Exploring the boundaries of air traffic management

A summary of SESAR
exploratory research results

2016-2020

SESAR
JOINT UNDERTAKING

Exploring the boundaries of air traffic management

A summary of SESAR exploratory research results

2016–2020

Table of contents

ATM excellence science and outreach

Automation, robotics and autonomy

Complexity, data science and information management

Environment and meteorology for ATM

Economics, legal and regulation

ATM application-oriented research

Knowledge Transfer Network (KTN)

About SESAR

SESAR is the technological pillar of the Single European Sky and a key enabler of the EU Aviation Strategy. The project pools the knowledge and resources of the entire aviation community to transform ATM into a more modular, scalable, automated, interoperable system that takes advantage of advances in digital and virtualisation technologies.

The SESAR Joint Undertaking (SESAR JU) is the public-private partnership set up to define and deliver technological solutions to make this transformation a reality. It works with all actors in the aviation value chain to agree on the research and development priorities, as well as technology roll-out plans, which are documented in the 2020 European ATM Master Plan.

Founded by the European Union and Eurocontrol, the SESAR JU has 19 members, who together with their partners and affiliate associations represent over 100 companies working in Europe and beyond. The SESAR JU also works closely with staff associations, regulators, airport operators, airspace users, the military and the scientific community.

Foreword

Florian Guillermet,
Executive Director,
SESAR Joint Undertaking

Our fascination with flying is as old as humankind itself. The pursuit of understanding how birds fly eventually led us to master the principles of flight, and design and manage the complex machines that we see in our skies today. Flying continues to fascinate us and push the boundaries of scientific exploration in the domain of aviation and air traffic management.

> *Flying continues to fascinate us and push the boundaries of scientific exploration in the domain of aviation and air traffic management*

This appetite to look beyond what's on horizon is critical to aviation in order to respond effectively and sustainably to changes in traffic demand and diversity of air vehicles that are taking to the skies. Harnessing innovation to tackle the opportunities and challenges that lie ahead is also very much in line with the vision set out in FlightPath 2050, the 2015 Aviation Strategy and the European ATM Master Plan, and matches the ambitions of the 'European Green Deal' and the 'Europe fit for the digital age' initiative.

At the SESAR Joint Undertaking we support long-term exploratory research and have created an innovation pipeline in our research programme that transforms innovative ideas into solutions to increase the performance of European aviation. This publication captures the results from some 36 completed exploratory projects. Taking place between 2016–2020, the selected projects have brought together over 100 academic and industry partners, such as universities, SMEs, research centres, airlines, manufacturers, air navigation service providers from across the European Union and EU Associated Countries.

The projects explored innovations and technologies coming not just from aviation and ATM, but also other sectors, such as automotive, robotics or system engineering, as well as in other safety critical industries, such as nuclear, space, etc. The most promising and mature technologies will now be considered for inclusion in the industrial research strand of the SESAR programme, with the ultimate goal of delivering smart, sustainable and safe air travel for Europe and its citizens.

The people behind the research

SESAR Scientific Committee

SESAR Inovation Days 2019

A SESAR exploratory research close-out meeting

The results contained in this publication were made possible thanks to the dedication of researchers from across Europe and the oversight of the SESAR JU and its Scientific Committee.

Introduction

EUROPEAN ATM MASTER PLAN
Digitalising Europe's Aviation Infrastructure

Executive view

2020 edition

Since its establishment, the SESAR JU has conducted exploratory research activities aimed at expanding the boundaries of our knowledge on ATM and aviation in Europe. These activities are set within the context of an every-changing aviation context and a broader programme of R&D work (SESAR 2020), which is delivering tangible solutions to improve all aspects of air traffic management (ATM) performance.

Digital European sky

SESAR aims to deliver an ATM system for Europe that is fit for the 21st century, making it more scalable, economically sustainable, environmentally efficient and resilient. As outlined in the European ATM Master Plan, this transformation centres on technologies that can increase the levels of automation, cyber-secure data sharing and connectivity in ATM, as well as the virtualisation of its infrastructure and air traffic service provision in all types of airspace, including for very-low and high altitude operations. In doing so, these technologies enable the system to become more modular and agile, while building resilience to disruptions and diversity of air vehicles.

SESAR 2020 and the innovation pipeline

Guided by the European ATM Master Plan, SESAR 2020 focuses on developing solutions in four key areas, namely airport operations, network operations, air traffic services and technology enablers. The programme also addresses emerging challenges such as the integration of drones and cyber security. The research is categorised into three strands: exploratory research, industrial research and validation and very large-scale demonstrations. These strands have been designed as an innovation pipeline through which ideas are transformed into tangible solutions for industrialisation. The pipeline is composed of exploratory and industrial research projects and demonstrators, more than 50 test sites and is staffed by 2,500 researchers, controllers, pilots and engineers from across Europe. Not only do SESAR JU members and partners come together to pool their resources and expertise, they also make sure that R&D is carried out in a cooperative and integrated manner following the vision of the European ATM Master Plan - the main planning tool for ATM modernisation – and in support of the Single European Sky and the EU Aviation Strategy.

EXPLORATORY RESEARCH	INDUSTRIAL RESEARCH & VALIDATION	VERY LARGE SCALE DEMONSTRATIONS
Explores new concepts beyond those identified in the European ATM Master Plan or emerging technologies and methods. The knowledge acquired can be transferred into the SESAR industrial and demonstration activities.	Assesses and validates technical and operational concepts in simulated and real operational environments according to a set of key performance areas. This process transforms concepts into SESAR Solutions.	Tests SESAR Solutions on a much larger scale and in real operations to prove their applicability and encourage the early take-up of solutions.

Delivering first building blocks for change

Since 2008, the SESAR JU has researched, validated and delivered a catalogue of more than 90 operational and technological solutions. These solutions are bringing tangible benefits in terms of enhanced safety, increased capacity, increased operational efficiency and resilience, lower running costs and an improved environmental footprint. Local implementations have already started, as well as synchronised deployment across 24 airports in Europe.

Exploring the boundaries

Through its exploratory research, the SESAR JU looks beyond the current R&D and what is already identified in the European ATM Master Plan. The aim is to investigate new ideas, concepts, and technologies, but also challenge pre-conceived notions about air traffic management and the aviation value chain. By advancing promising research ideas and embedding them in a broader programme of work, the SESAR JU is helping to future-proof Europe's aviation industry and to maintain its global competitive edge.

The key principles guiding SESAR 2020 exploratory research activities are:

► To bring together the brightest of minds in Europe to undertake research within but as well outside the scope of SESAR's industrial research programme;

► To consider innovations/technologies coming from non-ATM sectors, such as automotive, robotics, as well as in other safety critical industries, such as space, etc.;

► To foster a network of European ATM research capabilities and knowledge that will strengthen European competitiveness and its workforce;

► To create a mechanism in order to monitor and assess the maturity of exploratory research results and their integration into the SESAR innovation pipeline, where appropriate.

The SESAR Digital Academy seeks to bring together under one umbrella access to SESAR exploratory research activities and outreach relating to education and training, as well as professional learning opportunities offered by research centres, universities, industry partners and other entities within the ATM/aviation domain. The SESAR Digital Academy aims to nurture Europe's brightest minds and advance learning, scientific excellence and innovation in aviation and ATM. In this respect it promotes student mobility and a whole spectrum of learning opportunities, from fundamental research to industry-focussed applied research, and to enhance the knowledge, skills and employability of aviation professionals.

The mission and vision of the SESAR Digital Academy are complementary to those of existing aviation/aeronautics interest groups, associations and networks at European level, including the Knowledge Transfer Network.

What's beyond the horizon

Thanks to these building blocks and the innovation pipeline, SESAR is making progress towards more high performing aviation for Europe, underpinned by several key areas of R&D: automation, virtualisation, connectivity, data-sharing, and cybersecurity and safety. This progress is captured in the project results in this publication. With these results, SESAR enables the development of leaner, modular and more scalable systems that are easier to upgrade and interoperable with each other. In the longer term, virtualisation and the move towards "digitally connected aviation" will allow for more efficient and flexible use of resources, substantially improving safety and the cost efficiency of service provision (see next page).

SESAR innovations
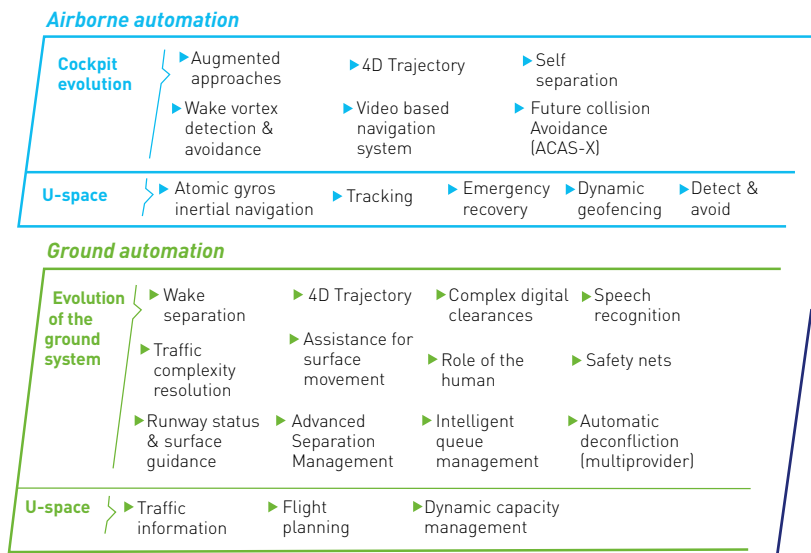
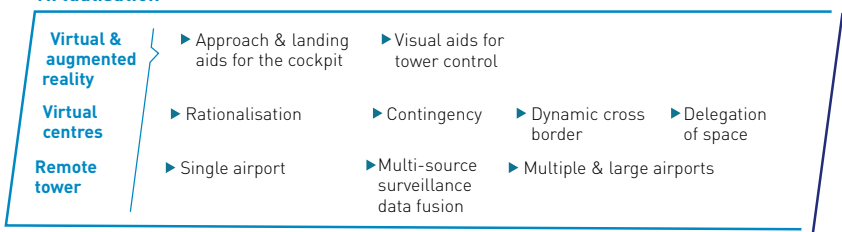**Coming next**
New standards for safety and security

Airborne automation

Cockpit evolution
- ▶ Augmented approaches
- ▶ 4D Trajectory
- ▶ Self separation
- ▶ Wake vortex detection & avoidance
- ▶ Video based navigation system
- ▶ Future collision Avoidance (ACAS-X)

U-space
- ▶ Atomic gyros inertial navigation
- ▶ Tracking
- ▶ Emergency recovery
- ▶ Dynamic geofencing
- ▶ Detect & avoid

Ground automation

Evolution of the ground system
- ▶ Wake separation
- ▶ 4D Trajectory
- ▶ Complex digital clearances
- ▶ Speech recognition
- ▶ Traffic complexity resolution
- ▶ Assistance for surface movement
- ▶ Role of the human
- ▶ Safety nets
- ▶ Runway status & surface guidance
- ▶ Advanced Separation Management
- ▶ Intelligent queue management
- ▶ Automatic deconfliction (multiprovider)

U-space
- ▶ Traffic information
- ▶ Flight planning
- ▶ Dynamic capacity management

Coming next:
- ▶ Urban air mobility
- ▶ Single pilot operations
- ▶ Autonomous cargo
- ▶ Autonomous large passenger aircraft
- ▶ Digital cockpit assistant
- ▶ Digital ground assistant
- ▶ Emulating U-space
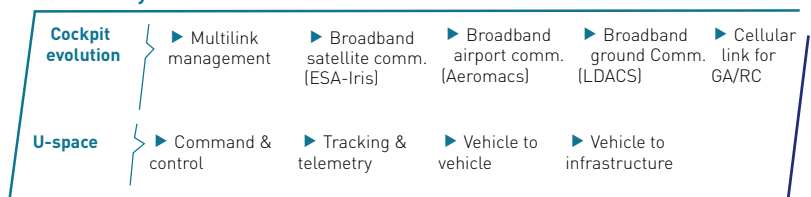- ▶ AI powered ATC environment

Automation levels
1 Decision Support
2 Task Execution Support
3 Conditional Automation
4 High Automation
5 Full Automation

Virtualisation

Virtual & augmented reality
- ▶ Approach & landing aids for the cockpit
- ▶ Visual aids for tower control

Virtual centres
- ▶ Rationalisation
- ▶ Contingency
- ▶ Dynamic cross border
- ▶ Delegation of space

Remote tower
- ▶ Single airport
- ▶ Multi-source surveillance data fusion
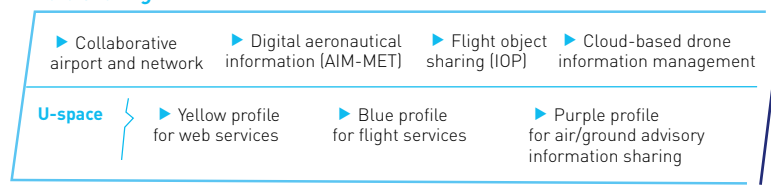- ▶ Multiple & large airports

Coming next:
- ▶ Defragmented European Sky
- ▶ All weather operations
- ▶ Pan European service provision capability
- ▶ Fully dynamic airspace
- ▶ Resilient operations
- ▶ Hyper connectivity for high automation
- ▶ Next generation links
- ▶ Internet of Things for aviation
- ▶ CNS as a service
- ▶ Future data services and applications
- ▶ Interconnected network
- ▶ Passenger centric ATM
- ▶ Open data
- ▶ Multimodality
- ▶ Advanced analytics for decision making

Connectivity

Cockpit evolution
- ▶ Multilink management
- ▶ Broadband satellite comm. (ESA-Iris)
- ▶ Broadband airport comm. (Aeromacs)
- ▶ Broadband ground Comm. (LDACS)
- ▶ Cellular link for GA/RC

U-space
- ▶ Command & control
- ▶ Tracking & telemetry
- ▶ Vehicle to vehicle
- ▶ Vehicle to infrastructure

Data sharing

- ▶ Collaborative airport and network
- ▶ Digital aeronautical information (AIM-MET)
- ▶ Flight object sharing (IOP)
- ▶ Cloud-based drone information management

U-space
- ▶ Yellow profile for web services
- ▶ Blue profile for flight services
- ▶ Purple profile for air/ground advisory information sharing

What is in this publication?

Building on the exploratory research conducted in its first programme and following a call for proposals (ER1) in 2016 the SESAR JU selected and launched 28 projects for a total of EUR 20.4 million in funding within the framework the EU's Horizon 2020 research and innovation programme.

Another call for proposals (ER3) was launched in 2017 and 8 projects were awarded, for a total of EUR 9.8 million in funding.

The projects covered a wide range of topics, which can be categorised into three streams:

ATM EXCELLENCE SCIENCE AND OUTREACH

ATM excellent science & outreach aims at bridging ATM research and the wider research community and providing the necessary scientific support to ATM change either directly or indirectly to other funded research areas in other disciplines or sectors in the following areas:

Automation, robotics and autonomy
ATM currently relies on high levels of human intervention in order to carry out essential controller tasks. Given the safety criticality of the industry, the uptake of automation has been slow. Several of the selected projects explored whether and in what ways automation could be used to deliver substantial and verifiable performance benefits while fully addressing safety concerns.

Complexity, data science and information management
ATM is a complex business since the system is composed of systems within systems, each of which are designed and managed by different stakeholders. A number of projects made use of data science to explore the use of large datasets for the purpose of information management, knowledge creation and improved optimising planning and execution of ATM.

Environment and meteorology for ATM
ATM has a critical role to play in reducing the environmental impact of aviation. This category of selected projects looks at different modelling tools with which to better assess and improve the environmental footprint of ATM/aviation. Projects were also selected to better understand the impact of weather phenomena and explore tools to better predict and integrate weather information into ATM processes.

Economics, legal and regulation
Large parts of the European aviation ATM industry are undergoing significant changes in their institutional and economic structures due to market pressures, the emergence of new market entrants and innovation in business models. Projects in this category sought to better understand aviation market dynamics - taking into account economic, policy, regulatory and legal frameworks - and explore innovative business and operating models and drivers for sustainable growth.

ATM APPLICATION ORIENTED RESEARCH

ATM application-oriented research aims to help mature new concepts for ATM beyond those identified in the European ATM Master Plan, as well as help to develop emerging technologies and methods to the level of maturity required to feed the applied research conducted in the SESAR JU. This research theme addressed the following areas:

High-performing airport operations

Airports in Europe are constrained by the availability of their busy runways. They are therefore in need of solutions to make their operations as efficient as possible. The selected projects looked at emerging technologies that can improve situational awareness for tower controllers, including new ways of displaying and presenting data on aircraft, vehicles and infrastructure in a manned airport visual control room (local or remote).

Advanced air traffic services

The future European ATM system will be characterised by advanced service provision, underpinned by the development of automation tools to support controllers in routine tasks. With this in mind, the selected projects looked at tools to enhance and integrate departure and arrival processes, to support separation management, improve air and ground safety nets and systems to support flight planning with no reference to pre-defined waypoints.

Enabling aviation infrastructure

Communication, navigation and surveillance (CNS) systems are the building blocks on which ATM operates. Despite many activities in the CNS domain there remain a number of areas where more fundamental research is needed, which were covered by several of the selected projects. These areas included assessing technologies developed outside ATM to support CNS and more flexible system architectures for ground and airborne systems, building on integrated modular avionics and an open interface approach to ground system development.

ATM operations, architecture, performance and validation

Selected projects in this area looked at opportunities and limitations to trajectory-based operations; ATM architecture using novel approaches from systems analysis, architecture or complexity science; and tools to allow for the micro and macro modelling of performance in ATM, capable of capturing the interdependencies between different key performance Areas (KPAs).

Optimised ATM network operations

Selected projects in this area addressed the application of trajectory-based operations in support of demand and capacity balancing (DCB) functions, independent to any specific system architecture allowing the extension of such functions to a global context leading to a consistent and coherent trajectory management approach within and between regions

KNOWLEDGE TRANSFER NETWORK (KTN)

The Knowledge Transfer Network, Engage, focuses on the assessment, transfer, communication and sharing of research results among the ATM community. The challenge is to support and encourage collaborative research on future and emerging innovative ideas, expertise and knowledge for the benefit of the future evolution of the European ATM system and its people. The Knowledge Transfer Network also includes the organisation and running of four interdisciplinary thematic challenges based around key ATM research subjects and SESAR JU exploratory research projects with the aim to stimulate learning and the exchange of knowledge between academia, the research community and industrial partners. Introducing knowledge from other disciplines will encourage the exploration of innovative and unconventional ideas in ATM (see page 56 for more details).

GEOGRAPHICAL COVERAGE

The selected projects brought together of 100 academic and industry partners, such as universities, SMEs, research centres, airlines, manufacturers, air navigation service providers from across the European Union and EU Associated Countries (Switzerland, Norway, Iceland, Serbia, Israel, Turkey).

	Country	Count	
🇦🇹	AUSTRIA	4	● ● ● ●
🇧🇪	BELGIUM	7	● ● ● ● ● ● ●
🇨🇿	CZECH REPUBLIC	3	● ● ●
🇫🇮	FINLAND	2	● ●
🇫🇷	FRANCE	7	● ● ● ● ● ● ●
🇩🇪	GERMANY	9	● ● ● ● ● ● ● ● ●
🇬🇷	GREECE	1	●
🇭🇺	HUNGARY	1	●
🇮🇸	ICELAND	1	●
🇮🇪	IRELAND	1	●
🇮🇱	ISRAEL	1	●
🇮🇹	ITALY	15	● ● ● ● ● ● ● ● ● ● ● ● ● ● ●
🇱🇺	LUXEMBOURG	1	●
🇲🇹	MALTA	1	●
🇳🇴	NORWAY	2	● ●
🇵🇹	PORTUGAL	3	● ● ●
🇷🇸	REPUBLIC OF SERBIA	1	●
🇸🇰	SLOVAKIA	1	●
🇪🇸	SPAIN	18	● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ●
🇸🇪	SWEDEN	1	●
🇨🇭	SWITZERLAND	4	● ● ● ●
🇳🇱	THE NETHERLANDS	5	● ● ● ● ●
🇹🇷	TURKEY	2	● ●
🇬🇧	UK	8	● ● ● ● ● ● ● ●

ATM excellence science and outreach

AUTOMATION, ROBOTICS AND AUTONOMY

COMPLEXITY, DATA SCIENCE AND INFORMATION MANAGEMENT

ENVIRONMENT AND METEOROLOGY FOR ATM
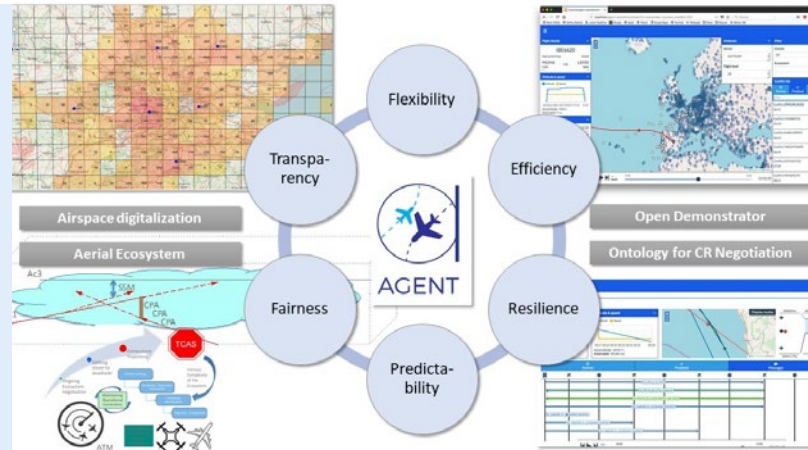
ECONOMICS, LEGAL AND REGULATION

AGENT

Improving conflict detection and avoidance

Adaptive self-governed aerial ecosystem by negotiated traffic – AGENT

Project Partners

ASLOGIC 2011

Cranfield University

Technische Universität Braunschweig

Universitat Autonoma de Barcelona (Coordinator)

Benefits

- Better conflict and collision avoidance resolution

- Increased situational awareness of forecasted collision

- Improved airspace capacity

- Maintained levels of safety

As the demand for air travel increases, so does the need to adapt the current traffic alert and collision avoidance system in order to preserve high levels of safety while improving airspace capacity and efficiency.

With this in mind, the AGENT project researched and developed a framework, proposing trajectory manoeuvres that take into account interdependencies between human behaviour, automation and aircraft performance.

The framework provides air traffic controllers and pilots with the means to deal with situations of conflict between planes by allowing them to choose the best solution when changing trajectories according to specific characteristics of each conflict. The framework is designed to be cooperative, as the proposed solutions factor in the interests of all parties involved.

The framework opens up the possibility of creating new connections between cities, increasing flight frequencies and avoiding fuel consumption due to unnecessary manoeuvres, which will in turn reduce emissions and fuel costs.

An open demonstrator has been implemented to validate the framework and allow scientific community to test their own tools. Results achieved in remotely-piloted aircraft systems (RPAS) missions confirms the potential benefits of AGENT framework in the configuration of U-space.

More information: www.sesarju.eu/projects/agent

Preparing the ATM workforce for an automated future

Facilitating the automation pace - AUTOPACE

Project Partners

Alma Mater Studiorum - Universita' di Bologna

Centro de Referencia Investigacion, Desarollo e Innovacion ATM (CRIDA) (Coordinator)

Universidad de Granada

Universidad Politecnica de Madrid

Univerzitet u Beogradu - Saobracajni fakultet

The progressive introduction of automation is changing ATM and in particular the way controllers work today. Controllers will focus on monitoring and supervising the system, with a minimum of tactical interventions. However, a challenge to automation is keeping the human in the loop, building trust and overcoming the fear of system failure.

AUTOPACE researched the skills and training strategies that will be necessary to address the challenges associated with automation and to enable controllers to do their job. The project first defined the most likely future operational scenarios in a 2050 timeframe for nominal and non-nominal situations. The project then developed a psychological model to better understand how human cognition and automation interact. With that the project was able to define a preliminary safety assessment detailing potential hazards for training strategies refinement.

The results of the project suggest that in the future, air traffic controllers should be offered not just technical training, but also psychological training covering: (a) cognitive training - to boost the use of appropriate cognitive processes to correctly monitor the system and (b) non-cognitive training – such as biofeedback to teach controllers to self-detect when their performance is decreasing and to react as needed.

The results of the AUTOPACE project are ready to be taken further into applied and industrial research.

More information: www.sesarju.eu/projects/autopace

> Automation is changing ATM and in particular the way controllers work today

> AUTOPACE proposes new controller training strategies to acquire not only technical competences but also psychological competences handling automated systems

Benefits

- Adapted training, equipping controllers with competences to work in automated environments

- Improved efficiency, by offering training of new competences in controlled simulation environments

- Enhanced safety

Keeping an eagle eye on automation

Mitigating negative impacts of monitoring high levels of automation - MINIMA

Project Partners

Alma Mater Studiorum - Universita' di Bologna

Deutsches Zentrum für Luft- und Raumfahrt (Coordinator)

Office national d'etudes et de recherches aerospatial (ONERA)

Benefits

- Improved interaction between controllers and automated system

- Increased levels of vigilance and situational awareness

- Improved safety and performance

Increasing automation in air traffic control is considered essential to improve the performance of Europe's air traffic management system. The challenge is to ensure that air traffic controllers remain in the loop to monitor effectively the system and step in when the task becomes too complex to handle for the automated system. However, experience in other domains shows that such a monitoring role can lower the attention span or results in a loss of situational awareness and skills.

With this in mind, the MINIMA project developed a vigilance and attention controller (VAC) tool using electroencephalography, which can measure in real-time controller vigilance and triggers adaptive automation functionalities when vigilance is waning.

The tool was tested by 15 controllers using two similar realistic scenarios: the first was a baseline scenario with the highest level of automation while the second scenario used the VAC tool to monitor and adapt the automation functionalities subject to vigilance levels. The VAC proved to successfully identify episodes of decreasing controller vigilance, and re-increase it through its adaptive automation system. The tool helped to introduce a level of interaction between the controllers and the system, making tasks more stimulating for the controllers.
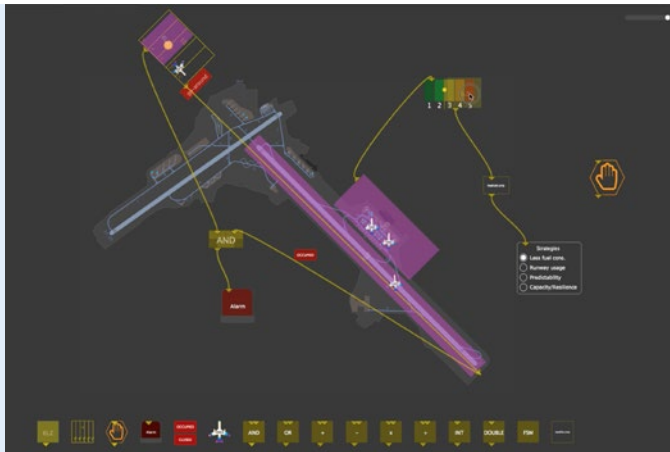
As a next step towards operational usability, researchers are looking at how to make the VAC more comfortable, easier to use and configure.

More information: www.sesarju.eu/projects/minima

Taking control of airport complexity

Take control - TaCo

Project Partners

Deep Blue (Coordinator)

Ecole Nationale de l'Aviation Civile
(ENAC)

Malta Air Traffic Services Limited
(MATS)

Airports are complex places, especially when it comes to managing the movements of civil and military aircraft and a myriad of service vehicles. It is not surprising then that SESAR members and partners have invested significant effort to research, develop and deliver a first set of automated tools to support controllers in managing airport surface movements.

The TaCo project took a fresh look at the challenge of complex surface operations especially in non-nominal conditions by exploring automation in other disciplines, such as robotics and gaming. Like air traffic control tools, video games such as real-time strategy games, use highly interactive graphics to enable gamers to manage the course of the game.

With these insights, TaCo partners developed a tool for guiding the controllers towards an optimised management of the movements of airport vehicles and aircraft: for example, it supports them in maximising the usage of the runway and minimising the global fuel consumption.

Moreover, the TaCo tool allows controllers to define the behaviour of alarms and automation through innovative user-programming techniques by using a domain specific graphic language. This tool can capture user requirments during the design phase of automation and has the potential to be applied to modify automation in real-time during operations.

The early results from TaCo indicate that automation strategies might be a valuable benefit in nominal circumstances even in airports that are not categorised as highly complex. In spite of the singularity of each airport, having a support tool that assists the controllers in achieving an optimised management of the movements is a transversal need that can be fulfilled by TaCo-like systems with no major changes in the concept.

More information: www.tacoproject.eu

Benefits
- Optimised management of airport surface operations
- Increased airport throughput
- Reduced fuel consumption

Taking the stress out of automation

Human performance neurometrics toolbox for highly automated systems design – STRESS

Project Partners

Anadolu University

Deep Blue (Coordinator)

ENAC

Eurocontrol

Universita' degli studi di Roma La Sapienza

Benefits

- Enhanced real-time assessment of the impact of automation on human performance
- Improved design of automation tools

STRESS examined the human performance issues, benefits and impacts of the shift towards increased automation. This refers to a new generation of air traffic control systems, expected to (partially) autonomously manage decision making and implementation tasks, currently carried out by air traffic controllers. The latter will still be responsible for running the system safely, but their role would be shifted from that of an active controller to one more like that of a monitor.

To tackle this topic, STRESS focused on the future human performance envelope (HPE) configuration. Based on the expected future controllers' role, STRESS chose vigilance, attention, mental workload, type of cognitive control on tasks and stress as relevant human factors to investigate, and developed neurophysiologic indicators for all of them. To study the impact of automation levels on the air traffic controllers' HPE, STRESS measured the neurophysiological signals of air traffic controllers' vigilance, attention, workload, stress and type of cognitive control during the execution of operational tasks, in a simulated air traffic control environment reproducing the complexity of future airspace scenarios and associated supporting technologies. As a result, the project provided automation design guidelines based on the HPE status.

The project delivered the following resources;

- Future ATC scenarios, including highly automated supporting technologies;

- A customised neurophysiological measurement toolbox for the future ATM, capable of monitoring the HP envelope in real time;

- Guidelines for the design of innovative technologies that are compatible with human capabilities and limitations.

The project's findings aim to provide insights into change management and the introduction of new systems. These insights aim to provide guidance not only for human performance assessment, but also for operational training design and delivery, as well as for the design of optimal competence profiles.

More information: www.stressproject.eu

Seeing the bigger picture

Passenger-centric big data sources for socio-economic and behavioural research in ATM - BigData4ATM

Project Partners

Agencia estatal consejo superior de investigaciones cientificas (CSIC)

Fraunhofer-Gesellschaft

Ingenieria de Sistemas para la Defensa de Espana (ISDEFE)

Nommon Solutions and Technologies (Coordinator)

The Hebrew University of Jerusalem

Universitat de les illes Balears

Air transport performance objectives and decision-making processes have often overlooked the passenger perspective, mainly due to the difficulties to collect accurate, updated and reliable data on passenger needs and behaviour. The BigData4ATM project investigated how new data sources coming from smart personal devices can be used to overcome this lack of information. The project objectives were to:

- Explore and characterise new emerging data sources potentially useful for ATM socioeconomic studies.

- Develop methodologies that integrate and analyse multiple sources of data to extract passengers' behavioural patterns.

- Develop theoretical models translating these behavioural patterns into relevant and actionable indicators.

- Evaluate the potential applications of the new data sources through a number of relevant case studies.

Passengers will benefit from a more efficient and predictable ATM system, enhancing the air transport experience

The use of big data sources from personal devices provides richer information about passenger behaviour at a reduced cost

Benefits

- Richer information on passenger behaviour

- Characterisation of door-to-door passenger journey

- Improved air traffic forecasts

- Better integration of air transport with other transport modes

- Enhanced coordination of airport landside and airside

- More efficient use of airport resources

The project successfully developed new approaches to characterise airport catchment areas, analyse the door-to-door passenger journey, and assess the impact of ATM disruptions on passenger behaviour. The insights gained from this information are expected to result in better integration of air transport with other transport modes, as well as in a more efficient coordination of airport landside and airside operations.

The project results show that new, unconventional data coming from smart personal devices open unprecedented opportunities for building a truly passenger-centric air transport system. Next steps will involve the application of the concepts and methodologies developed in BigData4ATM in one or more specific airports, which would work as a test environment to evaluate the benefits and practical implementation issues of the newly proposed solutions.

More information: www.bigdata4atm.eu

Trajectory prediction – letting the machine do the math

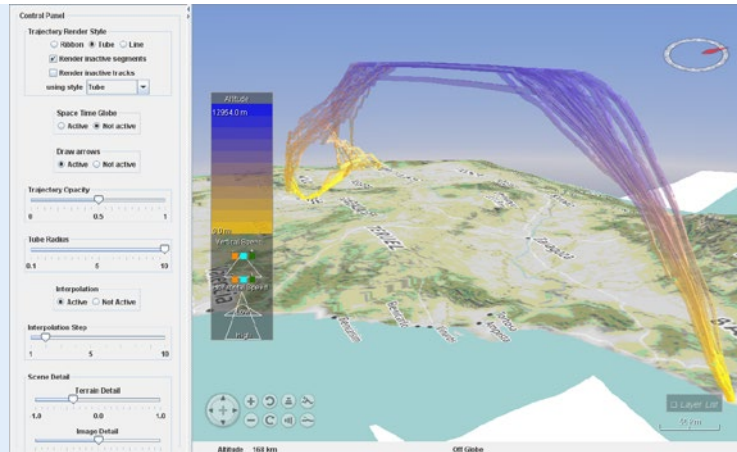Data driven aircraft trajectory prediction research - DART

Project Partners

Boeing Research and Technology Europe (BRTE)

CRIDA

Fraunhofer-Gesellschaft

University of Piraeus Research Center (Coordinator)

Benefits

- Increased predictability

- Reduced delays thanks to early resolution of DCB issues

- Advancing collaborative-decision making and planning tools

The complex ATM system worldwide has reached its limits in terms of predictability, efficiency and cost effectiveness. DART explored the potential of data-driven techniques for trajectory prediction, and agent-based modelling approaches for assessing the impact of traffic to individual trajectories, thus accounting for ATM complex phenomena.

> **DART delivered machine learning techniques to improve the accuracy of trajectory predictions, accounting for ATM network complexity effects**

Improvements with consequent benefits in these emerging areas of research can support the trajectory-based operations (TBO) paradigm.

The project focused on providing answers to the following major questions:

- What are the supporting data required for accurate trajectory predictions?

- What is the potential of machine learning algorithms to support high-fidelity aircraft trajectory prediction?

- How does the complex nature of the ATM system impact trajectory predictions?

- How can this insight be used to optimise the ATM system?

DART explored the potential of machine learning methods using historical data to increase the predictability for individual trajectories, and multi-agent collaborative reinforcement learning methods to resolve demand-capacity balancing (DCB) problems, supporting the incorporation of stakeholders' preferences into the planning process.

Results suggest that data-driven methods, compared to model-based approaches, can enhance trajectory prediction capabilities by exploiting patterns derived from historical data. In addition to that, agent-based methods can regulate flights effectively, reducing imposed delays, while resolving DCB problems.

> **DART shapes the future towards collaborative decision-making processes among the stakeholders in the ATM system**

The DART developments pave the way towards advanced collaborative decision-making processes that support multi-objective optimisation taking the requirements of the different stakeholders in the ATM system into account at the planning phase.

More information: http://dart-research.eu

Improving ATM efficiency through artificial intelligence

Machine learning of speech recognition models for controller assistance – MALORCA

Project Partners

Austro Control

Air Navigation Services
of the Czech Republic
(ANS CR)

Deutsches Zentrum für Luft- und
Raumfahrt (DLR) (Coordinator)

Fondation de l'Institut de Recherche
IDIAP

Universität des Saarlandes (USAAR)

Significant progress has been made in recent years in artificial intelligence (AI) and in particular in machine learning applications like automatic speech recognition (ASR). Thanks to these advances, new technologies are emerging in a variety of domains, including aviation.

Nowadays, instructions from air traffic control (ATC) to pilots are usually given via voice communication. Automatic speech recognition can be used to convert the spoken words into text and extract the relevant information. It therefore offers the means to avoid the manual input of given ATC commands. The MALORCA project is a natural follow-up of the following speech recognition projects:

- AcListant®, which combines ASR with a controller assistance system resulting in an assistant based speech recognizer (ABSR). Command recognition rates of 95% were achieved.

- AcListant®-Strips, based on AcListant® enables greater arrival throughput by reducing controllers' workolad for manual system input. Tested for Dusseldorf approach, the system allowed up to two more landings per hour.

However, there is a snitch in that these systems require manual adaptation for their deployment in new environments. To overcome this, the project designed a low-cost solution that adapts the speech recognition tools for use at other airports or approach areas. The solution automatically learns local acoustic and semantic patterns and controller models from radar and speech data recordings which are then automatically introduced into the ASR software.

The MALORCA project proposed to overcome the need for significant expert knowledge by employing novel machine learning algorithms that allow a semi-automatic adaptation of the initial basic ABSR system to a target-domain (i.e. Prague and Vienna approach).

The performance of the trained ABSR system was successfully evaluated by air traffic controllers in Vienna and Prague in January 2018. The next logical step is to bring the ABSR technology, continuously learning from daily-recorded data, into the ops room.

More information: www.malorca-project.de and www.aclistant.de

Benefits

- **Reduces command recognition error rates of the baseline system from 7.9% to under 0.6% for Prague approach and from 18.9% to 3.2% for Vienna approach**

Getting the "best" from data sharing

Achieving the benefits of SWIM by making smart use
of semantic technologies – BEST

Project Partners

Eurocontrol

Frequentis AG

Slot Consulting

SINTEF (Coordinator)

Universität Linz

Benefits

- Better understanding of the potential for using semantic technologies in ATM information management

- Enables filtering and distribution of information using meta-data

- Partial automation of (currently labour-intensive) compliance validation processes

- Automated modularisation, with potential benefits for governance

- Better understanding of scalability issues

SEMANTIC CONTAINERS: These can be combined with SWIM services to associate meta-data with ATM information, making it easier to find exactly the information required, and to automate its distribution and replication

OWL: short name for the web ontology language – a language for representing rich and complex knowledge about things as an ontology, in a form that be directly processed by computer software

Better and more accurate data exchange is critical for delivering high performance ATM and aviation worldwide. System-wide information management (SWIM) is a key enabler in this endeavour, providing the framework to allow seamless digital information sharing between the right stakeholders at the right time, no matter where they are located in the world.

However, the full benefits of SWIM can only be achieved if advanced support can be provided for developing smart SWIM-based applications that manage information effectively, and semantic technologies offer a promising way to do that. With this in mind, the BEST project investigated how semantic technologies can be used effectively to maximise the benefits of adopting SWIM.

Based ont several use cases, the project produced guidelines about how to use ontologies in flexible ways to describe meta-data, and how these can be used in innovative yet scalable ways. The project also demonstrated how the ATM information reference model (AIRM) and various data exchange models can be transformed into web ontology language (OWL) representations, allowing these models to be processed by semantic technologies.

The project produced tools to automate the transformation process, as well as compliance validation tools to automate consistency checking between different models. The project also developed a modularisation tool, allowing large and complex models (such as AIRM) to be automatically split into smaller, more manageable units.

More information: http://project-best.eu

Minimising the environmental impact of aviation

Air traffic management for environment - ATM4E

ATM4E

Project Partners

DLR (Coordinator)

Envisa

Technische Universität Hamburg

Technische Universiteit Delft

Manchester Metropolitan University

The University of Reading

With the increase in traffic in Europe, stakeholders are looking for ways to reduce the environmental impact of aviation, taking into account climate impact, air quality and noise issues simultaneously. However, comprehensive assessments with data on all three environmental aspects are not available for flight planning.

To address the situation, the ATM4E project developed a methodology to integrate multi environmental criteria into impact assessments done during the flight planning process. The method expands a concept developed for climate optimisation of aircraft trajectories, by introducing air quality and noise impact as additional criteria or dimensions, together with the climate impact of aircraft trajectory (CO_2 and non-CO_2 emissions).

The project also developed algorithms to determine environmental impacts based on meteorological information available through the system-wide information management (SWIM). Results showed that depending on the prevailing weather situation, high resolution environmental information provided as part of the MET service could enable the optimisation of aircraft trajectories with the potential to reduce the climate impact by around 20% for specific routes.

The results suggest that identifying those routes with a large reduction potential enables aviation to improve considerably its environmental performance.

More information: www.atm4e.eu

> Assessing environmental impact of aviation during flight planning is a prerequisite for environmental optimisation of aircraft operations

> Climate optimisation could lead to climate impact reduction of more than 20% with 1% fuel penalty

Benefits
- Improved environmental information
- Improved air quality
- Better environmental performance

Weathering the weather at airports

Probabilistic Nowcasting of Winter Weather for Airports - PNOWWA

PNOWWA
Probabilistic Nowcasting of Winter Weather for Airports

Project Partners

Austro Control

DLR

Finnish Meteorological Institute (FMI) (Coordinator)

Benefits

- Increased airport capacity (e.g. fewer delays, better ATM preparedness)

- Improved safety

- More efficient use of ATM resources

Adverse weather conditions can play havoc with airport operations, limiting or putting a stop to aircraft movements, runway maintenance, de-icing, tower control and even luggage handling. Having accurate meteorological data and forecasts means that airport operators can prepare for the worst in advance. But weather can change in a matter of hours. That is why partners in the PNOWWA project are turning to nowcasting, very short-term (0-3h) probabilistic winter weather forecasts with a 15-minute-time resolution.

The use of probabilistic forecasts in ATM are to support timely operations in surface management and ATM decision making, thereby increasing airport capacity, reducing delays and promoting safety

Focusing on snow, the partners extrapolated weather movements based on radar echoes and predictability of changes in snowfall intensity caused by underlying terrain (such as mountains and seas). Within these nowcasts, the projects provided information on the probability of a wide range of events, such as runways freezing over or decreased visibility. Over the course of the winter of 2017, the project partners demonstrated their model in Austria and Finland, allowing them to gather airport feedback on the applicability of the model and its scalability to other airports.

These results enable the quantification of the uncertainties related to delays in ground operations due to winter weather situations. When applied to ATM applications, the PNOWWA method will enhance timely operations in surface management and ATM decision making, thereby increasing airport capacity, reducing delays and promoting safety.

More information: http://pnowwa.fmi.fi

Mastering meterological uncertainty in aviation

Meteorological uncertainty management for trajectory-based operations – TBO-Met

Project Partners

Agencia Estatal de Meteorologia

MeteoSolutions

Paris-Lodron-Universität Salzburg

Universidad Carlos III de Madrid

Universidad de Sevilla (Coordinator)

A better understanding of the factors that lead to uncertainty in air traffic is key when planning, executing, monitoring and synchronising trajectories between ground systems and aircraft. Having more accurate trajectories that factor in uncertainty can in turn increase the predictability of traffic, which has knock on benefits such as increased capacity, improved efficiency and reduced environmental impact.

To this end, the TBO-Met project focused on three research topics: trajectory planning, storm avoidance, and sector demand analysis, considering meteorological forecast uncertainties.The weather forecasts were obtained from ensemble prediction systems and nowcasts, which provide information about wind uncertainty and convective zones (including individual storm cells).

To address mid-term trajectory planning, the project developed a stochastic optimisation approach to plan the most efficient trajectories with low levels of uncertainty. The methodology is capable of trading-off predictability and cost efficiency (flight time or fuel consumption). To address storm avoidance, the project developed a probabilistic trajectory predictor, which proactively proposes possible deviations in order to avoid stormy conditions. As for addressing sector demand, the project defined a methodology to provide a probabilistic sector demand based on the uncertainty of the individual trajectories. The approach is able to quantify the impact of improved trajectory planning considering weather forecast uncertainty on sector demand.

The overall conclusion of the project is that ATM efficiency can be enhanced by integrating weather forecast uncertainty.

More information: https://tbomet-h2020.com

When meteorological uncertainty is taken into account, the results show that:

- the predictability of aircraft trajectories can be increased

- storm avoidance can be better anticipated

- the prediction of sector demand can be improved

Benefits
- Reduction of airlines' buffer times
- Better-informed decision making
- Increase of declared sector capacities
- Better identification of demand-capacity balancing measures
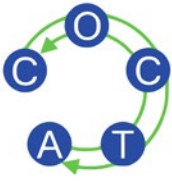
Flexible and efficient ATM service provision in Europe

Coordinated capacity ordering and trajectory pricing for better-performing ATM - COCTA

Project Partners

Hochschule Worms

University of Warwick

Univerzitet u Beogradu - Saobracajni fakultet (Coordinator)

Benefits

- More efficient provision of air navigation services

- Increased choice for airspace users

- Incentives for reduced CO_2 emissions

Air navigation service providers (ANSPs) have to decide on their capacity provision for a particular day of operation several weeks or even months in advance, whereas airspace users need flexibility in flight planning and prefer to make their route choice decisions at shorter notice. This contributes to a mismatch between planned capacity and actual demand in the European ATM system.

To tackle this problem, the COCTA project developed an innovative conceptual framework to improve efficiency of air navigation service provision in Europe by a better coordination of capacity and demand management:

On the capacity side, the Network Manager asks for airspace capacities in line with expected demand, employing a network-centred, demand-driven approach, as opposed to the current, largely supply-driven and piecemeal practice, with predominantly local (ANSP) perspectives.

Network-oriented capacity planning improves the overall cost efficiency of ATM in Europe

Innovative trajectory products/options enable airspace users to prioritise flights within the network in a fair and transparent manner

On the demand side, the Network Manager offers different trajectory options to the airspace users, including novel concepts of flexible trajectories. One option is for an airspace user to pay less in exchange for granting the Network Manager some flexibility to move the flight with pre-determined spatial and temporal margins. Another option allows airspace users to decide on a flight trajectory within certain margins shortly prior to departure and for a premium. These trajectory options or products are tailored to capture the different business and operational needs of airspace users, thereby contributing to an optimised network performance.

The project studied the potential improvements achievable through the proposed framework, as well as trade-offs between the different key performance indicators (KPIs) in a large-scale case study. According to initial results, the framework could accommodate the same traffic volume with significantly reduced capacity and dramatically reduced cumulative delay in the network.

More information: www.cocta-project.eu

An appetite to compete

Competition for Air Traffic Management - COMPAIR

Project Partners

Nommon Solutions and Technologies

Slot Consulting

The Hebrew University of Jerusalem

Transport & Mobility Leuven (Coordinator)

Europe is a patchwork of markets in ATM service provision. The question is: which market structure is most favourable to increasing the performance of ATM, including airports? The answer is a complex one that partners in the COMPAIR project addressed. Partners in the project looked at a number of options that could increase competition, including performance regulation with variations in ownership and governance models, tender of licenses for en-route air traffic services, and flight centric, sector-less operations. The project also analysed the effects of unbundling the terminal control in Sweden, UK, Spain and Germany (at mostly regional airports).

> ATM providers competing on a per-flight basis (from origin to destination) or per-airline, rather than per geographical zone could lead to a significant reduction in costs and requires advanced technology development

The models applied by the project suggest that introducing competition in the market via outsourcing service provision may lead to a reduction in charges by up to half the current levels. It also showed that open tendering is likely to lead to a defragmentation of the system as companies tend to win more than one tender. The results suggest that with these options a maximum allowed market share of 40% can ensure sufficient competition. Competition of this nature will determine the uptake of new technologies and enable a high performing ATM system.

More information: www.compair-project.eu

Benefits
- Increased efficiency of service provision
- Increased technology uptake
- Decreased fragmentation for some of the considered scenarios

Vista

Evaluating trade-offs in air traffic management

Market forces trade-offs impacting European ATM performance - Vista

Project Partners

Belgocontrol

Eurocontrol

Fundacion Instituto de Investigacion Innaxis

Icelandair

Norwegian Air Shuttle

Swiss International Air Lines

University of Westminster (Coordinator)
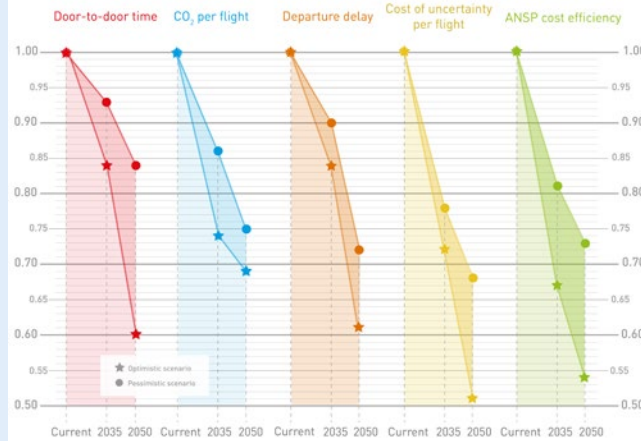
Benefits

- Flexible, modular 'what-if' simulator

- Demonstrated KPA synergies & conflicts

- Supported policy evaluation & target setting

- Current, 2035 & 2050 scenarios

What are the main trade-offs in air traffic management between the various key performance areas? The Vista project examined the effects of market forces (e.g. fuel prices, economic development), technologies and regulatory factors on European performance in ATM, through the evaluation of stakeholder and environmental indicators. Trade-offs were assessed and visualised within and between periods, and between stakeholders.

The tool evaluated indicators for airspace users, passengers, airports, air navigation service providers and the environment

New indicators were evaluated, such as door-to-door travel times, tactical costs of uncertainty incurred by airspace users, NO_x emissions, delay costs and reactionary effects

Vista models current and future timeframes, based on the evolution of these effects. The Vista model is holistic since it covers the three phases of ATM - strategic, pre-tactical and tactical. It captures a typical, busy day of operations. The model was able to estimate the impact of the above-mentioned factors on these different ATM phases independently and/or as a coupled system, providing a unique assessment of how indicators change in different scenarios and execution phases.

The model may readily be extended to support decision-making and network analysis. Furthermore, the tool may be used to simulate and assess long-term traffic and capacity projections.

More information: www.vista-eu.com

ATM application oriented research

HIGH-PERFORMING AIRPORT OPERATIONS

ADVANCED AIR TRAFFIC SERVICES

ENABLING AVIATION INFRASTRUCTURE

ATM OPERATIONS, ARCHITECTURE, PERFORMANCE AND VALIDATION

OPTIMISED ATM NETWORK SERVICES

A fully immersive airport tower experience

The embodied remote tower - MOTO

Project Partners

Deep Blue (Coordinator)

ENAC

Rijksuniversiteit Groningen

Universita' degli studi di Roma La Sapienza

Benefits

- Multimodal platform for VR simulation of tower operations to validate future augmented remote tower concept

- Neuro-physiological classifiers to monitor the sense of presence and human performance in remote towers

- Prototypes of augmented multimodal solutions to support remote tower operations

Europe is experiencing rapid growth in the number of remote control tower deployment projects in recent years. With advances in camera, sensor and infrared technology, controllers are given a realistic "out-of-the-window" view of the remotely-located airport allowing remote provision of all tower services. SESAR researchers are now investigating how to make this virtual experience even more immersive by exploiting controllers' senses in addition to their visual sight.

The project explored the introduction of multimodal stimuli (auditory and vibro-tactile), designing dedicated augmented prototypes aimed at supporting controllers performance in remote tower operations. Partners measured the impact of these stimuli, in terms of workload, performance, sense of presence and situational awareness.

Initial outcomes suggest that spatialised audio information may support controllers shifting attention towards potentially critical events, improving performance but, at the same time, requiring more resources (higher workload). Additional human-in-the-loop studies are recommended to further explore the obtained results in a wider range of operative scenarios.

The project also explored the advantages in the use of virtual reality and head mounted display (HMD) technologies to validate the impact of multimodal stimuli in remote tower operations. These advantages deriving from these technologies can also offer benefits for exploration of innovative ATM concepts and scenarios for future training activities.

More information: www.moto-project.eu

Keeping an augmented eye on air traffic control

Resilient synthetic vision for advanced control tower air navigation service provision - RETINA

Project Partners

Alma Mater Studiorum
Universita' di Bologna (Coordinator)

CRIDA

Consorzio SICTA - Sistemi Innovativi
per il Controllo del Traffico Aereo

ENAV

Eurocontrol

Luciad

Controllers in airport towers rely on being able to see aircraft taxying, taking off and landing in order to manage them safely and efficiently. But when bad weather sets in, their visual situational awareness can be impaired, leading to a reduction in throughput. The results from the RETINA project are showing the promise that augmented reality holds for enhancing air traffic control operations, particularly in low-visibility conditions.

As trust in digital data grows RETINA's concept will allow the controller to have a heads-up view of the airport traffic even in low visibility conditions similar to the synthetic vision currently used in the cockpit

Benefits

- Improved situational awareness for controllers

- Increased airport capacity and throughput

- Improved flight punctuality and reduced emissions

Using synthetic vision and augmented reality technologies, RETINA has developed a set of goggles through which controllers can see synthetic information overlaid on the actual "out-of-the-window" view. With these goggles, the controller can have a heads-up view of the airport traffic, call sign and aircraft type, supplemented by additional information, such as wind velocity and direction, airport layout and runway status, even during low-visibility procedures.

RETINA builds upon SESAR technologies, such as remote tower, safety nets, SWIM, to provide augment reality tools for the tower controller

From a technological perspective, RETINA investigated two different augmented reality systems: conformal head-up displays (to coincide with the tower windows) and see-through head-mounted displays.

For each augmented reality system, a proof-of-concept was implemented and validated in a laboratory environment by means of human-in-the loop real-time simulations where the external view was provided to the user through a high fidelity 4D model in an immersive environment that replicated the out-of-the tower view.

During the validation, both subjective qualitative information and objective quantitative data were collected and analysed to assess the RETINA concept. The results showed that the RETINA concept is a promising solution to improve the human performance in the control tower, increasing resiliency at airports to low visibility and preserving safety.

More information: www.retina-atm.eu

COPTRA

Improving trajectory prediction through understanding uncertainty

Combining probable trajectories – COPTRA

Project Partners
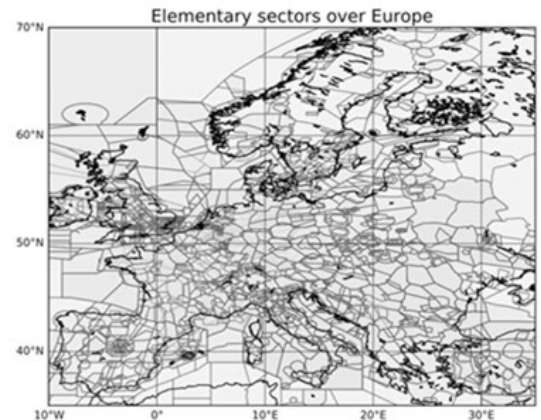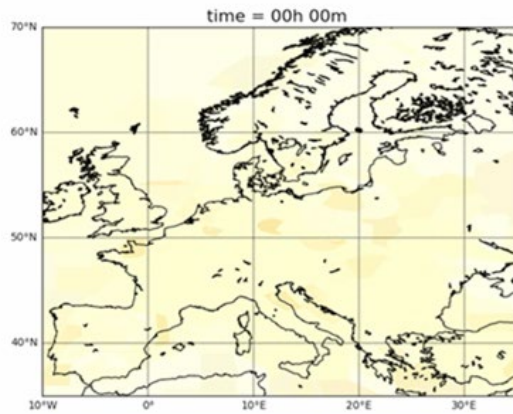
Boeing Research & Technology Europe (BRTE)

CRIDA (Coordinator)

Eurocontrol

Istanbul Teknik Universitesi

Universite Catholique de Louvain

time = 00h 00m

Elementary sectors over Europe

Benefits

- Visualisation of uncertainty

- More accurate and stable demand prediction

- Quantitative understanding of delay propagation dynamics in space and time

ATM is gradually moving towards the notion of allowing aircraft to fly their preferred trajectory, otherwise known as trajectory-based operations. One of the challenges related to the implementation of TBO is the ability to identify, model and manage the uncertainty associated to a trajectory.

> The work performed in COPTRA to model uncertainty, allows us to be certain of our uncertainty

The integration of the uncertainty models in the planning systems improves the trajectory predictions and supports the assessment of the feasibility of integrating the models into existing demand and capacity balancing (DCB) tools. The COPTRA project researched three areas related to uncertainty modelling:

- Defining and assessing probabilistic trajectories in a TBO environment;

- Combining probabilistic trajectories to build probabilistic traffic prediction;

- Applying probabilistic traffic prediction to air traffic control planning.

> Key to enabling TBO is the ability to deal with the numerous sources of uncertainties inherent in ATM

COPTRA showed that in addition to quantifying uncertainty through data analytics, it is possible to limit it through model-driven state estimation techniques. This enables not only to include flight intent or initial condition uncertainties but also to take into account model uncertainties.

COPTRA's models provide us with a clear quantitative understanding of delay propagation dynamics in space and time. The project results provide insight into how to achieve more efficient ATM operations in the future.

More information: www.sesarju.eu/projects/coptra

Generating user-preferred trajectories

An optimisation framework for trajectory based operations - OptiFrame

OptiFrame

Project Partners

Consorzio Futuro in Ricerca (CFR)

Eurocontrol

Lancaster University (Coordinator)

Netherlands Aerospace Centre (NLR)

The trajectory-based operations (TBO) concept is a cornerstone of the future ATM system. The OptiFrame project developed an optimisation framework for TBO, which assigns 4D trajectories to flights based on stakeholders' preferences and priorities. In other words, the OptiFrame approach incorporates the preferences and priorities of stakeholders in the design of the 4D trajectories.

These preferences were modelled by means of a multi-objective optimisation mathematical model that provides the capability of identifying the trade-offs between flight departure delays, flight efficiency, and flight route charges. In addition to visualising the listed trade-offs, the proposed approach offers the capability to analyse solutions at a microscopic level. Indeed, the project also looked in detail at alternative solutions , such as attributing values to the identified key performance indicators (KPI) for each airspace user and/or visualising the 4D trajectory as well as the values of the identified KPIs for each flight.

The framework includes preferences and priorities for TBO, enabling trade-off analysis among KPIs

The project's proposed approach raises the need for collaborative decision-making process that ensures convergence by all stakeholders towards a commonly-agreed solution.

More information: wp.lancs.ac.uk/optiframe

Benefits
- Better understanding of the trade-offs between departure delay, flight efficiency, and flight route charges

Partaking in better decison making in aviation

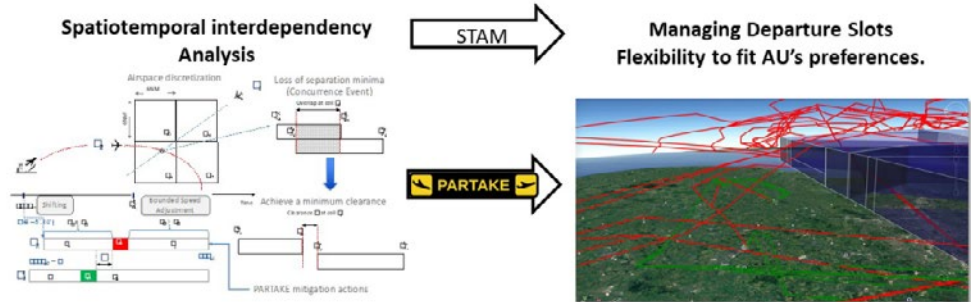## Cooperative departures for competitive ATM network service - PARTAKE

Project Partners

ASLOGIC 2011

Cranfield University

ENAC

Universitat Autonoma
de Barcelona (Coordinator)

Benefits

- Short-term ATFCM measures

- Advanced ATM Metrics

- Measurable hotspot detection

- ATM digitalisation

- Integration of micro and macro level dynamics

- Mitigation of downstream effects

- Multi-stakeholder transparency

Despite the availabilty of a huge amount of (real-time and forecast) data about airports, aircraft, airspace, no tools exist today that can analyze time-space interdependencies between these elements. The PARTAKE project has developed a decision support system to prioritise the departure of aircraft, taking into account information from the airport (on taxiways and runways status), as well as from the airspace users on their preferences and the aircraft, including its trajectory. With this data, the system can identify areas of airspace where the demand is higher than capacity. In doing so, action can be taken to delay departures or expand the separation between aircraft in congested traffic areas. More specifically, the research paves the way for new innovations in several areas:

- Advanced tactical capacity management: Design of new operational metrics to predict traffic behaviour and implement more efficient resources allocation mechanisms.

- Dynamic capacity balancing (DCB): A short-term ATFCM measures (STAM) fine tuning algorithm to compute the departure time without affecting the ATFCM pre-flight assignments.

- Optimised airspace user operations: Analysis of available airspace to fit with a new conflict free trajectory considering both: aircraft on the ground waiting for clearance and aircraft in flight.

The project tested the tool using traffic data (air and ground) from London's terminal manoeuvring area. It showed the tool helped to minimise the number of conflicts and the need for tactical capacity management measures. With that, the tool has the potential to improve punctuality while lowering fuel consumption and emissions.

More information: www.sesarju.eu/projects/partake

Optimising airspace through dynamic use of wake vortex

Wake vortex simulation and analysis to enhance en-route separation management in Europe - R-WAKE

Project Partners

A-Syst

Deep Blue

GTD sistemas de informacion (Coordinator)

M3 systems Belgium

Technische Universität Braunschweig

Universitat Politecnica de Catalunya

The R-WAKE project addressed the risk and safety study of the wake vortex encounter (WVE) hazards in en-route airspace, and the identification of potential enhancements to the current separation schemes. The aim is to enable traffic and trajectory management improvements, and expected benefits in safety, airspace capacity, and flight efficiency of the European ATM system. Applying a simulation-based approach, the project delivered five tangible results:

• An ATM simulator that includes high-fidelity WVE dynamic risk models, referred to as R-WAKE System, tailored to support the project research approach.

• A WVE hazard severity baseline, defined as a matrix of upset parameters thresholds per severity class, developed and assessed with contributions of experienced pilots and air traffic controllers.

• A public database of simulation results, which constitutes an evidence body to support new separation scheme proposals, containing the upset and severity class computed for a large number of encounter scenarios, involving different aircraft types, geometries, separations, and weather conditions.

• The R-WAKE-1 concept proposal, which consists of six new separation schemes designed to increase safety against WVE hazards and also airspace capacity, looking at the minimum wake separation in the three dimensions: lateral, vertical, longitudinal, and also combined lateral-vertical, and wind-dependent dynamic separations.

• A feasibility and impact assessment of the concept, concluding that there is enough justification for proposing R-WAKE-1 as a new SESAR Solution, as a first step in a roadmap of identified incremental evolutions towards a long-term R-WAKE concept for optimising en-route separation minima provision.

More information: www.rwake-sesar2020.eu

Benefits
■ Increased safety

■ Optimised airspace capacity

■ Increased flight efficiency

Total precision surveillance

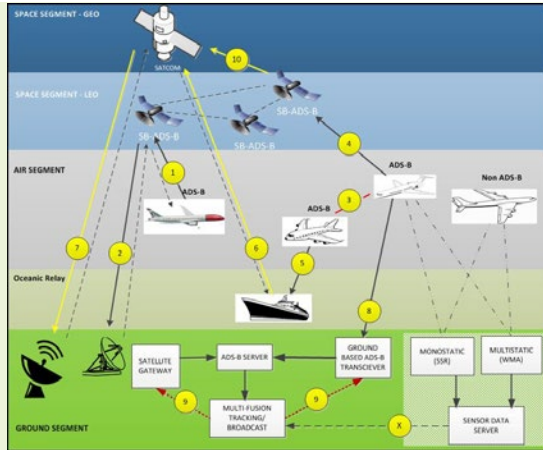Satellite ADS-B for lower separation minima application – SALSA

Project Partners

Airbus Defence and Space (Coordinator)

DLR

NAV Portugal

Redu space services

Benefits

- Improved safety
- Increased airpsace capacity
- Increased flight efficiency

Developed as a viable low-cost alternative to conventional radar, space-based automatic dependent surveillance-broadcast (ADS-B) can monitor and control aircraft with greater precision and in areas of airspace that have no radar coverage today. Because of its high precision capabilities, ADS-B has the potential to maximise airspace through the reduction of separation between aircraft.

The SALSA project evaluated the performance and value of ADS-B in the context of enhanced surveillance and revision to separation standards in the non-radar airspace. Specifically, the project looked at what conditions required for the introduction of lower separation minima on transoceanic flight routes, particularly between Europe and the US, where traffic density is considerably high during morning and evening peak periods.

By combining space-based ADS-B with other sources of surveillance based on ground, air and oceanic relays, SALSA developed a system-of-systems approach. It found that space ADS-B when augmented with the enhanced controller-pilot data links can maximise the use of enhanced surveillance and the operational benefit of revised separation minima.

The project provided recommendations on satellite-based air traffic surveillance using ADS-B and its application to reduced separation minima which could be used as the basis for further developments and eventual later certification.

More information: www.airbus.com/salsa.html

**Key recommendations include further study into the:**

- Maturity/viability assessment of space ADS-B, including the service availability monitoring

- Impact of CPDLC availability and recommendations

- Impact of navigational and surveillance integrity and recommendations

- Maturing validation models – collision risk, prediction, operator interfaces

Affordable surface movement surveillance for medium and small airfields

Enhanced situational awareness through video integration with ADS-B surveillance infrastructure on airports - ENVISION

ENVISION
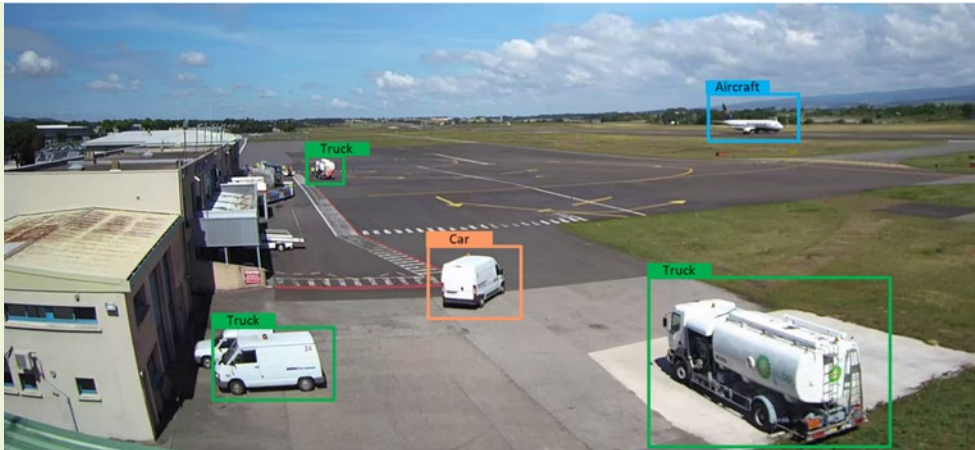
Project Partners

ALTYS Technologies (Coordinator)

ENAC

Eurocontrol

Graffica

Most of the world's largest airports have implemented advanced surface movement guidance and control system (A-SMGCS) functions along with the deployment of multilateration (MLAT) and surface movement radar (SMR) over the past decade. Secondary airfields experience similar pressure to increase capacity and safety, however surface surveillance systems used in air traffic management remain out of their reach because of prohibitive infrastructure costs. There is a need for gap-filler solutions in the near term in addition to longer term alternatives for these airfields.

The ENVISION consortium worked on the assessment of affordable sensor alternatives to SMR and MLAT for small to medium airfields including video cameras, light detection and ranging (LiDAR) and automatic dependent surveillance-broadcast (ADS-B).

The project explored in particular the potential of artificial intelligence (AI) and deep learning methods to detect and recognise non-cooperative targets operating on the airfield using video generated by closed circuit television cameras used for security purposes. The system performances were tested against equivalent A-SMGCS standards at two airfields: Muret, a general aviation airfield near Toulouse; and the regional airport of Carcassonne. After nearly two years' research, ENVISION demonstrated the ability to:

- Detect, recognise and track targets up to 500 metres from the camera,

- inject tracking plots into the airport tower controller working position using standard ASTERIX format, and

- automatically detecting airport collaborative decision-making (A-CDM) milestone events such as ten miles out, or actual off/in block times.

Further research is needed on complementary sensors to improve system accuracy, as well as situational awareness in low visibility conditions.

More information: http://www.envision-s2020.eu

> Artificial intelligence and deep learning methods applied in the field of video analytics proved effective in the detection, recognition and tracking of aircraft and vehicles operating on the airfield

> - Affordable video sensors can provide surface surveillance up to 500 metres at 109°
> - LiDAR provides cost-effective surface surveillance up to 100 metres at 360°

Benefits:
- Enhances controllers' and airport operator situational awareness
- Enhances safety of airport surface operations
- Enables higher automation levels in surface operations
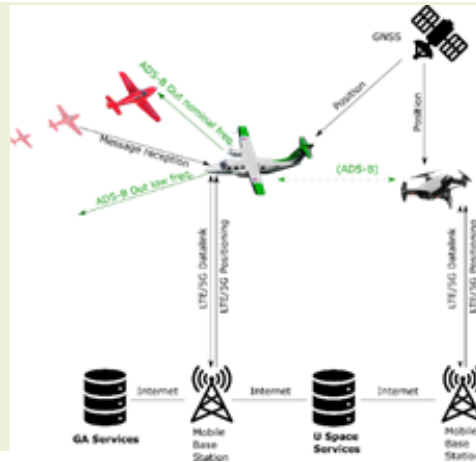- Improves operational efficiency and network throughput

Exploiting reliable and affordable communications in low level airspace

Empowering heterogeneous aviation through cellular signals - EMPHASIS

EMPHASIS

Project Partners

Airbus

Evektor-Aerotechnik

Honeywell (Coordinator)

Tampere University of Technology

Benefits:

- Improved safety
- Airspace access for all users
- Interoperability with commercial aviation and new users
- Improved information sharing

All airspace users in shared airspace need to avoid collisions, navigate safely and stay visible regardless of their size and function. Whether a drone, rotorcraft or general aviation, all users depend upon reliable communications, navigation and surveillance infrastructure to operate safely. The EMPHASIS project examined the safety and reliability of these enablers at low altitude and looked at existing and future mobile radio frequency networks as well as interoperability between airspace users.

Enhanced connectivity enabling access to ground services (including U-space), robust navigation in urban environment, and interoperability among a variety of airspace users are key objectives of EMPHASIS

The project simulated 4G and 5G cellular network communication channels and reviewed affordable surveillance systems. EMPHASIS concluded that 4G technology is technically capable of supporting low altitude operations, provided efficient interference mitigation techniques are in place. Future 5G networks offer further flexibility and possibilities especially when centimetre Wave (cmWave) channels are complemented with millimetre Wave (mmWave) links. In an urban environment, simulations showed that 4G positioning reference signals can technically deliver (in areas with dense 4G infrastructure) a range positioning accuracy comparable to satellite-based navigation and can thus mitigate its limitations in this environment.

4G/5G technologies have potential to offer affordable data link and positioning information in low altitude airspace

The project proposed, prototyped, and demonstrated a low-power Automatic Dependent Surveillance – Broadcast (ADS-B) Out concept for general aviation and rotorcraft, and showed this to be an efficient way to enhance interoperability with other aircraft without undue impact on 1090 MHz spectrum. Costs are also kept affordable by means of an innovative approach to certification.

Affordable low power ADS-B Out transceivers for general aviation can strongly enhance operational safety and interoperability with other airspace users

More Information: https://aerospace.honeywell.com/en/pages/emphasis-project

Preventing accidental and deliberate radio interference to satellite navigation signals

GNSS navigation threats management - GATEMAN
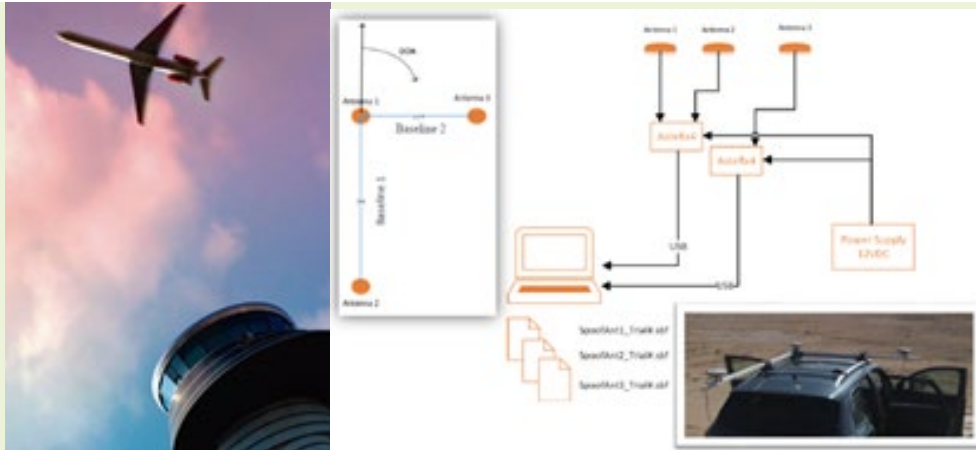
Project Partners

GMV Innovating Solutions (Coordinator)

Istituto Superiore Mario Boella (ISMB)

Tampere University of Technology

Global Navigation Satellite System (GNSS), such as the Galileo constellation, will become the primary means of aircraft navigation in the mid and long term. However, GNSS signals are vulnerable to threats, especially to jamming and spoofing, which may cause the total loss of navigation. These radio frequency interferences (RFI) can occur accidentally or intentionally. The GATEMAN project defined and evaluated the technical feasibility of a new concept to manage GNSS interferences on-board the aircraft, or in collaboration with other measures. It also considered how 5G might provide a cost-effective alternative if GNSS-based approaches are unavailable.

GATEMAN evaluated how the interference affecting airspace users can be mitigated, and validated this in a series of laboratory and open-field tests. Specifically, it addressed:

- The detection and localisation of GNSS jamming and spoofing using existing aircraft antennas with upgrades at software level;

- Mitigation of GNSS spoofing at signal-processing level using software algorithms to manage GNSS threats; and

- Alternative positioning technology based on 5G to support navigation during GNSS jamming events.

The research was carried out in the laboratory using software simulation with hardware-in-the-loop; and in open-field tests using a direction finder demonstrator mounted on a vehicle to localise jamming or spoofing interference signals.

The results show that direction finding is feasible with only three omnidirectional antennas, but the open-field results with the demonstrator called for greater accuracy of localisation.

The spoofing mitigation algorithm defined and evaluated in GATEMAN provided promising results, completely removing the GNSS spoofed signal in a wide range of scenarios.

More Information: http://gateman.gmv.com/

Benefits:

- **Detection of GNSS spoofing mitigates positioning integrity events**

- **Interference localisation on-board enables early deactivation of the interferer**

- **Using conventional GNSS antennas (also used for navigation) minimises hardware costs**

Spoofing mitigation removes the counterfeit signal, enabling safe navigation with the true GNSS signal

A low-cost navigation solution for small aircraft

Navigation of airborne vehicle with integrated space and atomic signals - NAVISAS

Project Partners

Centre Suisse d'electronique et de microtechnique SA - recherche et development (CSEM)

Shark.Aero

Tekever ASDS (Coordinator)

Thales Alenia Space Italia

Benefits

- Maintained and improved navigational capabilities
- Low-cost alternative to existing back-up systems

Airspace is a finite resource subject to mounting demand by all types of vehicles (commercial jets, military, small aircraft, helicopters, balloons and drones). Increasingly ATM stakeholders are looking towards satellite-navigation systems to manage the traffic more efficiently. However, these systems can fail like any other so a back-up is always needed.

The NAVISAS project developed a concept for small aircraft to obtain alternative positioning, navigation and timing (A-PNT) information when satellite navigation fails while keeping performance and efficiency consistent with the airspace requirements. NAVISAS investigated the possibility of combining navigation data from multiple constellations (e.g. Galileo and GPS) with an advanced inertial measurement unit (IMU) based on atomic gyroscopes implemented using microelectromechanical systems (MEMS) technology. The project scope was extended and included an assessment of vision-based navigation in flight, which was confirmed as a viable option for small aircraft.

> This low-cost navigational tool can serve as a backup to when an aircraft's satellite navigational capabilities are lost.
> It can also serve as a main navigation tool, for instance in specific drone operations

The results of NAVISAS could pave the way for a new cost-effective instrument that can be used by small aircraft to ensure navigation performance levels consistent with evolving airspace and air traffic. Atomic gyroscopes may become a technological enabler of future high-grade and low-cost inertial reference systems, hence opening high performance inertial system market to lower-end aircraft. The results of this project also suggest that these systems would offer a substantially lower cost alternative to grade laser gyros currently used by commercial aviation.

> Vision-based navigation could provide a low-cost APNT capability in the event of a satellite outage

The project also provided a roadmap on how this concept can be further matured, deployed and adapted to other aircraft beyond small aircraft in operations under visual flight rules (VFR) and instrument flight rules (IFR).
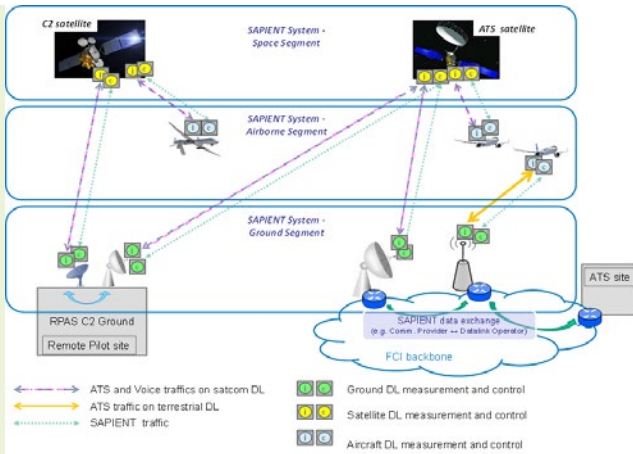
More information: https://navisas.tekever.com

A "disruptive" approach to air traffic management

Satellite and terrestrial architectures improving performance, security and safety in ATM - SAPIENT

Project Partners

Business Integration Partners

Frequentis

SITA Information Networking Computing

Thales Alenia Space Italia (Coordinator)

Universita' di Pisa

ViaSat Antenna systems

A better connection between the aircraft and ground systems in ATM is seen as the key that will unlock greater efficiency in our skies. The SAPIENT project looked at innovative applications in communications, navigation, surveillance (CNS), focusing on improvements to air-ground datalinks. It also looked at how to incorporate remotely piloted aircraft systems (RPAS) flying beyond line of sight missions.

Greater operational and cost efficiency is expected since the solution will reduce the need for voice communications as well as lower the use of spectrum

Benefits

- Improved predictability of data link performance

- Decreased level of air-ground communication issues

- Improved efficiency of ATM services delivery

The research looked at the integration of 4D trajectory estimates with data obtained through the dynamic and accurate monitoring and measuring of the performance of air-ground datalink communications between the aircraft transceivers and ground infrastructure.

The SAPIENT solution provides a new innovative communication application in the field of the future CNS/ATM system

The concept enables air and ground datalink equipment to monitor, process and exchange communication performance along a flight path, in order to confirm data link settings or report any possible anomalies that need to be managed in advance.

Taking a holistic view of ATM performance

Assessment of performance in current ATM operations and of new concepts of operations for its holistic enhancement - APACHE

Project Partners

Advanced Logistics Group

ENAC

Universitat Politecnica de Catalunya (Coordinator)

Univerzitet u Beogradu - Saobracajni fakultet (FTTE)

Benefits

- Better performance indicators

- Improved understanding of performance trade-offs and theoretical limits

- Initial assessment of new ATM concepts and historical analysis.

ATM is progressively transitioning to a performance based system. Yet, properly assessing ATM performance and conveniently capturing trade-offs among key performance areas (KPAs) still present some research challenges for the ATM community. In this context, APACHE addressed three main research needs:

- Some of the current performance indicators (PIs) are proxy indicators that complicate setting performance target levels or drawing clear conclusions.

- Current PIs might not be able to properly capture ATM performance in the future operational paradigm foreseen in the SESAR concept of operations.

- In the majority of cases, KPAs and/or SESAR Solutions show complex interdependences that are not well understood.

> The APACHE simulator can provide computations of optimal trajectories and/ or airspace sectorisations under several optimality criteria and/or constraints

APACHE provided a novel ATM simulation system, used with two different purposes: to simulate different operational contexts to perform what-if assessments; and to provide advanced models and optimisation tools that can support the implementation of novel and more accurate PIs. In this context, the developed system is able to generate optimal trajectories and airspace sectorisations considering a wide range of optimality criteria, supporting the calculation of new PIs using these trajectories/sectorisations as references.

The APACHE simulator and the new proposed PIs were demonstrated by:

- performing a preliminary impact assessment of long-term ATM concepts (such as free-routing and advanced demand and capacity balance mechanisms);

- monitoring performance from historical data sets;

- analysing interdependencies between some representative KPAs and SESAR solutions; and

- estimating the theoretical optimal limits for certain KPAs, under different optimality assumptions.

> Enhanced PIs complement current Performance Framework and can better capture ATM performance

Some of the proposed PIs showed the potential to complement current performance framework. A future research need is to enable a more accurate and robust computation of "advanced" performance indicators, in order to better capture and infer preferences and operational practices of AUs and ANSPs and to better isolate the contribution of the different stakeholders into the overall performance of the ATM system.

More information: https://apache-sesar.barcelonatech-upc.eu

Delivering high performing aviation

Advanced user-centric efficiency metrics for air traffic performance analytics – AURORA
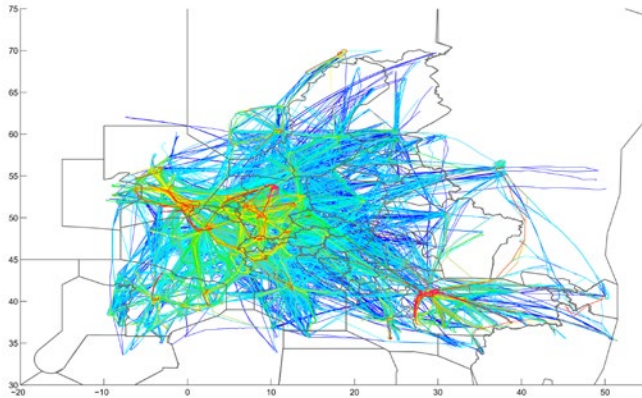
Project Partners

Boeing Research & Technology Europe

CRIDA (Coordinator)

Flightradar24

CeADAR - University College Dublin

A performance-driven ATM system is recognised as a critical element for the sustainability of Europe's aviation and air transport sectors. This requires performance indicators representing stakeholder needs. Currently, flight efficiency, as defined in the Single European Sky Performance Scheme, measures the horizontal excess en-route distance compared to the geodesic distance. This view of efficiency is very limited since it does not take into account other sources of inefficiencies, namely meteorological conditions or the vertical profile of the flight, and it does not address key aspects for the airlines' business strategies such as fuel consumption or costs.

Benefits
- Improved flight efficiency indicators considering weather
- Indicators based on fuel and costs
- Real-time indicators

AURORA's flight efficiency indicators compare actual fuel consumption and costs with achievable targets and clearly show possible efficiency improvements

AURORA sought to address this issue and explored new efficiency indicators that encapsulate fuel consumption, schedule adherence, route charges and overall cost efficiency of flights. A key difference between these new efficiency indicators and today's indicator is that their calculation requires the generation of user-preferred trajectories, i.e. fuel and cost-optimal trajectories, considering the impact of weather conditions and without the need of confidential information from airlines. AURORA demonstrated that flight inefficiency in terms of costs is not necessarily aligned with inefficiency in terms of horizontal difference, and that the new indicators can better capture these cost-based inefficiencies. The new indicators were validated by a group of airlines in terms of representativeness, transparency and usability.

The project also proposed indicators to measure how fairly the inefficiencies in the system are distributed among airlines. These indicators can serve to quantify the differences in the inefficiencies experienced by airlines in a given area.

AURORA also developed a methodology based on big data to calculate these new efficiency indicators in real time. AURORA demonstrated the benefits of monitoring efficiency indicators in real time for the resolution of short-term traffic imbalances, taking into consideration the impact on flight efficiency.

More information: www.sesarju.eu/projects/aurora

Assessing the coupling of ATM elements across the network

Novel tools to evaluate ATM systems coupling under future deployment scenarios - Domino
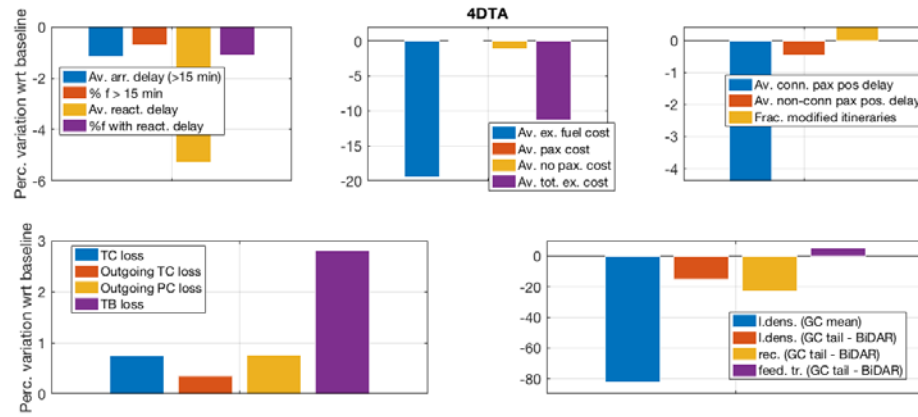

Project Partners

Eurocontrol

Innaxis Research Institute

Università di Bologna

Università degli studi di Trieste

University of Westminster (Coordinator)

Benefits:

- Trip centrality metrics for flights and passengers

- Extreme events causality metric

- Agent-based model capturing flights and passengers

- Flexible and expandable platform and methodology

Airspace management brings together multiple stakeholders and systems including flights, passengers, arrival managers and the Network Manager. The system evolves as a result of SESAR initiatives and other technology and policy changes. Such changes, even when applied locally, often have an impact on other sub-systems due to the high level of coupling across elements of the system. Domino explored such issues through the development of a toolbox based on a full European, agent-based model of the ATM system, featuring flights and passenger itineraries, also developing network metrics focused on centrality and causality.

Domino models the current state of the system, and its behaviour under the implementation of three mechanisms: 4D trajectory adjustments, flight prioritisation and flight arrival coordination. The agent-based system allows Domino to represent the behaviour of different stakeholders and to capture the emergent characteristics of the system. The model considers a full day of operations, including flights (with delays) and passengers' itineraries (with connections), executed in an event-driven simulator environment.

The network metrics can be applied to the outcome of Domino's model, or to historical datasets, providing a set of tools ready to be used by ATM system analysts.

More Information: www.domino-eu.com

The systematic approach used in the development of Domino's model provides a flexible platform able to model new mechanisms, regulations or agents' behaviours in a seamless manner

The new metrics on passenger trip centrality and extreme event causality have proven to be insightful for capturing complex, indirect interactions

Enhanced PIs complement current Performance Framework and can better capture ATM performance
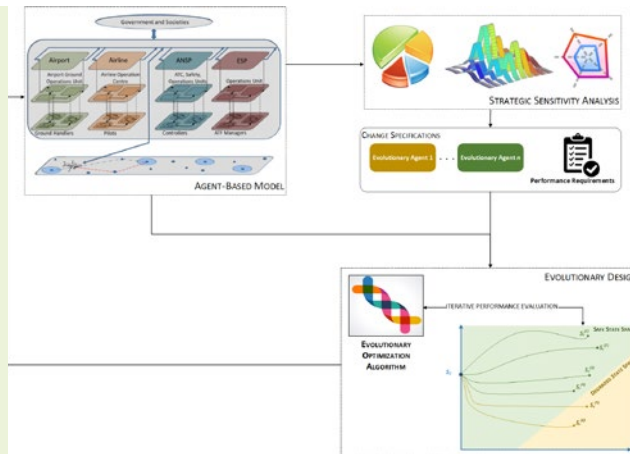
Key project outcomes include the development of an agent-based model and network metrics investigating three mechanisms

A methodology to assess the impact of new ATM concepts and maximise the expected performance

Evolutionary ATM - EvoATM

Project Partners

Centro italiano ricerche aerospaziali (CIRA) (Coordinator)

ASLOGIC 2011

Centro de Referencia de Investigación, Desarrollo e Innovación ATM (CRIDA)

Institute for Sustainable Society and Innovation (ISSNOVA)

Projecto, Empreendimentos, Desenvolvimento e Equipamentos Científicos e de Engenharia (Pedece)

Université autonome de Barcelone (UAB)

The introduction of new concepts in air traffic management can bring about more efficient technological developments but can also impact social behaviour. Both should be fully assessed from the start of a project in order to understand any unexpected performance results. There are fast modelling devices and stochastic methods designed to represent human response, but these fall short of analysing the causes behind behavioural change. The EvoATM project aims to help ATM experts by using new tools to gain a better understanding of changes, which influence the ATM system at micro-scale. The project explored an innovative approach to modelling and simulation by using a change impact assessment at the same time as evaluating human behaviour.

EvoATM paves the way for a new approach to fast time simulations. The new methodology helps to understand controller workload, variations in performance including safety, timeliness, fuel consumption, occupancy following a change, any regression, optimum design, and the impact of individual elements on whole system performance

Benefits:

- Early evaluation of new concepts including impact on human workload

- Early evaluation of trade-offs between new concepts

- More efficient than classical what-if analysis

- Optimisation of the change design to maximise performance

EvoATM developed a methodology, which combines agent-based representation to specify the ATM models alongside evolutionary computing to optimise the design of the change solutions. Project partners then developed a prototype to prove the capability of the proposed methodology. EvoATM modelled the introduction of free route Airspace and used the new approach to understand how ATM components influence performance of the whole system and to provide optimal configurations of free route.

Early validation of new concepts which impact human behaviour is necessary in order to save time and effort in ATM research and innovation

The project results showed that the methodology has the capability to improve predictions in several areas including: the impact of a change on the system and on human workload; the influence that each element may have on performance; and the optimum configuration of the solution. It is expected to increase cost-effectiveness of innovation in ATM.
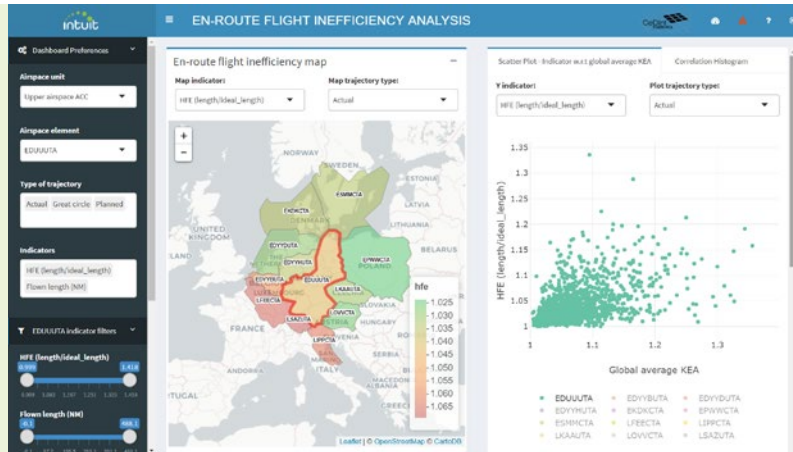
More Information: http://www.evoatm-project.eu

Visualising performance trade-offs in ATM

Interactive toolset for understanding trade-offs in ATM performance - INTUIT

Project Partners

Advanced Logistics Group

Fraunhofer-Gesellschaft

Nommon Solutions and Technologies (Coordinator)

Transport & Mobility Leuven

Universidad Politecnica de Madrid

Benefits

- Mapping of ATM performance datasets

- Better understanding of interdependencies between KPAs

- Visualisation tools for performance monitoring and analysis

The performance of the ATM system results from the complex interaction of interdependent policies and regulations, stakeholders, technologies and market conditions. Trade-offs arise not only between key performance areas (KPA), but also between stakeholders, as well as between short-term and long-term objectives.

INTUIT addressed the need for suitable performance modelling techniques and explored the potential of visual analytics and machine learning to improve our understanding of the trade-offs between KPAs and identify cause-effect relationships between indicators at different scales.

As a first step the project carried out a systematic characterisation of available ATM performance datasets, producing a data inventory that can serve as reference for future research activities. Then, a detailed review of the literature on performance interdependencies and a consultation process with ATM stakeholders led to the definition of a research agenda at the intersection of ATM performance and data science.

From the list of research questions included in this research agenda, three use cases were selected to demonstrate the potential of the investigated techniques. In the first case study, airline route choices were analysed and a model was developed to estimate the impact of changes in route charges on the overall ATM performance. The second case study showed how flight-inefficiencies within a particular area control centre are correlated with flight properties derived from both the flight plan and the ideal route, such as heading, altitude and airspace crossed. The third case study demonstrated how ATM performance can be measured at a finer spatial and temporal level and investigated the relationship between sector configurations and air traffic flow management (ATFM) regulations.

> Visual analytics and machine learning can provide innovative insights into ATM Performance

Interactive visual interfaces were developed for all use cases to enable human-information discourse and to facilitate interpretation and communication of the modelling results.

More information: www.intuit-sesar.eu

Gamifying change management in ATM

Participatory Architectural Change Management in ATM Systems - PACAS

Project Partners

Deep Blue

SINTEF

Universita' degli studi di Trento (Coordinator)

Universiteit Utrecht

The ATM system is a complex systems-of-systems and all of its subsystems synergistically co-operate, through the creation of tight interdependencies among the institutions, enterprises, humans, hardware and software systems. Due to strong interdependencies, any change introduced might trigger changes in other parts of the system and it is a challenge to understand all possible consequences of a design decision. For this reason, it is important to involve multiple ATM domain stakeholders in change management processes.

PACAS' main objective was to support change management by investigating how to better understand, model and analyse changes at different layers of the ATM system, while capturing how architectural and design choices influence the overall system. The project developed an innovative participatory change management process wherein heterogeneous stakeholders could actively participate in the architectural evolution of the ATM system.

Benefits

- Collaborative change management platform

- Involvement of heterogeneous stakeholders

- Increased participation through gamification

Due to strong interdependencies in an ATM system, architectural and design choices influence the overall system and collaborative multi-stakeholder multi-disciplinary change management is required to ensure a coherent and consistent approach. This may be strengthened by gaming, modelling and automated reasoning

The novelty of PACAS relies on three key components of the participatory change management process. First, the process is implemented as a gamified collaborative platform to increase participation. Second, domain specific modelling languages are supported to ease the contribution of multiple ATM domain stakeholders, each having a different view on the system. Third, the platform supports complex impact analyses through automated reasoning techniques. This allows better trade-offs and ultimately better change decisions to be made.

The web platform developed by the project has already been tested with a sample of a solution project of SESAR, results so far indicating that it could potentially be useful for supporting the design of new operational concepts and technologies being developed within SESAR.

Enabling better strategic planning in ATM

Advanced prediction models for flexible trajectory-based operations -ADAPT

adapt
Advanced prediction models for flexible trajectory-based operations

Project Partners

Deep Blue

TU Delft

University of Westminster

Università degli Studi di Palermo

Università degli studi di Trieste (coordinator)

MAIN FEATURES

Sectors criticality information

Critical sectors are identified in the map (red sectors). Detailed information about criticality index, capacity and constrained flights is provided.

MAIN FEATURES

ACC criticality information

Information can be aggregated to the level of ACC and FIR offering a higher level view of the situation in the airspace.

Hourly Geographic Trends

Analyse peak hours and location of the critical sectors (low flexibility) with the hourly maps. Identify most critical times of the day and drill down to access specific details.

9h -10h   10h-11h   11h-12h   12h-13h

Benefits:

- Early sharing of trajectory information

- Identification of timing flexibility around trajectories

- Identification of saturated parts of ATM network in advance

- Assessment of mitigation scenarios to improve network performance

Air traffic delays are mainly caused by unforeseen factors, like weather, but also a lack of accurate information exchange at the right time. While ANSPs plan the use of their airspace months in advance, a more accurate picture traffic demand is only known on the day of operations, leading inevitably to congestion in parts of the network. In order to close this gap, the ADAPT project developed a set of models, the results of which are integrated in a visualisation tool to enable better strategic and pre-tactical flight planning, and enhanced network management and performance.

The models make use of past and current flight route information, flight-time flexibility, and the level of saturation of sector or airports. The tool can also assign "user-preferred" trajectories to individual flights and measure quantitatively the impact on flights and the network. All of this information is then visualised and shared with the concerned stakeholders through the Network Operations Plan in order to allow for better decision-making on the best distribution of flights in view of the available capacity in the network.

The project designed and tested models and metrics enabling strategic planning (early information sharing). The project showed how shared information on flight flexibility and network critical elements could be integrated into the Network Operations Plan to serve as a basis for enhanced stakeholder collaboration.

Further analysis is needed to assess the impact in terms of costs and benefits of moving flight planning to the strategic phase of traffic management and how it would change the way airspace users and ANSPs operate.

More information: https://adapt-h2020.eu/
https://visualization.adapt-h2020.eu/

Optimising airspace capacity with the help of trajectory predictions

Capacity Optimisation in TrajecTory-based OperatioNs - COTTON
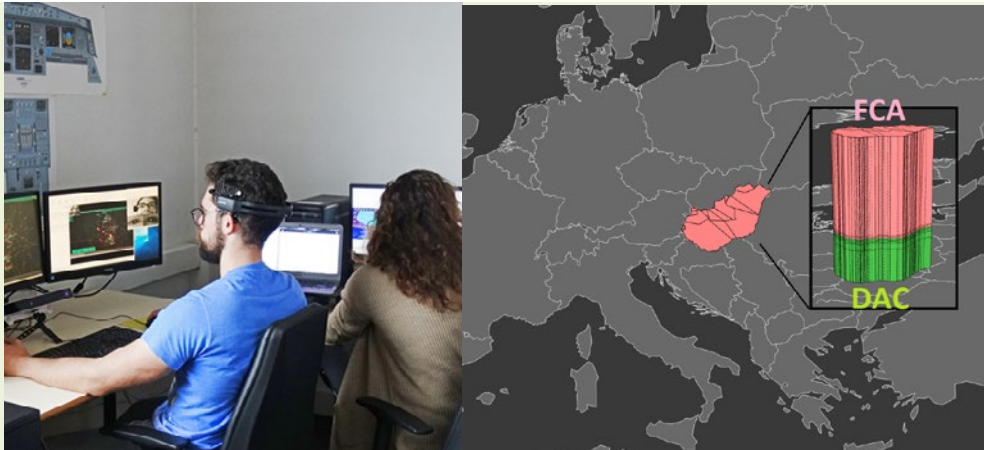
Partners

CRIDA (Coordinator)

Deutsches Zentrum für Luft- und Raumfahrt (DLR)

ENAC

Eurocontrol

TU Delft

Universidad Politécnica de Madrid (UPM)

The research addresses capacity management processes including dynamic airspace configuration (DAC) and flight centric ATC (FCA) to optimise airspace usage and improve flight trajectories. Both solutions rely on traffic flow complexity assessment processes and metrics to measure traffic flow and manage workload, however current methods do not properly account for trajectory uncertainty. The COTTON project explored alternative ways to assess volume and complexity of demand.

COTTON selected three complexity metrics - solution space, cognitive complexity and geometrical complexity - and developed complexity-based methods to assess capacity for each of them. The project found these enhanced metrics, which have sufficient granularity to address the specificities of DAC and FCA, are flexible enough to support each capacity management process during the planning phase.

COTTON proposed two operational improvements for integrationin SESAR, contributing to the effectiveness of SESAR capacity management solutions.

Benefits

- More accurate airspace capacity planning

- Improved demand capacity balancing

- More effective use of ATC resources

COTTON demonstrated that the enhanced metrics captured the most influencing complexity generators in DAC and FCA environments and improved decision-making. This resulted in better detection rates for overloads, improved airspace configuration planning, and increased capacity. This in turn reduced ATC resource requirements, helped to balance workload, and enhanced safety. Based on these results, COTTON proposes the integration of two operational improvements to the SESAR concept of operations:

- Traffic complexity and workload assessment adapted to TBO including time uncertainty;

- DAC capacity management process explicitly taking into account the time uncertainty inherent to 4D trajectory planning.

In addition, the project recommended further research on:

- FCA Capacity Management process explicitly taking into account the time uncertainty inherent to 4D trajectory planning

- An overall European ATM framework for capacity Management in TBO integrating Flight Centric ATC (FCA) into Dynamic Airspace Configuration (DAC) solution

More information: http://www.cotton-er.eu/

Knowledge Transfer Network (KTN)

Engage: The SESAR Knowledge Transfer Network

Project Partners

EUROCONTROL

European Aviation Safety Agency

Frequentis

Innaxis

Technical University Delft

University of Belgrade

University of Trieste

University of Westminster (coordinator)

Activities

- ▪ 'One-stop' European knowledge hub
- ▪ Supporting the SESAR Innovation Days
- ▪ Thematic challenge workshops
- ▪ Summer schools
- ▪ 10 PhDs (interdisciplinary)
- ▪ Multiple catalyst fund projects
- ▪ Supporting the SESAR Digital Academy

The Engage KTN is managed by a consortium of academia and industry, to promote and facilitate the development of ATM research in Europe. The main focus is two-fold: inspiring new researchers and helping to align exploratory and industrial research, through a wide range of activities and financial support actions. At the core of the KTN is the definition of various thematic challenges: new ideas suggested by the research community, not already included within the scope of existing SESAR projects. These include:

1. Vulnerabilities & global security of the CNS/ATM system

2. Data-driven trajectory prediction

3. Efficient provision & use of meteorological information in ATM

4. Novel & more effective allocation markets in ATM

Engage funding supports 'catalyst' projects, maturing research closer towards industry goals and objectives, and higher TRLs. Ten projects are running in the first wave, with a further set launching in 2020. As with the Engage PhDs, these projects may address a corresponding thematic challenge or be 'open'. Nearly all of the PhDs are receiving significant co-funding, e.g. from industry. Workshops, summer schools and the SESAR Innovation Days bring together these projects, PhDs, industry, and the wider research community.

- • Inspiring new researchers
- • Aligning exploratory and industrial research
- • Underpinned by thematic challenges
- • Building a community wiki and research repository

The KTN is committed to supporting academia and the future skilled workforce, plus student mobility, through travel grants for students, journal publication grants, and promoting internships and (industry) vacancies. It is publishing searchable under-/post-graduate course databases and distributing free lecture materials to the grass roots levels of education in Europe. It is thus continuously collaborating with the initiatives of the SESAR Digital Academy.

Engage's 'one-stop' European knowledge hub will be supported through an interactive wiki, launching in 2020, with a searchable research repository and associated mapping. This will also host a long-term ATM concepts roadmap.

More Information: engagektn.com

Engage PhDs

TU Braunschweig Jepeesen	**Decision support system for airline operation control hub centre**
	This PhD is investigating the use of artificial intelligence to support decision making in an airline operation control hub centre in highly complex scenarios, by detecting abnormal situations and dependencies in the diverse information flows. This is expected to result in fewer delays for passengers and better utilisation of resources at the airline level.
TC2 University of Piraeus Research Center CRIDA	**Trajectory planning for conflict-free trajectories: a multi-agent reinforcement learning approach**
	The objective is to explore and present novel algorithms for planning conflict-free trajectories at the pre-tactical phase of operations in computationally efficient ways, for a large number of trajectories in airspaces comprising multiple FIRs, following a methodology combining data-driven and agent-based approaches.
ENAC University of Oklahoma	**Detection, classification, identification and mitigation of GNSS signal degradations by means of machine learning**
	The objectives of the thesis are to detect, classify, identify and finally reduce impairments of GNSS signals received by on-board receivers, when the received signal is degraded. More specifically, it is proposed to assess the performance of machine learning methods on the signal, with regard to the correlator output.
TC2 Nommon Universitat Politècnica de Catalunya	**Machine learning techniques for seamless traffic demand prediction**
	The overall goal of this study is to investigate innovative approaches to air traffic demand forecasting based on the synergistic combination of physical models of aircraft trajectories with artificial intelligence and machine learning techniques, with particular focus on pre-tactical traffic forecasts, when most (final) flight plans are not yet available.
TC2 Autonomous University of Barcelona ASLOGIC	**Machine learning applications to extend AGENT's conflict resolution capabilities**
	AGENT (SESAR ER1) developed a system whereby the avoidance of potential loss of separation is achieved in a distributed, collaborative manner, between the involved aircraft. This thesis, building on AGENT's work, investigates possible improvements of several critical aspects of the system through applications of diverse machine learning techniques.

TC2&3	**Integrating weather prediction models into ATM planning**
Linköping University LFV University of Seville	Better integration of weather information into the ATM system will ultimately improve overall air traffic safety and efficiency. This thesis applies probabilistic models with corresponding weather data and prototype mathematical tools. The integration into solutions developed by industry will help to anticipate the influence of bad weather operationally.
TC2	**Advanced statistical signal processing for next generation trajectory prediction**
Universitat Politècnica de Catalunya ISAE-SUPAERO	This PhD investigates the trajectory prediction problem from a new probabilistic perspective, approaching this with powerful mathematical tools from the statistical signal processing field. More robust trajectory prediction and algorithms for the execution phase of flight, will increase safety, capacity, predictability and cost efficiency.
TC3	**A pilot/dispatcher support tool based on the enhanced provision of thunderstorm forecasts considering inherent uncertainty**
Universidad Carlos III de Madrid ETH Zürich Spanish Met Office GTD Systems	This research initiative is pursuing three main goals, regarding the development of: (i) new models for the stochastic evolution of thunderstorms; (ii) short-term, stochastic trajectory planning algorithms, also focusing on thunderstorms; and, (iii) a use case, in which to demonstrate a library support tool for pilots and/or dispatchers.
TC4	**Second generation agent-based modelling for improving APOC operations**
Amsterdam University of Applied Sciences ENAC University Paul Sabatier	This PhD research is developing an agent-based platform that allows the analysis of decisions in an airport operation centre (APOC). It integrates simulation, decision making, applied mathematics and behavioural science for a better alignment of the APOC's objectives and to improve the coordination and efficiency of airport operation.
TC4	**Stochastic control of tactical airline operations in hub airport networks**
TU Dresden	This thesis is developing a decision-support system for airline ground operations controllers at hub airports. The focal point is the introduction and evaluation of standardised schedule recovery actions. A microscopic optimisation model for stochastic ground operations will be integrated with network operations solutions and constraints.

More information at: https://engagektn.com/phd-abstracts/

Engage catalyst fund projects
(thematic challenge numbers indicated, where applicable)

TC3 University of Seville, MeteoSolutions	**Probabilistic weather avoidance routes for medium-term storm avoidance** This project is framed in the context of TBO-Met (SESAR ER1), which used a storm avoidance tool following an ensemble-based approach. The goal is to produce an algorithm capable of generating probabilistic weather avoidance routes. Integration of the uncertainty of meteorological disruptive events, aims at increasing the safety, efficiency, and predictability of ATM operations.
TC3 University of Padova LMU Munich GReD Leonardo	**Airport-scale severe weather nowcasting** Extreme convective systems have large impacts on aviation. This project combines the capabilities of a dense network of low cost, ground-based GNSS receivers and lightning detectors, together with vertical profiles from radio occultations and radiosondes, for nowcasting severe weather with high spatial resolution, demonstrated in the context of total airport management.
TC1 TU Kaiserslautern SeRo Systems	**Authentication and integrity for ADS-B** The provision of surveillance information in ADS-B by remote devices beyond the control of the end user poses a serious security theat. This project continues the work of PJ 15.04.06 by first investigating the performance of the ADS-B phase overlay under real-world conditions and then using these insights to design a realistic ADS-B authentication and integrity protocol.
TC2 University of Piraeus Research Center Boeing Research and Technology Europe	**Data-driven trajectory imitation with reinforcement learning** This project generates algorithms for data-driven imitation of trajectories, following deep reinforcement learning techniques. Building on DART (SESAR ER1), the learning process is: (i) an imitation process, where the algorithm tries to imitate 'experts' planning trajectories; (ii) exploiting raw trajectory data; and, (iii) based on reward models that are learned during imitation.

TC2 CRIDA Deep Blue ZenaByte	**A data-driven approach for dynamic and adaptive trajectory prediction** This initiative is developing a framework for data-driven, dynamic and adaptive trajectory prediction, with traffic forecasting, in the pre-tactical phase adjusted to different time scales, taking into account their level of predictability. This will be completed with a model that considers advanced tactical data to validate/enhance pre-tactical prediction.
TC3 Royal Belgian Institute for Space Aeronomy	**Operational alert products for ATM via SWIM** The main goal of this project is to contribute a new product to an existing early warning system: SACS (support to aviation control system). The new alert product targeted is real-time operational retrievals of the plume height of sulphur dioxide emitted during a volcanic eruption, a proxy for the volcanic ash height, which is notoriously difficult to measure.
TC2 ASLOGIC	**An interaction metric for efficient traffic demand management: requirements for the design of data-driven protection mechanisms** This project extends PARTAKE's (SESAR ER1) data-driven prediction methods. A key outcome will be a new interaction metric to evaluate the efficiency of sector regulations by identifying the demand-capacity imbalances of sectors in terms of flight interactions, resulting in interaction zones contributing to the better understanding of complex network dynamics.
TC3 DSNA Services MetSafe	**MET-enhanced ATFCM** Extending the forecasting of weather hazards from 1-hour horizons to 3 hours is currently being addressed by existing aeronautical forecasting products, with challenging unreliability beyond this period. This project's objective is the design and validation of a convection product, dedicated to enhanced ATFCM, targeting a 6-hour time horizon.
TC4 Nommon Solutions and Technologies	**Exploring future UDPP concepts through computational behavioural economics** ATFM delay represents a significant cost for airspace users. SESAR's user-driven prioritisation process (UDPP) was developed to improve such impacts. The goal of this project is to develop new modelling approaches, enabling a comprehensive study of highly flexible, advanced UDPP mechanisms by adopting the paradigm of computational behavioural economics.
TC1 Open University NATS	**The drone identity – investigating forensic readiness of U-Space services** The project is investigating the forensic readiness requirements of unmanned aerial systems (UAS). The goal is to ensure that the root causes of incidents can always be analysed, facilitated by evidence collected during operation. The project has a focus on drone data, examining ways in which key drone characteristics can be determined and recorded reliably.

The KTN is an outward-facing network, advancing innovation and collaboration. It continues to welcome the participation of new industry partners to join the large group: sign up on the website.

More information at: https://engagektn.com/cf-summaries/

Engage catalyst fund projects (wave 2)
(thematic challenge numbers indicated, where applicable)

Proof-of-concept: practical, flexible, affordable pentesting platform for ATM/avionics cybersecurity	TC1	University of Jyväskylä
Safe drone flight - assuring telemetry data integrity in U-Space scenarios	TC1	NATS Open University
Collaborative cybersecurity management framework	TC1	Winsland Movable-type MSDK BULATSA
Probabilistic information integration in uncertain data processing for TP	TC2	CIRA
Meteo sensors in the sky	TC3	NLR AirHub B.V.
Weather impact prediction for ATM	TC3	FRACS MetSafe
Role of markets in AAS deployment	TC4	Think Research
Flight centric ATC with airstreams	TC2	NEOMETSYS ENAC

CONCLUSION AND NEXT STEPS

The outcomes of the projects are exemplary of what can be achieved by going beyond the current horizon of knowledge in ATM and aviation and by applying tools and methodologies from other disciplines to address the challenges facing the industry. The project results described in this publication vary in maturity, but work is already underway to see how to integrate the most mature and promising of concepts into the industrial research activities of the SESAR JU.

At the same time, the SESAR JU has launched further research activities (see annex 2), addressing additional important challenges such automation and autonomy, complexity, data science & Information Management and the role of ATM in intermodal transport.

The SJU also launched its Digital Academy, a learning initiative supporting Europe's future aviation and ATM workforce. The mission is to nurture Europe's brightest minds and advance learning, scientific excellence and innovation in aviation and ATM. The Academy aims to promote student mobility and a whole spectrum of learning opportunities, from fundamental research to industry-focused applied research, and to enhance the knowledge, skills and employability of aviation professionals.

These activities will aim to ensure that promising research is progressed, and higher maturity results are delivered, thus supporting a more effective innovation pipeline in the context of the SESAR 2020 programme. Ultimately, through its exploratory research activities, the SESAR JU will support and facilitate the development of a future skilled workforce that is able to keep innovating and improving the ATM system.

ANNEXES

Annex 1

Completed SESAR exploratory research activities

Horizon 2020 research and innovation framework programme

The projects in this publication were funded by the SESAR Joint Undertaking, within the framework of the EU's Horizon research and innovation programme.

Acronym	Project name	Grant no.
ADAPT	Advanced prediction models for flexible trajectory-based operations	783264
AGENT	Adaptive self-Governed aerial Ecosystem by Negotiated Traffic	699313
APACHE	Assessment of Performance in current ATM operations and of new Concepts of operations for its Holistic Enhancement	699338
ATM4E	Air Traffic Management for environment	699395
AURORA	Advanced User-centric efficiency metRics for air traffic perfORmance Analytics	699340
AUTOPACE	AUTOMATION PACE	699238
BEST	Achieving the BEnefits of SWIM by making smart use of Semantic Technologies	699298
BigData4ATM	Passenger-centric Big Data Sources for Socio-economic and Behavioural Research in ATM	699260
COCTA	Coordinated capacity ordering and trajectory pricing for better-performing ATM	699326
COMPAIR	COMPetition for AIR traffic management	699249
COPTRA	COmbining Probable TRAjectories	699274
COTTON	Capacity Optimisation in TrajecTory-based OperatioNs	783222
DART	Data-driven AiRcraft Trajectory prediction research	699299
Domino	Novel tools to evaluate ATM systems coupling under future deployment scenarios	783206
EMPHASIS	EMPowering Heterogeneous Aviation through cellular SIgnalS	783198
Engage	Knowledge Transfer Network	783287
ENVISION	Enhanced Situational Awareness through Video Integration with ADS-B Surveillance Infrastructure on Airports	783270
EvoATM	Evolutionary ATM. A modelling framework to assess the impact of ATM evolutions	783189
GATEMAN	GNSS navigation threats management	783183
INTUIT	Interactive Toolset for Understanding Trade-offs in ATM Performance	699303
MALORCA	Machine Learning of Speech Recognition Models for Controller Assistance	698824
MINIMA	MItigating Negative Impacts of Monitoring high levels of Automation	699282
MOTO	the embodied reMOte Tower	699379

NAVISAS	Navigation of Airborne Vehicle with Integrated Space and Atomic Signals	699387
OptiFrame	An Optimization Framework for Trajectory Based Operations	699275
PACAS	Participatory Architectural Change Management in ATM Systems	699306
PARTAKE	cooPerative depArtuRes for a compeTitive ATM networK sErvice.	699307
PNOWWA	Probabilistic Nowcasting of Winter Weather for Airports	699221
RETINA	Resilient Synthetic Vision for Advanced Control Tower Air Navigation Service Provision	699370
R-WAKE	Wake Vortex simulation and analysis to enhance en-route separation management in Europe	699247
SALSA	SATELLITE-BASED ADS-B FOR LOWER SEPARATION-MINIMA APPLICATION (SALSA)	699337
SAPIENT	Satcom and terrestrial architectures improving performance, security and safety in ATM	699328
STRESS	Human Performance neurometricS Toolbox foR highly automatEd Systems deSign	699381
TaCo	Take Control	699382
TBO-Met	Meteorological Uncertainty Management for Trajectory Based Operations	699294
Vista	Market forces trade-offs impacting European ATM performance	699390

Completed U-space projects

The results of the following U-space projects are featured in a separate publication, supporting safe & secure drone operations.

Read the results: **www.sesarju/uspace**

Acronym	Project name	Grant no.
AIRPASS	Advanced Integrated RPAS Avionics Safety Suite	763658
CLASS	CLear Air Situation for uaS CLASS	763719
CORUS	Concept of Operations for EuRopean UTM Systems	763551
DREAMS	DRone European AIM Study	763671
DroC2om	Drone Critical Communications	763601
IMPETUS	Information Management Portal to Enable the inTegration of Unmanned Systems	763807
PercEvite	PercEvite - Sense and avoid technology for small drones	763702
SECOPS	An Integrated Security Concept for Drone Operations	763599
TERRA	Technological European Research for RPAS in ATM	763831

Ongoing SESAR exploratory research activities

Horizon 2020 research and innovation framework programme

The projects in this publication were funded by the SESAR Joint Undertaking, within the framework of the EU's Horizon research and innovation programme.

Automation and Autonomy

AISA - AI Situational Awareness Foundation for Advancing Automation	To implement advanced automation, AI and human need to be able to share situational awareness. Therefore, AISA project is exploring the effect of, and opportunities for, distributed human-machine situational awareness in en-route ATC operations. The project is developing an intelligent situationally-aware system by combining machine learning with reasoning engine.
MAHALO - Modern ATM via Human/Automation Learning Optimisation	To answer the question if automation should match human behaviour or be understandable to humans, MAHALO aims to develop an individually-tuned ML system to solve ATC conflicts and couple this to an enhanced en-route CD&R display. Insights will be used to define a framework to guide design of future AI systems.
TAPAS -Towards an Automated and exPlainable ATM System	TAPAS aims to explore highly automated AI-based scenarios through analysis and experimental activities applying eXplainable Artificial Intelligence (XAI) and Visual Analytics, in order to derive general principles of transparency which pave the way for the application of AI technologies in ATM environments, enabling higher levels of automation.

Information Management

AICHAIN – A Platform for Privacy-preserving Federated Machine Learning using Blockchain to enable Operational Improvements in ATM	AICHAIN proposes an innovative Digital Information Management concept combining Federated Machine Learning (FedML) and Blockchain technologies. This enables the cyber-secured exploitation of large private data sets by an privacy-preserving federated learning architecture in which neither the training data nor the training model need to be exposed.

Environment and Meteorology for ATM

CREATE - Innovative operations and climate and weather models to improve ATM resilience and reduce impacts	Air operations largely use weather information to make the air traffic flow safe, continuous and efficient. As climate changes are ongoing, available information on the weather on short and longer notice are increasing and technology is being improved. CREATE aims to achieve innovative procedures in ATM to reduce climate and environmental impact, while becoming more resilient to weather phenomena.
DYNCAT - Dynamic Configuration Adjustment in the TMA	DYNCAT aims to enable more environmentally friendly and more predictable flight profiles in the TMA, namely on approach, by supporting the pilots in configuration management.
FlyATM4E - Flying Air Traffic Management for the benefit of environment and climate	FlyATM4E aims to expand approved climate-assessment methods and optimization of aircraft trajectories to identify promising mitigation options suitable to solve the task of reducing overall climate impact of aircraft operations. The project will assess the feasibility of a concept for environmental assessment of ATM operations working towards environmental optimisation of air traffic operations.

FMPMet - Meteorological uncertainty management for Flow Management Positions	FMPMet aims to integrate meteorological forecast uncertainty information into the decision-making process for Flow Management Position (FMP). FMPMet aims to provide the FMP with an intuitive and interpretable probabilistic assessment of the impact of convective weather on the operations, up to 8 hours in advance.
SINOPTICA - Satellite-borne and IN-situ Observations to Predict The Initiation of Convection for ATM	SINOPTICA aims to explore the potential of assimilating remote sensing, GNSS-derived datasets and in situ weather stations data into very high-resolution, very short-range numerical weather forecasts to provide improved prediction of extreme weather events to the benefit of ATM operations.

Performance, Economics, Legal and Regulation

FARO - saFety And Resilience guidelines for aviatiOn	FARO aims to bring new insights about safety and resilience in ATM, with four objectives: to exploit existing safety knowledge, to quantify the impact of increasing automation on ATM safety, to analyse the impact of increasing automation on ATM resilience, and to provide design guidelines and identify future research needs.
BEACON - Behavioural Economics for ATM Concepts	BEACON aims to study the feasibility of extending User-Driven Prioritisation Process (UDPP) to allow multi-prioritisation processes in the airspace and exchange of slots between airlines. It will build two models: a strategic model and a detailed tactical simulator To properly capture the agents' behaviours, BEACON will make use of behavioural economics.
ITACA - Incentivising Technology Adoption for Accelerating Change in ATM	ITACA aims to accelerate the development, adoption and deployment of new technologies in ATM. ITACA will develop a new set of methodologies and tools enabling the rigorous and comprehensive assessment of policies and regulations aimed at amplifying the uptake of new technologies within ATM.

ATM Role in Intermodal Transport

Modus - Modelling and assessing the role of air transport in an integrated, intermodal transport system	Modus analyses the performance of the overall transport system by considering the entire door-to-door journey holistically. The project identifies (future) drivers for passenger demand and supply and assesses the impact on airside and landside processes and capacities. Based on these analyses, potential solutions to meet high-level European transport objectives are proposed.
TRANSIT - Travel Information Management for Seamless Intermodal Transport	TRANSIT aims to develop a set of multimodal key performance indicators (KPIs), mobility data analysis methods and transport simulation tools, allowing the evaluation of the impact of innovative intermodal transport solutions on the quality, efficiency and resilience of the door-to-door passenger journey.
X-TEAM D2D - eXTEnded AtM for Door2Door travel	X-TEAM D2D aims to define, develop and initially validate a Concept of Operations for the seamless integration of ATM and Air Transport into an overall intermodal network, including other available transportation means (surface, water), to enable the door-to-door connectivity, in up to 4 hours, between any location in Europe.

CNS for ATM

SINAPSE - Software defined networking architecture augmented with Artificial Intelligence to improve aeronautical communications performance, security and efficiency	SINAPSE aims to propose an intelligent and secured aeronautical datalink communications network architecture design, based on the Software Defined Networking (SDN) architecture model augmented with Artificial Intelligence (AI) to predict and prevent safety services outages, to optimise available network resources and to implement cybersecurity functions protecting the network against digital attacks.

ATM APPLICATION ORIENTED RESEARCH

High-performing airport operations

IMHOTEP - Integrated Multimodal Airport Operations for Efficient Passenger Flow Management	IMHOTEP aims to develop a concept of operations and a set of data analysis methods, predictive models and decision support tools that allow information sharing, common situational awareness and real-time collaborative decision-making between airports and ground transport stakeholders.

Advanced air traffic services

HAAWAII - Highly Automated Air Traffic Controller Workstations with Artificial Intelligence Integration	HAAWAII aims to research and develop a reliable, error resilient and adaptable solution to automatically transcribe voice commands issued by both air-traffic controllers and pilots, and to perform proof-of-concept trials in challenging environments. Also, the objectively estimated controllers' workload utilising digitised voice recordings of the complex London TMA will be assessed.

Optimised ATM network services

CADENZA - Advanced Capacity and Demand Management for European Network Performance Optimization	CADENZA aims to develop a detailed trajectory broker concept for the European network, incorporating advanced demand-capacity balancing mechanisms. The trajectory broker will balance capacity and demand through a coordinated capacity provision process and collaborative trajectory management (including a novel trajectory charging scheme). Significant improvements in cost-efficiency and delay are expected.
ISOBAR - Artificial Intelligence Solutions to Meteo-Based DCB Imbalances for Network Operations Planning	ISOBAR aims at the provision of a service- and AI-based Network Operations Plan, by integrating enhanced convective weather forecasts for predicting imbalances between capacity and demand and exploiting AI to select mitigation measures at local and network level in a collaborative ATFCM operations paradigm.
START - a Stable and resilient ATM by integrating Robust airline operations into the network	START aims to develop, implement, and validate optimisation algorithms for robust airline operations that result in stable and resilient ATM performance even in disturbed scenarios The main focus of the project is the optimization of conventional traffic situations while considering disruptive weather events such as thunderstorms.

Enabling aviation infrastructure

FACT - Future All Aviation CNS Technology	FACT aims to increase safety, security, efficiency, and robustness of future air traffic environment through development of integrated CNS functional architecture supporting the use of common performance based approach, addressing needs of large spectrum of airspace users across varied operational environments.

ATM operations, architecture, performance and validation

NOSTROMO - Next-Generation Open-Source Tools for ATM Performance Modelling and Optimisation	The ATM system is composed of elements that interact with each other generating a number of properties characteristic of complex adaptive systems. NOSTROMO aims to develop new approaches to ATM performance modelling able to reconcile model transparency, computational tractability and ease of use with the necessary sophistication required for a realistic representation of the ATM system.

IFR RPAS

INVIRCAT - IFR RPAS Control in Airports and TMA	INVIRCAT aims to create a concept of operations for remotely piloted aircraft systems in the terminal manoeuvring area of airports, assessing it through simulations and draft a set of recommendations for rulemakers and standardization bodies.
SAFELAND - SAFE LANDing through enhanced ground support	SAFELAND aims to support flight and landing of aircraft operated by a single pilot, in case of partial or total incapacitation of the pilot. SAFELAND will focus on the ground side, specifically on the role ATM could have in managing the transition from a single pilot operated flight to a status with reduced or absent contribution of the onboard pilot to landing.
URClearED - A Unified Integrated Remain Well Clear Concept in Airspace D-G Class	URClearED aims to support current study activities on the RWC functionalities by defining and analyzing operational scenarios, which allow to assess requirements and assumptions made in current standards and applicable documents, and then paving the way to future industrial level activities on such system.

U-space

BUBBLES - Defining the BUilding Basic BLocks for a U-Space SEparation Management Service	BUBBLES aims to formulate and validate the concept of a U-Space advanced (U3) 'separation management service'. It will develop algorithms to compute the collision risk of UAS, allowing to define separation minima and methods, so that a safety level stated in terms of overall probability of collision can be defined and maintained.
DACUS - Demand and Capacity Optimisation in U-space	DACUS aims to develop a service-oriented Demand and Capacity Balancing (DCB) process for drone traffic management. This overall objective responds to an operational and technical need in European drone operations for a tangible solution integrating the functionalities of the SESAR U-space services for Drone Traffic Management (DTM) to produce timely, efficient and safe decisions.
ICARUS - Integrated Common Altitude Reference system for U-Space	ICARUS aims to propose an innovative solution to the challenge of the Common Altitude Reference inside Very Low Level (VLL) airspaces with the definition of a new U-space service and its validation in a real operational environment.

More information at: https://www.sesarju.eu/exploratoryresearch

Annex 3
Glossary

ABSR	Assistant based speech recogniser
ADS-B	Automatic dependent surveillance-broadcast
AI	Artificial intelligence
AIRM	ATM information reference model
ANSPs	Air navigation service providers
A-PNT	Alternative positioning, navigation and timing
APOC	Airport operation centre
ASR	Automatic speech recognition
ATC	Air traffic control
ATFCM	Air traffic flow and capacity management
ATM	Air traffic management
AU	Airspace user
CNS	Communication, navigation and surveillance
DAC	Dynamic airspace configuration
DCB	demand and capacity balancing
ER1	First SESAR exploratory research call for proposals - ER1
EU	European Union
FCA	Flight centric ATM
GA	General aviation
GA/R	General aviation & rotorcraft
GNSS	Global navigation satellite system
GPS	Global positioning system
HMD	Head mounted display
HP	Human performance
HPE	Human performance envelope
IFR	Instrument flight rules
IMU	Inertial measurement unit
IR	Implementing rules
JU	Joint Undertaking
KPAs	Key performance areas
KPI	Key performance indicator
KTN	Knowledge transfer network
LIDAR	Light detection and ranging
MEMS	Microelectromechanical systems
NM	Network Manager
OWL	Web ontology language
PIs	Performance indicators
R&D	Research and development
RFI	Radio frequency interference
RPAS	Remotely piloted aircraft system
SACS	Support to aviation control system
SES	Single European Sky
SESAR	Single European Sky ATM Research
STAM	Short-term ATFM measures
SWIM	System-wide information management
TBO	Trajectory-based operations
UAS	Unmanned aerial systems
UDPP	User-driven prioritisation process
VAC	Vigilance and attention controller
VFR	Visual flight rules
WVE	Wake vortex encounter

NOTES

SESAR
JOINT UNDERTAKING

For more information, visit sesarju.eu

www.sesarju.eu

@SESAR_JU

You Tube SESAREuropanunion

Publications Office
of the European Union