)*
16:45	**118**	Using PBN for Terminal and Extended Terminal Operations	***Dijana Trenevska**, David De Smedt, (EUROCONTROL), Geert Moek (Netherlands Aerospace Centre)*

More tan 500 musical instruments and 30 computers were used to create the sculpture "IF VI WAS IX" at EMP Museum.

Wednesday • 28 June

06:00	**5K Fun Run**
07:00	**Registration Desk Open: *Prefunction - Great Room 1***

Wednesday • 28 June - Tracks

Track 1: Complexity and Big Data (continued): *Studio 1/2*

Session Chair: *Michael Ball (University of Maryland)*

Time	Paper	Title	Authors (presenter in ***bold***)
07:45	**66**	Modeling Aircraft Performance Parameters with Open ADS-B Data	***Junzi Sun***, *Joost Ellerbroek, Jacco Hoekstra (Delft University of Technology)*
08:30	**83**	Large-Scale ADS-B Data and Signal Quality Analysis	***Joost Ellerbroek***, *Ted Verbraak, Junzi Sun, Jacco Hoekstra (Delft University of Technology)*
09:15	**67**	Modeling Airspace Stability and Capacity for Decentralized Separation	***Emmanuel Sunil***, *Joost Ellerbroek, Jacco Hoekstra, Jerom Maas (Delft University of Technology)*
10:00	**97**	Self-Reorganized Supporting Tools for Conflict Resolution in High-Density Airspace Volumes	*Marko Radanovic,* ***Miquel Angel Piera Eroles****, Thimjo Koca (Universitat Autonoma de Barcelona), Francisco Javier Saez Nieto (Cranfield University)*

Track 2: Human Factors (continued): *Studio 4/5*

Session Chair: *Billy Josefsson (LFV)*

Time	Paper	Title	Authors (presenter in ***bold***)
07:45	**33**	Analysis of work patterns as a foundation for human-automation communication in multiple remote towers	***Åsa Svensson***, *Camilla Forsell, Jimmy Johansson, Jonas Lundberg (Linköping University)*
08:30	**37**	Learning Air Traffic Controller Workload from Past Sector Operations	***David Gianazza*** *(ENAC)*
09:15	**74**	Assessment of Air Traffic Controller Acceptability of Aircrew Route Change Requests	***Husni Idris*** *(NASA Ames), Kelly Burke, David Wing (NASA Langley), Gabriele Enea (Engility Corporation)*
10:00	**84**	Effectiveness of the application of the Human Performance Assessment Process in SESAR 1	***Renee Pelchen-Medwed*** *(EUROCONTROL), Sonja Biede (Airbus)*

Track 3: Separation: *Studio 2 A/B*

Session Chair: *John Robinson (NASA Ames)*

Time	Paper	Title	Authors (presenter in ***bold***)
07:45	**134**	A Constraint Programming Model with Time Uncertainty for Cooperative Flight Departures	***Juan Jose Ramos***, *Nina Schefers, Marko Radanovic, Miquel Angel Piera, (Universitat Autonoma de Barcelona), Pau Folch (ASLOGIC)*
08:30	**75**	Agent-based Formation Flight Coalition under Incomplete Information	***Yifei Zhao***, *Linghang Meng, Xiaohao Xu and Zengxian Geng (Civil Aviation University of China)*
09:15	**31**	Large Scale 3D En-Route Conflict Resolution	***Ruixin Wang***, *Cyril Allignol, Nicolas Durand, Alexandre Gondran, Nicolas Barnier (ENAC)*

Wednesday• 28 June - Tracks (continued)

10:00	**9**	Methods of Aircraft Re-categorizations for Reducing Wake Vortex Separations	***Zhiqiang Wei**, Zhiyuan Li, Fei Liu, Wei Liu (CAUC)*

10:45 **Coffee: *Prefunction - Great Room 1***

Track 1: Trajectory Prediction: *Studio 1/2*

Session Chair: *Craig Wanke (MITRE)*

Time	Paper	Title	Authors (presenter in ***bold***)
11:15	**25**	Bayesian Inference of Aircraft Initial Mass	***Junzi Sun**, Joost Ellerbroek, Jacco Hoekstra (Delft University of Technology)*
12:00	**94**	Statistical Modeling of Aircraft Takeoff Weight	*Yashovardhan Sushil Chati, **Hamsa Balakrishnan** (MIT)*
12:45	**121**	A simple method to integrate Mode S Indicated Airspeed with Ground Based Trajectory Prediction	***Bram Vandermeersch**, Jonathan Marmont (NATS)*

Track 2: Network and Strategic Flow: *Studio 4/5*

Session Chair: *Nicolas Durand (ENAC)*

Time	Paper	Title	Authors (presenter in ***bold***)
11:15	**15**	A Novel MIP-based Airspace Sectorization for TMAs	***Christiane Schmidt**, Tobias Andersson Granberg, Tatiana Polishchuk, Valentin Polishchuk (Linköping University)*
12:00	**80**	An optimization model for assigning 4D- trajectories to flights under the TBO concept	*Franklin Djeumou Fomeni, Konstantinos G. Zografos, **Guglielmo Lulli** (Lancaster University Management School)*
12:45	**139**	Including Linear Holding in Air Traffic Flow Management for Flexible Delay Handling	*Yan Xu, **Xavier Prats** (Technical University of Catalonia)*

Track 3: Safety and Resilience: *Studio 2 A/B*

Session Chair: *Dirk Schaefer (EUROCONTROL)*

Time	Paper	Title	Authors (presenter in ***bold***)
11:15	**46**	A Bayesian Network Model of Pilot Response to TCAS Resolution Advisories	***Robert Moss**, Edward Londner (MIT Lincoln Laboratory)*
12:00	**68**	Modeling the Intrinsic Safety of Unstructured and Layered Airspace Designs	*Martijn Tra, **Emmanuel Sunil**, Joost Ellerbroek, Jacco Hoekstra (Delft University of Technology)*
12:45	**13**	Topics and Trends in Incident Reports	***Kenneth Kuhn** (RAND Corporation)*

13:30 **Lunch: *Great Room 1***

Thursday • 29 June

07:00 **Registration Desk Open:** *Prefunction - Great Room 1*

Thursday • 29 June - Tracks

Track 1: Environment and Energy: *Studio 1/2*

Session Chair: *Tom Reynolds (MIT LL)*

Time	Paper	Title	Authors (presenter in ***bold***)
08:00	**98**	Fuel Burn Estimation Modeling for ATM Benchmark Applications Perspectives from an International Collaboration	***Gabriele Enea*** *(MITRE), Jesper Bronsvoort (Airservices Australia), Hartmut Fricke , Christian Seiß, Judith Rosenow, (TU Dresden), Almira Ramadani, Mike Paglione (FAA)*
08:45	**138**	Quantile Regression Based Estimation of Statistical Contingency Fuel	*Lei Kang,* ***Mark Hansen*** *(University of California, Berkeley)*
09:30	**17**	Have Descents really become more Efficient?	***Daniel Howell****, Rob Dean (Regulus Group)*

Track 2: Network and Strategic Flow (continued): *Studio 4/5*

Session Chair: *Guglielmo Lulli (University of Lancaster)*

Time	Paper	Title	Authors (presenter in ***bold***)
08:00	**55**	A Distributed Air Traffic Flow Management Model for European Functional Airspace Blocks	***Sameer Alam*** *(University of New South Wales), Supatcha Chaimatanan (Geo- informatics and Space Technology Development Agency), Daniel Delahaye (French Civil Aviation University), Eric Feron (Georgia Institute of Technology)*
08:45	**60**	Probabilistic Occupancy Counts and Flight Criticality Measures for ATM	***François Gonze****, Andrea Simonetto, Etienne Huens, Raphaël M. Jungers (Université catholique de Louvain), Jean Boucquey (EUROCONTROL ATM/RDS/ATS)*
09:30	**125**	A Distributed Framework for Traffic Flow Management in the Presence of Unmanned Aircraft	***Hamsa Balakrishnan*** *(MIT), Bala Chandran (Resilient Ops, Inc.)*

Track 3: Safety and Resilience (continued): *Studio 2 A/B*

Session Chair: *Natesh Manikoth (FAA)*

Time	Paper	Title	Authors (presenter in ***bold***)
08:00	**136**	Vulnerability Metrics for the Airspace System	***Sandip Roy****, Mengran Xue (Washington State University), Banavar Sridhar (Independent)*
08:45	**104**	Emergent Behaviour of Trajectory Based Operations Under Very High En-route Traffic Demand	***Henk Blom*** *(NLR and TUDelft), Bert Bakker (NLR)*
09:30	**59**	A Quantitative Approach to Resilience Engineering for the Future ATM System: Case Studies Results	***Roberto Palumbo****, Edoardo Filippone (CIRA – Italian Aerospace Research Center)*

10:15 **Coffee:** *Prefunction - Great Room 1*

Thursday • 29 June - Tracks (continued)

Track 1: Environment and Energy (continued): *Studio 1/2*

Session Chair: *Tom Reynolds (MIT LL)*

Time	Paper	Title	Authors (presenter in ***bold***)
10:45	**135**	Analytical Approach for Quantifying Noise from Advanced Operational Procedures	***Luke Jensen**, Jacqueline Thomas, Callen Brooks, Morrisa Brenner, R. John Hansman (MIT)*
11:30	**113**	Impact of Multi-critica Optimized Trajectories on European Air Traffic Density, Efficiency and the Environment	***Judith Rosenow**, Stanley Förster, Martin Lindner, Hartmut Fricke (Technische Universität Dresden)*

Track 2: Network and Strategic Flow (continued): *Studio 4/5*

Session Chair: *Midori Tanino (FAA)*

Time	Paper	Title	Authors (presenter in ***bold***)
10:45	**51**	Evaluation of Integrated Demand Management looking into Strategic & Tactical Flow Management	***Christoph Moehlenbrink**, Bonny Parke, Hyo-Sang Yoo, Connie Brasil, Nathan Buckley, Constantine Speridakos, Francisco Muro, Gita Hodell (San Jose State University Research Foundation), Paul Lee, Nancy Smith (NASA Ames)*
11:30	**101**	Generating Diverse Reroutes for Tactical Constraint Avoidance	***Christine Taylor**, Sheng Liu, Craig Wanke, Timothy Stewart (MITRE)*

Track 3: Weather in ATM: *Studio 2 A/B*

Session Chair: *Mark Weber (NOAA)*

Time	Paper	Title	Authors (presenter in ***bold***)
10:45	**8**	Translating Convective Weather Forecasts into Strategic Traffic Management Decision Aids	***Michael Matthews**, Mark Veillette, Joseph Venuti, Richard Delaura, James Kuchar (MIT)*
11:30	**137**	Modeling Ground Delay Program Incidence using Convective and Local Weather Information	***Yi Liu,** Mark Hansen, Danqing Zhang, Yulin Liu, Alexey Pozdnukhov (University of California, Berkeley)*

12:15 **Lunch:** *Great Room 1*

Track 1: Environment and Energy (continued): *Studio 1/2*

Session Chair: *Karen Marais (Purdue)*

Time	Paper	Title	Authors (presenter in ***bold***)
13:30	**108**	Operational Feasibility of Segmented Independent Parallel Approaches	***Tobias Finck**, Bernd Korn, Ana Paz Gonçalves Martins, Tim Stelkens-Kobsch (DLR – Institute of Flight Guidance)*
14:15	**124**	Human-in-the-loop Performance Assessment of Optimized Descents with Time Constraints: Results from Full Motion Flight Simulation and a Flight Testing Campaign	***Xavier Prats**, Ramon Dalmau (Technical University of Catalonia), Ronald Verhoeven, Frank Bussink (Netherlands Aerospace Center)*
15:00	**119**	Analyzing & Implementing Delayed Deceleration Approaches	***Tom Reynolds**, Emily Clemons (MIT Lincoln Laboratory), John Hansman, Jacquie Thomas (MIT)*

Thursday • 29 June - Tracks (continued)

Track 2: UAS and RPAS: *Studio 4/5*

Session Chair: ***Peter Hecker (TU Braunschweig)***

Time	Paper	Title	Authors (presenter in ***bold***)
13:30	**16**	A Path Planning Algorithm to Enable Well-Clear Low Altitude UAS Operation Beyond Visual Line of Sight	***Swee Balachandran*** *(National Institute of Aerospace), Anthony Narkawicz, Cesar Munoz, Maria Consiglio (NASA)*
14:15	**64**	Assessing the Robustness of a UAS Detect & Avoid Algorithm	***Cyril Allignol****, Nicolas Barnier, Nicolas Durand, Guido Manfredi (ENAC), Éric Blond (DSNA/DTI)*
15:00	**140**	Wind Efficient Path Planning and Reconfiguration of UAS in Future ATM	*Leopoldo Rodriguez, Fotios Balampanis,* ***Jose A. Cobano****, Ivan Maza, Anibal Ollero (University of Seville)*

Track 3: Finance and Policy: *Studio 2 A/B*

Session Chair: ***Mark Hansen (UC Berkeley)***

Time	Paper	Title	Authors (presenter in ***bold***)
13:30	**89**	Balancing Reliability, Efficiency and Equity in Airport Scheduling Interventions	***Alexandre Jacquillat*** *(Carnegie Mellon University), Vikrant Vaze (Dartmouth College)*
14:15	**111**	A Game-Theoretic Modeling Approach to Air Traffic Forecasting	*Vikrant Vaze,* ***Reed Harder*** *(Dartmouth College)*
15:00	**70**	A Step Towards Remote Tower Center Deployment: Optimizing Staff Schedules	***Christiane Schmidt****, Tatiana Polishchuk, Valentin Polishchuk, (Linköping University), Billy Josefsson (LFV)*

15:30 **Coffee:** ***Prefunction - Great Room 1***

Track 1: Weather in ATM (continued): *Studio 1/2*

Session Chair: ***Mark Weber (NOAA)***

Time	Paper	Title	Authors (presenter in ***bold***)
16:15	**99**	Strategic planning of North Atlantic Oceanic air traffic based on a new wind-optimal route structure	***Imen Dhief****, Nour Houda Dougui (ENSI), Daniel Delahaye (Ecole National D'Aviation Civile), Noureddine Hamdi (INSAT)*
17:00	**72**	Predicting & Quantifying Risk in Airport Capacity Profile Selection for Air Traffic Management	***James Jones****, Richard Delaura, Margo Pawlak, Seth Troxel, Ngaire Underhill (MIT Lincoln Laboratory)*

Track 2: UAS and RPAS (continued): *Studio 4/5*

Session Chair: ***Kenneth Allendoerfer (FAA)***

Time	Paper	Title	Authors (presenter in ***bold***)
16:15	**54**	Ensuring Interoperability between UAS Detect-and-Avoid and Manned Aircraft Collision Avoidance	***David Thipphavong****, Andrew Cone (NASA), Seungman Lee (Crown Consulting, Inc.)*
17:00	**76**	Flight Test Evaluation of an Unmanned Aircraft System Traffic Management (UTM) Concept for Multiple Beyond-Visual-Line-of-Sight	***Marcus Johnson****, Jaewoo Jung, Joseph Rios, Joey Mercer, Thomas Prevot, Daniel Mulfinger, Parimal Kopardekar (NASA)*

Thursday • 29 June - Tracks (continued)

Track 3: Finance and Policy: *Studio 2 A/B*

Session Chair: *Michael Standar (SJU)*

Time	Paper	Title	Authors (presenter in ***bold***)
16:15	**91**	Minimizing the Cost of Delay for Airspace Users	***Stephen Kirby***, *Nadine Pilon (EUROCONTROL)*
17:00	**132**	Service Level Expectation Setting for Air Traffic Flow Management: Practical Challenges and Benefits Assessment	***Michael Ball***, *Prem Swaroop (University of Maryland), Cynthia Barnhart , Chiwei Yan (MIT), Mark Hansen, Lei Kang, Yi Liu (University of California , Berkeley), Vikrant Vaze (Dartmouth College)*

19:00 **Dinner - Guest Speaker: *Great Room 1***

Greg Bowles, Vice President, Global Innovation and Policy, General Aviation Manufacturers Association (GAMA)

Friday • 30 June: *Great Room 1*

08:00

Perspectives from NextGen and SESAR

FAA Speaker:

James T. Eck, Assistant Administrator for NextGen

SESAR Speaker:

Michael Standar, Chief Strategy & External Affairs, SJU

Joint Question and Answer Session

09:30 **Coffee:** ***Prefunction - Great Room 1***

10:00

Panel Session - Innovation, New Entrants, and ATM

Panel Moderator: Parimal Kopardekar, Senior Technologist, Air Transportation System (NASA)

Gur Kimchi, Vice President, Amazon Prime Air

Joe Polastre, Senior Product Lead, A^3 by Airbus

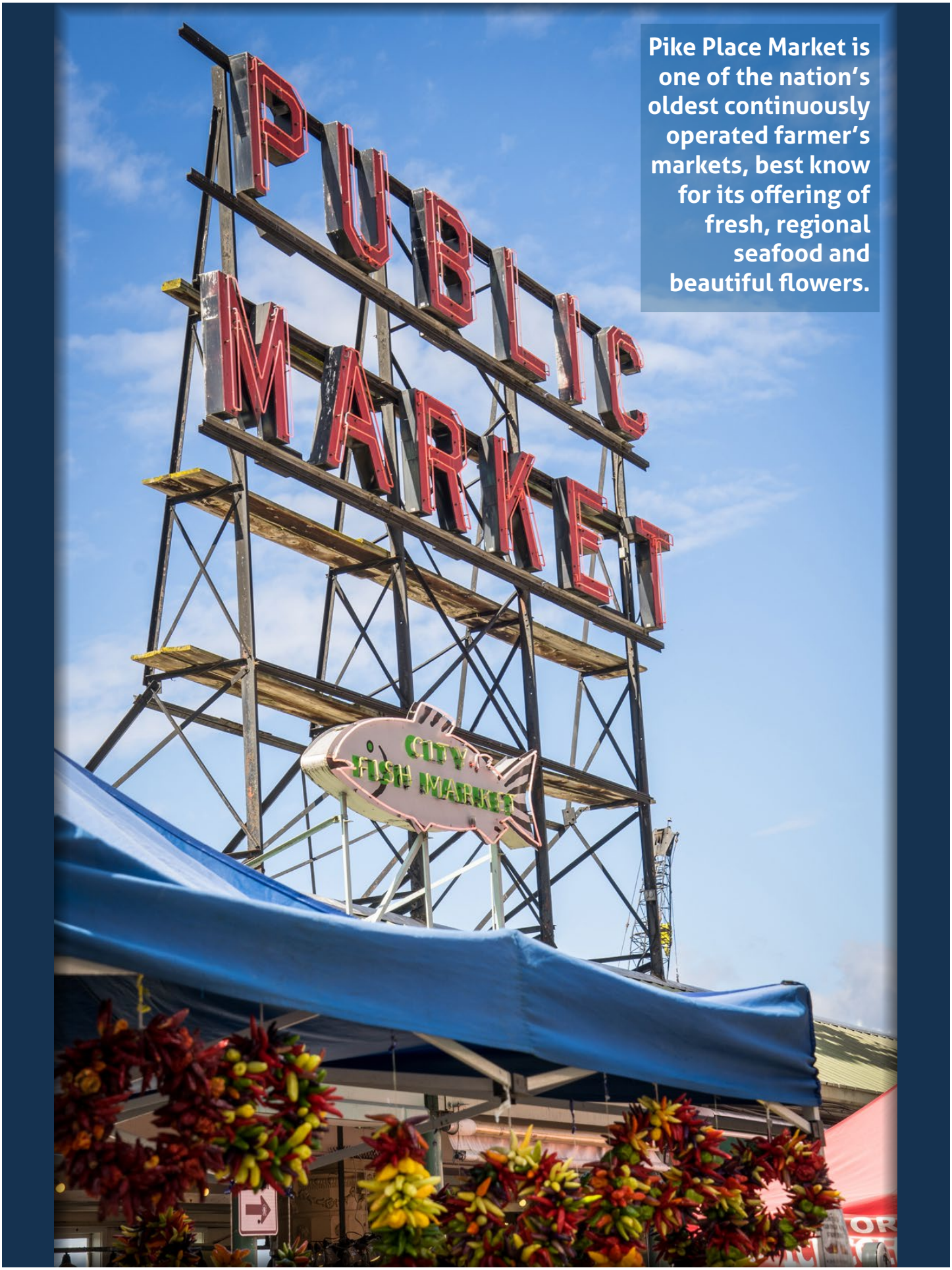
Alex Roetter, Vice President Software, KittyHawk Corporation

Greg Bowles, Vice President, Global Innovation and Policy, General Aviation Manufacturers Association (GAMA)

11:30

Best Paper Awards and Closing

Colin Meckiff (EUROCONTROL) and **Eric Neiderman** (FAA), ATM2017 Chairs



Pike Place Market is one of the nation's oldest continuously operated farmer's markets, best know for its offering of fresh, regional seafood and beautiful flowers.

Abstracts

Abstracts:
Complexity and Big Data

(52) A case study of non-linear dynamics of "human-flow" behavior in terminal airspace - *Lei Yang, et al.*

Air traffic is widely known as a complex and task-critical techno-social system mainly composed of airspace, procedures, aircraft and air traffic managers. In order to develop and deploy advanced operational concept and automation system scientifically and effectively, it is essential to take an in-depth research on the intrinsic air traffic dynamics and characteristics which haven't been widely discussed. A systematical empirical study of air traffic operation in Guangzhou terminal airspace is conducted by collecting synchronized flight and air-ground communication data. Three types of metrics are proposed to measure air traffic dynamics from "human-flow" perspective: flow-based metrics, controller-based metrics and chaotic metrics. Empirical results identify synchronized free, smooth, semi-stable and congested phase states from both flow and controllers performance evolutions. Meta-cognition is explained as one of critical underlying mechanisms that drive the phase transitions. Further, by studying data series of potential conflict in "flow system" and communication behaviors in "human system", air traffic system is proved to be a chaotic system, which presents higher short term chaotic predictability, caused by internal instability of semi-stable and congested status. These novel findings will provide theoretical basis for aggregated air traffic flow modeling, decision support system design and tactical flow management.

(66) Modeling Aircraft Performance Parameters with Open ADS-B Data - *Sun, et al.*

Open access to flight data from ADS-B (Automatic Dependent Surveillance Broadcast) has provided researchers more insights for air traffic management than aircraft tracking alone. With large quantities of trajectory data collected from a wide range of different aircraft types, it is possible to extract accurate aircraft performance parameters. In this paper, a set of more than thirty parameters from seven distinct flight phases are extracted for common commercial aircraft types. It uses various data mining methods, as well as a maximum likelihood estimation approach to generate parametric models for these performance parameters. All parametric models combined can be used to describe a complete flight that includes takeoff, initial climb, climb, cruise, descent, final approach, and landing. Both analytical results and summaries are shown. When available, optimal parameters from these models are also compared with the Base of Aircraft Data and Eurocontrol aircraft performance database. This research not only presents a comprehensive set of methods for extracting different aircraft performance parameters but also provides a first part of open-source parametric perfor-mance models that is ready to be used by the ATM community.

(67) Modeling Airspace Stability and Capacity for Decentralized Separation - *Sunil, et al.*

In the context of decentralized separation, airspace stability pertains to the propagation of conflict chain reactions as a result of tactical conflict resolution maneuvers. This notion of airspace stability has been used in previous literature to develop a semi-empirical method for determining the capacity of a decentralized direct-routing airspace concept in the horizontal plane. The present paper extends this method by explicitly mod-eling: a) the effect of a given Conflict Detection and Resolution (CD&R) strategy on the stability of the airspace; b) the influence of direct-routing on instantaneous conflict probability; and c) the impact of finite-time measurements on the determination of airspace states. To validate the resulting analytical capacity model, fast-time simulations were performed. The results indicate that the predictions of the analytical model are close to that of the previous semi-empirical approach. Thus, the analytical model can be used to obtain a first-order estimate of the maximum theoretical capacity, as along as simulation settings do not cause the 'local', or per aircraft, conflict rate to deviate significantly from assumptions made during the model derivation. Future work will focus on relaxing model assumptions, and extending the modeling approach to three-dimensional airspace.

(83) Large-Scale ADS-B Data and Signal Quality Analysis - *Ellerbroek, et al.*

To investigate the contradicting findings of previous studies that investigated ADS-B quality, a study was per-formed to analyze the data and signal quality of ADS-B. For this study, a large dataset of raw ADS-B messages was analyzed, regarding the quality of the data and the signal, differentiating between internal and external sources of errors. The conclusions from this analysis show that ADS-B indeed is a promising technology, where aircraft

are able to accurately report their navigational parameters, but that external factors (e.g., reception probability and malfunctioning on-board equipment) can cause issues with the usability of ADS-B as a primary means of surveillance.

(97) Self-Reorganized Supporting Tools for Conflict Resolution in High-Density Airspace Volumes - *Enea, et al.*

Present research on Air Traffic Management (ATM) is tending to improve airspace capacity, accessibility and the efficiency of operations in high-density areas, while maintaining or improving the safety performance indicators. Tactical interventions from the Air Traffic Control (ATC) system to preserve safety distances between aircraft have some inherent shortages when scalability problems arise, that could lead to a well-known capacity saturation. An increased number of detected conflicts in dense traffic volumes can affect not only the ATC procedures but also the full safety net, since the present Traffic alert and Collision Avoidance System (TCAS) has been designed only for low dense areas. To overcome these shortages at tactical level without appealing to the strategic airspace restrictions, this paper presents an innovative automation-based concept in future design of the ATM system supporting an irruptive shift from the centrally controlled ATM system to a distributed system, in which a set of aircraft constitutes a dynamic ecosystem, with self-governed capabilities, to find the optimal conflict-free resolution trajectories. The concept has been developed within the methodological approach "hotspot-cluster-ecosystem" which provides a smooth transition from trajectory management (TM), separation management (SM) to the collision avoidance (CA) layer, seeking for an advanced time horizon in which the airspace users would timely negotiate resolutions before an ATC directive is issued. A dynamic demand-capacity balance (DCB) approach is illustrated by identifying clusters and analyzing ecosystems considering deviations of pairwise conflicting aircraft to the surrounding traffic (ST). The ecosystem is described by its membership size and spatially temporal interdependencies (STIs), i.e. potential 4D positions of the members driven by defined maneuverability checks, and generated conflict intervals between each pair of members. Finally, computed interdependencies provide an insight of the ecosystem complexity through the ratio of a total number of feasible resolutions over the ecosystem time.

(129) The Structure and Dynamics of the Multilayer Air Transport System - *Wang, et al.*

The field of air traffic management (ATM) has a strong interdisciplinary nature, combining of technological, management, economic and regulatory aspects. The fully under-standing of the structure and dynamics underlying the system continues to be significant challenges in the field. Here we present a novel framework for the study of the structure and dynamics of the air transport system building upon recent advancement of network science and big data science, as well as taking into account of the unique operation practicals, thus bridging the gaps between academic field and operational world. We show that the structure of air transport system can be captured by four interdependent networks including airlines network, airport network, air route network, and ATM network. In particular, we present initial results on spatial-related dynamics of the system using one-year flight data records. We find by analyzing flight delay data that (i) airports with similar geographical locations exhibit similar dynamics; (ii) unlike other spatial-embedded complex systems, the propagation of flight delays or failure in the system decays slowly, and the correlations of the failure nodes reaching to 0 when the distance between them approaching to ~ 1, 000km. Our findings may have the implications for the efficient management of air transport system.

Abstracts:
Environment and Energy

(17) Have Descents really become more Efficient? - *Howell & Dean*

Several ANSPs have implemented procedures to permit fuel-optimal descents and additional ATM tools to enable these descents during times of congestion. Many studies have proposed metrics to estimate the potential benefits of optimizing the descent phase of flight. This study uses versions of the proposed metrics to examine if there have been significant changes in the vertical efficiency pools after implementation of multiple efforts at the FAA Core 30 airports. The trends in the vertical efficiency pools are examined both over time and for differing levels of congestion. The results are compared to more general metrics produced in a related NextGen scorecard and consider the impact of the initiatives that have been deployed at each site. If an initiative had the desired impact on descent efficiency, and appropriate normalization factors are chosen, then the pool of potential benefits should diminish after implementation. The results indicate that the vertical efficiency pool has decreased significantly for airports with both OPDs and time-based metering to the TRACON as compared to airports with OPDs only, metering only, or those without OPDs or metering.

(98) Fuel Burn Estimation Modeling for ATM Benchmark Applications Perspectives from an International Collaboration - *Enea, et al.*

Aircraft fuel burn reduction is often regarded as one of the benefits of new air transportation operational paradigms around the world. As phases of NextGen, SESAR and Australian AATMP come to maturity, the questions are pivoting from what benefits will be to what have we achieved. This pivot puts pressure on aircraft fuel modeling techniques being able to distinguish between the contribution of ATM and non-ATM factors. In addition, there are many fuel estimators used around the world, and their range of fidelity varies widely; in fact, fuel savings as result of ATM improvements are frequently of the same magnitude of the error produced by the models used for their estimation. This paper summarizes an initial collaboration between researchers from several globally recognized institutions to address the question of fidelity of fuel estimation that may be required for different types of benefit assessments of Air Traffic Management improvements. Interviews were conducted initially to categorize common elements that typical ATM studies share. An international team of fuel modelers was assembled and participated by running their models on a common set of inputs. The outputs generated by these models, were categorized using metrics on empirical trajectories and other operational data, including predicted fuel burn. This provided a foundation for studying impacts of different fuel estimation approaches and assumptions, and how they relate to the analysis of fuel efficiency.

(108) Operational Feasibility of Segmented Independent Parallel Approaches - *Finck, et al.*

Noise, especially in the vicinity of airports, is one of the most important factors of modern air transport systems, especially at major hub airports. New approach designs like curved Required Navigation Performance (RNP) procedures to independent parallel runway systems can decrease the noise footprint in sensitive ground areas without reducing airport capacity.

So far, only straight-in ILS (or MLS) approaches are allowed for independent parallel approach operations. To introduce RNP curved/segmented approaches as a further option for independent approaches to a parallel runway system, a safety concept has been developed by DLR in recent years based on the ICAO SaRPS for independent parallel approaches (ICAO Doc 9643). Following this concept, curved RNP approach operations should be possible at Frankfurt/Main airport enabling noise abatement even in high density traffic situations.

This paper considers the operational aspects of independent segmented parallel approach procedures at major airport-hubs with parallel runway systems like Frankfurt Airport. It reports about a new route design enabling the management of mixed aircraft equipage. The focus is on the operational feasibility of the new TMA design. This has been assessed by a real-time simulation with controllers of the German Air Navigation Service (DFS). The results of these simulations are presented in this paper.

(113) Impact of Multi-critica Optimized Trajectories on European Air Traffic Density, Efficiency and the Environment - *Rosenow, et al.*

Today, the European airspace is facing multiple capacity constraints, which are regulating the demand during busy traffic periods of the day. These capacity limits typically cause inefficiencies in flight and in airport ground handling, which are expecting to increase, because according to current market forecasts, passenger air traffic demand will continue to grow between 4.5 percent [1] and 4.8 percent annually [2]. To better manage rare airspace capacity, free routing performance based navigation and harmonized airspace structures are seen as efficient mitigation measures according to the Single European Sky ATM Research (SESAR) and the Next Generation Air Transportation System (NextGen) programs. However, a growing public awareness and a better understanding of the anthro-pogenic environmental impact necessitates further functions for flight planing and execution, beside today's minimum fuel and time objectives. In this paper we present a trajectory calculation model capable of exploiting the 3D free route optimization potential while considering these divergent targets, especially the costs of condensation trails depending on the time of the day. The model was implemented in the simulation environment TOMATO for a case study, which optimized the European's flight intentions for an entire day based on departure airport, arrival airport and departure time on July 2016. The resulting trajectories are evaluated against the number of separation infringements. The case study shows that this anticipated air traffic demand already stresses the free route capacity when considering the required airline efficiency, ecological compatibility and safety standards.

(119) Analyzing & Implementing Delayed Deceleration Approaches - *Reynolds, et al.*

Delayed Deceleration Approaches (DDAs) have the potential to be important elements of Optimized Profile Descents to minimize fuel burn and emissions by maintaining airspeed above the initial flap speed for as long as possible during approach. This reduces drag and associated engine power requirements. This paper provides a comprehensive summary of the work performed to analyze this topic over the last few years. First, flight data recorder analysis is presented which shows a 30-50% approach fuel and emissions reduction potential through use of DDAs. Second, analysis of approach procedures at a range of US airports are presented to identify specific opportunities for increased DDA use. Third, a noise study of DDA procedures relative to conventional approach procedures is presented which finds negligible noise impacts. Finally, given the significant benefits potential, airport opportunities and negligible noise impacts determined from these analyses, recommendations to increase the implementation of DDAs using appropriate speed targets on area navigation approach procedures are discussed.

(124) Human-in-the-loop Performance Assessment of Optimized Descents with Time Constraints: Results from Full Motion Flight Simulation and a Flight Testing Campaign - *Prats, et al.*

TEMO (time and energy managed operations) is a new concept that aims to optimise continuous descent operations, while fulfilling with a very high accuracy controlled time of arrival (CTA) constraints at different metering fixes. This paper presents the results and main lessons learnt from two human-in-the-loop experiments that aimed to validate the TEMO trajectory planning and guidance algorithm: a full motion flight simulation experiment and a flight testing campaign. Positive results were obtained from the experiments, regarding the feasibility of the concept and acceptance from the pilots. TEMO descents typically showed lower fuel figures than conventional step-down descents. Moreover, RTA adherence at the initial approach fix (IAF) showed very good performance. Time accuracy at the runway threshold, however, did not fulfil the (very challenging) time target accuracies. Further work is needed to enhance the current algorithm once the aircraft is established on the instrument landing system glideslope.

(135) Analytical Approach for Quantifying Noise from Advanced Operational Procedures - *Jensen, et al.*

This paper presents a method for improving the fidelity, accuracy, and utility of noise analysis techniques for the development and environmental review of advanced operational procedures. Advanced procedures have the potential to reduce aircraft noise using several methods including lateral track management (noise-preferred routes and track dispersion or concentration), vertical profile management, or speed and configuration management. Traditional noise analysis techniques such as the Aviation Environmental Design Tool model noise using a Noise Power Distance method, which does not fully capture aerodynamic and velocity effects. An alternative physics-based modeling approach has been developed to capture higher-fidelity noise impacts. This framework has been used to evaluate several candidate operational procedures for community noise impact.

(138) Quantile Regression Based Estimation of Statistical Contingency Fuel - *Kang & Hansen*

Reducing fuel consumption is a unifying goal across the aviation industry. One fuel-saving opportunity for airlines is the possibility of reducing contingency fuel loading. Airline flight planning system (FPS) provides recommended statistical contingency fuel (SCF) for dispatchers. However, due to limitations of the current SCF estimation procedure, the application of SCF is limited. In this study, we propose to use quantile regression based method to estimate more reliable SCF values. Utilizing a large fuel burn dataset from a major U.S. based airline, we find that the proposed quantile regression method outperforms airline's FPS. We also quantify the impact of implementing improved SCF values in saving fuel. While maintaining a same safety level, it has been found that for our study airline, the benefit of applying improved SCF models is estimated to be in the magnitude of $14 million annual savings as well as 98 million kilogram CO2 emission reduction. This study also builds a link between SCF95 estimation and aviation system predictability in which the proposed models can also be used to predict benefits from reduced fuel loading enabled by improved air traffic management (ATM) targeting on improved system predictability.

Abstracts:
Finance and Policy

(70) A Step Towards Remote Tower Center Deployment: Optimizing Staff Schedules - *Schmidt, et al.*

Remote Tower Service (RTSs) is one of the tech-nological and operational solutions delivered for deployment by the Single European Sky ATM Research (SESAR) Programme. This new concept fundamentally changes how operators provide Air Traffic Services, as it becomes possible to control several airports from a single remote center. In such settings an air traffic controller works at a so-called "multiple position" in the remote center, that is, he/she handles two or more airports from one Remote Tower Module (RTM), i.e the controller working position.

In this paper, we present an optimization framework for the traffic management at five Swedish airports that were chosen for remote operation using a Remote Tower Center designed to serve a number of airports. We highlight the problems experienced with real airport schedules, and present optimal assignments of the airports to the RTMs. We consider both scheduled traffic and special (non-scheduled) traffic at these five airports.

(89) Balancing Reliability, Efficiency and Equity in Airport Scheduling Interventions - *Jacquillat & Vaze*

In the absence of opportunities for capacity expan-sion or operational enhancements, air traffic congestion mitiga-tion may require scheduling interventions aimed to control the extent of over-capacity scheduling at busy airports. While existing approaches have focused on minimizing the overall impact of scheduling interventions across the airlines, this paper designs, optimizes, and assesses a novel approach for airport scheduling interventions that incorporates inter-airline equity objectives. It relies on a lexicographic modeling architecture based on efficiency (i.e., meeting airline scheduling preferences), equity (i.e., balancing scheduling adjustments fairly among the airlines), and reliability (i.e., mitigating airport congestion) objectives, subject to scheduling and network connectivity constraints. Theoretical and computational results show that ignoring inter-airline equity can lead to highly inequitable outcomes, but that our modeling approach achieves inter-airline equity at no, or small, losses in efficiency.

(91) Minimizing the Cost of Delay for Airspace Users - *Kirby & Pilon*

In European air traffic flow management, regulation is the assignment of take-off times to prevent the over delivery of flights to sectors and airports. Delay is assigned to flights according to the principle of 'first planned first served' for entry into the regulated volume. The take-off times (and hence delays) take no account of the relative importance of flights from the airspace user perspective. The user driven prioritization process (UDPP) aims to provide airspace users with the opportunity to modify the sequence of flights in a regulation/hotspot to minimize their cost of delay. This paper reports on the first human-in-the-loop validation exercise to assess the UDPP concept. These preliminary results indicate that significant cost savings are possible for airspace users while UDPP non-participants are not affected to an unacceptable degree.

(111) A Game-Theoretic Modeling Approach to Air Traffic Forecasting - *Vaze & Harder*

Federal, state and local aviation planners rely on air traffic forecasts for workforce staff planning (particularly for air traffic controllers), evaluation of current and future technological improvements at airports, planning of airport capacity expansion, and evaluation of federal funding requests for airport infrastructure improvements. While most existing forecasting models are econometric or statistical in nature, incorporating a more behavioral understanding of airline competition into the forecasts and planning process represents a significant opportunity to improve their efficacy. With these possibilities in mind, we develop a two-stage game-theoretic model of airline capacity allocation decisions under competition. We first demonstrate desirable theoretical properties and computational tractability of our model, and then exploit them to develop solution algorithms with very fast convergence properties to enable rapid generation of forecasts, requiring only a few seconds of run-time. We then solve our model to equilibrium of the two-stage game using a real-world dataset based on an 11-airport, four-airline network from the western United States. The out-of-sample validations of traffic predictions at the airport and OD (origin-destination) level indicate a good fit to real-world traffic data for various look-ahead times

and at various levels of granularity. We thus demonstrate that a behaviorally consistent two-stage game model of airline competition provides a good fit to observed airline operations at various levels of aggregation, in turn highlighting the potential of game-theoretic models to improve air traffic forecasting and scenario analysis.

(132) Service Level Expectation Setting for Air Traffic Flow Management: Practical Challenges and Benefits Assessment - *Ball, et al.*

This paper describes a mechanism for determining consensus service level expectations to be used in designing air traffic management initiatives (TMIs). Our approach, which employs the Majority Judgment voting mechanism, enables those flight operators impacted by a potential TMI to provide service level preference information to an air navigation service provider (ANSP) that initiates the TMI. The output of the process is a numeric vector that specifies performance goals for the TMI enabling the ANSP to tradeoff competing performance criteria, when designing the TMI. Earlier work has described key compo-nents of the overall approach. This paper gives a comprehensive view and also gives the results of a fast-time simulation benefits assessment and a human-in-the-loop simulation.

Abstracts:
Human Factors

(20) Read Back Error Detection using Automatic Speech Recognition - *Kopald, et al.*

In the last few years, the Federal Aviation Administration (FAA) has been investigating the use of automatic speech recognition in safety monitoring capabilities, with an initial focus on the tower domain. One application of speech recognition technology is the automatic detection of pilot read back errors that are not corrected by the controller. Uncorrected read back errors are one cause of runway incursions, one of the FAA's primary surface safety concerns. To inform the FAA's investigation into future speech recognition applications and mitigate the risk associated with future capability development, the MITRE Corporation (MITRE) is conducting research into the feasibility of a read back error detection capability that uses speech recognition to compare controller and pilot intent spoken in radio transmissions from the tower domain. Through this research, MITRE has developed a concept of use for the capability that includes a high level system design and a graphical user interface design. Additionally, MITRE conducted an evaluation of speech recognition performance on controller and pilot radio transmissions to assess the accuracy achievable with established speech recognition technology and tuning methods. Preliminary results from the research indicate that speech recognition performance on controller and pilot speech is promising, but more research is needed to refine the capability logic, improve speech recognition accuracy, and assess operational acceptability of its performance.

(22) Increasing ATM Efficiency with Assistant Based Speech Recognition - *Helmke, et al.*

Initiatives to integrate Automatic Speech Recognition into Air Traffic Management (ATM) exists at least since the late 90s. Some success to replace pseudo pilots have been reported, but its integration into controller assistant tools is missing. Ger-man Aerospace Center (DLR) and Saarland University devel-oped Assistant Based Speech Recognition (ABSR) enabling com-mand recognition rates better than 95%. However, good recogni-tion rates are no convincing argument for decision makers. Therefore, we conducted an ABSR validation study with eight air traffic controllers to quantify the benefits with respect to work-load and efficiency. The study validates that ABSR does not just reduce controllers' workload, which would already be a lot, but this paper presents that ABSR significantly increases ATM effi-ciency. Fuel reductions of 60 liters (16 gallons) per flight and a throughput increase by two arrivals per hour are possible.

(33) Analysis of work patterns as a foundation for human-automation communication in multiple remote towers - *Svensson, et al.*

Implicit communication and higher levels of automation will be more important in the future multiple remote towers, in order to make the work of the Air Traffic Controller (ATCO) more efficient. However, the ATCO still needs to be in the control loop to make critical decisions. Human-automation collaboration requires teamwork, based on common ground and implicit communication. To design automation that supports teamwork and implicit communication, the automation must know how the ATCO is working. Sensors, like eye-tracking, and work patterns of the ATCO can give important information regarding the current situation in order for the automation to provide situation based support, through implicit communication to the ATCO. This paper addresses the current lack of teamwork and implicit communication between the ATCO and the automation in today's air traffic control towers. Two case studies, using eye-tracking, were conducted. One study in a single tower simulator and one in a multiple remote tower simulator with three airports. The results show varying work patterns in three different stages of managing aircraft arrivals. This paper also discusses the potential for implicit communication and how work patterns are a foundation for designing air traffic control systems allowing teamwork.

(37) Learning Air Traffic Controller Workload from Past Sector Operations - *Gianazza*

In this paper, we compare several machine learning methods on the problem of learning a model of the air traffic controller workload from historical data. This data is a collection of workload mesurements extracted from past sector operations and of ATC complexity measurements computed from radar records and airspace data (sector geometry).

We assume that the workload is low when a given sector is collapsed with other sectors into a larger sector, normal when it is operated as is, and high when it is split into smaller sectors assigned to several working positions.

This learning problem is modeled as a classification problem where the target variable is a workload category (low, normal, high) and the explanatory variables are the air traffic control (ATC) complexity metrics.

Several classifiers are compared on this problem: linear dis-criminant analysis, quadratic discriminant analysis, naive Bayes classifiers, neural networks, and gradient boosted trees. The performance of these models is assessed on a separate test set. The best methods show a rate of correct predictions around 82%.

(74) Assessment of Air Traffic Controller Acceptability of Aircrew Route Change Requests - *Idris, et al.*

NASA developed the traffic aware strategic aircrew requests concept for a cockpit automation that identifies route improvements and advises the aircrew to request the change from the air traffic controller. In order to increase the chance of air traffic control approval, the automation ensures that the route is clear of known traffic, weather, and airspace restrictions. Hence the technology is anticipated to provide benefits in areas such as flight efficiency, flight schedule compliance, passenger comfort, and pilot and controller workload. In support of a field trial of a prototype of the technology, observations were conducted at the Atlanta and Jacksonville air traffic control centers to identify the main factors that affect the acceptability of aircrew requests by air traffic controllers. Observers shadowed air traffic controllers as the test flight pilot made pre-scripted requests to invoke acceptability issues and then they interviewed voluntarily fifty controllers with experience ranging from one to thirty-five years. The most common reason for rejecting requests is conflicting with traffic followed by violating air traffic procedures, increasing sector workload, and conflicting with major arrival and departure flows and flow restrictions. Quantitative parameters such as the distance that a route should maintain from sector boundaries and special use airspace were identified and recommended for inclusion in the automation.

(84) Effectiveness of the application of the Human Performance Assessment Process in SESAR 1 - *Biede & Pelchen-Medwed*

This paper introduces a comprehensive and systematic process to analyze the effectiveness of the application of the Human Performance Assessment Process (HPAP), which had been developed during the SESAR 1 program. An effectiveness evaluation was conducted over a selection of indicators addressing the process as well as the final outcome. These indicators considered the coverage of the HPAP, the involvement of human factors (HF) specialists, the number of identified issues and recommendations, as well as the status of closing these assessments at a defined level of maturity. The analysis shows that the process was widely applied, but variations in methods and tools of application were observed. It can hence be concluded that there is still some need for harmonization. In order to prepare its effective transition towards SESAR 2020, this analysis allows providing recommendations for the next steps.

Abstracts:
Integrated Airport/Airside Operations

(3) Airport – Collaborative Decision Making (A-CDM) Local and Network Impact Assessment - *Huet & Pickup*

Airport Collaborative Decision Making (A-CDM) is about sharing of information between all stakeholders that actively participate in the management of the arrival, turnaround and departure of an aircraft. The concept aims to integrate systems and processes to provide improved levels of turnaround predictability and take-off time accuracy that are of benefit to the ground operation locally and the Network Manager Operations Centre (NMOC) respectively.

A 12 month study was initiated by EUROCONTROL to investigate the impact of A-CDM on local and ATM operations. The local assessment was driven primarily by information shared by the first 17 fully implemented CDM airports. Local benefits that were confirmed as part of the study include the reduction in average taxi-out times and push-back delays, increased ground handling resource utilisation and more expeditious recovery from adverse conditions. The network assessment was developed based on the significant improvement in take-off time predictability generated by CDM airports. The EUROCONTROL NEST tool was used to conduct simulations of the entire European ATM network in which CDM airports departed flights more predictably than non A-CDM airports. This study verified that increasing the number of implemented airports would deliver increases to enroute capacity due to the reduction in sector overload potential within the most congested area of the European airspace. Results suggest that a 3.5%-5.5% increase in enroute capacity could be realised when Europe's top 50 airports become integrated. In addition, a discrete event simulation of a single enroute sector was developed to investigate the localised effects of increasing the proportion of flights arriving on each entry stream that originated from an airport that was transmitting Departure Planning Information (DPI) messages.

(23) What to say when: Guidelines to Decision Making - *Papenfuss, et al.*

Because airports are currently a bottleneck in the ATM system research and development effort is spent in creating high performing airport operations. In order to actively influence airport performance, joint decisions made in an Airport Operations Control Center (APOC) are proposed. This idea raises several research questions; one is in how far guidelines for a structured communication process mitigate factors like conflicts and personality which might prevent an effective and efficient decision making in the APOC. This paper explores the impact of a concept for cooperation for airport stakeholders in a planning task. Four teams with four airport experts took part in a high-fidelity study. The guidelines significantly improved experienced team effectiveness. Results show that guidelines lead to a more pro-active, information driven decision making and mitigate some effects of individual interaction behavior.

(105) Analysis of Saturation at the Airport-Airspace Integrated Operations - *Rodriguez-Sanz, et al.*

This paper develops a functional analysis of the operations that represent the aircraft flow through the airport-airspace system. In this analysis, we use a dynamic spatial boundary associated with the Extended Terminal Maneuvering Area (E-TMA) concept, so inbound and outbound timestamps can be considered. The aircraft path is characterized by several temporal milestones related to the Airport Collaborative Decision Making (A-CDM) method, which allows us to study the successive hierarchical tasks. By considering the accumulated delay across the different processes and its evolution, different metrics are proposed to evaluate the system's state and its ability to ensure an appropriate aircraft flow in terms of time-saturation. The objective is to establish a taxonomy that classifies the system's capacity to "receive and transmit" the expected aircraft flows. Finally, the relationships among the factors that influence the aircraft flow are evaluated to create a probabilistic graphical model, using a Bayesian Network approach. This model predicts outbound delays given the probability of having different values at the causal control variables. The methodology is developed through a case study at Adolfo Suárez Madrid-Barajas Airport (LEMD): a collection of 1,500 turnaround operations (registered at the peak month of 2015) is used to statistically determine the aircraft path characteristics. The contribution of the paper is twofold: it presents a new methodological approach to evaluate the system's state at the rotation stage and it also provides insights on the interdependencies between factors influencing performance.

(107) A novel machine learning model to predict abnormal Runway Occupancy Times and observe related precursors - *Herrema, et al.*

Accidents on the runway triggered the development and implementation of mitigation strategies. Therefore, the airline industry is moving toward proactive risk management, which aims to identify and predict risk percursors and to mitigate risks before accidents occur. For certain predictions Machine Learning techniques can be used. Although many studies have explored and applied novel Machine Learning techniques on different aircraft Radar and operational Taxi data, the identification and prediction of abnormal Runway Occupancy Times and the observation of related percursors are not well developed. In our previous papers, three feasible methods were introduced: Lasso, Multi-Layer Perceptiona and Neural Networks to predict the Taxi-Out Time on the taxiway and the time to Fly and True Airspeed profile on final approach. This paper presents a new Machine Learing method, where we merge these feasible Machine Learning techniques for prediction the abnormal Runway Occupancy times of unique radar data patterns. Additionally we use in this study the Regression Tree method to observe key related precursors extracted from the top 10 features. Compared with existing methods, the new method no longer requires predefined criteria or domain knowledge. Tests were conductioned using runway and final approach aircraft radar data consisting of 78,321 Charles de Gaulle flights and were benchmarked against 500,000 Vienna flights.

(116) Aircraft Boarding – Data, Validation, Analysis - *Schultz*

The aircraft boarding is always on the critical path of the turnaround. Efficient boarding procedures have to consider both operational constraints and the individual passenger behavior. In contrast to the processes of fueling, catering and cleaning the boarding is mainly driven by passengers not by airport or airline employees. There are several approaches to model and simulate the aircraft boarding. In this paper a microscopic approach is used to model the passenger behavior, where the passenger movement is defined as a one dimensional, stochastic, and time/space discrete transition process. To validate the research results achieved in the past years, field trials of boarding procedures and measurements of specific processes are recorded, analyzed and transferred to the simulation environment.

Abstracts:
Network and Strategic Flow

(15) A Novel MIP-based Airspace Sectorization for TMAs - *Schmidt, et al.*

We present a MIP-based airspace sectorization framework for Terminal Maneuvering Areas (TMAs). It in-corporates an airspace complexity representation, as well as various constraints on the sectors' geometry, e.g., the requirement that points that demand increased attention from air traffic controllers should lie in the sector's interior to allow for enough time to resolve possible conflicts. In contrast to earlier inte-ger/constraint programming approaches, which used synthesis methods with variables per elementary airspace piece that were glued together to form sectors, our IP formulation uses a variable per potential edge on the sector boundary. It is also the first step towards an integrated design of routes, the resulting complexity, and a sectorization. We present results for Stockholm TMA.

(51) Evaluation of Integrated Demand Management looking into Strategic & Tactical Flow Management - *Moehlenbrink, et al.*

The motivation behind Integrated Demand Management (IDM) research explores possible improvements to United States National Airspace System (NAS) performance that could be realized through procedural integration of strategic traffic flow management capabilities, such as the Collaborative Trajectory Options Program (CTOP), and tactical capabilities, such as Time Based Flow Management (TBFM). An initial IDM concept for clear weather operations was developed and evaluated for potential benefits, including efficiency, delay reduction, predictability and throughput, and to identify any major issues that might represent a showstopper for a fielded application. Newark Liberty International Airport (EWR) arrival operations provided a use case for concept development. EWR uses miles-in-trail (MIT) metering to regulate demand into TBFM during high volume operations, and short-haul flights are often penalized with excessive, last-minute ground delays when the overhead stream is saturated. IDM addresses this problem by replacing MIT conditioning with CTOP to better manage the demand delivery to the TBFM entry points. A "quasi-real time" high-fidelity simulation that would normally involve participants was conducted using heuristic-based procedures that mimicked operators' behaviors instead. Five total conditions were compared: two baseline conditions with MIT delivery to TBFM entry points using two different TBFM settings; and three IDM conditions: one with airborne speed control using an Required Time of Arrival (RTA) capability, a second without RTA, and a third with no wind forecast errors. Results suggest that the IDM concept can deliver traffic more efficiently by shifting the delays from airborne to ground for both RTA and non-RTA conditions, while maintaining a target throughput rate. The results also suggest that with good predictability of airport capacity, excessive TBFM ground delay can be minimized by applying more strategic CTOP delay, increasing predictability for the airline operators. Overall findings indicate that the implementation of an IDM concept under clear weather conditions can improve NAS system performance. Future IDM research aims to expand the concept to address demand/capacity imbalance due severe weather.

(55) A Distributed Air Traffic Flow Management Model for European Functional Airspace Blocks - *Alam, et al.*

Functional airspace blocks (FAB) concept is adopted by the European airspace to allows cooperation between airspace users to manage the air traffic flow, while ensuring efficiency, safety, and fairness without constraints of geographical boundaries. This integration of airspace in-troduces more flexibility to manage aircraft trajectory and airspace usage. In this paper, we propose a distributed air traffic flow management model to address four-dimensional trajectory planning over the European FAB. The goal is to enable effective information sharing between airspace blocks in strategic planning, and to minimize interaction between trajectories. The proposed model and overall methodology is implemented and tested with a full day air traffic data over the European airspace. Interaction-free 4D trajectories are produced within computational time acceptable for the oper-ational context, which shows the viability of the distributed model and interaction minimization approach for effective FAB implementation.

(60) Probabilistic Occupancy Counts and Flight Criticality Measures for ATM - *Gonze, et al.*

Airspace congestion is a major challenge for future European ATM. When air traffic control (ATC) believes that a sector will exceed its maximal capacity, a regulation is applied to it, which limits the number of aircraft entering the sector. These actions have a large cost, as they affect all the flights that cross the sector. Moreover, they are based on the partial data available to the controller and do not take into account the network situation.

First, we propose a probabilistic framework for modeling air traffic occupancy count and sector congestion. This allows us to provide ATC with more precise information on the probability of sector overload. Second, based on this framework, we define metrics for individual flights that measure their impact on the congestion of the whole network. These metrics are intended to be used in demand and capacity balancing tools, allowing for optimized choices for the whole network.

We present numerical experiments for one day of European data, which included 33,219 flights in 1,991 elementary sectors. The simulations advocate our metrics and show how actions taken on selected flights have a positive impact on the network congestion.

(80) An optimization model for assigning 4D-trajectories to flights under the TBO concept - *Fomeni, et al.*

The objective of thispaper is to present a mathematical model that will contribute to the optimization and optimum configuration of the TBO concept. We develop a binary integer programming model whose aim is to assign a 4D-trajectory to each flight in order to optimize the efficiency of the ATM system. The modelconsiders the preferred 4D-trajectory of all the flights in the pre-tactical planning phase and outputs an optimalpre-departure 4D-trajectory for each flight to be shared or negotiated with other stakeholders and subsequently managed throughout the flight. These output trajectories are obtained by minimising the deviation (in terms of time delay, lateral and vertical deviation) from the original preferred trajectories. Theparticularities of this model are that it considers thecomplete 4D-trajectory for each flight as well as it incorporates the preferences and priorities of the ATM stakeholders. Some computational results are presented, which show that our optimization model has the ability to identify some trade-offs between the objectives of the stakeholders of the ATM system under the TBO concept.It can also provide the network manager with useful decision tools to choose a trajectory for each flight.

(101) Generating Diverse Reroutes for Tactical Constraint Avoidance - *Taylor, et al.*

Decision support capabilities that provide flight-specific reroutes around constraints can enable more flexible and agile management of the airspace. For this benefit to be realized, automation must reliably provide operationally-acceptable alternatives to traffic managers. This paper proposes an approach for generating a small number of diverse, feasible solutions for further evaluation by traffic managers. Using a variation on Dijkstra's shortest path algorithm, reroutes are designed for one or more flights, where multi-flight problems promote the active design of reroute flows. A multi-objective genetic algorithm is employed to evaluate trade-offs between multiple criteria of operational acceptability, removing the need to pre-define relative metric weightings. Finally, a combination of Principal Components Analysis and Spectral Clustering is used to identify distinct groups of solutions and representative reroutes that capture different trade-offs between metrics of operational acceptability. Results are generated for a historical convective weather event and evaluated for their characterization of the trade-space.

(125) A Distributed Framework for Traffic Flow Management in the Presence of Unmanned Aircraft - *Balakrishnan, et al.*

The integration of unmanned aircraft systems (UAS) into the airspace system is a key challenge facing air traffic management today. An important aspect of this challenge is how to determine and manage 4-dimensional trajectories for both manned and unmanned aircraft, and how to appropriately allo-cate resources among different aircraft. An integrated approach requires solving the traditional Air Traffic Flow Management (ATFM) problem to balance the capacity and demand of airport and airspace resources, but at a significantly larger scale. In doing so, aircraft connectivity constraints of commercial flights must be satisfied. In addition to these and the resource capacity constraints, geofencing constraints for unmanned aircraft that keep them within or outside a certain region of the airspace, must also be incorporated.

This paper presents a distributed implementation of an integer programming approach for solving large-scale ATFM problems in the presence of unmanned aircraft. Given desired mission plans and flight-specific operating and delay costs, the pro-posed approach uses column generation to determine optimal trajectories in space and

time, in the presence of network and flight connectivity constraints, airport and airspace capacity constraints, and geofencing constraints. Using projected demand for the year 2030 from the United States with approximately 48,000 passenger flights and 29,000 UAS operations (on a wide range of missions) per day, we show that our implementation can find nearly-optimal trajectories for a 24-hour period in less than 4 minutes. Furthermore, a rolling horizon implementation (with 6-8 hour time windows) results in run times of less than a minute. In addition to being the largest instances of the ATFM problem solved to date, these results represent the first effort to incorporate UAS trajectories into airspace and airport resource sharing problems.

(139) Including Linear Holding in Air Traffic Flow Management for Flexible Delay Hand - *Prats & Xu*

This paper introduces a strategy to include linear holding into air traffic flow management (ATFM) initiatives, together with the commonly used ground holding and airborne holding measures. In this way, ATFM performance can be improved when handling delay assignment with uncertainty. Firstly, a trajectory generation method is presented, aiming at computing, per flight, the maximum linear holding realizable using the same fuel as the original nominal flight. This information is assumed to be computed and shared by the different airlines and it is then used to build a network ATFM model to optimally assign ATFM delays, in the scope of trajectory based operations. Hence, the best distribution of delay is optimized at given positions along the flight trajectory (combining the three holding practices together) and taking into account the cost of delay, especially in the fuel consumption. The problem is formulated as a mixed integer linear programming and solved with a commercially-of-the-shelf solver. An illustrative example is given, showing that under the circumstance of capacity recovered ahead of schedule, including linear holding contributes to a notable delay reduction compared to the case where only ground and/or airborne holding apply.

Abstracts:
Performance Measurement and Management

(50) Causal Inference for ATM Counterfactual Estimation - *Shah*

We propose that the Rubin potential outcomes framework of causal inference can be used to statistically estimate counterfactuals, by definition never observable, of Traffic Flow Management Initiatives (TFMI), as a novel means of quantifying the performance of Air Traffic Management (ATM) actions, despite confounding factors. Specifically, we apply the method of Propensity Scores to estimate counterfactuals and compute the increase in hourly average airborne delay which would have resulted without a Ground Delay Program, using an eleven month span of hourly weather, traffic, and delay data at JFK. Our introduction also summarizes the concepts of causal inference required for our analysis. We also offer suggestions to improve and extend our initial application of casual inference. Technical details of propensity score modeling are further covered in an appendix.

(110) Open source software and crowd sourced data for operational performance analysis - *Koelle*

This paper explores the feasibility of using open data and an open source toolbox for ensuring reproducibility in operational performance analysis of air navigation services. To date the access to operational data in support of research claims or observed performance benefits is limited. Though the majority of related data sets are established and curated by government authorities, open data access is still in its infancy. ICAO promotes a performance based approach. In that light there is stronger interest in performing regional and international benchmarking comparisons. To advance the state of the art it is important to establish common methods and tools. This paper reports on the conceptualization of the benchmarking process as a data analytical workflow and the supporting developments of an open-source data-analytical toolbox. This feasibility study demonstrates the use of the process and open data to provide a framework under which official results can be validated. The benefits of this approach have been demonstrated throughout the on-going regional benchmarking projects. The toolbox developed offers scope to expand the functionality and make operational ANS performance analyses accessible to a wider audience interested in applying harmonized global standards.

(123) A Comparative Analysis of Models for Predicting Delays in Air Traffic Networks - *Gopalakrishnan & Balakrishnan*

In this paper, we compare the performance of different approaches to predicting delays in air traffic networks. We consider three classes of models: A recently-developed aggregate model of the delay network dynamics, which we will refer to as the Markov Jump Linear System (MJLS), classical machine learning techniques like Classification and Regression Trees (CART), and three candidate Artificial Neural Network (ANN) architectures. We show that prediction performance can vary significantly depending on the choice of model/algorithm, and the type of prediction (for example, classification vs. regression). We also discuss the importance of selecting the right predictor variables, or features, in order to improve the performance of these algorithms.

The models are evaluated using operational data from the National Airspace System (NAS) of the United States. The ANN is shown to be a good algorithm for the classification problem, where it attains an average accuracy of nearly 94% in predicting whether or not delays on the 100 most-delayed links will exceed 60 min, looking two hours into the future. The MJLS model, however, is better at predicting the actual delay levels on different links, and has a mean prediction error of 4.7 min for the regression problem, for a 2 hr horizon. MJLS is also better at predicting outbound delays at the 30 major airports, with a mean error of 6.8 min, for a 2 hr prediction horizon. The effect of temporal factors, and the spatial distribution of current delays, in predicting future delays are also compared. The MJLS model, which is specifically designed to capture aggregate air traffic dynamics, leverages on these factors and outperforms the ANN in predicting the future spatial distribution of delays. In this manner, a trade-off between model simplicity and prediction accuracy is revealed.

(128) Predicting Performance of Ground Delay Programs - *Estes, et al.*

Models are proposed to estimate the performance of Ground Delay Programs as air traffic management initiatives. We apply Random Forest and Gradient-Boosted Forest regression techniques within the context of Geographically Weighted Regression. We estimate both the mean and 90th percentile responses for two performance indicators: average arrival delay and the number of cancelled arrivals.

(130) Causal Analysis of En Route Flight Inefficiency – the US Experience - *Liu, et al.*

En route inefficiency is measured in terms of extra distance flown by an aircraft, above the theoretical shortest distance (great circle) route. Three sources of inefficiency are explored: convective weather, miles-in-trail restrictions, and winds. Historical flight records are projected onto a small set of nominal trajectories clustered from historical data, and compared against the history of the potential causal factors. Statistical models reveal the estimated influence of the factors. In this case, convective weather was the most influential factor in seeming to cause flights to deviate from what would have been a less costly trajectory. Winds and miles-in-trail restrictions are also important for some origin-destination pairs, but less significant than convective weather.

This paper introduces a new technique, which is based on a more powerful model of accident causality — called systems-theoretic accident model and process (STAMP) — that can capture behaviors that are prevalent in these complex, software-intensive systems. The goals are to (1) develop rigorous, systematic tools for the analysis of future ATM concepts in order to identify potentially hazardous scenarios and undocumented assumptions, and (2) extend these tools to assist stakeholders in the development of concepts using a safety-driven approach.

Abstracts:
Safety and Resilience

(13) Topics and Trends in Incident Reports - *Kuhn*

The Aviation Safety Reporting System includes over a million confidential reports describing safety incidents. Natural language processing techniques allow for relatively rapid and largely automated analysis of large collections of text data. Meaningful interpretation of the results and further investigations by subject matter experts can follow. This article describes the application of structural topic modeling to Aviation Safety Reporting System data. Results reveal that the application is able to identify known issues. The method also has the potential to identify previously unknown connections that may warrant further, more manual, study. Results reported here highlight the importance of fuel pump, tank, and landing gear issues and the relative insignificance of smoke and fire issues for private aircraft. The results also uncovered evidence of the prominence of the Quiet Bridge Visual and Tip Toe Visual approach paths at San Francisco International Airport in safety incident reports.

(46) A Bayesian Network Model of Pilot Response to TCAS Resolution Advisories - *Moss & Londner*

The effectiveness of an airborne collision avoidance system (CAS) is influenced by the manner in which pilots respond to the system's advisories. Current pilot response models used in CAS modeling and simulation are agnostic to parameters affecting pilot response in individual encounters and therefore treat all encounters equally. Simulations using these models can potentially underestimate collision risk in encounters where pilot response probability is low. This paper proposes a parametric pilot response model built from operational data using Bayesian networks. A network was constructed from radar recordings of TCAS encounters and the encounter parameters with the strongest influence on pilot response were identified. These pa-rameters can be used to predict the probability of pilot response for individual encounters. The model was employed in simulation of safety-critical encounters. Results showed that standard pilot response models may underestimate collision risk. These results have implications for the design and performance evaluation of separation advisory systems, including collision avoidance and detect and avoid systems.

(59) A Quantitative Approach to Resilience Engineering for the Future ATM System: Case Studies Results - *Palumbo, et al.*

This paper presents the application to some noticeable case studies of a novel methodology proposed for the resilience engineering of the future ATM system. The paper first summarizes an original resilience engineering definition and approach, as proposed by the authors in a SESAR Long-Term Research funded project. This approach is based on a quantitative measure of the ATM system global performance which is seen as the fulfillment of the performance expectations in the 11 Key Performance Areas defined by ICAO plus Human Performance. Resilience is thus expressed as the level of residual ATM global performance resulting from a task and authority re-allocation strategy required to mitigate a disruptive event. This methodology is then applied to two case studies and the discussion of the results highlights how the approach has been already translated into an algorithmic method suitable for deriving measurable results. Finally the paper discusses the current weaknesses of the approach and the required future developments to allow its actual application.

(68) Modeling the Intrinsic Safety of Unstructured and Layered Airspace Designs - *Tra, et al.*

Previous research relating airspace structure and ca-pacity has shown that a decentralized layered airspace concept, in which each altitude band limited horizontal travel to within a predefined heading range, improved safety when compared to unstructured airspace. However, the extent of the safety benefits of such layered airspace designs were not quantified. To this end, in this paper, conflict rate models are developed to determine the intrinsic safety of unstructured and layered airspace designs. In comparison to previous work, the present models consider con-flicts between aircraft in different flight phases. Thus, conflicts for climbing and descending traffic, as well as for cruising aircraft, are taken into account when computing the total conflict rate. To validate the models, fast-time simulations were performed for several different layered airspace concepts, and for unstructured airspace. The results indicate that the models are able to estimate the conflict rate for high traffic densities using a model fit for low densities. When comparing the different layered airspace concepts tested, the model predicted, and the simulation results confirmed, a clear safety improvement when the permitted heading range per altitude

band is reduced. Thus the models can be used to study the effect of airspace design parameters on the safety of unstructured and layered airspace concepts.

(104) Emergent Behaviour of Trajectory Based Operations Under Very High En-route Traffic Demand - *Blom & Bakker*

Effective collaboration between planning controller, tactical controller and pilots in handling various uncertainties and hazards is the result of decades of evolutionary development. The forthcoming paradigm shift to Trajectory Based Operations (TBO) requires a similarly effective collaboration between the TBO layer and a tactical layer. Through agent-based modelling and simulation the authors have recently shown that in a pure airborne self-separation environment these two layers together can yield remarkably positive emergent behaviour in managing uncertainties and hazards, as a result of which very high en-route traffic demands can safely be accommodated. The current paper addresses the question if similarly good emergent behaviour is feasible with a ground based TBO design. The key findings are twofold. A negative finding is that ground-based TBO is not providing the remarkably positive emergent behaviours of pure airborne TBO. Though a positive finding is that ground-based TBO has the potential to safely accommodate high en route traffic demands.

(136) Vulnerability Metrics for the Airspace System - *Roy, et al.*

Simple topological vunerability metrics are defined for the air transporation system, that are meant to reflect the impact levels of potential disruptions including severe weather and man-made threats (e.g., cyber attacks). Specifically, a flow- vulnerability metric is defined using the Laplacian matrix of the air traffic network's graph. In turn, even and total vulnerability metrics are posited. The main focus of this study is to evaluate and parameterize these metrics using simulations of flow-level models of the airspace system, together with some formal analysis. These simulations suggest that the vulnerability metrics show promise as indicators of disruption impact.

Abstracts:
Separation

(09) Methods of Aircraft Re-categorizations for Reducing Wake Vortex Separations - *Wei, et al.*

The current criteria of wake vortex separation may limit the capacity of the busy airports despite ensuring flight safety. Based on plenty of measured data together with the knowledge of wake vortex behavior, the concept of Re-categorization (RECAT) has been proposed by the international air traffic researchers. This concept has attracted more and more interests, as it can apply to reduce separations with more precision by increasing the amount of aircraft categories. The methods for classifying aircraft categories were studied systematically, and the parameters termed as Required Decay Distance (RDD) and Wake Vortex Impedance (WVI) were proposed by authors to consider the influence of leading aircraft's wake vortex circulation, and the resistant ability of following aircraft when encountering wake vortex. By comparing RECAT-I with RECAT-EU, the standard we proposed called RECAT-NEW can obtain more balanced and reasonable results in safety domain. Furthermore, on the basis of the data in airport peak operation conditions, the RECAT-NEW is expected to increase 2.2% of airport capacity.

(031) Large Scale 3D En-Route Conflict Resolution - *Wang, et al.*

En-route conflict resolution is a good example of a large-scale combinatorial optimization problem. On the one hand, it has been modeled in many different ways, most of the time depending on the tools that were proposed to solve it. On the other hand, many different resolution methods can be tested and compared on such problems but a common model needs to be used to validate the comparison.

In this paper we extend the 2D-framework introduced in 2013, which separates the model from the solver. First, we introduce a 3D-model and add new refinements on the uncertainty model taking into account, inter alia, delays due to human factors. Second, we compare the performance of a complete Constraint Programming solver and an approximation algorithm based on a Memetic Algorithm, an efficient metaheuristic combining Genetic Algorithm with Tabu Search.

To this aim, we generate a benchmark of conflict resolution problems built with scenarios involving 15 to 100 aircraft, 3 different levels of uncertainty and maneuvers in both horizontal and vertical planes. The two methods are able to efficiently solve moderate size problems in near real time, but the execution time of the complete algorithm exponentially rockets with larger instances whereas the metaheuristic scales much better with the number of aircraft. However, the former is able to prove optimality or infeasibility on reasonable problems, which allows the assessment of the quality of the solutions produced by the latter.

(75) Agent-based Formation Flight Coalition under Incomplete Information - *Meng, et al.*

The continued increasing air traffic demand and the corresponding fuel consumption urge the innovations of technologies and operating modes in commercial aviation community. Formation flight, due to its potential for reducing fuel use, are widely recognized as one of the most effective ways to improve aviation fuel saving. This study addresses the commercial formation coalition problem under incomplete information. First, a mathematical formulation is redefined to fit well the agent-based computation. Second, a BDI agent-based formation coalition model is developed to capture the structural characteristics of formations and the mental and behavioral characteristics of flights under incomplete information. Third, a Bayesian negotiation algorithm is constructed, within which Harsanyi transformation is used to transform the formation coalition problem under incomplete information to a Bayesian-equivalent coalition problem under imperfect information. Experiments indicate that the model proposed in this study is fast convergent and produces an equitable formation flight economy split among fleets. Besides, the unknown information prediction accuracy is better than MAS cooperative coalition model.

(134) A Constraint Programming Model with Time Uncertainty for Cooperative Flight Departures - *Ramos, et al.*

The lack of a proper integration of strategic ATM decision support tools with tactical ATC interventions usually generates a negative impact in the Reference Business Trajectory adherence, and in consequence affects the

potential of the TBO framework. In this paper, a new mechanism to reduce the amount of ATC interventions at tactical level while preserving ATFM planned operations is presented as part of the PARTAKE project. The project fosters adherence of air space user's trajectory preferences enhancing Trajectory Based Operation (TBO) concepts by identifying tight interdependencies between trajectories and introducing a new mechanism to improve aircraft separation at the hot spots. The underlying philosophy is to capitalize present freedom degrees between layered Air Traffic Management (ATM) planning tools, when sequencing departures at airports by considering the benefits of small time stamp changes in the assigned CTOT departures.

Abstracts:
Surveillance and Navigation

(27) PBN Hybrid Procedures as an Enabler for Airport Accessibility in Challenging Terrain - *Schaad*

Along with many other advantages, Performance Based Navigation (PBN) has given aviation new technological and operational standards to safely perform flights to and from airports in critical terrain [1], which under conventional navigation standards would have produced prohibitively high weather minima. Therefore, PBN clearly acts as a contributor to safety and accessibility of terrain-challenged airports [2]. However, in some cases, the design criteria for Required Navigation Performance (RNP) procedures show disadvantages over conventional criteria when it comes to the geometric layout of obstacle protection areas. In such cases, the strict separation between PBN and conventional procedures may not support the best operational solution whereas relinquishing this separation in favor of a hybrid approach to ICAO procedure standards can produce very promising results. The concrete example of the development of a hybrid procedure for one of the world's most complex airport locations will be shown in this paper to advocate the use of both PBN and conventional design criteria in a "mixed toolbox" concept to achieve even higher levels of accessibility to critical terrain airports whilst maintaining the highest levels of safety.

(118) Using PBN for Terminal and Extended Terminal Operations - *Trenevska, et al.*

Radar track data was collected during one year from three major Air Navigation Service Providers in Europe, providing Air Traffic Control to the international airports of Paris Charles de Gaulle, Amsterdam Schiphol and London Heathrow. The data consisted of departure, arrival and approach transition instrument flight procedures. Using a custom built application and filtering process, tactical interventions from Air Traffic Control were removed from the dataset. The remaining dataset was used to compute cross-track deviations from the route centerline of the procedures, both along straight segments and in turns. For the turns the route centerline was defined by an average turn radius which was calculated for each turn in the procedure. These cross-track deviations were used to compute lateral navigation performance distributions for straight segments, turns and for different speed and turn angle categories. The general observation was that according to these computed performance distributions, the actual lateral navigation performance of the current fleet in Europe operating to the three major airports from which data was collected, is outstanding and far better than the required navigation performance defined in the ICAO standards. For example, the lateral track keeping accuracy along straight segments, for groundspeeds exceeding 350 knots, had a standard deviation of only 0.07NM. Subsets of data consisting of aircraft navigating without GNSS were also analyzed. Finally the performance distributions were injected in a Collision Risk Model (CRM) to determine the required route spacing for a set of sample parallel route configurations in function of a target level of safety. It was concluded that, thanks to the excellent actual navigation performance, navigation performance is not the prevalent factor anymore in route spacing determination in a radar environment. Instead, radar separation minima and human factors such as the controller's screen resolution and ATC sector size are the more dominant elements for the determination of route spacing minima.

Abstracts:
Terminal Area Operations

(30) Analysis of the Use of Estimated Time of Arrival Broadcast for Interval Management - *Priess, et al.*

Interval Management (IM) is a NextGen application that requires accurate Estimated Times of Arrival (ETAs) in order to achieve a desired inter-aircraft spacing at a downstream point. Current standards require that the IM avionics calculate an ETA for the Target aircraft against which the IM aircraft is managing its relative spacing interval. In the future, this requirement could be replaced by a requirement that the Target aircraft broadcast the ETA generated by its Flight Management System (FMS). This ETA is expected to be more accurate than the ETA calculated by the IM avionics, and should thus result in more precise inter-aircraft spacing. This paper presents a comparison of IM performance between the current standards environment and a future environment where the Target aircraft broadcasts its ETA. Intuitively, basic technical IM performance metrics would improve when using the Target aircraft's broadcast ETA, but simulation results did not show increased performance benefit over the current IM avionics standard. This is due both to the environment under study, and the IM closed-loop performance being robust to inaccuracies in the calculation of the Target aircraft's ETA.

(43) Measuring Performance of Initial Ground-based Interval Management - Spacing (GIM-S) Operations - *Lascara, et al.*

The Time Based Flow Management (TBFM) automation system provides scheduling and scheduling-management tools to Air Traffic Control (ATC) to support time-based metering operations. Time-based metering is used to develop an orderly and efficient flow of traffic in en route airspace to coordinate delivery to the terminal. Recent enhancements to TBFM include the introduction of Ground-based Interval Management–Spacing (GIM-S). GIM-S introduces three new functions to improve time-based metering operations: extended metering, coupled scheduling, and speed advisories. The expected benefits of GIM-S include increased meter point delivery accuracy, reduced vectoring, and increased use of Performance Based Navigation (PBN) procedures. These benefits are expected to translate into more consistent and predictable arrival operations for air carriers. This paper presents a methodology for assessing the impact of GIM-S operations relative to the aforementioned benefits. Results indicate that time-based metering operations are improved with the use of GIM-S; however, the varied and inconsistent use of GIM-S between en route facilities reduces the data available for review and reflects operational models that are not necessarily consistent with the envisioned use to maximize benefits.

(57) Design Considerations of Vertically-Constrained PBN Procedures for Trajectory Management - *Bronsvoort, et al.*

This paper investigates the interdependencies between the design of PBN procedures, FMS operating logic, and the concept of 4 Dimensional Trajectory Downlink (4D-TRAD). Constraints that are added to PBN procedures, e.g. altitude and speed constraints, can impact on the potential to absorb delay through airborne time-of-arrival-control capabilities in a concept like 4D-TRAD. Logically, speed constraints are detrimental to the delay absorption potential, but the appropriate use of altitude constraints can lead to increased delay absorption potential. Forcing the aircraft to descent earlier than the optimal top of descent, increases the flight time window at the expense of additional fuel burn. In this paper a concept is investigated whereby an altitude requirement can be dynamically set by ATC to increase the delay absorption potential, when required, while providing a closed-loop clearance that can be entered in the FMS. Typical delay absorption potential by airborne time-of-arrival-control capabilities is compared to a sample of actual flight data. It is concluded that typical delay is generally in excess of what can be absorbed. Therefore, even if delay-potential allowances are designed into PBN procedures, like discussed in this paper, there will be a strong reliance on improved air traffic flow management procedures, to enable full 4D trajectory management, runway to runway.

(61) Analysis on the Impact of Pop-Up Flight Occurrence when Extending the Arrival Management Horizon - *Vanwelsenaere, et al.*

The occurrence of pop-up flights negatively affects the (extended) arrival manager. This issue is known already for a long time by operational experts, but the extent thereof has now been assessed during experiments. An

arrival manager research model was developed and integrated in BlueSky, an open-source air traffic management simulator. Fast-time simulations showed that extended arrival management is significantly negatively affected by pop-up flights, in terms of flight crew and air traffic control task load, sequence stability and delay (cost). Simulations also indicated that this impact could be mitigated by pre-planning pop-up flights prior to departure, using their take-off time estimates. This will, however, only be beneficial when these estimates are sufficiently accurate. With currently achievable accuracies, and using currently available systems, it is better to discard these estimates in the context of extended arrival management.

(103) Toward the characterisation of sequencing arrivals - *Christien,et al.*

This paper proposes a novel approach to understand and characterise the sequencing of arrivals. The proposed approach, essentially data driven, relies on the analysis of the spacing evolution over time between consecutive aircraft. As a case study, it was applied to different sequencing techniques (a baseline and two new ones) in the same approach environment, using track data from human in the loop simulations. The analysis conducted enables to characterise how the spacing evolves in time, and reveals differences among the three techniques in terms of convergence speed. The spacing deviation containment decreases faster with the new techniques, suggesting that the sequencing is anticipated and performed earlier. Typical sequencing patterns have been identified that also reveal the early sequencing. Future work will involve considering different environments and extending the horizon of analysis to capture the complete arrival process.

Abstracts:
Trajectory Prediction

(25) Bayesian Inference of Aircraft Initial Mass - *Sun, et al.*

Aircraft mass is a crucial piece of information for studies on aircraft performance, trajectory prediction, and many other ATM topics. However, it is a common challenge for researchers who have no access to this proprietary information. Previously, several studies have proposed methods to estimates aircraft weight, most of which are focused on specific parts of the flight. Often due to inaccurate input data or biased assumptions, a significant number of estimates can result outside of the weight limitation boundaries. This paper proposes an approach that makes use of multiple observations to get a better estimate for a complete flight. By looking at flight data from a complete trajectory and calculating aircraft mass at different flight phases based on different methods, together with fuel flow models, multiple observations of aircraft initial mass can then be derived. Using the Bayesian inference method, final estimates can be made with a higher level of confidence.

(94) Statistical Modeling of Aircraft Takeoff Weight - *Chati & Balakrishnan*

The Takeoff Weight (TOW) of an aircraft is an important aspect of aircraft performance, and impacts a large number of characteristics, ranging from the trajectory to the fuel burn of the flight. Due to its dependence on factors such as the passenger and cargo load factors as well as operating strategies, the TOW of a particular flight is generally not available to entities outside of the operating airline. The above observations motivate the development of accurate TOW estimates that can be used for fuel burn estimation or trajectory prediction.

This paper proposes a statistical approach based on Gaussian Process Regression (GPR) to determine both a mean estimate of the TOW and the associated confidence interval, using observed data from the takeoff ground roll. The predictor variables are chosen by considering both their ease of availability and the underlying aircraft dynamics. The model development and validation are conducted using Flight Data Recorder archives, which also provide ground truth data.

The proposed models are found to have a mean TOW error of 3%, averaged across eight different aircraft types, resulting in a nearly 50% smaller error than the models in the Aircraft Noise and Performance (ANP) database. In contrast to the ANP database which provides only point estimates of the TOW, the GPR models quantify the uncertainty in the estimates by providing a probability distribution.

Finally, the developed models are used to estimate aircraft fuel flow rate during ascent. The TOW estimated by the GPR models is used as an input to the fuel flow rate estimation. The proposed statistical models of the TOW are shown to enable a better quantification of uncertainty in the fuel flow rate as compared to the deterministic ANP models, or to models that do not use the TOW as an explicit input.

(121) A simple method to integrate Mode S Indicated Airspeed with Ground Based Trajectory Prediction - *Vandermeersch & Marmont*

Decision support tools in the London Area Control Centre provide the Air Traffic Control Officers (ATCO) with the information to quickly identify potential interactions between aircraft. These tools are underpinned by a trajectory predictor.

Research has shown that more accurate inputs to these trajectory prediction (TP) algorithms yield more accurate results. Previous research has focussed on aircraft mass and more accurate meteorological data. This study investigated the effect of including downlinked Mode S Indicated Airspeed (IAS) as a Calibrated Airspeed (CAS) value into the TP calculation. The effect was measured on the accuracy and stability of the prediction during the climb portion of each flight. Five potential approaches were implemented in a MATLAB test harness and the performance was compared against the accuracy and stability of the Eurocontrol Base of Aircraft Data (BADA) baseline implementation.

To test the approaches a dataset consisting of all the flights on a typical busy day in the UK airspace was used. This dataset yielded 2,219 climb segments from 715 flights to analyse. The dataset resulted in almost 280,000

performance points, distributed over the different evaluated TP models. These results show that the effect of including Mode S IAS on the vertical accuracy is marginal. The along track accuracy shows significant improvement when Mode S IAS is included. The inclusion of Mode S IAS does have a detrimental effect on the TP CAS stability as the CAS is no longer a constant in the climb portion.

Of the tested approaches, a one dimensional Kalman filter shows most promise in terms of trade-off between TP accuracy and CAS stability. Furthermore, the Kalman filter should be easier to prove in a safety environment and expanded to include other parameters in order to provide better accuracy and performance.

Abstracts:
UAS and RPAS

(16) A Path Planning Algorithm to Enable Well-Clear Low Altitude UAS Operation Beyond Visual Line of Sight - *Balachandran, et al.*

The availability of reliable and efficient algorithms to avoid obstacles, geofences, and other traffic is an essential functionality for safe autonomous operation of Unmanned Aircraft Systems (UAS) in low altitude airspace beyond visual line of sight. This paper presents a path planning algorithm that enables UAS to fly specified missions while accommodating real time traffic geofence constraints. This planning algorithm integrates a rapidly exploring random tree planning technique with formally verified algorithms for maintaining well clear with respect to traffic aircraft and for detecting geofence conflicts. A simple heuristic that determines when to terminate tree expansion leads to low average computation times making this approach suitable for UAS with limited onboard computing power.

(54) Ensuring Interoperability between UAS Detect-and-Avoid and Manned Aircraft Collision Avoidance - *Thipphavong, et al.*

The Unmanned Aircraft Systems (UAS) community in the United States has identified the need for a "collision avoidance region" in which UAS Detect-and-Avoid (DAA) vertical guidance is restricted to preclude interoperability issues with manned aircraft collision avoidance system vertical resolution advisories (RAs). This paper documents the process by which the collision avoidance region was defined. Three candidate definitions were evaluated on 1.3 million simulated pairwise encounters between UAS and manned aircraft covering a wide range of horizontal and vertical closure rates, angles, and miss distances. Each definition was evaluated with regard to UAS DAA interoperability with manned aircraft collision avoidance in terms of how well it achieved: 1) the primary objective of restricting DAA vertical guidance prior to RAs when the aircraft are close, and 2) the secondary objective of avoiding unnecessary restrictions of DAA vertical guidance at DAA alerts when the aircraft are further apart. The collision avoidance region definition that fully achieves the primary objective and best achieves the secondary objective was recommended to and accepted by the UAS community in the United States. By this definition, UAS and manned aircraft are in the collision avoidance region where DAA vertical guidance is restricted when the time to closest point of approach (CPA) is less than 50 seconds and either the time to co-altitude is less than 50 seconds or the current vertical separation is less than 800 feet.

(64) Assessing the Robustness of a UAS Detect & Avoid Algorithm - *Allignol, et al.*

In this article, we evaluate the robustness of a detect and avoid algorithm designed for the integration of UASs in terminal control areas. This assessment relies on a realistic modeling of navigation accuracy on positions and velocities and was carried out on thousands of scenarios built from recorded commercial traffic trajectories. The tested scenarios involved two different types of UASs – flying at 80 kts and 160 kts – with various missions, and three strategies for separation: one focussing on the separation distance, one focussing on the UAS mission and and combination of both.

Fast-time simulation was used to evaluate each scenario against a wide range of accuracy levels corresponding to required navigation precision standards and linked to on-board navigation and communication systems. Experiments reveal a strong robustness of the separation algorithm up to relatively high uncertainty levels, indicating that UASs equipped with low accuracy navigation systems can still manage proper separation. However, the maneuvering cost for separation increases when the accuracy deteriorates. Nevertheless, a UAS with GPS-based navigation in a collaborative environment (e.g. aircraft providing their navigation parameters through ADS-B) can expect robustness at a reasonable cost.

(76) Flight Test Evaluation of an Unmanned Aircraft System Traffic Management (UTM) Concept for Multiple Beyond-Visual-Line-of-Sight Operations - *Johnson, et al.*

This study evaluates a traffic management concept designed to enable simultaneous operations of multiple small unmanned aircraft systems (UAS) in the U.S. national airspace system (NAS). A five-day flight-test activity is described that examined the feasibility of operating multiple UAS beyond visual line of sight (BVLOS) of their respective

operators in the same airspace. Over the five-day campaign, three groups of five flight crews operated a total of eleven different aircraft. Each group participated in four flight scenarios involving five simultaneous missions. Each vehicle was operated BVLOS up to 1.5 miles from the pilot in command. Findings and recommendations are presented to support the feasibility and safety of routine BVLOS operations for small UAS.

(140) Wind Efficient Path Planning and Reconfiguration of UAS in Future ATM - *Rodriguez, et al.*

Unmanned Aerial Systems (UAS) integration to future airspace is one of the greatest challenges in Air Traffic Management. The use of UAS for covering wide areas implies the consideration of airspace restrictions and static and dy-namic obstacle avoidance. This results in complex shapes that need to be partitioned adequately to ensure coverage. Another important element for consideration in the generation of safe and efficient trajectories of UAS is the wind field. Typically, in severe wind scenarios, wind is considered often a hazardous condition. However, recent studies show that proper identification of the wind field could be used to increase the energy efficiency of the mission. This paper presents a novel method of area decomposition and partition that ensures coverage by generating a triangular mesh to optimize the coverage in the presence of urban areas, airspace restrictions or even the presence of an obstacle. The waypoint sequencing considers the wind field in order to perform on-line adjustments to ensure energy gains or to minimize energy losses with the identified wind field. For this purpose, an innovative method for wind identification is proposed which analyses the statistical behavior of wind vector estimates in order to identify specific features and characterize given models. Given the design philosophy and architecture, this system can be integrated into next generation autonomous UAS flight management systems as part of the waypoint sequencing and trajectory optimization functions. A test case in the north-Seattle area is presented, which is simulated using a 6DOF model with different wind scenarios which resulted into considerable energy gains either by heeding the wind field during the waypoint sequencing and during the mission execution. Results show that there is a significant improvement on the energy efficiency with an energy consumption reduced by 10% in the presence of wind.

Abstracts:
Weather in ATM

(08) Translating Convective Weather Forecasts into Strategic Traffic Management Decision Aids - *Matthews, et al.*

This paper presents a method to translate strategic convective weather forecasts into a metric that estimates the impact of convective weather on air traffic flows. The translation method is validated by measuring the flow rates of aircraft using weather impacted airspace in both en route and terminal airspace. Validation results show agreement between the airspace permeability estimates produced by the model and flow rates measured across airspace resources controlling arrival and departure flows. Features from single and ensemble storm-resolving forecasts, combined with two different probabilistic forecasts, were used to generate 0-12 hour estimates of airspace permeability including prediction intervals. The skill of the combined forecast and each contributing forecast was quantified across varying forecast horizons. The algorithms were implemented in a real-time system that was evaluated at several U.S. facilities between 2014 - 2016.

(72) Predicting & Quantifying Risk in Airport Capacity Profile Selection for Air Traffic Management -*Jones, et al.*

There is currently no data-driven approach widely used by air traffic managers and controllers to predict the capacity at airports. Instead controllers rely on rules-of-thumb to define the airport acceptance rate (AAR). As the approach is inherently subjective, it can lead to poor definition of Traffic Management Initiatives (TMIs) which rely on accurate airport capacity estimates and can lead to under-delivery or over-delivery of flights to airports. In this paper we propose a methodology for estimating airport capacity and capacity uncertainty based on the environmental conditions within the terminal and airport arrival routes and the projected arrival demand and aircraft spacing. To make these predictions we used a gradient tree boosting model in which the prediction model estimates are time-lagged and conditioned on the previous states. Additionally, estimates from previously predicted states are also used to condition the model based on the history of the predictor variables. The concept was validated against observations from historical data recorded at Newark Liberty Airport (EWR). The proposed method provides accurate prediction of airport capacity and produces a strong quantification of uncertainty in the form of a prediction interval. To explore the implications of applying information about the capacity uncertainty into planning in ground delay programs (GDPs), a stochastic integer programming model for GDP planning was created using the specific quantiles to define a constraint on airport capacity. This model allows the decision maker to make trades based on quantified levels of capacity deviation uncertainty. The results of a sensitivity analysis suggest that the decision maker may benefit from adopting a modest risk premium when planning GDPs.

(99) Strategic planning of North Atlantic Oceanic air traffic based on a new wind-optimal route structure - *Dhief, et al.*

Recently, air traffic is steadily increasing all over the world. Particularly, the air traffic over the North Atlantic airspace has witnessed an incessant increase. This increase was expected since it connects two densely-populated areas, namely North America and Europe. Otherwise, up to now the efficiency of trans-Atlantic flights is low due to the limited navigational equipment and radar coverage. The availability of Automated Dependent Surveillance-Broadcast (ADS-B) systems represents a new opportunity to better the strategic planning of flights over the oceanic area by reducing the separation standards. Besides, oceanic flights are subject to very strong winds. Recently, several researches proved that flying wind-optimal route yields to a significant fuel and time savings for each flight. Thus, optimizing trans-Atlantic routes and providing reliable flight trajectories become a primordial issue for the oceanic air traffic management.

In this paper, we propose a new trans-Atlantic route structure that benefits from the jet streams in order to construct wind-optimal flight trajectories. First, we describe the methodology used to design our new route structure. Then, an optimization model for detecting and resolving conflicts is introduced. The analysis was carried out in real traffic data to prove the efficiency of the developed method. Experimental findings show that our approach provides encouraging results in terms of conflict resolution and time savings.

(137) Modeling Ground Delay Program Incidence using Convective and Local Weather Information - *Kang & Hansen*

In this work, we model the impact of weather condition on ground delay program (GDP) incidence using support vector machine (SVM) and logistic regression. We use SVM to analyze how spatial patterns of convective weather affect GDP occurrence and produce heatmaps to visualize the impact. Additionally, the SVM results are combined with local airport weather variables and airport traffic level indicator to yield a logistic model that considers both local conditions at the airport and convective weather in the surrounding area. We apply our methods to five airports: Newark Liberty International airport, John F. Kennedy International airport, LaGuardia airport, Philadelphia International airport, and Atlanta International airport. We find that the importance of convective weather depends on both its distance and direction from the airport. From the logistic regression we learn that both regional convective weather, as captured by the weights found in the SVM, and local weather are statistically significant. Convective weather is, however, the most important factor. Our models are found to have high accuracy and low false positive rates, but also low true positive rates because of the imbalance in our data.

Keynote Speaker and Panelist Biographies

Sealth was a chief of the Suquamish tribe at the time the first white settlers arrived in 1851. Seattle is a derivative of the Indian name "Sealth".

Biographies:
Keynote Speakers and Panelists

Gregory J. Bowles is the Vice President, Global Innovation & Policy for the General Aviation Manufacturers Association (GAMA) where he is responsible for the identification of key technological opportunities and the development of critical paths to success which will evolve the safety and success of aviation. Greg currently leads the worldwide standards committee (ASTM F44) which is chartered to develop globally acceptable means of compliance for the design of airplanes carrying up to 19 passengers. Greg has been an advisor to several long-standing ICAO panels and the industry co-chair on the FAA's Part 23 Reorganization ARC which has been developed the rewrite of FAA part 23 regulations to assure they will address the aircraft of the next twenty years. Greg also leads the Electric Propulsion & Innovation Committee (EPIC) which represents the world's leading on-demand mobility development companies along with traditional aviation manufacturers as this community strives to enable new kinds of public transportation through the air.

Greg brings a broad array of real world engineering experience from both large and small scale aerospace companies. Prior to joining GAMA, Greg worked as a certification engineer at Keystone Helicopter (currently Sikorsky) in Philadelphia, Pennsylvania. In this role Greg coordinated with the FAA, EASA, and various other foreign authorities on design certification activities for various rotary and fixed winged aircraft. Greg began his career as a design engineer at Cessna Aircraft Company (Currently Textron Aviation) in Wichita, Kansas.

Greg holds a Bachelors of Science in Aerospace Engineering from Embry-Riddle Aeronautical University and a Masters of Business Administration degree from Webster University. Greg is an avid sailor and an active instrument rated general aviation pilot.

James T. Eck is the Assistant Administrator for NextGen at the Federal Aviation Administration. The NextGen Organization is responsible for leading the modernization of the National Airspace System, the move to a smarter, satellite-based system with digital technologies and advanced procedures that will ensure safe and efficient air travel for decades to come. Eck leads a federal workforce of about 900 employees and manages the $1 billion annual budget of the Next Generation Air Transportation System (NextGen). His office also oversees the world's leading aviation research complex at the William J. Hughes Technical Center in Atlantic City, N.J.

Formerly, Jim served as the Vice President of the Program Management Organization (PMO) responsible for all NextGen program activity, infrastructure modernization programs, and service to legacy NAS infrastructure. Jim has worked acquisition programs since joining the FAA in 1996. In addition to program development and execution, he has been active in leading acquisition management policy and workforce development. Prior to joining the FAA, Jim spent 18 years working for the U.S. Navy, concluding his work with the Naval Command Control and Ocean Surveillance Center in tactical communications research and development.

Jim is a BSEE graduate from the Pennsylvania State University, and MSE System Engineering graduate from the University of Pennsylvania.

Kourosh Hadi serves as the director of Airplane Product Development for Boeing Commercial Airplanes. In this role, he is responsible for the development of all new and derivative airplanes. Named to this position in 2012, Hadi is also responsible for advanced concepts and the analysis of competitors' airplanes.

Prior to this position, Kourosh Hadi was the 767 Chief Project Engineer, including Tanker, and held that position

from 2009 to 2012. He was responsible for providing engineering leadership for the 767 Program for technical integrity and quality of engineering design, certification and safety. His responsibilities included production airplanes, all design changes, product improvements and Boeing modifications developed for the 767 airplane fleet ensuring product safety, reliability, and economic viability.

Previously, Hadi served as Chief of Product Development for Derivatives of all BCA models (737/747/767/777/787) where he led the preliminary design and successful launch of programs including 747-8, 777F, 747 Large Cargo Freighter, and 787-9.

Hadi has served as 747-400 Deputy Chief Project Engineer & Integration Leader in 2006 and 2007 and 747-400ER Integration Leader in 1998. He was also the 767-400ER Wing Integrated Product Team (IPT) leader in 1997. Hadi was promoted into Management in Configuration and Engineering Analysis group in 2000, leading product development programs for 747, 767, and new airplane programs. He joined the Company as an engineer in Noise Research in 1985, worked in Aerodynamics supporting 737/757 from 1986 to 1990, and in Product Development from 1991 to 2000, and a one-year rotation in Finance in 1996.

Hadi received his Master and Bachelor degrees in Aeronautical and Astronautical Engineering from University of Washington. He also completed the Stanford Executive Program in 2007. Hadi serves as the Boeing Executive focal working with the University of Washington's William E. Boeing Department of Aeronautical and Astronautical Engineering since 2007. He and his wife, Diane, and three children live in Bothell, WA.

Gur Kimchi is co-founder and vice president of Prime Air, Amazon's future drone delivery system designed to safely transport packages to customers in 30 minutes or less. In this role, Kimchi leads a growing team of aviation, robotics, hardware and software experts in the development of Prime Air vehicles, systems and operations.

Previously, Gar was overall Architect for Microsoft's Virtual Earth, Local Search and Mobile Search efforts. Prior to Virtual Earth, Gur was Lead Program Manager for Microsoft's Unified Communications managing the server side of Live Communications Server 2003, 2005 and Federation Pack. At the time Gur worked with Yahoo and AOL on the landmark Presence/IM/VoIP public federation agreement connecting over 500M consumers to each other and to enterprise customers running Microsoft UC.

Prior to Microsoft, Gur was a serial entrepreneur involved in starting 5 companies as Chief Architect, CTO/COO or EIR. The longest tenure prior to Microsoft was with VocalTec communications, the inventor of VoIP, between 1995 and 2002, where Gur was Chief Architect and helped to take the company public. Gur is married and has 3 kids, worked as a chef, plays classical violin and is a fanatic skier.

Parimal Kopardekar (PK) serves as NASA's Senior Technologist for Air Transportation System where he develops concepts and technologies to increase efficiency of current operations and enabling future airspace operations. He also serves as the Principal Investigator for UAS Traffic Management (UTM) to safely enable large-scale UAS operations in the low altitude airspace.

He managed Safe Autonomous System Operations project, which is focused on autonomy/autonomicity in civil aviation, as part of the Airspace Operations and Safety Program. The project's goal is to develop gate-to-gate concepts and technologies aimed at improving aircraft and airspace efficiency, capacity, mobility, throughput, reduce delays, and overall airspace operations productivity. His portfolio covers technologies for flight deck, airline operations center, and air navigation service provider. He is particularly passionate about identifying and initiating high-risk and high-reward, game-changing, and disruptive innovations.

He is recipient of numerous awards: NASA Exceptional Technology Achievement Medal, NASA Outstanding Leadership Medal, NASA Ames Honors Award for Project Management, NASA Ames Engineer of the Year, and AIAA Distinguished Service Recognition Award. He has published more 40 articles with two best paper awards.

He holds Ph.D. and M.S. degrees in Industrial Engineering and Bachelor's degree in Production Engineering. He also serves as the Co-Editor-in-Chief of the Journal of Aerospace Operations.

Colin Meckiff is head of long-term research activities at the Eurocontrol Experimental Centre, Brétigny sur Orge, France. He joined EUROCONTROL in 1990 and has since worked on ATM research as project and programme manager for many Europe-wide activities. Prior to this he spent 10 years in industry in the UK. He has a bachelor's degree in electrical engineering and a PhD in computer-aided design.

Eric Neiderman is the Manager of the Federal Aviation Administration's Aviation Research Division at the William J. Hughes Technical Center in Atlantic City, NJ. The division develops scientific solutions to current and future air transportation challenges by conducting applied research and development in collaboration with industry, academia, and government. Research areas include: fire safety, human factors, airport technology, software and systems, and structures and propulsion. He has more than 19 years of government experience, beginning with the FAA as an engineering research psychologist working in aviation security. Dr. Neiderman holds a bachelor's degree in industrial psychology from La Salle University, and a master's degree and Ph.D. in human factors from George Mason University. He also holds a master's degree in public administration from the University of Pennsylvania and is a certified project management professional.

Joe Polastre is the Senior Product Lead at A^3 (A-cubed) by Airbus. Prior to Airbus, he was a Presidential Innovation Fellow at The White House and went on to co-found 18F, the U.S. government's digital innovation team. Joe held product leadership roles at Medium, the blog publishing network, and founded Sentilla, an analytics startup acquired by Ericsson. Joe holds a Ph.D. degree from the University of California, Berkeley where he researched low power mesh networking applications leading to many Internet of Things standards. In his free time, Joe is an avid sailor and aspiring private pilot.

Bo Redeborn has over 40 years' experience in air traffic management having started his career as an air traffic controller in Sweden.

He joined Eurocontrol as Director ATM Strategies in 2004, leading the development of the Agency's strategic contribution to the Single European Sky initiative. In 2011 he became Principal Director ATM and Director SESAR and Research. In this role he was responsible for overseeing the organisation's ATM policy and development and for managing high level strategic relations with key partners, ICAO in particular. He oversaw Eurocontrol's contribution to the SESAR Joint Undertaking work programme.

Bo is currently a senior executive consultant in aviation serving government agencies, airports, air navigation service providers and industry.

Alex Roetter is the VP of Software at the Kitty Hawk Corporation, which is accelerating the adoption of affordable, efficient and clean personal transportation using electric aircraft.

Prior to joining Kitty Hawk, Alex was the Senior Vice President of Engineering at Twitter, where he was

responsible for software and hardware engineering, analytics and operations. Earlier in his career at Twitter, he helped to start the ads engineering team and led it to over $2 billion in annual revenues.

Prior to joining Twitter in 2010, he was Director of Engineering at the Laufer Wind Group, developing radar technology for renewable energy applications. Earlier, he spent seven years at Google as a software engineer and technical lead, on the founding team for AdSense and later on a variety of systems and ads quality projects.

Alex holds a B.S. with Honors and an M.S. in Computer Science from Stanford University. He is an FAA Commercial Multi-Engine Pilot.

Michael Standar is the Chief Strategy & External Affairs at the SESAR Joint Undertaking based in Brussels, Belgium since January 2015. Michael started at the SESAR Joint Undertaking 2008 as Chief Operational Concept & Validation and was promoted to Chief ATM 2011 and to Chief Strategies and International Relations 2012. He is responsible for the SJU Strategic direction, Communication and External Relations, including international collaborations notably with the FAA and ICAO. He holds the chair of the EU-US MoC SESAR/ NextGen Coordination Committee and leads the SJU collaboration with ICAO under the EU umbrella. Michael has nearly 40 years' experience in ATM and started his career as an Air Traffic Controller in the Swedish Air Force and the Swedish CAA and in LFV whilst maintaining his officer status in the Swedish Air Force Reserve. Michael did during his operational ATCO career hold a PPL and validated a full book of ratings for all ATC operational areas including supervision and training. His operational background includes work in Sweden, the UAE and Bahrain. Michael´s comprehensive background also includes active membership in ICAO Air Traffic Management Operational Concepts Panel, ATMCP - which developed the ICAO Global ATM Operational Concept Document and later in the in the ICAO Air Traffic Management Requirements and Performance Panel, ATMRPP.

David C. Suomi became the Federal Aviation Administration (FAA) Office of Finance and Management's Deputy Regional Administrator for Northwest Mountain Region, ANM-2, in July 2009. Under the leadership of Regional Administrator, ANM-1, they serve as the principal representatives of the FAA and senior FAA officials in ANM. Mr. Suomi provides corporate leadership in cross-organizational matters and represents the FAA before industry, the public, and government organizations. He also serves as the United States (U.S.) Department of Transportation (DOT) Regional Transportation Coordinator, which carries out critical functions for DOT in response to disasters as documented in the National Response Framework.

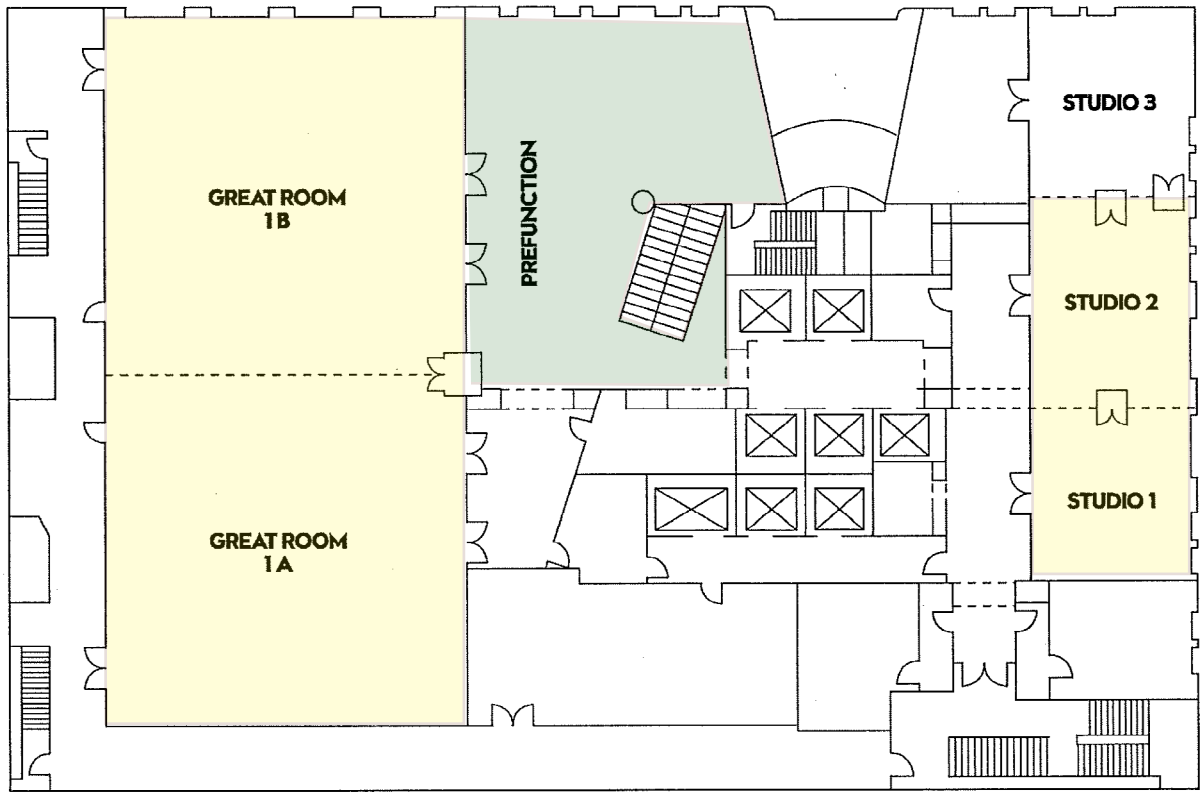
Previously, Mr. Suomi served as the national Manager of Airport Improvement, where he oversaw project identification, prioritization, eligibility, and ultimate obligation for approximately 2,500 grants annually. Prior to joining the FAA, Mr. Suomi served in a variety of senior executive roles, including vice president of BAA U.S.A., Inc., the U.S. subsidiary of BAA PLC, the United Kingdom private sector airport company that owned and operated London Heathrow, as well as other major aviation facilities around the world.

Mr. Suomi holds a Bachelor of Science in Aviation Management from Embry-Riddle Aeronautical University, and has completed graduate work at the University of Central Florida, State University of New York, University of Pennsylvania, and George Mason University.

Mr. Suomi is an accredited executive with the American Association of Airport Executives and has served as an officer or board member in various state aviation organizations and as a university instructor in Airport Development and Operations. He holds a pilot certificate, has written articles and papers on airport issues, and has spoken on various airport/airline subjects around the country.

Event Floor Plans

Beautiful artwork and architecture can be found throughout the Chinatown-International District, adding to the enighborhoods rich history and culture.



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