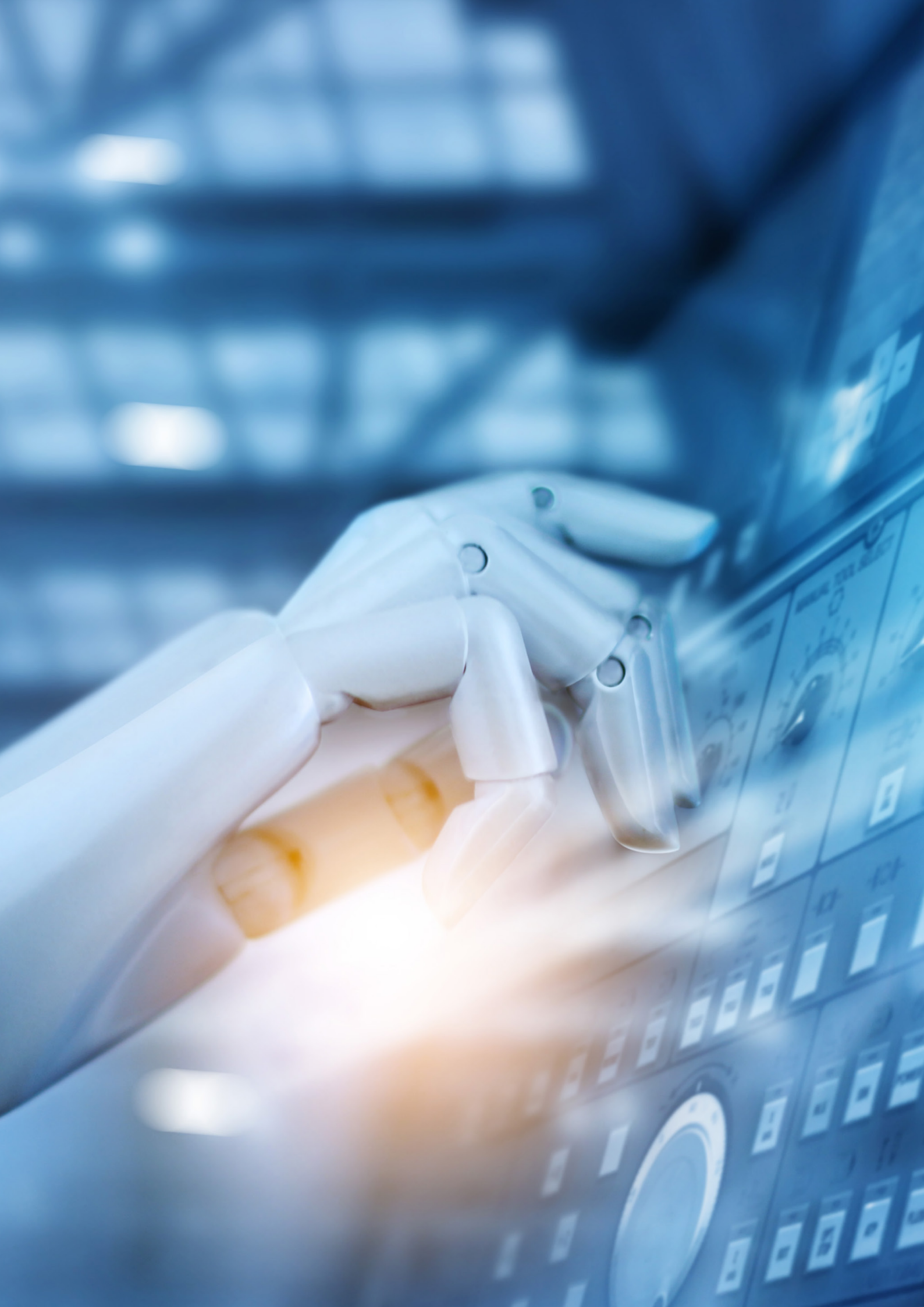
Fourteenth USA/Europe Air Traffic Management Research and Development Seminar

SUPPORTING EUROPEAN AVIATION

ATM Seminar: http://www.atmseminar.org/

Contents



Seminar at-a-glance

Day 1: 20 Septembre 2021

CET	ET						
15:00	09:00	**Grand Opening** **Welcome and Logistics** ***Dirk Schaefer*** *(EUROCONTROL, European chair)* & ***Eric Neiderman*** *(FAA, US Chair)*					
15:15	09:15	**NextGen update** ***Steve Bradford*** *(FAA)* **SESAR update** ***David Batchelor*** *(SESAR JU)*					
		ROOM 1		**ROOM 2**		**ROOM 3**	
		UAM/AAM I		**COMPLEXITY SCIENCE, ANALYTICS AND BIG DATA FOR ATM I**		**NETWORK AND STRATEGIC FLOW OPTIMISATION**	
15:50	09:50	66	Henk Blom	41	Christine Taylor	73	Marta Sánchez Cidoncha
16:30	10:30	24	Hartmut Fricke	58	Raphael Christien	83	Christopher Chin
17:10	11:10	**Coffee**					
		UAM/AAM II		**ENVIRONMENT AND ENERGY EFFICIENCY**		**INTEGRATED AIRPORT/ AIRSIDE OPERATIONS**	
17:20	11:20	27	Robert Brühl	32	Sandeep Badrinath	33	William J. Coupe
18:00	12:00	1	Valentin Polishchuk	49	Jovana Kuljanin	26	Ehsan Asadi
18:40	12:40	82	Karthik Gopalakrishnan	77	Ramon Dalmau	62	Duc-Thinh Pham
19:20	13:20	**Wrap-up, close**					

Day 2: 21 Septembre 2021

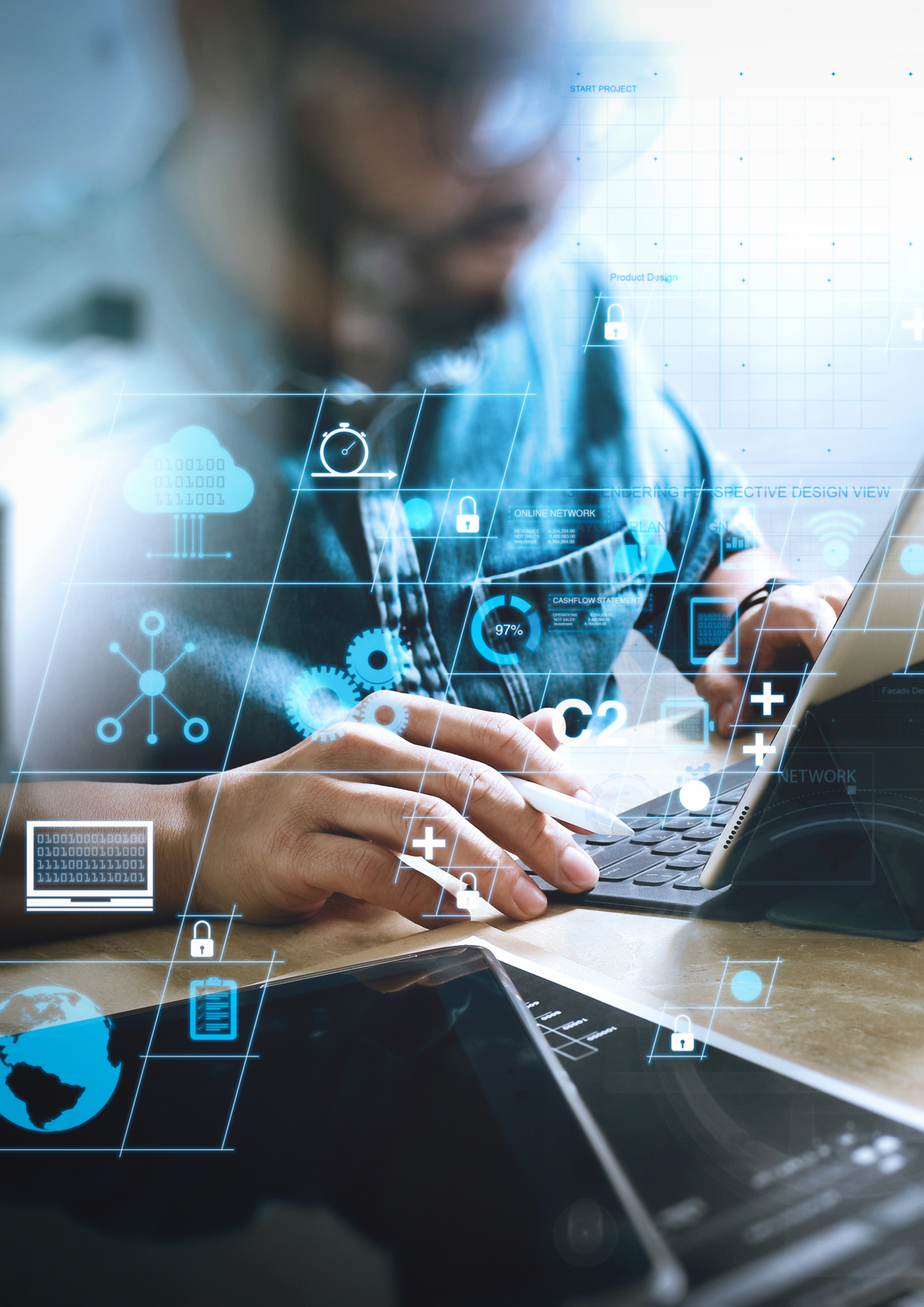
CET	ET						
15:00	09:00	**Plenary** **Welcome and Overview** ***Eric Neiderman*** *(FAA)*					
		ROOM 1		**ROOM 2**		**ROOM 3**	
		UTM/U-SPACE		**ECONOMICS, FINANCE AND POLICY I**		**TRAJECTORY PLANNING I**	
15:10	09:10	34	Maxim Egorov	12	Jan Evler	25	Xavier Olive
15:50	09:50	57	Yan Xu	85	Ying Zhou	44	Raúl Sáez
16:30	10:30	**Coffee**					
		COMPLEXITY SCIENCE, ANALYTICS AND BIG DATA FOR ATM II		**ECONOMICS, FINANCE AND POLICY II**		**TRAJECTORY PLANNING II**	
16:40	10:40	14	Ramon Dalmau	36	Saskia van der Loo	17	Fanruiqi Zeng
17:20	11:20	63	Loïc Shi-Garrier	51	David Mocholí González	47	Shumpei Kamo
18:00	12:00	**Panel on Global Standards** ***Terry McVenes*** *(RTCA)*, ***Christian Schleifer*** *(EUROCAE)* & ***François Triboulet*** *(EASA)*					
19:00	13:00	**Wrap-up, close**					

Day 3: 22 Septembre 2021

CET	ET						
15:00	09:00	**Welcome and Overview** ***Dirk Schaefer*** *(EUROCONTROL)* **Keynote** ***Marc Baumgartner*** *(IFATCA)*					
		ROOM 1		**ROOM 2**		**ROOM 3**	
		COMPLEXITY SCIENCE, ANALYTICS AND BIG DATA FOR ATM III		**ENHANCED SURVEILLANCE AND NAVIGATION**		**SAFETY, RESILIENCE AND SECURITY**	
15:40	09:40	15	Ramon Dalmau	39	Noboru Takeichi	59	Tejas Puranik
16:20	10:20	79	Lu Dai	78	David Lovell	69	Alberto Bonifazi
17:00	11:00	**Coffee**					
		SEPARATION		**WEATHER IN ATM**		**HUMAN FACTORS**	
17:10	11:10	31	Mudhakar Srivatsa	5	Gabriele Enea	4	Dominik Janisch
17:50	11:50	72	Ralvi Isufaj	21	Marius Marinescu	40	Pallavi Mohan
18:30	12:30	42	Sarah Degaugue	16	James Jones	7	Hartmut Helmke
19:10	13:10	**Wrap-up, close**					

Day 4: 23 Septembre 2021

CET	ET						
15:00	09:00	**Welcome and Overview** ***Eric Neiderman*** *(FAA)*					
		ROOM 1		**ROOM 2**		**ROOM 3**	
		ATM PERFORMANCE MEASUREMENT AND MANAGEMENT I		**AVIATION AND THE PANDEMIC I**		**TRAJECTORY PREDICTION AND TRAJECTORY AND QUEUE MANAGEMENT I**	
15:10	09:10	13	Marie Carré	84	Lu Dai	46	Daichi Toratani
15:50	09:50	80	Ke Liu	75	Michael Schultz	6	Gabriele Enea
16:30	10:30	**Coffee**					
		ATM PERFORMANCE MEASUREMENT AND MANAGEMENT II		**AVIATION AND THE PANDEMIC II**		**TRAJECTORY PREDICTION AND TRAJECTORY AND QUEUE MANAGEMENT II**	
16:40	10:40	23	Hiroko Hirabayashi	54	Javier García Moreno	65	Martin Lindner
17:20	11:20	52	Phuoc Dang	18	Richard DeLaura	22	Lucas Ligny
18:00	12:00	**The COVID-19 Pandemic and U.S. Aviation: System Adaptation and Performance Impact** ***Mark Hansen*** *(University of California, Berkeley)*					
18:45	12:45	**Best Paper Awards, Announcement 2023 Seminar**					
19:15	13:15	**Wrap-up, close**					


START PROJECT
Product Design
ONLINE NETWORK
CASHFLOW STATEMENT
97%
C2
NETWORK

Full programme

Day 1: 20 September 2021

GRAND OPENING

CET	ET	
15:00	09:00	**Welcome and Logistics** ***Dirk Schaefer*** *(EUROCONTROL, European chair) &* ***Eric Neiderman*** *(FAA, US Chair)*
15:15	09:15	**NextGen update** ***Steve Bradford*** *(FAA)*
		SESAR update ***David Batchelor*** *(SESAR JU)*

20 September 2021 - ROOM 1

URBAN AND ADVANCED AIR MOBILITY I - Session Chair: *Dirk Schaefer (EUROCONTROL)*

Time CET	ET	Paper	Title	Authors (presenter in ***bold***)
15:50	09:50	66	Safety risk posed to persons on the ground by commercial UAS-based services	***Henk Blom*** *& Chengpeng Jiang (TU Delft)*
16:30	10:30	24	Mid-air collisions with drones	***Hartmut Fricke,*** *Stanley Foerster, Robert Bruehl (TU Dresden), William J. Austen (QuinetiQ) & Christoph Thiel (GfL)*
17:10	11:10		**Coffee**	

URBAN AND ADVANCED AIR MOBILITY II - Session Chair: *Georg Trausmuth (Frequentis)*

Time CET	ET	Paper	Title	Authors (presenter in ***bold***)
17:20	11:20	27	Air taxi flight performance modeling and application	***Robert Bruehl,*** *Hartmut Fricke & Michael Schultz (TU Dresden)*
18:00	12:00	1	Ground risk vs. efficiency in urban drone operations	*Leonid Sedov,* ***Valentin Polishchuk*** *(Linköping University) & Vishwanath Bulusu (Crown Consulting)*
18:40	12:40	82	Protocol-based congestion management for advanced air mobility	*Christopher Chin,* ***Karthik Gopalakrishnan****, Hamsa Balakrishnan (MIT), Maxim Egorov & Antony Evans (Airbus UTM)*
19:20	13:20		**Wrap-up, close**	

20 September 2021 - ROOM 2

COMPLEXITY SCIENCE, ANALYTICS AND BIG DATA FOR ATM I - Session Chair: *Craig Wanke (MITRE)*				
Time		**Paper**	**Title**	**Authors (presenter in *bold*)**
15:50	**09:50**	41	Reinforcement learning for traffic flow management decision support	***Christine Taylor***, *Erik Vargo, Emily Bromberg & Everett Carson (MITRE)*
16:30	**10:30**	58	Predicting arrival delays in the terminal area five hours in advance with machine learning	***Raphael Christien,*** *Bruno Favennec, Pierrick Pasutto, Aymeric Trzmiel, Jerome Weiss & Karim Zeghal (EUROCONTROL)*
17:10	**11:10**	**Coffee**		

ENVIRONMENT AND ENERGY EFFICIENCY - Session Chair: *Chris Dorbian (FAA)*				
Time CET	**ET**	**Paper**	**Title**	**Authors (presenter in *bold*)**
17:20	**11:20**	32	Spatial modeling of airport surface fuel burn for environmental impact analyses	***Sandeep Badrinath,*** *James Abel, Hamsa Balakrishnan (MIT), Emily Joback & Tom Reynolds (MIT Lincoln Lab)*
18:00	**12:00**	49	Fuel-based flight inefficiency through the lens of different airlines and route characteristics	***Jovana Kuljanin****, Jordi Pons-Prats & Xavier Prats (UPC)*
18:40	**12:40**	77	Fuel inefficiency characterisation and assessment due to early execution of top of descents	***Ramon Dalmau*** *(EUROCONTROL), Junzi Sun (TU Delft) & Xavier Prats (UPC)*
19:20	**13:20**	**Wrap-up, close**		

20 September 2021 - ROOM 3

NETWORK AND STRATEGIC FLOW OPTIMISATION - Session Chair: *Jose Miguel de Pablo (CRIDA)*				
Time CET	**ET**	**Paper**	**Title**	**Authors (presenter in *bold*)**
15:50	**09:50**	73	Probabilistic Complexity in support of Airspace Capacity Management Optimisation	*Danlin Zheng, Eva Puntero &* ***Marta Sánchez Cidoncha*** *(CRIDA)*
16:30	**10:30**	83	Airport Ground Holding with Hierarchical Control Objectives	***Christopher Chin****, Max Li, Karthik Gopalakrishnan & Hamsa Balakrishnan (MIT)*
17:10	**11:10**	**Coffee**		

INTEGRATED AIRPORT/AIRSIDE OPERATIONS - Session Chair: *Dirk Kügler (DLR)*				
Time CET	**ET**	**Paper**	**Title**	**Authors (presenter in *bold*)**
17:20	**11:20**	33	Shadow evaluation of the ATD-2 phase 3 trajectory option set reroute capability in the north Texas metroplex	***William J. Coupe,*** *JDivya Bhadoria, Yoon Jung (NASA), Eric Chevalley (San Jose State University) & Greg Juro (Cavan)*
18:00	**12:00**	26	Estimating stochastic air transport process times using the fuzzy critical path method	***Ehsan Asadi****, Wei Chen & Hartmut Fricke (TU Dresden)*
18:40	**12:40**	62	Real-time departure slotting in mixed-mode operations using deep reinforcement learning	***Duc-Thinh Pham****, Li Long Chan, Sameer Alam (NTU Singapore) & Rainer Koelle (EUROCONTROL)*
19:20	**13:20**	**Wrap-up, close**		

Day 2: 21 September 2021

PLENARY

CET	ET	
15:00	09:00	**Welcome and Overview** ***Eric Neiderman*** *(FAA)*

21 September 2021 - ROOM 1

UTM/U-SPACE - Session Chair: *Billy Josefsson (LFV)*

Time CET	ET	Paper	Title	Authors (presenter in ***bold***)
15:10	**09:10**	34	Evaluation of UTM strategic deconfliction through end-to-end simulation	***Maxim Egorov,*** *Antony Evans, Scot Campbell (Airbus UTM), Sebastian Zanlongo & Tyler Young (John Hopkins University)*
15:50	**09:50**	57	An integrated approach for dynamic capacity management service in U-space	*Yiwen Tang,* ***Yan Xu****, Gokhan Inalhan & Antonios Tsourdos (Cranfield University)*

16:30	**10:30**	**Coffee**

COMPLEXITY SCIENCE, ANALYTICS AND BIG DATA FOR ATM II - Session Chair: *Sameer Alam (NTU Singapore)*

Time CET	ET	Paper	Title	Authors (presenter in ***bold***)
16:40	**10:40**	14	A machine learning approach to predict the evolution of air traffic flow management delay	***Ramon Dalmau,*** *Brice Genestier, Camille Anoraud, Peter Choroba & Darren Smith (EUROCONTROL)*
17:20	**11:20**	63	Predicting air traffic congested areas with long short-term memory networks	***Loïc Shi-Garrier****, Daniel Delahaye (ENAC) & Nidhal Bouaynaya (Rowan University)*

18:00	**12:00**	**Panel on Global Standards** ***Terry McVenes*** *(RTCA),* ***Christian Schleifer*** *(EUROCAE) &* ***François Triboulet*** *(EASA)*
19:00	**13:00**	**Wrap-up, close**

21 September 2021 - ROOM 2

ECONOMICS, FINANCE AND POLICY I - Session Chair: *Joseph Post (FAA)*

Time CET	Time ET	Paper	Title	Authors (presenter in ***bold***)
15:10	**09:10**	12	Flight prioritization and turnaround recovery	***Jan Evler**, Michael Schultz & Hartmut Fricke (TU Desden)*
15:50	**09:50**	85	Measuring the resilience of airline operation networks	***Ying Zhou** & Yanjun Wang (Nanjing University)*
16:30	**10:30**	**Coffee**		

ECONOMICS, FINANCE AND POLICY II - Session Chair: *Mark Hansen (UC Berkeley)*

Time CET	Time ET	Paper	Title	Authors (presenter in ***bold***)
16:40	**10:40**	36	Split incentive problem in the uptake of new ATM technology	***Saskia van der Loo,** Christophe Heyndrickx & Eef Delhaye (TML)*
17:20	**11:20**	51	Exploring future UDPP concepts through computational behavioural economics	***David Mocholí**, Rubén Alcolea & Ricardo Herranz (Nommon)*
18:00	**12:00**	**Panel on Global Standards** ***Terry McVenes** (RTCA), **Christian Schleifer** (EUROCAE) & **Francois Triboule** (EASA)*		
19:00	**13:00**	**Wrap-up, close**		

21 September 2021 - ROOM 3

TRAJECTORY PLANNING I - Session Chair: *Eric Hoffman (EUROCONTROL)*

Time CET	Time ET	Paper	Title	Authors (presenter in ***bold***)
15:10	**09:10**	25	A framework to evaluate aircraft trajectory generation methods	***Xavier Olive** (ONERA), Junzi Sun (TU Delft), Mayara Condé Rocha Murça (Aeronautics Institute of Technology) & Timothé Krauth (ZHAW)*
15:50	**09:50**	44	A fast and flexible emergency trajectory generator	***Raúl Sáez**, Homeyra Khaledian, Xavier Prats (UPC), Andréas Guitart, Daniel Delahaye (ENAC) & Eric Feron (Georgia Institute of Technology)*
16:30	**10:30**	**Coffee**		

TRAJECTORY PLANNING II - Session Chair: *Eric Hoffman (EUROCONTROL)*

Time CET	Time ET	Paper	Title	Authors (presenter in ***bold***)
16:40	**10:40**	17	Trajectory planning for mission survivability of autonomous vehicles in moderately to extremely uncertain environments	***Fanruiqi Zeng** (GeorgiaTech), Husni R. Idris (NASA) and John-Paul Clarke (The University of Texas at Austin)*
17:20	**11:20**	47	Robust CDO trajectory planning under uncertainties in weather prediction	***Shumpei Kamo**, Judith Rosenow, Hartmut Fricke (TU Dresden) & Manuel Soler (Universidad Carlos III)*
18:00	**12:00**	**Panel on Global Standards** ***Terry McVenes** (RTCA), **Christian Schleifer** (EUROCAE) & **Francois Triboule** (EASA)*		
19:00	**13:00**	**Wrap-up, close**		

Day 3: 22 September 2021

CET	ET	
15:00	**09:00**	**Welcome and Overview** ***Dirk Schaefer*** *(EUROCONTROL)* ***Keynote: Marc Baumgartner*** *(IFATCA)*

22 September 2021 - ROOM 1

COMPLEXITY SCIENCE, ANALYTICS AND BIG DATA FOR ATM III -
Session Chair: ***Marc Bourgois (EUROCONTROL)***

Time CET	ET	Paper	Title	Authors (presenter in ***bold***)
15:40	**09:40**	15	Early detection of night curfew infringements by delay propagation with neural networks	***Ramon Dalmau,*** *Giuseppe Murgese, Yves de Wandeler, Ricardo Correira & Alan Marsden (EUROCONTROL)*
16:20	**10:20**	79	Having a bad day? Predicting high delay days in the National Airspace System	***Lu Da****, Mark Hansen (UC Berkeley), Michael Ball & David Lovell University of Maryland)*
17:00	**11:00**	**Coffee**		

SEPARATION - Session Chair: ***Jacco Hoekstra (TU Delft)***

Time CET	ET	Paper	Title	Authors (presenter in ***bold***)
17:10	**11:10**	31	Towards AI-based air traffic control	***Mudhakar Srivatsa,*** *Raghu Ganti, Linsong Chu (IBM Research), Martin Christiansson, Sofia Rydell & Billy Josefsson (LFV)*
17:50	**11:50**	72	Towards conflict resolution with deep multi-agent reinforcement learning	***Ralvi Isufaj****, David Aranega Sebastia & Miquel Angel Piera (UAB)*
18:30	**12:30**	42	Learning uncertainty parameters for tactical conflict resolution	***Sarah Degaugue****, Jean-Baptiste Gotteland & Nicolas Durand (ENAC)*
19:10	**13:10**	**Wrap-up, close**		

22 September 2021 - ROOM 2

ENHANCED SURVEILLANCE AND NAVIGATION - Session Chair: *Joseph Post (FAA)*				
Time CET	**ET**	**Paper**	**Title**	**Authors (presenter in *bold*)**
15:40	**09:40**	39	Modeling of flight time prediction uncertainty for four-dimensional descent trajectory management	***Noboru Takeichi*** *(Tokyo Metropolitan University)*
16:20	**10:20**	78	Leveraging local ADS-B transmissions to assess the performance of air traffic at general aviation airports	*Danae Mitkas,* ***David Lovell*** *(University of Maryland), Sandeep Venkatesh & Seth Young (Ohio State University)*
17:00	**11:00**	**Coffee**		

WEATHER IN ATM - Session Chair: *Mark Weber (MIT Lincoln Lab)*				
Time CET	**ET**	**Paper**	**Title**	**Authors (presenter in *bold*)**
17:10	**11:10**	5	Shortfall analysis of departure throughput during convective weather in complex airport regions	***Gabriele Enea,*** *Margita Pawlak, Tom Reynolds (MIT Lincoln Lab), Dave Knorr & Martin Durbin (FAA)*
17:50	**11:50**	21	Wind profile estimation from aircraft derived data using Kalman Filters and Gaussian Process Regression	***Marius Marinescu****, Alberto Olivares, Ernesto Staffetti (Rey Juan Carlos University) & Junzi Sun (TU Delft)*
18:30	**12:30**	16	Recommending strategic air traffic management initiatives in convective weather	***James Jones****, Zach Ellenbogen & Yan Glina (MIT Lincoln Lab)*
19:10	**13:10**	**Wrap-up, close**		

22 September 2021 - ROOM 3

SAFETY, RESILIENCE AND SECURITY - Session Chair: *Natesh Manikoth (FAA)*				
Time CET	**ET**	**Paper**	**Title**	**Authors (presenter in *bold*)**
15:40	**09:40**	59	Fusion and analysis of data sources for assessing aircraft braking performance on non-dry runways	*Wenxin Zhang, Carter Tegen,* ***Tejas Puranik****, David Anvid, Rukmini Roy & Dimitri Mavris (Georgia Institute of Technology)*
16:20	**10:20**	69	Modeling and detecting anomalous safety events in approach flights using ADS-B data	***Alberto Bonifazi,*** *Junzi Sun, Jacco Hoekstra (TU Delft) & Gerben van Baren (ILENT)*
17:00	**11:00**	**Coffee**		

HUMAN FACTORS - Session Chair: *Sandy Lozito (NASA)*				
Time CET	**ET**	**Paper**	**Title**	**Authors (presenter in *bold*)**
17:10	**11:10**	4	Development and testing of a collaborative display for UAV traffic management and tower control	*Daan van Aken,* ***Dominik Janisch*** *& Clark Borst (TU Delft)*
17:50	**11:50**	40	Embodied multimodal interaction with a portable mixed reality-based digital tower	***Pallavi Mohan****, Sameer Alam, Mohammed Nadirsha, Nimrod Lilith (NTU Singapore) & Åsa Svensson (LFV)*
18:30	**12:30**	7	Readback error detection by automatic speech recognition to increase ATM safety	***Hartmut Helmke*** *(DLR) et al*
19:10	**13:10**	**Wrap-up, close**		

Day 4: 23 September 2021

CET	ET	
15:00	**09:00**	**Welcome and Overview** ***Eric Neiderman*** *(FAA)*

23 September 2021 - ROOM 1

ATM PERFORMANCE MEASUREMENT AND MANAGEMENT I -
Session Chair: *Tom Reynolds (MIT Lincoln Lab)*

Time CET	ET	Paper	Title	Authors (presenter in ***bold***)
15:10	**09:10**	13	Equity within air transportation management – an analysis of inequity index for multi-stakeholders optimisation	***Marie Carré,*** *Eric Nantier (Swiss), Séverine Durieux & Laurent Piétrac (Institut Pascal)*
15:50	**09:50**	80	Miles-in-trail restrictions and aviation system performance: Chicago O'Hare case study	***Ke Liu*** *& Mark Hansen (UC Berkeley)*

16:30	**10:30**	**Coffee**

ATM PERFORMANCE MEASUREMENT AND MANAGEMENT II -
Session Chair: *Guglielmo Lulli (Lancaster University)*

Time CET	ET	Paper	Title	Authors (presenter in ***bold***)
16:40	**10:40**	23	Feasibility study of free routing airspace operation over the North Pacific airspace	***Hiroko Hirabayashi*** *(Tokyo Metropolitan University/ENRI), Mark Brown (ENRI) & Noboru Takeichi (Tokyo Metropolitan University)*
17:20	**11:20**	52	A machine learning-based framework for aircraft maneuver detection and classification	***Phuoc Dang****, Phu Tran, Sameer Alam & Vu Duong (NTU Singapore)*

18:00	**12:00**	**The COVID-19 Pandemic and U.S. Aviation: System Adaptation and Performance Impact** ***Mark Hansen*** *(University of California, Berkeley)*
18:45	**12:45**	**Best Paper Awards, Announcement 2023 Seminar**
19:15	**13:15**	**Wrap-up, close**

23 September 2021 - ROOM 2

AVIATION AND THE PANDEMIC I - Session Chair: *Midori Tanino (FAA)*

Time CET	Time ET	Paper	Title	Authors (presenter in ***bold***)
15:10	**09:10**	84	Quantifying the impact of air travel on growth of COVID-19 pandemic in the United States	***Lu Dai,*** *Ivan Tereshchenko & Mark Hansen (UC Berkeley)*
15:50	**09:50**	75	COVID-19: passenger boarding and disembarkation	***Michael Schultz*** *(TU Dresden), Majid Soolaki, Elnaz Bakhshian (University College Dublin), Mostafa Salari (University of Calgary) & Jörg Fuchte (Diehl Aviation)*

16:30 10:30 Coffee

AVIATION AND THE PANDEMIC II - Session Chair: *Shannon Zelinski (NASA)*

Time CET	Time ET	Paper	Title	Authors (presenter in ***bold***)
16:40	**10:40**	54	On-line platform for the short-term prediction of risk of expansion of epidemics	***Javier García Moreno*** *(CRIDA) et al*
17:20	**11:20**	18	Modeling impacts of aviation mitigations & ATC delay on passenger COVID-19 infection risk	***Richard DeLaura*** *& Tom Reynolds (MIT Lincoln Lab)*

18:00 12:00 The COVID-19 Pandemic and U.S. Aviation: System Adaptation and Performance Impact
Mark Hansen *(University of California, Berkeley)*

18:45 12:45 Best Paper Awards, Announcement 2023 Seminar

19:15 13:15 Wrap-up, close

23 September 2021 - ROOM 3

TRAJECTORY PREDICTION AND TRAJECTORY AND QUEUE MANAGEMENT I - Session Chair: *Nicolas Durand (ENAC)*

Time CET	Time ET	Paper	Title	Authors (presenter in ***bold***)
15:10	**09:10**	46	Data-driven analysis method for calculated time over in air traffic flow management	***Daichi Toratani,*** *Yoichi Nakamura & Megumi Oka (ENRI)*
15:50	**09:50**	6	Evaluation of aircraft speed and wind modeling accuracy in automation for trajectory based operations	***Gabriele Enea****, Michael McPartland & Timothy Bonin (MIT Lincoln Lab)*

16:30 10:30 Coffee

TRAJECTORY PREDICTION AND TRAJECTORY AND QUEUE MANAGEMENT II - Session Chair: *Nicolas Durand (ENAC)*

Time CET	Time ET	Paper	Title	Authors (presenter in ***bold***)
16:40	**10:40**	65	Aircraft performance-optimized departure flights using traffic flow funnels	***Martin Lindner,*** *Thomas Zeh, Hannes Braßel & Hartmut Fricke (TU Dresden)*
17:20	**11:20**	22	Aircraft Emergency Trajectory Design: A Fast Marching Method on a Triangular Mesh	***Lucas Ligny,*** *Andréas Guitart, Daniel Delahaye (ENAC) & Banavar Sridhar (FAA)*

18:00 12:00 The COVID-19 Pandemic and U.S. Aviation: System Adaptation and Performance Impact
Mark Hansen *(University of California, Berkeley)*

18:45 12:45 Best Paper Awards, Announcement 2023 Seminar

19:15 13:15 Wrap-up, close

Book of Abstracts

Urban and Advanced Air Mobility I

66 ***Henk Blom*** *& Chengpeng Jiang (TU Delft)*

Safety risk posed to persons on the ground by commercial UAS-based services

Abstract: The unique capabilities of an Unmanned Aircraft System (UAS) creates opportunities for commercial services. The key question is what is an acceptable level of risk posed to third parties on the ground that have no direct benefit from commercial UAS flights. In literature the common view is that an acceptable level of Third Party Risk (TPR) posed by UAS operations follows from an Equivalent Level Of Safety (ELOS) criterion, which means that per flight hour a UAS should not pose more safety risk to persons on the ground than a commercial aircraft does. However in commercial aviation there are also TPR indicators in use that are directed to accident risk posed by all annual commercial flights to the population around an airport. These population directed indicators find their origin in TPR posed by hazardous installations to its environment. The aim of this paper is to improve the understanding of risk posed to the population by annual UAS-based services through learning from TPR knowledge and regulation for airports and hazardous installations. As main result this paper develops an analytical approach to evaluate the annual risk posed by a commercial UAS-based parcel delivery service in urban and metropolitan areas. The obtained results show that the TPR indicators that stem from hazardous installations and airports provide novel insight regarding TPR of commercial UAS-based service.

24 ***Hartmut Fricke,*** *Stanley Foerster, Robert Bruehl (TU Dresden), William J. Austen (QuinetiQ) & Christoph Thiel (GfL)*

Mid-air collisions with drones

Abstract: Recent technological developments have led to the emergence of affordable and increasingly capable remotely-piloted aircraft or 'drones' within the global marketplace. Whilst this presents substantial opportunities, it also presents a potential threat to the safety of crewed aviation. This paper discusses ongoing work by the authors to evaluate and mitigate the risk and threats associated with mid-air collisions as part of multiple initiatives to maintain and improve the high standards of aviation safety in a rapidly evolving environment. The work reported in this paper includes activities in support of two activities. The first is an ongoing 'Horizon 2020'-funded project for the European Union Aviation Safety Agency (EASA) and led by QinetiQ in the UK, which aims to deepen the understanding of the effects of a potential mid-air collision and identify drone design strategies to mitigate their severity. The second is research at TUD estimating aircraft collision risks using stochastically acting vehicles and pilots in an agent-based simulation, now tailored to regions where commercial drones may operate in the vicinity of airports or existing and emerging urban air operations. Work in support of QinetiQ's programme includes novel fusion and processing of multiple large datasets (including ADS-B histories) to derive probabilistic models of potential collision speeds for different classes of aircraft; this will inform ongoing collision simulation and testing studies. Work at TUD estimates probabilities for an example urban scenario using that data; results of this study indicate that management of risks within acceptable limits is possible and proposals are made to integrate this type of agent simulation as 'air risk' assessment in SORA.

Complexity Science, Analytics and Big Data For ATM I

41 ***Christine Taylor****, Erik Vargo, Emily Bromberg & Everett Carson (MITRE)*
Reinforcement learning for traffic flow management decision support
Abstract: Recent advances in Artificial Intelligence and Machine Learning are being harnessed to solve increasingly complex problems across a variety of domains, including Air Traffic Management. Application of these methods to the domain of Traffic Flow Management, however, remains a challenge as it is first necessary to effectively represent the dynamics of weather forecasts – and the uncertainty in the resulting constraints – within the construct of the decision-making process. In this paper, we propose a novel approach for capturing weather forecast uncertainty in a reinforcement learning process that generates Traffic Flow Management strategies in a real-time environment. Specifically, we leverage Monte Carlo Tree Search to explore and evaluate potential traffic management actions against an ensemble of weather futures. The results demonstrate that under the assumptions of the operational environment developed and the objective defined, the algorithm can generate effective solutions for managing uncertain constraints, adapt to changing information, and do so in a real-time context.

58 ***Raphael Christien,*** *Bruno Favennec, Pierrick Pasutto, Aymeric Trzmiel, Jerome Weiss & Karim Zeghal (EUROCONTROL)*
Predicting arrival delays in the terminal area five hours in advance with machine learning
Abstract: This paper presents a study aiming at predicting the arrival delays occurring in the terminal area up to five hours in advance. The motivation for the participating airlines is to better take into account the impact of weather at destination on fuel planning. Due to the uncertainty at these time horizons, we decided to consider delay intervals (low <5 minutes, moderate 5-10 minutes, high >10 minutes) over 30 minutes periods. We selected four European airports occasionally or frequently subject to high arrival delays (London Heathrow, Dublin, Lisbon and Zurich). The problem was framed as a classification problem and different machine learning models were developed using arrival delay, traffic demand and weather historical data from 2013 to 2019. A random forest model was found to beat the reference and outperformed the other models, although still below a perfect prediction. The performance indicator increases from 0.3 (reference) to around 0.5. In terms of prediction error, compared to the reference, the model has slightly lower performance for the low delays, similar for the moderate delays and better for high ones. Finally, a simplified case study with airlines data illustrated the potential for benefits. Indisputably, there should be a "performance barrier" due to the intrinsic uncertainty, essentially in terms of take-off times. Still, the future work should aim at determining whether the performance may be increased, by analyzing the prediction errors and the delay class overlaps.

Network and Strategic Flow Optimisation

73 *Danlin Zheng, Eva Puntero &* ***Marta Sánchez Cidoncha*** *(CRIDA)*
Probabilistic Complexity in support of Airspace Capacity Management Optimisation
Abstract: The present paper addresses innovative ATM solutions for Demand and Capacity Balance, in particular Dynamic Airspace Configuration. Capacity Management processes in these environments require more critically the use of support complexity metrics tailored to the relevant use cases. An Enhanced Complexity Management including both the improvement of the metrics introducing demand uncertainty and their integration into the overall process is presented. The assessment of this Enhanced Complexity Management is presenting, assessing its technical and operational feasibility and showing its improvements in capacity and cost-efficiency.

83 ***Christopher Chin,*** *Max Li, Karthik Gopalakrishnan & Hamsa Balakrishnan (MIT)*
Airport Ground Holding with Hierarchical Control Objectives
Abstract: Disruptions in the air transportation system, perhaps due to extreme weather, often result in unexpected, or off-nominal, delays at airports. A resilient air traffic management system seeks to restore airport delays to their nominal values quickly after such disruptions. Two primary factors make the design of efficient recovery algorithms for air transportation networks challenging: the lack of a high-fidelity model for predicting and controlling airport delay dynamics, and poor computational tractability of large-scale flight rescheduling optimization problems. We propose a two-stage hierarchical control strategy for rescheduling aircraft (i.e., assigning delays) after network disruptions. Our high-level planner leverages a low-fidelity approximation of airport delay dynamics to propose a reference plan based on user preferences. This reference plan accounts for complex objectives such as ensuring a "smooth" redistribution of delays across airports (quantified by the total variation). The low-level controller then solves the multi-airport ground holding problem (MAGHP), augmented to track the reference plan. The solution to the augmented MAGHP yields a revised flight schedule with lower total variation than the original MAGHP, while still satisfying operational constraints. We illustrate the benefits of our proposed methodology using six disruption case studies of the National Airspace System (NAS).

Urban and Advanced Air Mobility II

27 ***Robert Bruehl****, Hartmut Fricke & Michael Schultz (TU Dresden)*
Air taxi flight performance modeling and application
Abstract: Urban air mobility encompasses the idea of extending urban transportation to the airspace. For this purpose, several aircraft manufacturers and start-up companies have developed aircraft concepts for flying completely electrical. Electric aircraft have different behavior concerning flight performance, which mostly depends on battery characteristics. Due to this, electric vertical take-off and landing aircraft (eVTOL) are more limited in their flight performance concerning range and endurance than conventional aircraft. Nowadays data on that topic is mostly published by eVTOL manufacturers and seems to be quite ambitious concerning the current state of battery technology. This paper aims at determining flight performance by considering state-of-the-art battery characteristics. Each flight segment has a different influence on battery discharge, due to different power requirements. Based on an application case, the range capabilities of three eVTOLs are estimated. Therefore, the results reveal a range of around 115 km for vectored thrust eVTOL, around 70 km for lift & cruise eVTOL, and around 50 km for multicopter eVTOL.

1 *Leonid Sedov,* ***Valentin Polishchuk*** *(Linköping University) & Vishwanath Bulusu (Crown Consulting)*
Ground risk vs. efficiency in urban drone operations
Abstract: This paper explores trade-offs between ground impact and efficiency of drone flights in urban scenarios. We give an algorithm which produces a set of routes with different lengths and varying number of people affected by the drone. We also present an interactive online visualization tool allowing the user to modify flightpaths in order to explore routing options. Our path finder and the GUI are implemented for a metropolitan area of Norrköping municipality in Sweden. The methods studied in this paper may give UTM service provider the tools to negotiate flightplans which will be acceptable by both the regulator and the drone operator.

82 *Christopher Chin,* ***Karthik Gopalakrishnan****, Hamsa Balakrishnan (MIT), Maxim Egorov & Antony Evans (Airbus UTM)*
Protocol-based congestion management for advanced air mobility
Abstract: Advanced air mobility operations (e.g., air taxis and drone deliveries) are expected to significantly increase the demand for limited airspace resources. Two key characteristics of these operations are that flights will be scheduled with short lead times, and operators may be unable or reluctant, for reasons of privacy, to share flight intent information. Consequently, there is a need for congestion management algorithms that are efficient and fair in dynamic, reduced-information settings. In this paper, we address these challenges by designing a protocol that determines the rules-of-the-road for airspace access under these settings. The proposed protocol centers on the construction of priority queues to determine access to each congested volume of airspace. We leverage the concepts of backpressure and cycle detection to avoid gridlock and promote efficiency, and present several flight- and operator-level prioritization schemes. We evaluate the impacts of the prioritization schemes on system-wide and operator-level efficiency and fairness through extensive simulations of three scenarios: random flight patterns, cross-flows, and hub-based operations. In all scenarios, we find that backpressure prioritization yields the most efficient solution, and that accrued delay or dominant resource prioritization is the most fair depending on the user's choice of fairness metric.

Environment and Energy Efficiency

32 ***Sandeep Badrinath****, James Abel, Hamsa Balakrishnan (MIT), Emily Joback & Tom Reynolds (MIT Lincoln Lab)*
Spatial modeling of airport surface fuel burn for environmental impact analyses
Abstract: The assessment of the fuel burn and emissions impact of airport surface operations is a key part of understanding the environmental impacts of aviation. These assessments are needed at two levels: the analysis of inventories (the total amount of fuel burned and emissions discharged over some period of time), and the analysis of spatial distributions (the amount of emissions experienced at a particular location within or near the airport). While the availability of taxi times for the operations of interest is sufficient for inventory analysis, the analysis of spatial distributions requires estimates of where on the airport surface an aircraft is located as it consumes fuel. In this paper, we show how a data-driven queuing network model can be developed in order to estimate the time that an aircraft spends at different congested locations on the airport surface. These models are useful both in spatial distribution analysis and in accurately predicting taxi times in the absence of measurements (e.g., for projected demand sets). We use measurements of Ultra Fine Particles (UFPs) at Los Angeles International (LAX) airport to demonstrate that the proposed model can help predict the measured emissions at different monitoring sites located in the vicinity of the airport. In the process, we show how one could develop a machine learning model of the spatial distribution of airport surface emissions, given pollutant measurements, air traffic demand, and prevailing weather conditions. Finally, we develop a clustering-based method to evaluate the generalizability of our surface operations modeling framework.

49 ***Jovana Kuljanin****, Jordi Pons-Prats & Xavier Prats (UPC)*
Fuel-based flight inefficiency through the lens of different airlines and route characteristics
Abstract: In the light of the ambitious environmental targets for future ATM (Air Traffic Management) paradigms, there is a need in the enhancement of current performance indicators, with the objective to facilitate the identification of different sources of environmental inefficiencies, and to enable large scale and systematic post-operational analyses. Based on a previously published methodological framework to compute fuel-based performance indicators, this paper aims at exploring these inefficiencies at different granularity of the results. For this purpose, a set of filters has been applied on a data-set of 24h of traffic within the ECAC (European Civil Aviation Conference) area, encompassing different airspace users categories, route length and flight frequencies. The results show that the carriers prone to low-cost business models have, on average, the highest value of total fuel inefficiency in absolute terms with a median around 530 kg (17%); compared to full-service carriers with a median around 432 kg (20%); observing as well that relative fuel inefficiency significantly drops as the stage length of the routes increases. These figures are obtained when the reference trajectory used to derive fuel inefficiency is a full free route trajectory at maximum range and without considering en-route charges. Moreover, results reveal that the busiest the routes are, the higher fuel inefficiencies they accrue. For routes with less than 5 departures per day, the fuel inefficiency accounts for 19.1% in relative terms, if compared with the total fuel burnt; whereas for the routes from the category between 12 and 20 daily departures the relative fuel inefficiency rises to 22.6% when the reference trajectory is constrained to the current structured en-route network, current flight level allocation and orientation schemes, and maximum range operations. It is acknowledged, however, that a larger data-set needs to be considered in the future to generalise the validity of the obtained results.

77 ***Ramon Dalmau*** *(EUROCONTROL), Junzi Sun (TU Delft) & Xavier Prats (UPC)*
Fuel inefficiency characterisation and assessment due to early execution of top of descents
Abstract: The vertical trajectory plan (altitude and speed) corresponding to the descent phase of a modern airliner is computed by the on-board flight management system while the aircraft is still in cruise. As long as the constraints on the arrival procedure allow, this system plans for an idle descent and the exact location of the (optimal) top of descent (TOD) is determined in this process. In busy terminal airspace, however, air traffic control officers -- motivated by the needs to maintain a safe and expeditious flow of aircraft -- might require to start the descents before the TOD computed by each particular arriving aircraft. In such situations, most flight guidance systems aim to intercept the original altitude plan from below, by using a shallower descent angle while keeping the speed plan, requiring in this way, additional thrust. This leads, consequently, to higher fuel consumption figures. The objective of this paper is threefold. Firstly, it characterises and quantifies these fuel inefficiencies for an Airbus A320, using accurate aircraft performance data and a trajectory computation software from the manufacturer. Secondly, it proposes a methodology to automatically identify early descents and to extract the key parameters required to compute the fuel inefficiencies by only observing ADS-B (automatic dependent surveillance-broadcast) data. Finally, the method is applied to a case study with 4,139 real ADS-B trajectories in Amsterdam-Schiphol (The Netherlands) terminal airspace; showing that early descents are very frequent and that they increase the fuel consumption by a 5%, in average.

Integrated Airport/ Airside Operations

33 ***William J. Coupe****, Divya Bhadoria, Yoon Jung (NASA), Eric Chevalley (San Jose State University) & Greg Juro (Cavan)*
Shadow evaluation of the ATD-2 phase 3 trajectory option set reroute capability in the north Texas metroplex
Abstract: This paper presents results of NASA's Airspace Technology Demonstration 2 Phase 3 Trajectory Option Set reroute capability designed to resolve a demand capacity imbalance along the terminal airspace boundary. We focus on Candidate flights generated during the Stormy 2020 Shadow Evaluation which was the result of using the system to passively collect predictions for each flight at the OUT event. Benefit metrics associated with the predictions are defined for the individual rerouted flight and also the system-wide savings. Candidate flights are grouped into three distinct use cases and the benefit mechanism is explained for each use case along with illustrative data. Analysis of the different use cases shed light on the underlying causes of the reroute opportunities. Lessons learned from the Stormy 2020 Shadow Evaluation including the importance of reroutes during recovery from Severe Weather Avoidance Programs and also reroutes in the absence of terminal airspace restrictions will be incorporated into the Phase 3 Field Evaluation in 2021 to maximize reroute opportunities.

26 ***Ehsan Asadi****, Wei Chen & Hartmut Fricke (TU Dresden)*
Estimating stochastic air transport process times using the fuzzy critical path method
Abstract: Predicting both optimal and reliable aircraft turnaround time is one of the most critical tasks in ACDM flight scheduling plans. Considering the effects of randomness and fuzziness on the turnaround process duration, we transform the probability distribution of well-fitted sub-processes into a cumulated density function, equivalent to the fuzzy membership function (FMF), then identify the fuzzy membership grade of each turnaround sub-process by goodness-of-fit. Based on the Critical Path Method (CPM) technique and fuzzy set theory, the turnaround time, considering stochastic effects, is evaluated using the fuzzy critical path method (FCPM). To validate this calculation, we constructed the FMF from historical data and compared it with FCPM-based turnaround times. In addition, we utilize these historical data to generate fuzzy sets of different arrival delays using Frankfurt airport data of summer 2017 and conclude that delays are positively correlated with the FCPM-based turnaround process through a linear regression model.

62 ***Duc-Thinh Pham****, Li Long Chan, Sameer Alam (NTU Singapore) & Rainer Koelle (EUROCONTROL)*
Real-time departure slotting in mixed-mode operations using deep reinforcement learning
Abstract: A mixed-mode runway operation increases the runway capacity by allowing simultaneous arrival and departure operations on the same runway. However, this requires careful evaluation of safe separation by experienced tower controllers. In daily operation, tower controllers need to make real-time decisions for departure slotting. However, an increase in runway capacity is not always guaranteed due to the stochastic nature of arrivals and departures and associated environmental parameters. To support controllers in making real-time departure slotting decisions, this paper proposes a Deep Reinforcement Learning approach to suggest departure slots within an incoming stream of arrivals while considering operational constraints and uncertainties. In this work, novel state representation and reward mechanisms are designed to facilitate the learning process. Experimentation on A-SMGCS data from Zurich air-port shows that the proposed approach achieves an efficiency ratio of more than 83.8% of the expected runway capacity while maintaining safe separation distances in mixed-mode operations. The results of this work have demonstrated the potentials of DeepReinforcement Learning in solving decision-making problems in Air Traffic Management.

UTM/U-Space

34 ***Maxim Egorov**, Antony Evans, Scot Campbell (Airbus UTM), Sebastian Zanlongo & Tyler Young (John Hopkins University)*
Evaluation of UTM strategic deconfliction through end-to-end simulation
Abstract: This paper provides an initial analysis of the ability of volume-based deconfliction to mitigate air risk between cooperative unmanned operations in an Unmanned Traffic Management (UTM) setting. Namely, we use high-fidelity simulation in combination with a collection of UTM services to evaluate the functional and performance requirements for strategic deconfliction that are emerging from the standards work in UTM. Our objective is to assess how well the requirements developed by standards groups can support end-to-end safety. We consider two key aspects of strategic deconfliction within our evaluation: how operational volumes are constructed, and how well unmanned vehicles are able to conform to their planned operational volumes in the presence of system error. To that end, we outline an end-to-end simulation framework that can be used to evaluate system level implications of UTM requirements. We apply the framework to (1) provide quantitative guidance for the risk reduction associated with strategic deconfliction in UTM, and to (2) provide operational recommendations that would enable operators to meet safety targets prescribed by conformance rate and strategic deconfliction requirements in the UTM ecosystem.

57 *Yiwen Tang, **Yan Xu**, Gokhan Inalhan & Antonios Tsourdos (Cranfield University*
An integrated approach for dynamic capacity management service in U-space
Abstract: This paper presents an integrated approach for the Dynamic Capacity Management service to be offered in U-space. The approach involves three main threads, including flight planning (demand), airspace configuration (capacity) and demand-capacity balancing (DCB). The flight planning thread produces UAS (unmanned aerial systems) trajectories for each flight that together reflect the estimated traffic demand. The airspace configuration thread defines the fundamental airspace structure and proposes dynamic adjustment schemes that determine the capacity distribution. It also enables the flight planning to reschedule alternative trajectory options to route away from possible congested areas. The last DCB thread takes the previous inputs and then computes for the optimal slot allocation and trajectory selection, as well as the optimal airspace configuration. Simulation case studies have been performed through mimicking a future U-space operating scenario. Results suggest that the integrated approach can achieve the best outcome in almost all the key performance areas than any other cases where only partial functions can be realised.

Economics, Finance and Policy I

12 ***Jan Evler****, Michael Schultz & Hartmut Fricke (TU Desden)*

Flight prioritization and turnaround recovery

Abstract: The SESAR ATM Master Plan describes the goal to fully integrate airports into the ATM network, such that airspace user operations are facilitated and related user costs are reduced. The corresponding flight prioritization mechanisms of the user-driven prioritization process are in the process of being validated at several airports across Europe. This article studies the benefits of the underlying concept of tactical ATFCM slot swapping in relation to resource-constrained turnaround management of an airline. A case study at Frankfurt airport analyses different situations in which the airport is expected to operate with reduced capacity, such that a local hub carrier can prioritize its arrival (and departure) flights. Results indicate that arrival slot swapping in hot spots is very efficient as long as fixed departure flights of the same aircraft obtain no critical delays for the downstream network. In our case study, such critical delays for the network occur at around 60~minutes of departure delay, such that flights which are assigned with higher delays require the additional flexibility of departure slot swapping in order to achieve significant cost reductions. We further find that optimal delay margins, which are calculated with our approach, suffice for the confidential communication of flight priorities, such that complex scoring and credit trading systems might be omitted. In exchange, we propose a secondary trading scheme, for which our model can define efficient slot prices while considering the operational constraints of an airline.

85 ***Ying Zhou*** *& Yanjun Wang (Nanjing University)*

Measuring the resilience of airline operation networks

Abstract: Incorporating resilience into the airline's network planning and assessment prepares the airline for disruptive events. To measure and improve the resilience of an airline's network, quantitative or qualitative metrics are required. In this work, we first propose a novel modeling approach by the leverage of temporal network theory to analyze the resilience of an airline's operation network. A two-layer network is generated from an airline's scheduling data and operation data using the proposed approach. By taking interactions of the network's components and time-attributed information into consideration, the instantaneous network efficiency is defined to measure the performance of the network. We then develop a new resilience metric, average efficiency loss ratio (AELR), for airline's operation network based on the instantaneous network efficiency. The proposed approach and metric are applied to four major U.S. airlines' networks, including AA, UA, DL and WN using a publicly accessible dataset. Results show that the proposed AELR is able to detect abnormal operations and identify different phases under perturbations. Our work may open an avenue for managing the resilience of airline's networks.

Trajectory Planning I

25 ***Xavier Olive**, ONERA), Junzi Sun (TU Delft), Mayara Condé Rocha Murça (Aeronautics Institute of Technology) & Timothé Krauth (ZHAW)*

A framework to evaluate aircraft trajectory generation methods

Abstract: Aircraft trajectory generation is a widely addressed problem with applications including emergency trajectory generation, collision risk models, air traffic flow and capacity management or airspace design. State of the art methods to generate individual trajectories and optimise some performance or emergency criterion may lack of realism with respect to common situations implemented by air traffic controllers. On the other hand, statistical data-driven methods to generate aircraft trajectories excel at imitating operational practice but may be difficult to implement even in simulations due to aircraft performance limitations. This contribution proposes a common baseline to compare literature and bleeding-edge methods to generate air traffic trajectories. Keeping in mind that the most appropriate criterion should always depend on the targeted application, we present here an extensive set of metrics to evaluate the quality of generated trajectories, before assessing two generation methods in light of these indicators.

44 ***Raúl Sáez**, Homeyra Khaledian, Xavier Prats (UPC), Andréas Guitart, Daniel Delahaye (ENAC) & Eric Feron (Georgia Institute of Technology)*

A fast and flexible emergency trajectory generator

Abstract: We present an automated emergency trajectory generator to compute the best emergency trajectory for a given landing site. A combination of the optimized version of the rapidly exploring random tree algorithm and Dubins paths is used to compute a path connecting the aircraft position with the landing site, which avoids the obstacles in the way. Then, this path is used as input for a trajectory prediction (TP) algorithm, which computes a four-dimensional trajectory by taking into account the current aircraft performance and weather. The set of vertical profiles considered in the TP has been designed in order to cover the widest possible range of emergency situations. Moreover, the aircraft intents considered in these profiles are chosen by taking into account the operational requirements of the air traffic operation system and the input of the flight crew. Among these profiles, two have been tested during the study, to verify the result of the proposed algorithm and its computing time, which is one of the main success criteria. This concept is expected to be part of an advanced flight management system on-board function to help the pilot take efficient and effective decisions in emergency situations and adverse conditions.

Complexity Science, Analytics and Big Data for ATM II

14 ***Ramon Dalmau****, Brice Genestier, Camille Anoraud, Peter Choroba & Darren Smith (EUROCONTROL)*
A machine learning approach to predict the evolution of air traffic flow management delay
Abstract: In Europe, the most common air traffic flow management measure used by the network manager to resolve imbalances between demand and capacity is to impose regulations, which delay flights on ground. The ground delay assigned to a regulated flight may change from the time it is caught by the regulation(s) to the actual departure. This variability of the delay stems from the mechanisms used by the computer-assisted slot allocation system to manage the slots of the regulations. At present, the information on the delay evolution of a regulated flight is very limited for the airspace users, raising high uncertainty on the delay propagation and the operations management throughout the day. This paper describes the architecture of a machine learning model that, trained on historical data, is able predict the evolution of the delay for a regulated flight. Such evolution is expressed by using various indicators, which were selected by the airspace users involved in the project. The proposed model is able to predicted the trend of the delay with an accuracy of 0.75. Furthermore, results show that the model is able to reduce the prediction error (measured as the difference between the actual and the predicted delay) up to 63%, if compared to the current delay as reported by the enhanced tactical flow management system.

63 ***Loïc Shi-Garrier****, Daniel Delahaye (ENAC) & Nidhal Bouaynaya (Rowan University)*
Predicting air traffic congested areas with long short-term memory networks
Abstract: The Extended ATC Planning (EAP) function aims at bridging the gap between Air Traffic Flow & Capacity Management (ATFCM) and Air Traffic Control (ATC) by predicting air traffic congested areas tens of minutes before their formation, and by suggesting real-time and fine-tuning measures to alleviate airspace "complexity". Current Air Traffic Flow Prediction methods focus on crude aircraft count in a sector, and hence are unable to distinguish between low and high complexity situations for a similar aircraft count. Complexity indicators, on the other hand, aggregate air traffic measurements and workload to describe the perceived complexity. However, the evaluation of workload is a long-debated issue and an inherently ill-posed problem. In this work, we present an intrinsic complexity metric, independent of any traffic control system, and address the prediction task of the EAP function using a novel Encoder-Decoder Long Short-Term Memory (LSTM) neural network. The complexity is measured by the eigenvalues of a linear dynamical system fitted to the aircraft's speed vectors. The Encoder-Decoder LSTM network uses a sequence of (discrete) aircraft states to predict the complexity of the air traffic in all areas of an airspace, in a time horizon of 40 minutes. Simulated traffic corresponding to one day of traffic over the French airspace is used to train and validate the model. Our experiments show that the proposed model achieves a Mean Absolute Error of 0.08 in predicting the normalized complexity value 40 minutes in the future.

Economics, Finance and Policy I

36 ***Saskia van der Loo**, Christophe Heyndrickx & Eef Delhaye (TML)*

Split incentive problem in the uptake of new ATM technology

Abstract: We analyse the problem of split incentives between Air Navigation Service Providers (ANSP) and airlines in adopting disruptive technologies. We develop a simple theoretical model which allow us to analyse the uptake of technologies based on the potential efficiency gains of both the ANSP and the airlines. Next, we illustrate this model numerically. Our first, intuitive, result is that while regulation of navigation fees is necessary, it also hinders the investments in new technologies. Secondly, we see that the uptake of technologies would be faster in a one-to-one setting. Thirdly, it is not certain that increased competition between ANSPs will stimulateinnovation. Finally, an overall technological mandate can be welfare improving as it reduces uncertainty.

51 ***David Mocholí**, Rubén Alcolea & Ricardo Herranz (Nommon)*

Exploring future UDPP concepts through computational behavioural economics

Abstract: This paper presents an agent-based modelling (ABM) approach aimed at enabling a rigorous and comprehensive study of flight prioritization mechanisms in the context of demand and capacity imbalances. The implemented model adopts the paradigm of agent-based computational economics, as a particularly suitable framework for the representation of features that are not properly captured by classical approaches, such as bounded rationality or hyperbolic discounting. The main components are described, including a simplified network environment, the agents, the applied behavioral rules and the included prioritization mechanisms: SFP, E-SFP and slot auctioning. Finally, a comparative performance analysis of the prioritization concepts is presented, evaluating their impact on punctuality, cost-efficiency, equity and robustness in the presence of non-rational behaviors. Results show how SFP, counterintuitively, worsens the baseline performance in some scenarios, due to unexpected network effects, while the slot auctioning concept provides the best performance. In general, behavioral biases worsen performance of the mechanisms; however, the auction mechanism results are not significantly affected by the modelled behavioral biases.

Trajectory Planning II

17 ***Fanruiqi Zeng*** *(GeorgiaTech), Husni R. Idris (NASA) and John-Paul Clarke (The University of Texas at Austin)*
Trajectory planning for mission survivability of autonomous vehicles in moderately to extremely uncertain environments
Abstract: Trajectory planning is a particularly challenging task for autonomous vehicles when the uncertainties in their operating environment cannot be characterized statistically. In this paper, we propose a receding horizon control strategy with novel trajectory planning policies that enable dynamic updating of the planned trajectories of autonomous vehicles operating in environments where potential conflicts are, from a statistical perspective, either partially known or completely unknown. The proposed policies utilize two metrics: (1) the number of feasible trajectories; and (2) the robustness of the feasible trajectories. We measure the effectiveness of the suggested policies in terms of mission survivability, which is defined as the probability that the primary mission is accomplished or, if that is not possible, the vehicle lands safely at an alternative site. We show that a linear combination of both metrics is an effective objective function when there is a mix of partially known and unknown uncertainties. When the operating environment is dominated by unknown disturbances, maximizing the number of feasible trajectories results in the highest mission survivability. These findings have significant implications for achieving safe aviation autonomy.

47 ***Shumpei Kamo****, Judith Rosenow, Hartmut Fricke (TU Dresden) & Manuel Soler (Universidad Carlos III)*
Robust CDO trajectory planning under uncertainties in weather prediction
Abstract: Uncertainties are inherent in aircraft trajectory planning. Trajectories designed under deterministic assumptions can cause significant performance degradation or constraint violation if the actual situation significantly differs from the assumed conditions. This study proposes computational strategies to plan a robust trajectory in terms of weather prediction, focusing on continuous descent operations. The members of the Global Ensemble Forecast System are used as a set of weather scenarios to reflect the nature of uncertainty in weather prediction along the flight execution. A robust optimal control problem is formalized, which simultaneously considers a set of trajectories for each of the weather scenarios while minimizing the expected value of the overall operational costs. Numerical simulations prove that the generated trajectories are robust for the predicted set of weather scenarios without violating the imposed constraints. Simulations with various cost index settings and pre-set required time of arrival further show that the proposed robust optimal control can cope with these varying operational settings.

Complexity Science, Analytics and Big Data for ATM III

15 ***Ramon Dalmau,*** *Giuseppe Murgese, Yves de Wandeler, Ricardo Correira & Alan Marsden (EUROCONTROL)*
Early detection of night curfew infringements by delay propagation with neural networks
Abstract: Airport night curfews are restrictions applied at some airports that prohibit operations during certain hours of the night, aiming to reduce noise nuisance in the surrounding neighborhood. Despite effectively reducing noise exposure for local residents, these environmental measures can have a negative economic and operational effects on the airspace user and the airport, as well as a negative experience for the passenger. This paper presents a model that, for each flight and well before the starting time of the curfew period, is able to provide the probability (risk) of night curfew infringement. The risk of night curfew infringement is computed from the start time of the restriction and the distribution of in-block times. The former is known for each airport, while the latter is provided by a neural network which was trained on historical data to predict the propagation of arrival delay along the sequence of flights of an aircraft. Results show that the model significantly improves the in-block time predictions, if compared to the current solution. Furthermore, the risk indicator could assist in identifying flights with potential risk of night curfew infringements within a reasonable time frame to implement effective mitigation actions.

79 ***Lu Dai,*** *Mark Hansen (UC Berkeley), Michael Ball & David Lovell University of Maryland)*
Having a bad day? Predicting high delay days in the National Airspace System
Abstract: Experiencing high delays is a "bad day" for the National Airspace System (NAS). We apply machine learning algorithms to model the system delay and predict high delay days in the NAS for the 2010s. A broader scope of factors that may affect the system delay is examined, including queueing delays, terminal conditions, convective weather, wind, traffic volume, and special events. We train models to relate the system delay to these features spatially and temporally, and compare the performance of penalized regressions, kernelized support vector regressions, and ensemble regressions. The learned weights of the selected model reveal the spatial pattern and time consistency of the feature importance. Queuing delays, convective weather, and wind are found to be the most significant causative factors for system delays. We then identify high delay days using the model-predicted delay and observe an increasing trend over the past decade. The counterfactual analysis results suggest worsening convective weather after 2014, and a surge in demand in 2013 that was subsequently compensated by increased capacity.

Enhanced Surveillance and Navigation

39 ***Noboru Takeichi*** *(Tokyo Metropolitan University)*
Modeling of flight time prediction uncertainty for four-dimensional descent trajectory management
Abstract: This study presents a model for flight-time prediction uncertainty on descent trajectories. Providing the magnitude of flight-time prediction uncertainty on descent trajectories is expected to enable efficient management of traffic flow towards congested airports without affecting safety. Flight-time prediction uncertainty inevitably increases as a flight progresses, owing to fluctuations of atmospheric conditions and aircraft control. In addition, atmospheric conditions and aircraft ground speed can vary significantly in descent trajectories. To develop a model for flight-time prediction uncertainty on descent trajectories, first a model of the increase in flight-time prediction uncertainty over short trajectory segments is derived theoretically. Its coefficients are determined through clustering and regression analysis of actual flight data and numerical weather forecast data. Then, a theoretical model of flight-time prediction uncertainty over descent trajectories is formulated to enable the calculation of flight-time uncertainty of descent trajectories using the short trajectory segment data. Through analysis of modeling accuracy of flight-time prediction uncertainty over a large number of actual descent trajectories, the proposed method is demonstrated to provide accurate flight-time prediction uncertainty of descent trajectories even under calm and severe weather conditions.

78 ***Danae Mitkas****, David Lovell (University of Maryland), Sandeep Venkatesh & Seth Young (Ohio State University)*
Leveraging local ADS-B transmissions to assess the performance of air traffic at general aviation airportsks
Abstract: This paper presents details of a novel hardware and software architecture for locally and automatically recording air traffic operations data at general aviation airports, including those that primarily serve smaller aircraft and may not have any other means, such as control towers, to collect such data. The platform is based on ADS-B data collected at 1090 and 978 MHz. We describe its deployment on the Amazon Web Services cloud computing environment. Various pre-processing and filtering stages are demonstrated to clean up the data. Some techniques for dealing with unreliable data are described. Finally, we show how to use the resulting data to compile air traffic performance metrics of interest for small airports, including aircraft approach speeds and runway occupancy times. These metrics may then be used to support enhanced models of airport capacity for these facilities.

Safety, Resilience And Security

59 *Wenxin Zhang, Carter Tegen,* ***Tejas Puranik****, David Anvid, Rukmini Roy & Dimitri Mavris (Georgia Institute of Technology)*
Fusion and analysis of data sources for assessing aircraft braking performance on non-dry runways
Abstract: Aircraft landing safety is among the important concerns in the aviation industry due to accidents related to runway/taxiway excursions. Following the Southwest Airlines Flight 1248 accident on Dec 8, 2005 the Federal Aviation Administration (FAA) adopted the position that to enhance safety, new procedures were required for airplane operators to assess landing and braking performance at the time of arrival and would include defined field length performance margins. The literature published as a result of the FAA's mandate, has explored the relationship between adverse weather conditions and braking performance from a qualitative perspective. Factors such as the weather condition, pavement texture characteristics, and slope can all play critical roles in determining braking performance. While the literature has explored how these factors individually may impact braking, no studies have explored the multivariate relationship between such factors and reported braking action by pilots over a wide source of operational landings and considering a variety of data sources. In this paper, the quantitative relationship between different factors that may work to cause or prevent poor braking performance is explored. In order to conduct this analysis, a data fusion framework is developed that is able to collect and fuse sources of data such as runway conditions, runway and airport characteristics, prevailing weather conditions, runway condition codes, and pilot reported braking action. The framework is demonstrated on data collected between the years 2016–2020 at various U.S. airports where field condition reports were available. The analysis indicates that this initial statistical distribution and binning of the data substantiates the value of the Runway Condition Code (RwyCC) modeling in predicting actual braking action. Further investigation and development of more refined models is identified for future work.

69 ***Alberto Bonifazi****, Junzi Sun, Jacco Hoekstra (TU Delft) & Gerben van Baren (ILENT)*
Modeling and detecting anomalous safety events in approach flights using ADS-B data
Abstract: Not all flight data anomalies correspond to operational safety concerns. But anomalous safety events can be linked to anomalies in flight data. During the final phases of a flight, two significant safety events are unstable approach and go-around. In this paper, using Automatic Dependent Surveillance-Broadcast (ADS-B) data, we develop several exceedance and anomaly detection techniques to identify these events. Rule-based algorithms and data-driven Gaussian Mixture Models (GMM) are proposed to identify unstable approaches. A fuzzy logic approach is developed to model and to identify go-arounds. We extend our analysis combining runway information and meteorological reports to provide deeper insights on flight safety during the approach. These identification models are also applied to the ADS-B data from the Schiphol Airport area in Amsterdam in 2018. By using a reference report provided by the Dutch transportation regulatory agency, the chosen GMM model can identify 25% to 30% of reported unstable approaches, and the go-around detection model can identify 98% of go-arounds.

Separation

31 ***Mudhakar Srivatsa****, Raghu Ganti, Linsong Chu (IBM Research), Martin Christiansson, Sofia Rydell & Billy Josefsson (LFV)*
Towards AI-based air traffic control
Abstract: Air traffic, despite the recent dip due to Covid, is expected to grow 30-40% year on year. With the potential inclusion of UAVs (Unmanned Aerial Vehicles) into controlled airspace over the next decade, it is anticipated that the congestion levels in air space will increase 10 fold. This paper presents an AI-based approach to air traffic control, with the aim of alleviating the load and improving the efficiency of human-agents (air traffic controllers). One of the primary goals of air traffic control is to safely navigate an aircraft through controlled airspace using real-time control actions - such as changes to ground speed, heading (direction of travel) and altitude of an aircraft. The risk sensitive nature of this environment calls for precise explanations (why take an action) and counterfactual(why not take an action) explanations, real-time responsiveness, the ability to present succinct actions to a human agent, while simultaneously optimizing for air traffic delays, fuel burn rates, and weather conditions. This paper presents algorithms and a system architecture for anticipating separation losses (conflicts in airspace) and a lattice-based search space exploration AI planner to recommend actions to avoid such conflicts. The key contributions of the paper include: (i) fast detection (prediction) of conflicts in a controlled airspace, and (ii) fast lattice space exploration based AI solver to produce a set of feasible resolutions for the detected conflicts. Additionally, this paper discuss how to weight the different resolutions and how future work on optimisation techniques could improve the efficiency of the algorithm and address various known limitations of the current approach from both technical and human-agent perspective. The evaluations are conducted against an air traffic simulator, Narsim, showing the ability to avoid separation losses, while minimizing the number of actions even at 2-3x normal air traffic loads.

72 ***Ralvi Isufaj****, David Aranega Sebastia & Miquel Angel Piera (UAB)*
Towards conflict resolution with deep multi-agent reinforcement learning
Abstract: Safety in ATM at the tactical level is ensured by human controllers. Automatic Detection and Resolution (CD&R) tools are one way to assist controllers in their tasks. However, the majority of existing methods do not account for factors that can affect the quality and efficiency of resolutions. Furthermore, future challenges such as sustainability and the environmental impact of aviation must be tackled. In this work, we propose an innovative approach to pairwise conflict resolution, by modelling it as a Multi-Agent Reinforcement Learning (MARL) to improve the quality of resolutions based on a combination of several factors. We use Multi-Agent Deep Deterministic Policy Gradient (MADDPG) to generate resolution maneuvers. We propose a reward function that besides solving the conflicts attempts to optimize the resolutions in terms of time, fuel consumption and airspace complexity. The models are evaluated on real traffic, with a data augmentation technique utilized to increase the variance of conflict geometries. We achieve promising results with a resolution rate of 93%, without the agents having any previous knowledge of the dynamics of the environment. Furthermore, the agents seem to be able to learn some desirable behaviors such as preferring small heading changes to solve conflicts in one time step. Nevertheless, the non-stationarity of the environment makes the learning procedure non-trivial. We argue ways that tangible qualities such as resolution rate and intangible qualities such as resolution acceptability and explainability can be improved.

42 ***Sarah Degaugue****, Jean-Baptiste Gotteland & Nicolas Durand (ENAC)*
Learning uncertainty parameters for tactical conflict resolution
Abstract: Assisting air traffic controllers in their deconfliction task is challenging. A five nautical mile separation standard in the horizontal plane and one thousand feet vertically are required in the upper airspace between aircraft. However, air traffic controllers generally need to take extra margins in their mental process. These margins can impact efficiency and capacity but are essential to manage safely the evolving traffic situations. It is necessary to model uncertainties on controllers trajectories predictions in order to imagine assistance tools that can mimic their perception of conflict risk. This article models uncertainties on the speed prediction, pilots reaction times when a maneuver is started or ended, and heading change accuracy. A method is proposed to estimate these values on deconflicted trajectories benchmarks. First we apply our method to benchmarks that where artificially created with an automatic solver calibrated with specific known uncertainty parameters. We show that the uncertainty on speed prediction, maneuver start time and heading change can be retrieved afterwards with a good accuracy. Then we apply our method to benchmarks of conflicts solved by qualified air traffic controllers. The method works but the quality of the results is questionable because of the small data size and the big variability in the air traffic controllers decisions.

Weather in ATM

5 ***Gabriele Enea****, Margita Pawlak, Tom Reynolds (MIT Lincoln Lab), Dave Knorr & Martin Durbin (FAA)*
Shortfall analysis of departure throughput during convective weather in complex airport regions
Abstract: This study identified the pool of potential additional departures that could be achieved during convective weather days by providing traffic managers with enhanced information not available today, and by improving the information exchange with aircraft and airport operators. To quantify the shortfall of departures, historical data from the 2019 convective season at the three major airports in New York was evaluated. Route Availability Planning Tool (RAPT) data were used as a starting point for the quantification. RAPT is a real-time decision support tool used by controllers to identify departure routes out of busy terminal areas clear of convective weather so they can be used more efficiently. Additional effort was necessary to improve the fidelity of RAPT data and to include downstream sector capacity information (which is not currently captured by RAPT) into the analysis. An estimated total of 952 potential additional departure opportunities were identified for the entire convective weather season of 2019 for the three major New York airports. Over seventy days impacted by convective weather, an average of 13.6 potential additional departure opportunities were identified per weather day (4.5 per airport). Benefits against this pool may be realizable by providing controllers, pilots and airline operators with training and additional information in the future which is not available today. The methodology presented in this paper can be adapted to other regions where convective weather impacts departure operations.

21 ***Marius Marinescu****, Alberto Olivares, Ernesto Staffetti (Rey Juan Carlos University) & Junzi Sun (TU Delft)*
Wind profile estimation from aircraft derived data using Kalman Filters and Gaussian Process Regression
Abstract: Accurate wind information is crucial in air traffic management, for instance, to improve trajectory predictability and precision in controlled time of arrival. Nowadays air traffic management relies on Numerical Weather Prediction, which usually has low resolution and low update rate. A potential approach to improve the resolution and accuracy of the weather predictions consist on using airborne aircraft as meteorological sensors. Aircraft surveillance systems such as ADS-B and Mode S, transmit data related to weather conditions, automatically or in response to interrogation by air traffic control surveillance radars. In this paper, three different methods to construct wind profiles from surveillance data have been applied and a comparison between them has been carried out. The first two methods being modifications of the Kalman Filter have been referred to as Adapted Kalman Filter and Smooth Adapted Kalman Filter. The third one is based on Gaussian Process Regression. The Kalman Filter based methods are able to assimilate nearby data in a straightforward way and update the wind speed estimation in real-time. Gaussian Process Regression is a very flexible and general regression model that can smoothly interpolate in space and extrapolate in time. These three methods have been validated using a test data set, achieving a reduction of 50% of the prediction uncertainty in comparison to a baseline model. Moreover, the Gaussian Process methodology has been applied to reconstruct and forecast the wind field.

16 ***James Jones****, Zach Ellenbogen & Yan Glina (MIT Lincoln Lab)*
Recommending strategic air traffic management initiatives in convective weather
Abstract: The presence of uncertainty in weather forecasts poses significant challenges for air traffic managers. These challenges can have major repercussions on stakeholders in terms of their impact on the delay within the system. In this paper, we discuss an approach for recommending Traffic Management Initiative (TMI) parameters during uncertain weather conditions. We propose four methods for TMI selection. The first two favor random exploration of TMI decisions. An epsilon-greedy approach and a softmax algorithm are also evaluated against the two random exploration approaches. A parallel fast-time simulation framework is presented for evaluating the proposed methods over a range of weather forecast scenarios. A set of regional TMIs is applied and tested against a case day in which the airspace capacity in the Northeast United States was compromised by convective weather. Both the softmax and epsilon-greedy approaches demonstrate strong performance relative to the other methods. The results suggest that the approach could potentially aid air traffic stakeholders in understanding how to best deal with weather forecast uncertainty.

Human Factors

4 *Daan van Aken, **Dominik Janisch** & Clark Borst (TU Delft)*

Development and testing of a collaborative display for UAV traffic management and tower control

Abstract: The forecasted increase in unmanned aerial vehicle (UAV) traffic in lower airspace raises concerns for maintaining the safety of flight operations at towered airports. Regulatory bodies envision a collaborative environment between UAV Traffic Management (UTM) and air traffic management to facilitate safe UAV operations within controlled airspace. This will require the development of an interface for tower controllers to interact with UTM concerning UAV flights within the aerodrome control zone. In this study we present relevant design considerations for such a display and introduce a concept for dynamically segregating UAVs from manned aircraft using geofences. Remote human-in-the-loop simulations with air traffic controllers were performed to test our assumptions. Results confirm the utility of several interface elements, in particular UAV priority and routing indications. Furthermore, results show that providing controllers with a grid of geofences was considered a useful tool in re-routing UAVs. Surprisingly, the control strategy for geofences was not different from existing control strategies for manned aircraft. Performance could be improved by increasing transparency and predictability of UAV routing with novel display elements, as well as providing more authority over UAV locomotion. Further work is needed to investigate controller behavior and performance in an environment which requires oversight of both UAV and manned traffic, higher levels of UTM sophistication as well as simulating a broader range of UAV missions and scenarios.

40 ***Pallavi Mohan**, Sameer Alam, Mohammed Nadirsha, Nimrod Lilith (NTU Singapore) & Åsa Svensson (LFV)*

Embodied multimodal interaction with a portable mixed reality-based digital tower

Abstract: A major topic of air traffic research in the past decade has been of digital towers (DTs) that replace physical air traffic control towers by reproducing live camera feeds of out-of-tower (OOT) views using massive immersive spatial displays. With the recent pandemic-induced decline in air traffic, the quest to introduce cost-effective alternative solutions for DTs seems especially urgent. Recent developments in mixed reality (MR)-based visualizations have allowed complex spatial data to be better represented in a stereoscopic virtual space. Moreover, the immersion that MR offers is highly customizable, allowing controllers to maintain their view of the environment along with the OOT view, similar to a physical tower. Additionally, the increasingly robust technical capabilities of self-contained MR-based Head-Mounted Devices (HMDs) (such as Microsoft HoloLens 2) gives rise to the possibility of designing a cohesive and self-contained DT system on such a platform, making the DT system cost-effective, portable and interactive. In this paper, we have developed a simulated Digital Tower environment in mixed reality using Microsoft HoloLens 2, with intuitive embodied and multimodal interactive capabilities. The system incorporates several visual features from real-world air traffic control environment and visualizes them in mixed reality with added interactive capabilities for aircrafts, gates and runways. We then evaluate the preliminary system with experienced air traffic controllers and our findings show that such a mixed reality representations of air traffic control is accepted by controllers as a useful way to visualize information on the OOT view. We also find that the visual and interactive affordances provided by the system shows promising potential to augment, and possibly replace present digital tower set-ups as a self-contained, interactive and portable DT system.

7 ***Hartmut Helmke** DLR) et al*

Readback error detection by automatic speech recognition to increase ATM safety

Abstract: One of the crucial tasks of an air traffic controller (ATCo) is to evaluate pilot readbacks and to react in case of errors. Undetected readback errors, when not corrected by ATCos, can have a dramatic impact on air traffic management (ATM) safety. Although they seldomly occur, the benefits of even one prevented incident due to automatic readback error detection justifies the efforts. This, however, requires highly reliable detections, which is be-yond the performance of currently available automatic speech recognition implementations. The HAAWAII project aims to achieve false alarm rates below 10% and readback error detection rates better than 50%. After performing a preliminary analysis by comparing ATCo utterances with pilot readbacks on word level, this approach proves to be very ineffective. Callsigns are abbreviated or not even pronounced, altitude and speed units are often not used, for example “nineteen eight” is the same as “one one nine decimal eight”. Therefore, the presented approach trans-forms recognized word sequences into so-called ATC concepts, as agreed with the ontology of the SESAR project PJ.16-04. Detecting readback errors on concept level is more reliable and robust as it also considers different forms of conveying the same semantic messages and is also more tolerant to partially misrecognized words. Nevertheless, a good recognition rate on word level is essential to correctly transform words into concepts, which will be achieved by integrating voice data from ATCo utterances and pilot readbacks with context information such as data concerning radar, flight plans, and weather. This paper presents relevant use cases, the ontology-based algorithm, and initial results regarding callsign recognition accuracy for automatic readback error detection purposes.

ATM Performance Measurement and Management I

13 ***Marie Carré**, Eric Nantier (Swiss), Séverine Durieux & Laurent Piétrac (Institut Pascal)*
Equity within air transportation management – an analysis of inequity index for multi-stakeholders optimisation
Abstract: Current equity definition hampers innovation within the Air Traffic Management (ATM). Even if different definitions are currently well established, summer 2018 and 2019 highlighted the urgent need for flexibility and efficiency that current equity definitions cannot cover anymore. Moreover, in any group decision targeting the best performances for the group can be at the expenses of some stakeholders. Therefore, new equity perspectives must be proposed. In our paper, we propose a new paradigm, and explore the first steps. Equity has a multi-criteria based definition, and should be guaranteed over time instead of ensuring it in every situation. We first introduce the context of our research and point out, thanks to a literature review, three inequity indexes successfully used in other fields. We analyze their sensitiveness and pertinence according to our problem. We discuss then the results and the following research paths.

80 ***Ke Liu** & Mark Hansen (UC Berkeley)*
Miles-in-trail restrictions and aviation system performance: Chicago O'Hare case study
Abstract: Miles-in-Trail (MIT) is the most common Traffic Management Initiatives (TMI). An MIT places a minimum spacing requirement between aircrafts at a specific location to manage the imbalance between capacity and demand at a given airport, or to support merging streams in the sectors. This paper focuses on the improvement opportunities from the reduction of MIT. We design a model including estimation of planned arrival time and a deterministic model to assess the impacts of a given MIT or a set of MITs. Our model is applied to ORD airport of 2018 as a case study. As results show, if all ORD-sourced MITs were eliminated, the overall queueing delay would increase by 3.3 hours per day on average while arrival delay would decrease by 14.7 hours per day. We also found that ORD during 8:00-9:00, 11:00-12:00, and 17:30-18:30 tends to experience more throughput reduction when implementing MITs and those delayed flights are allocated into 9:00-10:00, 12:00-13:00, and 18:30-19:30 respectively. Our results strongly suggest that ORD-sourced MITs, while relieving some build-up of flights in the ORD terminal area, do so at a substantial penalty in the form of increased arrival delay and throughput shortfalls

Aviation and the Pandemic I

84 ***Lu Dai****, Ivan Tereshchenko & Mark Hansen (UC Berkeley)*

Quantifying the impact of air travel on growth of COVID-19 pandemic in the United States

Abstract: This paper develops models to quantify the dynamics of the impact of air travel on the spread of the COVID-19 pandemic, using a wide range of datasets covering the period from March to December 2020. With the help of flight operation data, we first develop a novel approach to estimate the county-level daily air passenger traffic, which combines passenger load factor estimates and information about the air traffic distribution. Cross-sectional models using aggregated county-level variables are estimated. While this study focuses on air travel variables, we also control for potential spatial autocorrelation and other relevant covariates, including vehicle miles traveled (VMT), road network connectivity, demographic characteristics, and climate. The model results indicate that air travel has a strong and positive impact on the initial pandemic growth rate for both case-based and fatality-based aggregate models.

75 ***Michael Schultz*** *(TU Dresden), Majid Soolaki, Elnaz Bakhshian (University College Dublin), Mostafa Salari (University of Calgary) & Jörg Fuchte (Diehl Aviation)*

COVID-19: passenger boarding and disembarkation

Abstract: Passenger boarding and disembarkation are important handling processes and take place in the confined space of the aircraft cabin. While boarding can be controlled to a certain extent, passenger disembarkation at the end of a flight takes place in a less controllable environment. Under the current COVID-19 boundary conditions, cabin processes must not only be efficient in terms of time but also significantly reduce any potential risk of virus transmission to passengers. For this complex challenge, we have developed a mathematical model that takes these conflicting objective functions into account to optimize both boarding and disembarkation. Using improved seat allocations, genetic algorithms provide improved sequences for groups of passengers (e.g. families or couples). The selected use cases indicate a significant reduction in boarding and disembarkation time when physical distances between passenger groups are mandatory to satisfy pandemic regulations. In particular, we propose to activate the cabin lights at the seats in a dedicated way to inform passenger groups about the disembarkation sequences. Thus, our methods can be already applied to real flights.

Trajectory Prediction and Trajectory and Queue Management I

46 ***Daichi Toratani,*** *Yoichi Nakamura & Megumi Oka (ENRI)*

Data-driven analysis method for calculated time over in air traffic flow management

Abstract: Due to limited airspace and airport capacity, excessive traffic demand overwhelms air traffic control and causes traffic delays. Air traffic flow management (ATFM) is widely used to prevent excessive traffic demand. ATFM regulates air traffic using traffic management initiatives (TMIs), such as ground delay, miles-in-trail, and speed adjustment. In Japan, the Calculated Fix Departure Time (CFDT), also known as the Calculated Time Over, is being developed as an additional TMI, and trials on CFDT operation have been conducted. The CFDT can be performed if pilots accept the CFDT assigned by the ATFM system. Therefore, a CFDT procedure with a high acceptance rate by pilots is necessary to establish effective CFDT operation. To estimate the acceptance rate, this study develops an analysis method for CFDT operation using data collected in trial operations. With the estimated acceptance rate, the potential performance of the CFDT operation can be quantitatively discussed. The proposed analysis method can contribute to the design of an efficient procedure for CFDT operation by providing the estimated acceptance rate.

6 ***Gabriele Enea****, Michael McPartland & Timothy Bonin (MIT Lincoln Lab)*

Evaluation of aircraft speed and wind modeling accuracy in automation for trajectory based operations

Abstract: Trajectory Based Operations (TBO) is a new approach to manage air traffic being implemented in many part of the world, including US and Europe. A study which evaluates aircraft descent speed modeling and the impact of wind data into TBO systems is presented in this paper. Differences between the descent speed models used by TBO systems and descent speed derived by aircraft interrogations through Mode S Enhanced Surveillance (EHS) vary depending on aircraft types between 1.4% and 7.7%. Modest improvements in the performance of the Time-Based Flow Management (TBFM) system were observed by using wind data derived by a more accurate forecast than currently used. For the best performing flights in the sample analyzed, the Root Mean Squared Error (RMSE) of the Estimated Time of Arrival (ETA) error improved by almost 7%. Larger improvements for the best performing flights seem to be achievable during days impacted by high winds with a reduction of the ETA RMSE error of 24%. Future work will explore how larger benefits to TBO performance will be enabled through other enhancements, such as to trajectory prediction algorithms.

ATM Performance Measurement and Management II

23 ***Hiroko Hirabayashi*** *(Tokyo Metropolitan University/ENRI), Mark Brown (ENRI) & Noboru Takeichi (Tokyo Metropolitan University)*

Feasibility study of free routing airspace operation over the North Pacific airspace

Abstract: A fast-time simulation study was conducted to examine the expansion of flexible track operations into the area occupied by the five NOPAC (North PACific) Air Traffic Service (ATS) routes, an area of high traffic demand. In this study, User-preferred routes (UPR) were created in a proposed NOPAC Free Route Airspace (FRA) area, in which airspace users (AU) may design routes with few constraints, and compared with current fixed NOPAC route structure by fast-time simulation. To reflect the effect of daily and seasonal wind variations, a clustering analysis approach was applied to select representative wind conditions for flight route generation. Fuel burn was used to evaluate the effect of the NOPAC FRA on the efficiency of flight operations, and Potential Loss of Separation (PLOS) was examined for three minimum lateral separations to evaluate the effects of Communication, Navigation and Surveillance (CNS) performance on airspace capacity and Air Traffic Control (ATC) workload. The simulation results show a trend of increased efficiency of individual NOPAC FRA flight routes and reduced overall PLOS time. This indicates that a NOPAC FRA could improve capacity and efficiency while maintaining or increasing safety.

52 ***Phuoc Dang****, Phu Tran, Sameer Alam & Vu Duong (NTU Singapore)*

A machine learning-based framework for aircraft maneuver detection and classification

Abstract: The increasing availability of historical air traffic data (e.g., Automatic Dependent Surveillance-Broadcast (ADS-B) data) has enabled more advanced post-analysis of traffic scenarios, which leads to a better understanding of decision making in air traffic control. Such kind of analysis is often complex and requires a careful design of analysis tools. Advanced machine learning techniques have been shown to be very effective in dealing with the complexity of air traffic data analysis. This paper presents a machine learning-based framework to detect and classify aircraft maneuvers in past traffic data and classify the maneuver into three keys air traffic maneuvers. Aircraft maneuvers are identified in the ADS-B data using Isolation Forest algorithm, followed by maneuver clustering using K-means algorithm. Three time-dependent contextual features are proposed for dynamic traffic scenario representation and shown to be effective for maneuver clustering. Each maneuver cluster is associated with a label provided by Air Traffic Controllers (ATCOs), indicating the reason for such maneuver which took place in the past. Experiments were conducted on the framework using a dataset of 2793 arrival trajectories over 30 days in two Singapore Flight Information Region sectors. The results show that the framework efficiently allows post-analysis of air traffic scenarios, by which one can gain better insights into the decision making patterns of ATCOs in response to various air traffic scenarios.

Aviation and the Pandemic II

54 ***Javier García Moreno*** *(CRIDA) et al*

On-line platform for the short-term prediction of risk of expansion of epidemics

Abstract: This paper proposes a novel approach for the prediction of the risk of expansion of local epidemics to 3rd regions or countries in the world through the air traffic network. The approach relies on the definition of a new indicator, the Imported Risk, which represents the overall risk of having infected individuals entering an airport from any other airport with connections. We performed a proof-of-concept of the proposed approach by using daily data of the air traffic movements on a global scale and of the evolution of the COVID-19 epidemic at the beginning of 2020. For that purpose, we developed a complex network model based on Tagged Graphs to calculate the Imported Risk indicator, together with other complementary indicators showing the centrality of the air traffic network weighted with the Imported Risk. We implemented our complex network model into an on-line platform which provides the daily risk of expansion of the epidemic to other regions or countries. The platform supports the identification of the components of the network (airports, routes…) that have a major impact on the risk of expansion. The paper also provides findings on how the short-term prediction of diseases' expansion through the Imported Risk indicator allows the identification of effective measures to take control of the virus spread.

18 ***Richard DeLaura*** *& Tom Reynolds (MIT Lincoln Lab)*

Modeling impacts of aviation mitigations & ATC delay on passenger COVID-19 infection risk

Abstract: The aviation system has been hugely impacted by COVID-19 but will be a critical enabler of economic recovery. There is an urgent need for models to help understand the potential infection risks posed by air travel, as well as the impact of different mitigations available to aviation stakeholders. This paper presents a modeling system to address these needs. Elements of the model are described and it is then exercised to explore the relative effectiveness of airport and aircraft cabin passenger density restrictions, air turnover rate and passenger mask utilization. The model is then extended to explore the impacts on infection risk of different ATC delay scenarios. The model can be built upon in the future to not only help in the recovery from COVID, but also to develop system robustness strategies to better prepare for future challenges.

Trajectory Prediction and Trajectory and Queue Management II

65 ***Martin Lindner****, Thomas Zeh, Hannes Braßel & Hartmut Fricke (TU Dresden)*

Aircraft performance-optimized departure flights using traffic flow funnels

Abstract: Aircraft departures often follow standardized and restrictive routes intended to guarantee a safe transition to the en-route network. These procedures are usually designed for a wide range of aircraft types, but often without its individually optimized flight intent. This paper presents an approach, where flights can fly their optimal profile within a procedural space, which is based on actual flight performance intended to replace standard routes. For this, common traffic flow funnels are identified with an algorithm based on DBSCAN for a set of radar tracks as well as individually optimized flight trajectories. For the latter, an 3D path finding grid is developed, which expands dynamically using the flight performance. A set of funnels is created along a mean trajectory, which begins at the runway and provides a restricted space for individual trajectory optimization. The procedure is applied exemplary for Munich Airport where the size of the funnels and the associated fuel saving potential is determined. The results indicate an average fuel saving potential of 0.4% compared to the trip fuel.

22 ***Lucas Ligny****, Andréas Guitart, Daniel Delahaye (ENAC) & Banavar Sridhar (FAA)*

Aircraft Emergency Trajectory Design: A Fast Marching Method on a Triangular Mesh

Abstract: In this paper, an efficient algorithm to generate a short and safe trajectory for an aircraft in a situation of emergency is proposed. The algorithm is to be run on a Flight Management System, hence the computation performance, the size of the stored data and the quality of the solution are taken as primary stakes. The algorithm is based on a front propagation algorithm, the Fast Marching method. Fronts are propagated on a single glide slope, allowing the algorithm to provide a flyable trajectory in a very short time (a few seconds). The algorithm is tested in a mountainous environment, and both shortness and safeness are obtained in response to a critical emergency.

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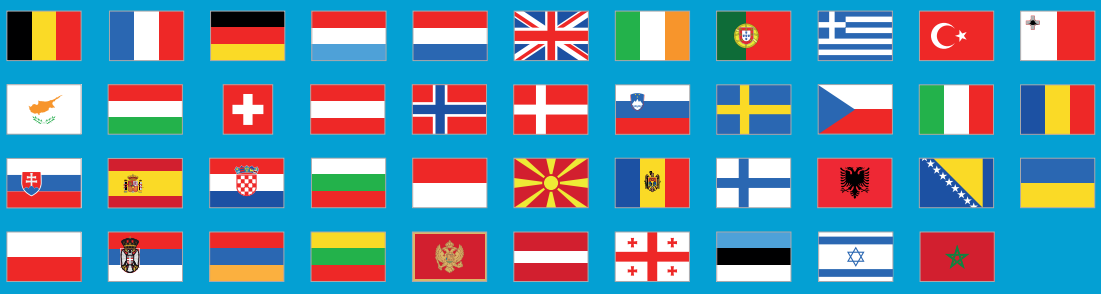

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