ISSN 2599-8293

European Commission

CORDIS Results Pack on

# AI in air traffic management

A thematic collection of innovative EU-funded research results

October 2022

# Bringing intelligent and trustworthy automation to Europe's aviation sector

Research and Innovation

# Contents



# Editorial

## Bringing intelligent and trustworthy automation to Europe's aviation sector

Artificial intelligence offers applications that can learn autonomously and advise on complex problems across various industries. Aviation is no exception.

Artificial intelligence (AI) has been around for more than 60 years, but has become a transformative technology in recent years thanks to exponential advances in computing power, data availability and widespread networks of devices.

The industry is taking a keen interest in the potential of AI and subsets such as machine learning and deep learning, to develop intelligent maintenance, engineering and prognostics tools, applications to streamline business processes, supply chains and customer services, and more.

Air traffic management (ATM) is an ideal candidate for greater automation and augmentation through AI. With their repetitive procedures generating huge amounts of data, aviation and ATM can make use of AI and higher levels of automation to improve the efficiency of their operations in many ways and allow human operators to focus on safety-critical tasks.

Machine learning digital assistants can mine huge amounts of historical data to support human operators in taking the best possible decisions. Automated marketplaces can help airlines define flight allocations without revealing commercially sensitive pricing data. And a better understanding of passenger journeys can build the framework for seamless multimodal travel.

Across industries, the increased use of AI brings with it serious ethical questions. Because aviation is safety-critical and human-centric, it is essential that AI solutions in this space are understandable and trustworthy. An ethical approach to AI is central to strengthening citizen trust in digital development, and to building a competitive advantage for European companies.

The SESAR 3 Joint Undertaking is an institutionalised European partnership between private and public sector organisations set up to accelerate through research and innovation the delivery of the Digital European Sky. It is enabling the expansion of AI in aviation and ATM through research that builds innovative, transparent and trustworthy AI solutions that seek to support human operators.

This Results Pack highlights recent advances made by 15 projects supported by EU funding through the SESAR 3 Joint Undertaking. The projects featured address all phases of flight from strategic and pre-tactical planning to tactical operations themselves.

Thanks to the application of machine learning, deep learning and big data analytics, delivered through the joint support of the private and public sectors, the EU aviation industry will be able to surpass the complexity of the existing system, making it more scalable, economically sustainable, environmentally efficient and resilient.

# Cutting costs (and delays) at airports using predictive AI

Gathering and sharing sensitive data from airlines could help air navigation service providers better predict and plan flight allocations. EU researchers are developing a machine learning system that facilitates this while guaranteeing cybersecurity and data privacy.

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Artificial intelligence based on collaborative data-driven machine learning has the potential to transform air traffic management (ATM).

Encouraging the participation of all stakeholders, including airlines, will be critical to achieving successful outcomes in the future.

"Airlines are today reluctant to share their private data to contribute to collaborative decision-making," explains AICHAIN (A platform for privacy-preserving Federated Machine Learning using Blockchain to enable Operational Improvements in ATM) project coordinator Javier Busto from [SITA eWAS Application Services](#) in Spain.

*We'd really like to see more airlines providing data in a federated and privacy-preserving manner.*

"Once they have filled out their flight plans, the planning and management of the network resources and airspace capacities tend to take place more or less without the full coordination with airlines."

Feeding airline data on sensitive issues such as costs, flight priorities and passenger and crew connections into the decision-making process could contribute to more efficient predictive models, and lead to smoother capacity management and flight allocations in the future.

"The challenge here is not just technological; it is also about encouraging stakeholder participation in building common global models for the benefit of ATM as a whole," continues Busto. "This data tends to be commercially very sensitive, covering fuel costs and staffing issues."

## Predictive flight allocation

AICHAIN was funded within the framework of the SESAR Joint Undertaking, a public-private partnership set up to modernise Europe's ATM system. The project sought to improve flight allocations by applying machine learning to sensitive (and non-sensitive) data in a decentralised, protected way. The idea was that this would provide airlines with the security and confidence needed to share their data.

"We developed a federated machine learning system that could be trained with this sensitive data from airlines," adds AICHAIN scientific coordinator Sergio Ruiz from the EUROCONTROL Innovation Hub based in France. "The Network Manager, in this case EUROCONTROL, could then use this secured information to enhance the prediction of the flight routes chosen by the airlines and the expected take-off times, to ensure smoother operations."

Federated machine learning has been used in industries such as pharmaceuticals and healthcare, and AICHAIN wanted to demonstrate that the concept was feasible for ATM. The team focused on two specific end use cases – take-off time prediction and flight route prediction. Greater predictability for these aspects is important for achieving better management of traffic and reducing latent capacities, which in turn would reduce the ATM costs for airlines and passengers.

"Data can be processed in the nodes (e.g. airlines systems), where data is located," says Ruiz. "We used blockchain and identified other privacy enabling technologies to complement federated machine learning."

## Getting airlines on board

The project team then assessed the efficacy of the system in terms of technological feasibility, operational value and acceptance by stakeholders. "Federated machine learning is a fairly mature technology, though not too well known in this sector," remarks Busto. "We demonstrated that we could develop a bespoke system that fully protects privacy and generates the due trust and incentives for the airlines to participate."

AICHAIN also worked closely with relevant authorities to ensure that the machine learning tools could be certified for use in ATM. This is an essential step for introducing new technologies in such a safety-critical domain.

"This is a very complex domain that is still evolving," adds Ruiz. "In this way, the project has been able to exert a positive influence on the certification process, in particular when data privacy and process transparency are both required."

The project also demonstrated the power of blockchain technology in terms of traceability and generating trust. "For us, this is a decentralised data technology," notes Ruiz. "Data is not on a platform as such, but stays with the owners of the data, who remain in full control. From there it can be exploited by the network manager through the federated learning platform, while privacy is protected."

Both Busto and Ruiz see AICHAIN as having made a valuable contribution not only to helping improve automation in ATM but also to the field of federated machine learning as a whole.

"We'd like to explore new use cases," says Ruiz. "Some of this technology could be developed fairly quickly. What we'd really like to see is more airlines providing data in a federated and privacy-preserving manner. The good news is that more airlines have expressed an interest in this project."

**PROJECT**

**AICHAIN – A platform for privacy-preserving Federated Machine Learning using Blockchain to enable Operational Improvements in ATM**

**COORDINATED BY**

SITA eWAS Application Services in Spain

**FUNDED UNDER**

Horizon 2020-TRANSPORT

**CORDIS FACTSHEET**

cordis.europa.eu/project/id/894162

**PROJECT WEBSITE**

aichain-h2020.eu

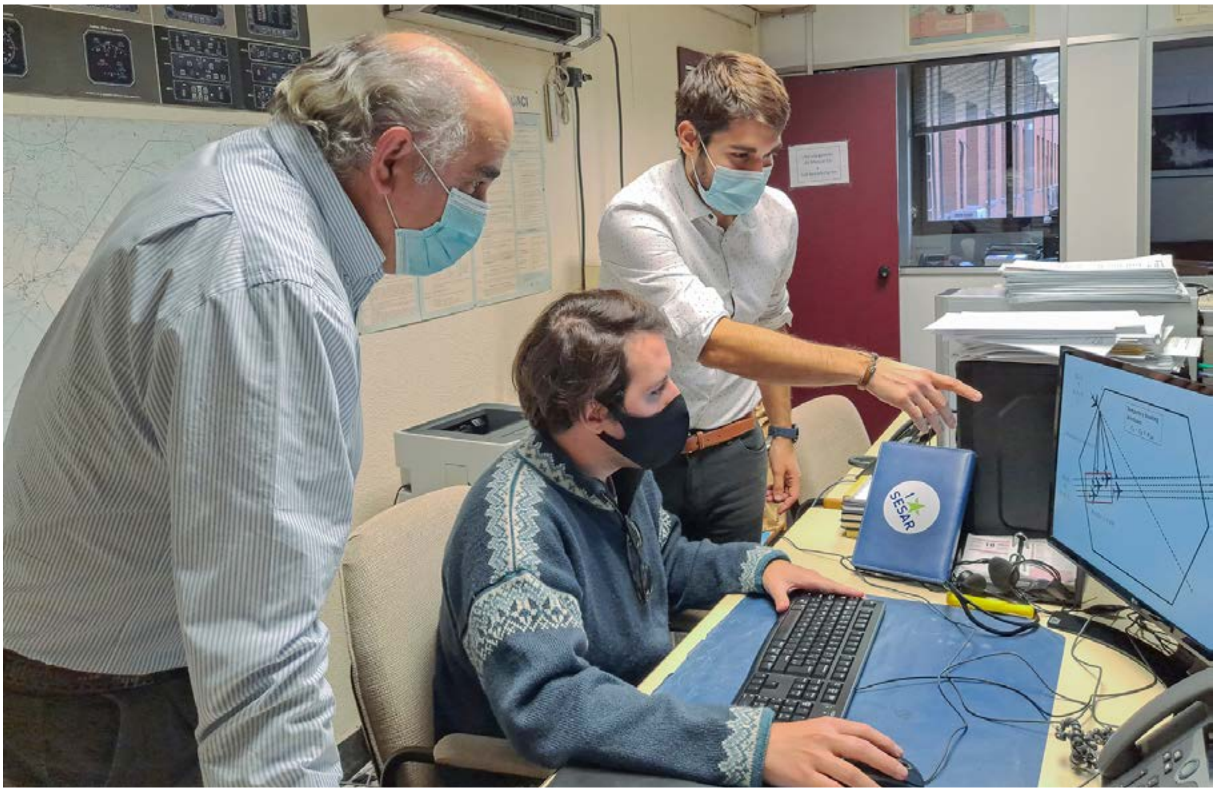
# AI assistant helps air traffic controllers maintain situational awareness

**While automation in air traffic management can improve efficiency, such tools must be fully reliable and complement the work of controllers. An intelligent, situationally aware system could provide the framework in which machine learning tools safely thrive.**

Aviation capacity – both on the ground and in the air – is limited by the workload capacity of air traffic controllers. During busy periods, flights are routinely delayed or directed away from potentially congested airspace, wasting time and fuel.

Consequently, the air traffic management (ATM) sector has been examining ways of applying automation to help handle workload, and to free up the mental capacity of controllers so they can handle more aircraft and focus on safety-critical tasks.

"Much of this work has focused on automating particular tasks, such as detecting conflicts," explains AISA (AI Situational Awareness Foundation for Advancing Automation) project coordinator Tomislav Radisic from the Faculty of Transport and Traffic Sciences at the University of Zagreb in Croatia. "A conflict is a situation where two aircraft are on track to be too close at some point in time. This usually means being within five nautical miles of each other."



## Automated situational awareness

The challenge facing air traffic controllers is that they have hundreds of individual tasks to perform daily. Instead of looking at automating individual tasks therefore, AISA sought to take a step back and develop a more foundational system. The project was funded within the framework of the SESAR Joint Undertaking, a public-private partnership set up to modernise Europe's ATM system.

"We wanted to develop something that would first actually monitor all existing tools, to give the system a kind of artificial situational awareness," adds Radisic. "By keeping track of many things at the same time, we thought we could also automate a number of existing monitoring tasks."

The project team set about developing the prototype system. This was based on something called knowledge graphs, automatically generated from available aviation data.

"These knowledge graphs help to explain relationships between different objects and concepts," says Radisic. "So, for example, if we want to gain new knowledge about the situation, we can do that by reasoning over the facts we know to be true."

This kind of 'mapping' helped the project team to develop a system with much more situational awareness, capable of determining if the output of a particular automated tool reflected reality.

"If, say, an automated tool suggests that two aircraft are in conflict, we can see in the knowledge graph that this is perhaps not the case," explains Radisic.

## Meeting industry needs

A number of simulated experiments with air traffic controllers were then conducted. The project team wanted to see how effective the system was at monitoring the performance of automated tools – whether it picked up anything that human controllers didn't – and how useful the automation of certain monitoring tasks was.

"The first thing to say is that the system worked as expected," notes Radisic. "There were no lapses in situational awareness, and in fact the system was able to react to outputs that did not reflect reality, which human controllers were at times unable to."

Automated monitoring designed to support controllers received more nuanced feedback. "Input was delivered to controllers via pre-recorded messages, at specific points we thought would be relevant," he says.

"Controllers however generally didn't like this way of receiving information, as they expect only pilots to talk to them. Another issue was uncertainty over when to present this information; some controllers found the information delivered too early."

Such feedback is critically important. The involvement of critical end users early in this technological development will help to ensure that the final system is ideally suited to their needs. "This project began by looking into how this could fit into current systems, but we are also interested in shaping future ATM concepts past 2035," adds Radisic.

*A conflict is a situation where two aircraft are on track to be too close at some point in time. This usually means being within five nautical miles of each other.*

Next steps therefore will include a closer look at how best to present these automated monitoring alerts to controllers, and when this information should be presented. Radisic envisages the development of a visual human-machine interface. "This is all about understanding the needs of the traffic controller," remarks Radisic.

The project also underlines the sector's overarching commitment to safety. While machine learning tools can undoubtedly achieve efficiencies and boost safety in aviation, it is critical controllers can be assured that they are performing properly. To this end, the AISA project has made an important contribution in this ongoing conversation.

**PROJECT**
**AISA – AI Situational Awareness Foundation for Advancing Automation**

**COORDINATED BY**
University of Zagreb in Croatia

**FUNDED UNDER**
Horizon 2020-TRANSPORT

**CORDIS FACTSHEET**
cordis.europa.eu/project/id/892618

**PROJECT WEBSITE**
aisa-project.eu

# Artificial intelligence plots a safe route through hazardous skies

A prototype artificial intelligence system that offers precise information on natural events such as thunderstorms and volcanic ash clouds could help aircraft avoid danger and disruption.

Natural events such as thunderstorms and volcanic ash clouds present serious safety challenges for the aviation sector. The cost of storm-induced disruption to aviation across Europe was estimated to be EUR 2.2 billion in 2019.

In addition, aerosols and gases arising from natural hazards such as forest fires and desert dust can also severely reduce visibility and damage engines. Even space weather – such as the solar wind – can impact aviation by disrupting satellite communication and increasing radiation exposure.

*Aviation traffic management could use this technology to identify climate hotspots and limit air traffic in that area.*

"The problem for aviation is not that there is a lack of information on such phenomena, but that this information does not have enough granularity," explains ALARM (multi-hAzard monitoring and earLy wARning systeM) project coordinator Manuel Soler from University Carlos III Madrid, Spain.

"Air traffic management (ATM) and pilots need more precision. For example, they need to know how high a volcanic plume of ash and $SO_2$ gas is rising. Forecasting large areas where convection (with associated thunderstorm activity) will occur is relatively easy; what is tricky is predicting exactly the development of the thunderstorm itself, in which localised area, such as over an airport, and at what specific time."

## Forecasting the future

The ALARM project was funded within the framework of the SESAR Joint Undertaking, a public-private partnership set up to modernise Europe's ATM system. It sought to move the aviation sector towards this objective by developing a prototype monitoring and early warning system for various hazards.

To achieve this, near real-time data from ground-based and satellite systems was gathered. This highly granular information was then processed and fed into models for identifying the displacement of particles and gases derived from natural hazards, as well as extreme weather situations.

"The first step was to provide a kind of snapshot of what is happening," adds Soler. "For this, we combined data from low Earth orbit and geostationary satellites, to be able to monitor and differentiate particles in the atmosphere. This enabled us to improve the quality of information on volcanic eruptions, sandstorms and forest fires."

The second step was to develop predictive models. Soler and his team wanted to be able to provide the aviation sector with forecasts of between one hour ahead and a day ahead. The goal was to make this data useful: ATM could use these predictive models to make in-flight deviations, or reschedule flights altogether.

To achieve this, artificial intelligence (AI) was applied to observational data and historical observations. The project's prototype AI system 'learned' from past localised forecasts and weather observations, in order to be able to better predict the likely evolution of any given natural event. This might be used, for example, to accurately predict the behaviour of a severe thunderstorm over an airport.

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## Climatic hotspots

Delivering a protype real-time monitoring service, as well as forecasting tools for thunderstorms, volcanic eruptions, dust clouds and space weather, has been a key success of the ALARM project. Illustrative examples have been carried out at airports such as Brussels and Milan Malpensa, and the alert system platform is freely available to access.

The project also broke new ground by focusing on aviation-induced climate change. "In ALARM, we recognised environmental impact as an additional aviation hazard," remarks Soler. "Studies have shown that $CO_2$ and non-$CO_2$ aviation emissions, such as $NO_x$, water vapour and condensation trails, have a negative impact on climate change."

Numerical weather forecasts along with climate change functions have been used to identify and forecast potential climatic hotspots that should be avoided. This could contribute to limiting aviation's negative impact on the environment.

"We are currently working on indicators such as temperature, humidity, pressure and cloud cover, which could help us to better predict the emergence of climatic hotspots," says Soler. "Our idea is that aviation traffic management could use this technology to identify hotspots and limit air traffic in that area, in the same way as some cities ban certain cars during times of high pollution."

This technology is still in its infancy, but underlines the ambitions of the ALARM consortium in harnessing the power of AI to improve ATM.

**PROJECT**
**ALARM – multi-hAzard monitoring and earLy wARning systeM**

**COORDINATED BY**
University Carlos III Madrid in Spain

**FUNDED UNDER**
Horizon 2020-TRANSPORT

**CORDIS FACTSHEET**
cordis.europa.eu/project/id/891467

**PROJECT WEBSITE**
alarm-project.eu

# Building trust in air traffic management AI

While artificial intelligence supports many air traffic management tasks, the underlying algorithms often remain inscrutable. The EU and industry-funded ARTIMATION project sheds light on these, and investigates how users respond.

Artificial intelligence (AI) increasingly simplifies complex tasks and automates mundane ones entirely. In air traffic management (ATM), a lack of transparency around AI techniques such as neural networks and deep learning has serious consequences for trust and implementation.

The ARTIMATION (Transparent Artificial Intelligence and Automation to Air Traffic Management Systems) project, funded under the SESAR Joint Undertaking to modernise Europe's ATM system, has developed 'explainable AI' (XAI) algorithms that reveal the working of ATM's increasing range of AI solutions.

"As well as ensuring AI's reliability and functionality for ATM tasks, our approach is to make it more acceptable, by making it more explainable," says Shahina Begum, deputy leader of the Mälardalen University AI and Intelligent Systems group.

ARTIMATION has developed algorithms using XAI techniques to support two common operational tasks: air traffic conflict resolution (such as rerouting aircraft to avoid collisions) and delay propagation (understanding the reasons for delayed flights).

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"We have successfully developed proof of concept transparent AI models – generic enough to be adopted for a range of tasks, as well as adaptable over time, offering safe and reliable decision support," remarks project coordinator Mobyen Uddin Ahmed, also from Mälardalen University, the project host.

## From proof of concept to *in situ* testing

After a literature review of ATM AI options, the ARTIMATION team selected off-the-shelf open access algorithms such as Random Forest as their preferred solutions. Working with ATM experts across three online workshops, the team customised these.

The tweaked algorithms were then lab-tested by representatives from Mälardalen University and project partner, the French National School of Civil Aviation (ENAC). The result was an XAI prototype which increased user understanding of the stages leading up to a critical decision, alongside the underlying logic driving that process.

*Begum envisions AI systems in the future, which interface with the human brain – effectively reading the intention of users to speed up operator control.*

Users follow AI explanations using headsets integrated with 3D visualisation tools, such as data-driven storytelling and immersive analytics. Explanations cover the three levels of automation developed by the team. In level one, users have the most control; in level three, the AI does.

User testing is currently underway at the ENAC premises in France, exploring simulated air traffic conflict resolution and delay propagation scenarios, in conjunction with partners Deep Blue and Sapienza University, both in Italy. "Our prototype was able to accurately predict delays 90 % of the time," adds Ahmed.

## Future possibilities on the horizon

There are tests of the prototype planned at ENAC's ATM simulators in France. This qualitative assessment will explore in more detail issues around acceptability, safety, roles and task allocation.

"We will delve deeper into how different levels of transparency and visualisation techniques influence trust, as well as the performance of both humans and the system," explains Ahmed. "We will investigate how users respond physiologically and psychologically to AI, using various neurophysiological measurements."

These measures will especially assess workload, stress and operator acceptance of different XAI levels. Begum even envisions AI systems in the future which interface with the human brain – effectively reading the intention of users to speed up operator control – hosted within immersive environments, such as virtual reality.

As ARTIMATION's solution follows adaptability design principles, it could be further rolled out to additional ATM tasks, such as object detection.

According to Begum: "Automated monitoring, control and decision support could even one day lead to a 'virtual or remote-control tower' removing the need for any of the physical assets we see now."

The team are currently also working on AI guidelines for delay propagation and conflict resolution, designed for air traffic controllers and AI communities.

**PROJECT**
**ARTIMATION – Transparent Artificial Intelligence and Automation to Air Traffic Management Systems**

**COORDINATED BY**
Mälardalen University in Sweden

**FUNDED UNDER**
Horizon 2020-TRANSPORT

**CORDIS FACTSHEET**
cordis.europa.eu/project/id/894238

**PROJECT WEBSITE**
artimation.eu

# AI assesses the safety and resilience impacts of changes to ATM systems

The EU- and industry-funded FARO project has developed a methodology for assessing the safety and resilience of air traffic management that combines knowledge-based and data-driven approaches.

While automation offers solutions for better management of our increasingly crowded skies, it also brings risks, if not properly mitigated. The high numbers of people travelling by air, coupled with an expanded range of non-conventional aircraft, including various unmanned vehicles, makes the skies ever more challenging to manage.

The FARO (saFety And Resilience guidelines for aviatiOn) project was funded within the framework of the SESAR Joint Undertaking, a public-private partnership set up to modernise Europe's air traffic management (ATM) system.

SESAR aims to increase the efficiency and environmental friendliness of European airspace by developing and harnessing cutting-edge technologies – especially those that automate operations. To quantify their likely impact, SESAR applies cost-benefit analysis to key performance areas like safety, capacity and operational efficiency.

To support this performance-driven approach, the EU- and industry-funded FARO project has developed a set of methodologies and techniques to assess ATM safety and resilience.

"Stakeholders have remarked that our pioneering approach allows them to take real events, such as adverse weather conditions, and assess the benefits that system changes, such as new traffic procedures, bring to safety/resilience levels," says Christian Eduardo Verdonk Gallego, project coordinator.

Benefiting from the collective expertise of its consortium, including air navigation service providers, the project is also developing safety and resilience guidelines. Additionally, the team's investigation techniques have already been outlined in 'Open Research Europe'.

*Our techniques could prove a milestone in helping operators quantify safety levels and identify resilience strategies, key to keeping European citizens flying confidently.*

## Balancing safety and resilience

Changes to the operating environment of ATM, including technological upgrades and procedural changes, can have unintended, sometimes dangerous, consequences. If operators could evaluate the likely impact of changes beforehand, they could mitigate them.

FARO's approach identifies features – such as workload, weather conditions and number of delayed aircraft – that are relevant for modelling safety and resilience from technical, organisational, human and procedural perspectives.

The project's key innovation is a computer model, based on Bayesian Belief Networks, which can graphically represent the probable relationship between different variables in a system and its impact on safety.

"This model captures how the competing goals of ATM systems, especially during unexpected events, ultimately influence air traffic safety, including indications of where the ATM proves resilient alongside the reasons why," adds Verdonk Gallego from CRIDA (website in Spanish only), the project host.

The project used natural language processing to extract detail from the free text of Spanish and British air safety reports, and then applied computational techniques, like topic modelling and clustering, to categorise factors that contributed to incidents but were often overlooked, such as excessive workload.

## Redesigning Barcelona ATM

FARO validated its approach in three real-world ATM use cases in Spain. Two were operational changes: the deployment of 'direct route airspace' around Santiago – studied in conjunction with project partner ENAIRE; and the 'resectorisation' of the airspace above Barcelona feeding the Balearic islands.

The third case study was concerned with automation, with approach controllers at Barcelona airport receiving information directly downlinked from aircraft. FARO accessed and analysed data going back to 2013 to be able to compare the situation before and after the changes in each use case were introduced.

"In each case our model accurately predicted safety levels, and also, for the first time, captured operators' strategies as they responded to changing traffic levels," explains Verdonk Gallego. "For example, the new route above Barcelona reduced the need for operators to solve conflicts between aircraft, increasing capacity while maintaining safety."

Supporting the EU's Single European Sky initiative, SESAR's vision for European ATM looks for increased capacity, operational efficiency and sustainability. FARO's contribution highlights the impact these drivers might have on safety and resilience performance.

"Our techniques could prove a milestone in helping operators quantify safety levels and identify resilience strategies, key to keeping European citizens flying confidently," concludes Verdonk Gallego.

**PROJECT**
**FARO – saFety And Resilience guidelines for aviatiOn**

**COORDINATED BY**
CRIDA in Spain

**FUNDED UNDER**
Horizon 2020-TRANSPORT

**CORDIS FACTSHEET**
cordis.europa.eu/project/id/892542

**PROJECT WEBSITE**
faro-h2020.eu

# Better automatic speech recognition for safer air traffic control

## Effective communication between pilots and controllers is vital to safety. HAAWAII's advanced speech recognition technology can flag mistakes while reducing workload.

While speech recognition is becoming increasingly sophisticated in consumer products, some sectors that could really benefit are lagging behind.

Air traffic control digital assistants access air and ground traffic sensors, but voice communication between controllers and pilots is not automatically available to them, despite being the most valuable source of information.

To digitise voice communications, controllers must transcribe the information, which takes up to one third of their time. The HAAWAII (Highly Automated Air Traffic Controller Workstations with Artificial Intelligence Integration) project, funded within the framework of the SESAR Joint Undertaking, has developed new speech recognition software based on deep neural networks.

"As Alan Turing pointed out in the 1950s, speech recognition is not speech understanding, so we also worked on that," says Hartmut Helmke, project coordinator from the German Aerospace Center, the project host. "We've achieved a word error rate of under 5 %, translating to a command recognition rate of over 85 % for air traffic controllers."

## Readback error detection for ATM

Speech recognition of air traffic controllers and pilots remains challenging due to local versions of standardised phraseology, different English accents (the international language of aviation), different speaking speeds and noisy channels. HAAWAII partners NATS and Isavia, the United Kingdom's and Iceland's air navigation service providers respectively, recorded over 500 hours of controller-pilot voice communications. Forty hours of this was then manually transcribed word-for-word.

*Speech recognition of air traffic controllers and pilots remains challenging due to local versions of standardised phraseology, different accents, different speaking speeds and noisy channels.*

After supplying the HAAWAII speech recogniser software with just one hour of manually transcribed data, word recognition improved twofold. After training it on all the transcribed and untranscribed data, the word recognition rate was over 95 % for controllers and over 90 % for pilots.

"The real problem with incorrectly recognised words is when they relate to safety-critical information, such as call signs or waypoint names. Combining voice with radar data enabled our system to improve at the semantic level. For example, we achieved a recognition rate of 97 % for aircraft call signs used by controllers," remarks Helmke.

Machine learning was also used to create a Readback Error Detection Assistant (REDA). Readback errors are where, for example, a controller gives clearance for a pilot to climb to 7 000 feet but the pilot repeats this as 8 000 feet, risking a collision if undetected. The REDA generates an alert when these errors occur.

The REDA was evaluated in a laboratory by five air traffic controllers from Iceland. "The number of readback errors detected during these lab tests was over 80 % from offline evaluations of transcriptions from real-life data, with a false alarm rate below 20 %," adds Helmke. Trials with NATS controllers are planned for this year, with Isavia also intending to demonstrate the REDA in their own operational environment.

## Increased accuracy and reduced workload

By reducing the workload and increasing the accuracy of air traffic controllers, effective speech recognition and understanding could significantly increase air safety. Thousands of hours of transcriptions also offer air navigation service providers useful management information, such as how often certain commands are given or repeated per aircraft, both suggesting high workloads.

Speech recognition could also be used to support on-the-job simulations, making training cheaper and possible remotely. "Our prototype has worked around London, Europe's most congested air space and also in Isavia's airspace, covering over 5 000 000 square kilometres. It understood pilots' voices, with a word error rate under 10 %, despite accents from around the world, not to mention very noisy voice channels," concludes Helmke.

**PROJECT**
**HAAWAII – Highly Automated Air Traffic Controller Workstations with Artificial Intelligence Integration**

**COORDINATED BY**
German Aerospace Center in Germany

**FUNDED UNDER**
Horizon 2020-TRANSPORT

**CORDIS FACTSHEET**
cordis.europa.eu/project/id/884287

**PROJECT WEBSITE**
haawaii.de/wp

# Putting the passenger at the centre of multimodal mobility

## As airports evolve into transport hubs, AI can help map the passenger journey, laying the groundwork for a seamless and sustainable travel experience.

The airport of tomorrow will be more than a place to land and take off. It will be the hub of a multimodal mobility system that includes everything from trains, planes and automobiles to flying taxis, ride-share services and last mile connections.

At the centre of this hub will be the passenger.

"The problem with legacy transport systems is that all too often the passenger is treated as an afterthought," says Ricardo Herranz,

CEO at Nommon Solutions and Technologies. "Instead, the industry needs to take a passenger-centric approach to mobility, where the passenger journey is the backbone on which the entire transport network is built."

Funded within the framework of the SESAR Joint Undertaking, a public-private partnership set up to modernise Europe's air traffic management system, the IMHOTEP (Integrated Multimodal Airport Operations for Efficient Passenger Flow Management) project is leading an effort to make such a system possible. "Our vision is that airports will become multimodal connection nodes where passengers can seamlessly travel door-to-door in an efficient, sustainable and resilient manner," adds Herranz.

*The problem with legacy transport systems is that all too often the passenger is treated as an afterthought.*

To make this vision a reality, the project is developing the interconnected platforms and services that will enable real-time collaboration between airports and ground transportation. The result will be a more efficient management of passenger flows.

## Flexible transport models and decision tools

Creating a passenger-centric experience starts with knowing what the passenger trip is and how passengers will use a multimodal network to complete it. "Our project is using data from a range of sources as a means of reconstructing the entire passenger experience – from door-to-gate and from gate-to-door," explains Herranz.

The project is using data collected from personal mobile devices and digital sensors. This data is then fed into a set of algorithms capable of reconstructing passenger flows in real time and for different stages of the passenger journey.

The outcomes of this process are delivered in the form of so-called Activity-Travel-Diaries. These diaries can be used for calibrating predictive models for forecasting the short-term evolution of airport and ground transport performance.

"We also developed a set of predictive models and what-if decision support tools that can forecast passenger flow evolution within a typical day of operation," remarks Herranz. "These models enable common situation awareness across transport modes, coordinated decision-making, and enhanced passenger information services."

Another key outcome of the project is a concept of operations for making the most of these tools by including ground transport stakeholders in airport collaborative decision-making.

## A roadmap for future research in transport

According to Herranz, developing an integrated prediction model of passenger behaviour, both inside and outside the airport, was a huge challenge. "We are very proud to say that the IMHOTEP project has successfully solved this puzzle," he says.

Using this methodology, the project is conducting case studies at London City and Palma de Mallorca airports, in the United Kingdom and Spain respectively. The studies, which are being done in collaboration with the airports and ground transport operators such as Transport for London and EMT Palma, will assess the benefits of using IMHOTEP's solutions in various scenarios.

"These studies will serve as a roadmap for future research, with the goal of evolving IMHOTEP's technology to higher levels of maturity and achieving its transition to SESAR Industrial Research," concludes Herranz.

**PROJECT**
**IMHOTEP – Integrated Multimodal Airport Operations for Efficient Passenger Flow Management**

**COORDINATED BY**
Nommon Solutions and Technologies in Spain

**FUNDED UNDER**
Horizon 2020-TRANSPORT

**CORDIS FACTSHEET**
cordis.europa.eu/project/id/891287

**PROJECT WEBSITE**
imhotep-h2020.eu

# AI models help air traffic managers weather big storms

**ISOBAR's predictive models can help air traffic management better anticipate weather disruption, meaning fewer delays and cancellations.**

The skies above Europe are more crowded than ever, and unpredictable events such as thunderstorms can sometimes push operations beyond the capacity of controllers.

"Air traffic management (ATM) can only safely handle so many aircraft within a given airspace at a given time," says Marta Sánchez, an ATM R&D engineer at Spain's CRIDA (website in Spanish only). "When demand outpaces this capacity, flights get delayed."

With the support of the SESAR Joint Undertaking set up to modernise Europe's ATM system, the ISOBAR (Artificial Intelligence Solutions to Meteo-Based DCB Imbalances for Network Operations Planning) project is leading an effort to

use artificial intelligence (AI) and other advanced technologies to better predict – and mitigate – capacity and demand imbalances that can lead to travel disruption.

## Using AI to precisely predict thunderstorm activity

One factor that can quickly cause an imbalance in the airspace is weather, particularly thunderstorms. When thunderstorms are forecast, ATM often make the decision to reduce capacity in that airspace, which translates into delays, rerouting and cancellations.

*Air traffic management can only safely handle so many aircraft within a given airspace at a given time. When demand outpaces this capacity, flights get delayed.*

"The problem is that today's forecasts aren't very accurate," explains Manuel Soler, an aerospace engineer at Spain's University Carlos III who leads ISOBAR's meteorological forecasting activities. "Although they can tell you when conditions are indicative of a thunderstorm, they can't pinpoint exactly when and where that storm will happen."

This means ATM end up closing the entire airspace where a thunderstorm might occur, even if it turns out that the storm only affects a small area for a short period of time, says Soler.

Having more precise information would allow ATM to make decisions confined to the immediate vicinity of the weather event. The ISOBAR project is using AI, Earth Observation satellite data and advanced weather forecasting to better predict thunderstorm activity, altitude, severity and probability.

## Reacting to imbalances in flight capacity

However, a thunderstorm's impact isn't limited to the immediate airspace. Disruption at one point tends to cause a domino effect. "When a thunderstorm impacts airspace X, those delayed and rerouted flights will increase demand in airspace Y," explains Sánchez. "When airspace Y's capacity is reached, ATM will delay or reroute flights into another airspace, which will impact its demand-capacity balance, and so on."

Here ISOBAR can help. "We created a second model for predicting demand and capacity," remarks Sánchez. "Using AI, it looks at scheduled flight plans, how flights are rerouted in severe weather, and how those decisions will impact demand and capacity outside the immediately affected airspace."

With this 'hotspot' model, used in conjunction with the weather forecasting model, ATM can predict where they can expect to see an imbalance in demand and capacity.

ISOBAR then created a third model that provides alternative flight plans for avoiding so-called hotspots. "ATM can use this information, in coordination with the other models, to proactively make decisions that will reduce traffic and congestion and thus mitigate flight disruptions," concludes Sánchez.

The ISOBAR models are currently available as a prototype, which will serve as the basis for developing, testing and validating their use within various ATM services and solutions.

**PROJECT**
**ISOBAR – Artificial Intelligence Solutions to Meteo-Based DCB Imbalances for Network Operations Planning**

**COORDINATED BY**
CRIDA in Spain

**FUNDED UNDER**
Horizon 2020-TRANSPORT

**CORDIS FACTSHEET**
cordis.europa.eu/project/id/891965

**PROJECT WEBSITE**
isobar-project.eu

# Finding automation's place within air traffic control systems

Machine learning and artificial intelligence could reduce delays, improve efficiency and increase safety. But these technologies must first be certified and accepted by controllers.

Automated systems already play a big role within the aviation industry. Airlines regularly use artificial intelligence (AI) for everything from planning new routes to communicating with customers, optimising fuel efficiency, and even conducting predictive aircraft maintenance.

Yet the technology's role has largely been limited to what the industry refers to as non-safety-critical applications. It hasn't yet found its way into air traffic control (ATC) systems.

"Aviation is extremely safety-conscious – and for good reason," says Stefano Bonelli, project coordinator of the MAHALO (Modern ATM via Human/Automation Learning Optimisation) project. "Today's AI models simply lack the accuracy needed to meet aviation's stringent safety standards."

## Training and certifying AI for ATC

Bonelli, head of Innovative Human Factors at project host Deep Blue, explains that even if the models could pass the safety test, that still wouldn't translate into immediate use.

"Before implementation, an AI system would have to go through a complex certification process," he adds. "Because neural networks are comprised of thousands of trainable parameters, it would be nearly impossible to inspect and certify each and every one of them."

There's also the issue of training the model. "ATC is so complex, accounting for every possible variable and scenario imaginable, that training an AI system would require gathering vast amounts of data," explains Bonelli.

Does this mean there's no place for AI inside the ATC tower? According to Bonelli, not necessarily. "Using AI would allow for better use of the airspace, help reduce traffic jams and delays, improve fuel efficiency, and, most importantly, increase safety," he says. "The challenge is finding the right balance between automation and human control."

Funded within the framework of the SESAR Joint Undertaking, MAHALO aimed to better understand the type of automation best suited for ATC systems. "Instead of assuming that AI would replace the entire system, we looked at such factors as how much AI should be used, where it would be most beneficial, and whether it should perform tasks autonomously or serve as a tool to support the human controller's decision-making," explains Bonelli.

To answer such questions, the project developed and tested a hybrid machine learning system. This was trained to solve critical ATC tasks such as detecting and resolving en route traffic conflicts.

## Putting trust at the centre of AI systems

The main focus of the MAHALO project, however, was how air traffic controllers interact with such systems. "If AI is to succeed, the individual controller must not only understand how to use it, they must also accept what it can do and, even more importantly, trust that it can do it," remarks Bonelli. "If they don't trust the system, they simply won't use it."

*If AI is to succeed, the individual controller must not only understand how to use it, they must also accept what it can do and, even more importantly, trust that it can do it.*

Researchers found that controllers were more open to using systems that aligned with their preferred solutions and that did not increase individual workloads. They also found that while controllers were open to using the machine learning system, they were less enthusiastic about accepting every proposed solution and basing decisions on the system's outputs without first inspecting them.

According to Bonelli, this last point shows why involving end users is absolutely critical when developing new ATC solutions. "One of the most important issues raised by air traffic controllers was the importance of taking their needs and opinions into account," he concludes. "For me, this is one of the project's biggest successes – we put the human at the centre of AI."

**PROJECT**
**MAHALO – Modern ATM via Human/Automation Learning Optimisation**

**COORDINATED BY**
Deep Blue in Italy

**FUNDED UNDER**
Horizon 2020-TRANSPORT

**CORDIS FACTSHEET**
cordis.europa.eu/project/id/892970

**PROJECT WEBSITE**
mahaloproject.eu

# Integrating predictive AI into air traffic management workflows

Predictive machine learning could make traffic management systems safer and more efficient. The EU- and industry-funded SafeOps project sought the best way to integrate this information into human operator workflow.



Organising the skies above Europe is a delicate operation that depends on the collaborative efforts of airlines and ground authorities. Next-generation air traffic management (ATM) systems are driven by two sometimes conflicting goals: to make ATM processes more efficient, while also increasing safety.

Artificial intelligence (AI) could play a major role in this evolution. AI systems can parse through large volumes of data, bringing enhanced automation and new decision support tools based on predictive information.

For example, air traffic controllers could be advised about potential missed approaches by planes well ahead of time, allowing them to better organise landing traffic, departing traffic and runway capacity. This could mitigate the knock-on effects that result when a plane is forced to loop around the airfield rather than land, known as a go-around event.

*Predictive systems must show that they can increase capacity and be cost-efficient, or improve safety and resilience of air traffic management.*

Yet while current state-of-the-art air traffic control systems are based on information that is known to be true, AI predictions are based on probabilities, which introduces an element of uncertainty. Safety is paramount in aviation, so controllers will have to trust the information they are receiving.

The SafeOPS project, funded within the framework of the SESAR Joint Undertaking, set out to discover how such predictive technologies can be best integrated into existing human-driven ATM systems, to build trust in AI predictions among controllers.

"Predictive systems must show that they can increase capacity and be cost-efficient, or improve safety and resilience of ATM," says project coordinator Lukas Beller from the Technical University of Munich in Germany. "Ideally both," he adds.

## Predicting go-around events ahead of time

To investigate the impacts of integrating AI into ATM, the SafeOPS team first ran a series of workshops with experts, tower controllers and other aviation specialists.

"In these workshops, we defined reference scenarios – in which go-arounds are challenging to handle – using the state-of-the-art methods and tools," Beller explains.

Once these situations had been defined, the team set about designing a prototype system that simulated these reference scenarios using information created through predictive machine learning, a subset of AI. Using this prototype, the team could gather initial quantifiable estimates of how good predictions of go-around events could be. "Go-arounds are very rare events, so quantifying this isn't trivial," Beller remarks.

The team then discussed the results of the prototype experiments in further workshops with air traffic controllers, to see if the reference scenarios were still a reasonable reflection of reality, and adapted the results accordingly. This back and forth fine-tuning between human and machine will hopefully lead to better integration into the existing workflow.

At the same time, the SafeOPS team worked to adapt existing risk frameworks within the ATM industry, taking into account the estimated possible risks of introducing AI predictions.

## High-confidence predictions for air traffic control

There have been surprising results already, says Beller. Initial research shows that air traffic controllers find it acceptable if AI fails to predict every single go-around event, as long as predicted events carry 90 % confidence. This makes sense from an operational perspective, says Beller.

The SafeOPS project is due to conclude at the end of 2022. "I hope that we can show and measure a positive impact of the AI tool on the safety and resilience of ATM," concludes Beller.

**PROJECT**
**SafeOPS – From Prediction to Decision Support - Strengthening Safe and Scalable ATM Services through Automated Risk Analytics based on Operational Data from Aviation Stakeholders**

**COORDINATED BY**
Technical University of Munich in Germany

**FUNDED UNDER**
Horizon 2020-TRANSPORT

**CORDIS FACTSHEET**
cordis.europa.eu/project/id/892919

**PROJECT WEBSITE**
safeops.eu

# Machine learning methods to model Europe's crowded skies

The computational power needed in air traffic modelling is increasing. The EU- and industry-funded SIMBAD project developed powerful artificial intelligence-based simulation models that make evaluating new air traffic scenarios far easier.

With ever more planes travelling across Europe, air traffic management (ATM) is becoming increasingly complex. New technologies and concepts hold the promise of making Europe's air transport industry more efficient, safe and sustainable.

The SIMBAD (Combining Simulation Models and Big Data Analytics for ATM Performance Analysis) project has developed state-of-the-art modelling techniques based on artificial intelligence, using new machine learning approaches to improve on current air traffic microsimulations, the highly detailed models necessary to integrate new technologies into ATM systems.

"Given the complexity and computational cost of large-scale, microscopic air traffic simulation tools, simulations are necessarily restricted to a limited number of scenarios, which are often insufficient to obtain conclusive results," explains David Mocholí, aviation director at Nommon Solutions and Technologies. "The machine learning techniques investigated

by SIMBAD help us overcome these shortcomings," says Mocholí, who coordinated the project.

## Creating hyperrealistic air traffic scenarios

Funded within the framework of the SESAR Joint Undertaking, a public-private partnership set up to modernise Europe's ATM system, SIMBAD focuses on three fundamental problems with current performance evaluation models.

The first is how to estimate hidden variables in flight, such as the aircraft weight on take-off. While not directly observable, these have a tangible effect on flight trajectories in simulations.

*We are confident that SIMBAD will make valuable contributions to ATM performance analysis.*

Secondly, the project seeks to make the simulations more effective and efficient using a variety of machine learning clustering techniques that can establish a representative set of air traffic scenarios.

Finally, SIMBAD is applying active learning techniques to build metamodels. These metamodels are simpler and less computationally costly approximations of microsimulations, which leads to more efficient and insightful evaluation of new ATM technologies.

SIMBAD metamodels are being developed in collaboration with the EU-funded NOSTROMO project, which has developed an API that facilitates the process of building these metamodels.

## Modelling air traffic at different spatial and temporal scales

While the SIMBAD project is ongoing at the time of writing, there have been several key developments already.

The new algorithms for traffic pattern characterisation have shown their ability to identify representative traffic scenarios at different spatial and temporal scales, which will result in more comprehensive simulation experiments. Additionally, SIMBAD's metamodels have proven to be more efficient and faster than existing simulations when modelling new ATM technologies.

The team were also able to find hidden variables through the analysis of historical air traffic data. "We have accurately estimated two hidden variables related to airspace users – cost index and landing weight – for a set of trajectories in different weather conditions," remarks Mocholí.

The project is now moving into the evaluation phase, after which more conclusive results are expected. "The first tests and validations performed so far have been very promising, and we are confident that SIMBAD will make valuable contributions to ATM performance analysis," he says.

The team hopes to further develop the work started in SIMBAD under the SESAR 3 Joint Undertaking. "This would be a great opportunity for getting closer to the ultimate goal of integrating this solution into Europe's air transport management system," Mocholí concludes.

**PROJECT**
**SIMBAD – Combining Simulation Models and Big Data Analytics for ATM Performance Analysis**

**COORDINATED BY**
Nommon Solutions and Technologies in Spain

**FUNDED UNDER**
Horizon 2020-TRANSPORT

**CORDIS FACTSHEET**
cordis.europa.eu/project/id/894241

**PROJECT WEBSITE**
simbad-h2020.eu

# New AI software defends aeronautical systems against cyberattack

Disruptions to air communications networks present a serious threat to safety and efficiency. New artificial intelligence software can predict and prevent this hazard.

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Like any digital network, aeronautical communications systems are susceptible to temporary or permanent disruptions. These can be caused by local conditions, like a high number of aircraft trying to send or receive data with ground operators, or a lack of coverage between aircraft and ground centres. These systems are also vulnerable to cyberattacks, a growing concern within the aeronautical industry.

"In the most extreme case, it takes six minutes for a disruption to be confirmed, a period during which controllers' orders cannot be executed by pilots," explains Kanaan Abdo, chief technical officer at ALTYS Technologies in France.

Any disruption experienced by one aircraft has indirect implications for other aircraft in the vicinity, as airspace capacity is degraded and planes may be delayed or rerouted. "Any anticipation or prediction of these outages helps to reduce their impact on overall traffic," says Abdo.

The project SINAPSE (Software defined networking architecture augmented with Artificial Intelligence to improve aeronautical communications performance, security and efficiency), funded within the framework of the SESAR Joint Undertaking to modernise Europe's air traffic management system, is creating a new software that uses artificial intelligence (AI) to predict such outages.

"SINAPSE is accelerating the transformation towards intelligent aircraft connectivity by researching the implementation and adoption of new technologies," Abdo remarks.

## A new network architecture fit for the 21st century

The SINAPSE software is based on software-defined networking (SDN), a dynamic and efficient network infrastructure.

SDN is a distributed software architecture that allows for increased configuration over the network, with everything monitored by a central controller layer. In traditional systems, this controller-like concept relies on humans, but SINAPSE introduced AI as the controller, to more efficiently manage the system.

*In the most extreme case, it takes six minutes for a disruption to be confirmed, a period during which controllers' orders cannot be executed by pilots.*

The AI automatically checks for faults in the networks, and using predictive information can proactively adjust the system and perform maintenance.

SINAPSE uses an algorithm based on machine learning to analyse the network traffic for signatures known to match cyberattacks. The network's architecture means that only the AI's models are shared among users, without the need for underlying data to be shared, further enhancing security.

"This type of solution will be a crucial building block for a secured future aeronautical communication infrastructure," notes Abdo.

## Predicting communication breakdown in aviation

SINAPSE uses real-time operational data and network monitoring to predict communication failures. During the project, the SINAPSE team assessed the technology with Controller Pilot Data Link Communications (CPDLC) data, captured in real time from the operational Aeronautical Telecommunication Network (ATN), a global exchange for air communications.

A targeted use case demonstrated that SINAPSE could continuously predict and forecast disruption events 10 minutes before they happened. "This information could be very useful, and could eventually prevent communication loss events in different ways," he adds.

The SINAPSE project was formed by a pan-European consortium from ALTYS, ENAIRE, Frequentis and the University of Bradford.

The team aims to foster adoption of the new system and its concepts among ATN users. Abdo hopes this will lead to a collaborative initiative in which operational data is shared widely (while respecting data privacy) to train AI models for the benefit of the whole ATN community.

PROJECT
**SINAPSE – Software defined networking architecture augmented with Artificial Intelligence to improve aeronautical communications performance, security and efficiency**

COORDINATED BY
ALTYS Technologies in France

FUNDED UNDER
Horizon 2020-TRANSPORT

CORDIS FACTSHEET
cordis.europa.eu/project/id/892002

PROJECT WEBSITE
sinapse-s2020.eu

# AI-powered flight allocation cuts costs and delays

## A secure digital marketplace could allow airlines to swap flight slots without exposing commercially sensitive information.

Balancing air traffic demand with capacity is critical to ensuring the smooth and orderly flow of flights. With rising passenger numbers and increased flight volumes, new innovative technologies will be needed to help flexibly manage ever more congested airspace.

"For flights, air traffic flow management slots are allocated times of departure, arrival or passage through a particular airspace sector," explains SlotMachine (A Privacy-Preserving Marketplace for Slot Management) project coordinator and senior lead scientist Eduard Gringinger from Frequentis in Austria. "These are issued by the EUROCONTROL Network Manager, to regulate traffic in congested areas of airspace."

To ease congestion, simple swaps between two flights can currently take place. Such exchanges help airlines to prioritise certain flights, according to flight cost structures, to minimise costs and reduce passenger delays. For airlines, the allocation – and swapping – of these flight slots is therefore a critical cost issue.

"A challenge here is that flight cost structures, which influence how airlines prioritise flights and may vary for any number of

reasons, are highly confidential," notes Gringinger. "This is not information that airlines necessarily want to share with others. This has hampered slot swapping between different airlines."

## Efficient flight allocation using blockchain

The EU- and industry-funded SlotMachine project sought to harness the power of artificial intelligence (AI) technology to create a semi-automated flight allocation swap platform, based on the cost structure priorities of different airlines. The project was funded within the framework of the SESAR Joint Undertaking, a public-private partnership set up to modernise Europe's air traffic management system.

To achieve its aims, the project consortium investigated the potential of a lightweight distributed ledger that securely links records together using cryptography. This enables several users to make calculations using combined data, without revealing their individual input.

"At the centre of the system is the Controller component," explains Gringinger. "This relays information to airlines about current airspace use." An AI platform based on these technologies has been built, and is designed to facilitate more flexible, fast and completely private slot sequence transactions.

*This is not information that airlines necessarily want to share with others.*

Airspace users can securely input their flight preferences, together with supporting data, via a graphic interface. This data is sent to the system's heuristic optimiser, where algorithms are applied to the combined data, to find incrementally improved solutions in terms of flight prioritisation.

Finally, these flight lists are evaluated by the platform's privacy engine, which helps to calculate the improvement gained or compensation due for each flight in terms of credits. The credits amassed by airlines over the course of multiple flight exchange sessions can be securely stored, while blockchain technology ensures that transactions are trustworthy for all stakeholders.

"We have used real data to test the concept in various validation runs," adds Gringinger. "We have also used simulated data to create realistic situations, to really put the SlotMachine concept to the test."

## Slot management marketplace

These simulations demonstrated that multiparty computing and blockchain technology are effective at determining the optimal flight sequence for airlines while hiding sensitive information.

The project's success lays the foundations for further development of what could be an essential element of air traffic management in the future. A trustworthy and effective AI-powered marketplace for swapping slots will encourage better use of existing resources and achieve better airline efficiencies. This will lead to lower emissions and shorter delays.

SlotMachine's achievements will feed into the existing user-driven prioritisation process solution, currently being developed through SESAR. In addition, a follow-up project to update SlotMachine's technology and involve more airlines is in the pipeline. "The goal here is to deliver results from research to the real world faster," says Gringinger.

**PROJECT**
**SlotMachine – A Privacy-Preserving Marketplace for Slot Management**

**COORDINATED BY**
Frequentis in Austria

**FUNDED UNDER**
Horizon 2020-TRANSPORT

**CORDIS FACTSHEET**
cordis.europa.eu/project/id/890456

**PROJECT WEBSITE**
frequentis.com/en/research/projects/slotmachine

# Explainable AI for increased trust in air traffic management software

**Techniques that provide transparency for automated flight management systems could hasten their integration into safety-critical operations.**



While artificial intelligence (AI) is used in air traffic management (ATM) support functions, like post-incident analysis or demand forecasting, it is not yet fully integrated across operations.

AI does not fit into traditional engineering work cycles, which favour linear steps with predictable outcomes. This makes it especially difficult for national authorities to validate and certify for safety-critical functions.

According to José Manuel Cordero, from CRIDA (website in Spanish only): "While AI can enhance ATM performance – increasing capacity, reducing delays and improving safety – as controllers are still ultimately responsible for their decisions, building trust remains fundamental to AI adoption."

The TAPAS (Towards an Automated and exPlainable ATM System) project was funded within the SESAR Joint Undertaking, a public-private partnership set up to modernise Europe's ATM system.

Coordinated by CRIDA, it has identified which additional features should be considered in AI systems to increase their acceptance. The project has designed and tested two explainable AI (XAI) prototypes, while also developing AI in ATM guidelines.

## Unpacking the 'black box' of AI

AI techniques are often not readily understandable to human operators. The self-contained design of most AI means that users typically don't understand why one decision was taken over another, making it difficult to reverse-engineer a successful or failed outcome.

"We need to increase AI's explainability, that is to make its inner workings – its rules, abilities and limitations – more transparent to potential users," adds Cordero, TAPAS project coordinator.

*It's like chess: some plays are self-explanatory, some need a little explanation, others a lot more.*

So TAPAS used XAI techniques which explain decisions, while the system is actually making them.

The project first identified key criteria, building an explainability framework. To then calibrate the detail and range of explanations required, this framework was integrated into real-time simulations of various scenarios. Air traffic controllers from ENAIRE (the Spanish air navigation service provider), trainers and industry representatives tested these simulations at CRIDA in Madrid.

TAPAS added enhanced AI features to existing ATM systems running on traditional (deterministic) algorithms. Different levels of automation were explored, with machines progressively taking over more functions and humans becoming more monitor than operator.

"It's like chess: some plays are self-explanatory, some need a little explanation, others a lot more. But there is a point where exhaustive explanations don't add value because they are too complex and users simply have to trust the underlying logic," explains Cordero.

These processes enabled TAPAS to develop their XAI prototypes combined with visual analytics, which extracts information from the AI's functioning, displaying it on-screen in user-friendly formats. The project tested their XAI in two use cases: non-safety-critical air traffic flow and capacity management, and safety-critical conflict detection and resolution.

These were conducted with air traffic controllers and air traffic control operational platforms for a week. To explore a range of system behaviours, different automation and traffic levels were again explored, including during challenging conditions.

"Observation and feedback indicated impressive user acceptance. We have also included recommendations in our general explainability framework to help guide future applications," remarks Cordero.

## Ready for take-off

The AI techniques explored by TAPAS are considered by the European ATM Master Plan key enablers of higher aviation automation levels, promising to boost air travel capacity – an EU aviation strategy priority.

With scientific papers already available in the Outcomes section of the project website and a workshop in the pipeline, Cordero points out that TAPAS is ready to start making its contribution. "Our explainability framework could already help spur on adoption of 'capacity on demand', for example, as a priority automated application," he says.

The European Union Aviation Safety Agency has also expressed interest in incorporating the results of the project's work on higher automation levels into the next edition of their AI guidelines.

**PROJECT**
**TAPAS – Towards an Automated and exPlainable ATM System**

**COORDINATED BY**
CRIDA in Spain

**FUNDED UNDER**
Horizon 2020-TRANSPORT

**CORDIS FACTSHEET**
cordis.europa.eu/project/id/892358

**PROJECT WEBSITE**
tapas-atm.eu

# AI to help connect all the steps in your journey

## By integrating air traffic management with ground transport networks, data analytics and modelling can open the door to a multimodal future.

In the not-so-distant future, travellers will land at an airport, take an air taxi to the city centre, transfer to a train or underground to the suburbs, and then ride a shared bicycle to their final destination. Better yet, this won't happen as four separate segments but as one seamless journey.

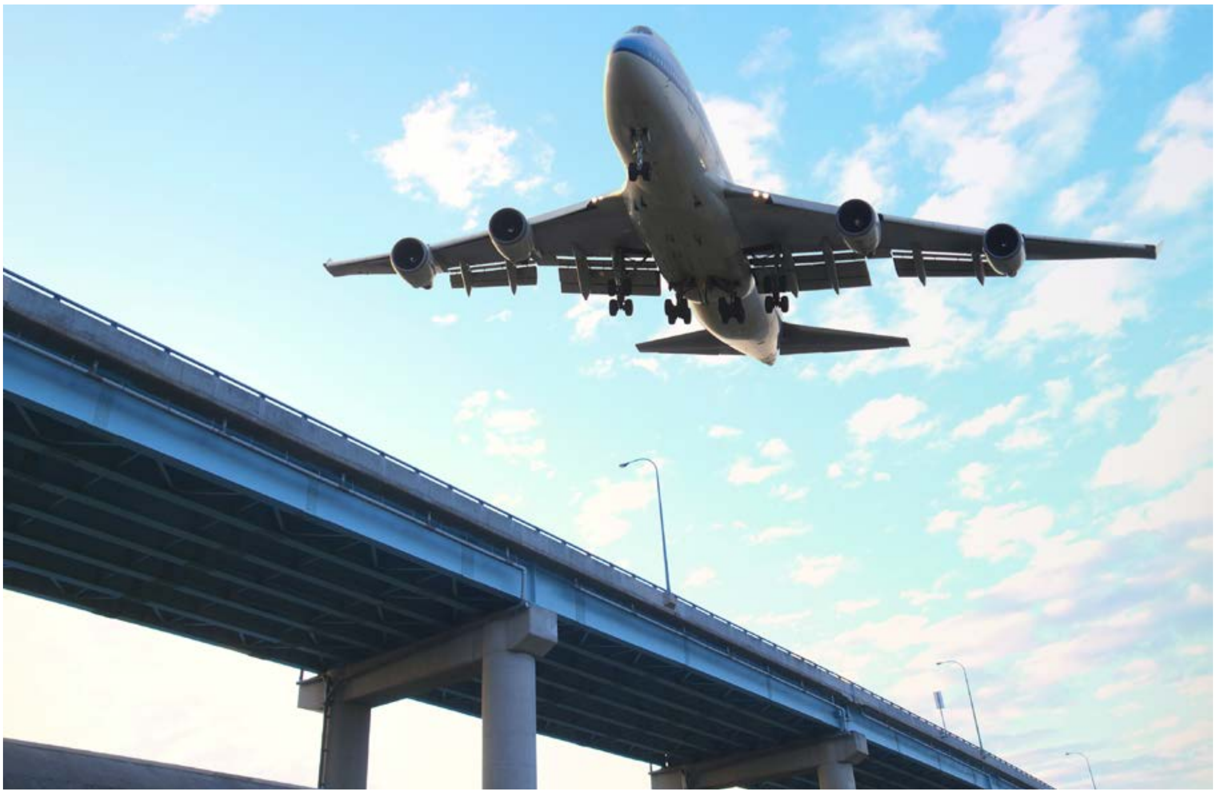
"The future of transport is multimodal, but building that future requires integrating today's air traffic management system with existing ground transport modes," says Ricardo Herranz, CEO at Nommon Solutions and Technologies.

The benefits of having such a seamless, multimodal mobility ecosystem include lower administrative burden for the passenger, decreased risk of delays, and more efficient route planning.

"Our vision is to create a multimodal European transport system where the different modes are seamlessly integrated, allowing passengers to travel door to door in an efficient, sustainable and resilient manner," explains Herranz.

Realising this vision requires coordinated planning and collaborative decision-making across all involved transport modes. It also means developing multimodal information systems that enable passengers to plan and reconfigure their journeys in real time.

The TRANSIT (Travel Information Management for Seamless Intermodal Transport) project set out to achieve both. It was supported by the SESAR Joint Undertaking, a public-private



partnership set up to modernise Europe's air traffic management system.

"By bringing together recent advances in mobility data analytics and long-distance multimodal travel modelling, we aim to develop a methodological framework and a set of software tools to support the design, implementation and evaluation of new intermodal concepts and solutions," adds Herranz, who serves as the project's coordinator.

## Understanding the passenger journey

At the heart of the project's work is an Intermodality Assessment Framework, a unique tool for evaluating how a specific transport solution would impact the overall passenger journey. This framework includes a set of multimodal, passenger-centric, door-to-door performance indicators that can be used to look at such things as travel time, travel time reliability, affordability, environmental impact and resilience.

*Our vision is to create a multimodal European transport system where the different modes are seamlessly integrated.*

"We also created data analytics techniques that combine big data with customer input, allowing one to accurately reconstruct long-distance, multimodal trips," notes Herranz.

Another key feature of the framework is an open-source tool for simulating long-distance travel demand and airport access in an integrated manner. Although researchers originally planned on developing this tool using an existing travel demand library called C-TAP, they soon found that it was unable to meet the needs of multimodal simulation. Instead, they designed their own.

"Our J-TAP library is designed so it can be easily used by developers to create and manipulate multimodal networks," remarks Herranz. "Although this required considerably more work than was planned, we believe it will maximise the future reuse and extension of the project's results."

## Towards a multimodal transport future

In addition to the framework itself, the project is also developing several intermodal solutions. For example, the Intermodal Timetable Synchronisation tool enables the design of synchronised timetables between air and ground transport modes. The Intermodal Disruption Management Tool is designed to facilitate information sharing between air traffic management and ground transport suppliers as a means of mitigating unplanned disruptions.

The effectiveness of these tools will be evaluated using the Intermodality Assessment Framework.

"By filling the gaps between various modes of transportation, solutions like these will pave the way towards a seamless, multimodal future," concludes Herranz.

**PROJECT**
**TRANSIT – Travel Information Management for Seamless Intermodal Transport**

**COORDINATED BY**
Nommon Solutions and Technologies in Spain

**FUNDED UNDER**
Horizon 2020-TRANSPORT

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cordis.europa.eu/project/id/893209

**PROJECT WEBSITE**
transit-h2020.eu

# CORDIS Results Pack

**Available online in 6 language versions:** cordis.europa.eu/article/id/442211

**Published**
on behalf of the European Commission by CORDIS at the
Publications Office of the European Union
2, rue Mercier
L-2985 Luxembourg
LUXEMBOURG

cordis@publications.europa.eu

**Editorial coordination**
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|---|---|---|---|---|
| Print | ISBN 978-92-78-43170-9 | ISSN 2599-8285 | doi:10.2830/703682 | ZZ-AK-22-012-EN-C |
| HTML | ISBN 978-92-78-43168-6 | ISSN 2599-8293 | doi:10.2830/205554 | ZZ-AK-22-012-EN-Q |
| PDF | ISBN 978-92-78-43169-3 | ISSN 2599-8293 | doi:10.2830/968365 | ZZ-AK-22-012-EN-N |

Luxembourg: Publications Office of the European Union, 2022

## The pros and contrails of flight – The aviation sector is indispensable, but how can we reduce its environmental impact?

Episode #02 of the CORDIScovery podcast talked to three researchers whose work on making flying cleaner, more efficient and less invasive for those living under flight paths, may offer some answers.

Listen on to find out: bit.ly/CORDIScovery_Ep_02




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