RPAS and AI in Aviation

Six SESAR ER projects together to present their results

Rome, Italy

November 3-4, 2022

URClearED

A Unified Integrated Remain Well Clear Concept in Airspace D-G Class

Project duration: May 2020 - October 2022

27
hours of Real Time Simulation

141
different encounter conditions

265,114
RWC encounters with cooperative intruders

16,989
RWC encounters with non cooperative intruders

WHAT IS THE PROJECT FOCUS?

URClearED is a SESAR Joint Undertaking Exploratory Research project investigating the concept of a Remain Well Clear (RWC) function of a Detect & Avoid system that supports the pilots of certified unmanned air vehicles - flying Instrumental Flight Rules (IFR) in airspace classes D to G - to constantly maintain a safe trajectory in relation to the surrounding traffic.

WHAT DID THE PROJECT DO?

The project aimed to support current study activities on the Remain Well Clear (RWC) functionalities by analysing operational scenarios, and defining and implementing the concept of a Remain Well Clear (RWC) function for European airspace classes D to G. The proposed RWC concept was also partially validated under the functional and operational acceptability of both Remote Pilots and Air Traffic Controllers (ATCOs) by performing several Fast and Real Time simulation campaigns.

With reference to airspace classes D to G the URClearED research activities aimed at:

- Defining the operating conditions (Operational Scenarios) of a European RWC.
- Proposing the functional requirements and capabilities for such RWC.
- Proposing Surveillance Sensors and Data Link performance assumptions.
- Developing a baseline RWC prototype algorithm and related HMI to support evaluation of assumptions and requirements.
- Performing Fast-Time and Real-Time Human in the Loop (including Remote Pilots and ATCOs) Simulations.
- Analysing procedures for the management of IFR RPAS flying in airspace classes D-G, including U-Space interaction.
- Disseminating the findings to the relevant stakeholders.

WHAT DID THE PROJECT ACHIEVE?

URClearED's most reliable results helped to better define some features for a European Remain Well Clear system, thanks to the achieved specification of the RWC module requirements for drones and the overall associated concept of operations in airspace classes D-G. The project validation tests also estimated the workloads and acceptability of the RWC by remote pilots and air traffic controllers. Moreover, the project was able to identify gaps and, most importantly, the next relevant steps for a full development and assessment of the RWC system, paving the way to possible future activities on an industrial level on this purpose.

Real-Time test campaign at DLR's premises - second round of simulations, April 2022

WHAT'S IN IT FOR AVIATION?

The project results are a step forward for the aviation sector, allowing a safer integration of drones, a more efficient usage of the airspace, and the growth of new services related to the use of drones for the population. Drones' integration in the civil air traffic is one of the most ambitious goals for the future of aviation, and the research and results that URClearED has produced is relevant to achieve this within the SESAR JU framework.

WHAT'S NEXT?

URClearED's technical recommendations for future research concern the need for advanced sensor filtering techniques, improved field of view limitations of non-cooperative sensors, and inclusion of alerting functions that accounts for intruders' maneuvers. It has been also identified the need for developing suitable European encounter models for airspace class G and related pilot models to allow a full evaluation of the RWC risk ratio. Moreover, a more intense and structured RTS campaign with the definition of additional scenarios shall be performed, to carry out more accurate and quantitative Human Performance and safety analyses and to better identify training gaps. Finally, a detailed evaluation of the impact of security risks, mainly related to the use of the ADS-B IN surveillance sensor would be necessary.

Real-Time test campaign at CIRA's premises - second round of simulations, April 2022

CONTACTS

Project Coordinator **Federico Corraro - *CIRA* -** f.corraro@cira.it

Dissemination Manager: **Damiano Taurino - *Deep Blue* -** damiano.taurino@dblue.it

urcleared.eu | Sesarju.eu/projects/urcleared | URClearED Project

INVIRCAT

Investigate IFR RPAS Control in Airports and TMA

Project duration: July 2020 - December 2022

7 European partners

3 simulation sites

1 common objective

WHAT IS THE PROJECT FOCUS?

*INVIRCAT aims to **integrate unmanned aircraft into the existing air traffic environment and airport infrastructures** with a special focus on the impact of latency, automatic take-off and landing systems, and handover of control between remote pilot stations. This is achieved by creating a concept of operations, defining requirements, and stating recommendations for standardization bodies.*

WHAT DID THE PROJECT DO?

The INVIRCAT project started the work with an **analysis of the state of the art** of integrating remotely piloted aircraft systems (RPAS) into the airport environment under instrument flight rules (IFR).
As a basis for the upcoming validation exercises, a set of representative **nominal and non-nominal use cases** have been defined in detail. Afterwards, an **initial concept of operations** described the system and subsystems of the IFR RPAS at airports as well as the RPAS operations and the relevant environment. An initial set of **operational and functional requirements** has also been compiled.
Then, the concept and the requirements were evaluated using **three validation exercises** at three simulation facilities, each focusing on specific use cases and situations. The validation results were then used to refine the concept of operations and the requirements. A two-step implementation strategy for the concept has been created, along with advantages, disadvantages and gaps of key areas and technologies.
Finally, impacts on key performance areas and **recommendations** for rule makers have been established. External stakeholders were involved through dedicated meetings and workshops throughout the project.

WHAT DID THE PROJECT ACHIEVE?

The INVIRCAT project **established a concept of operations for IFR RPAS in airport environments,** incorporating valuable validation findings and stakeholder feedback. The validation exercises showed that the integration of IFR RPAS is feasible and resulted in qualitative and quantitative assessment of the key performance areas Safety, Human Performance, Operational Efficiency, Capacity, and Equity. A list of more than 100 operational, functional and non-functional requirements has been established. Finally, the INVIRCAT project attracted many stakeholders in four Advisory Board meetings and was visible at several external events.

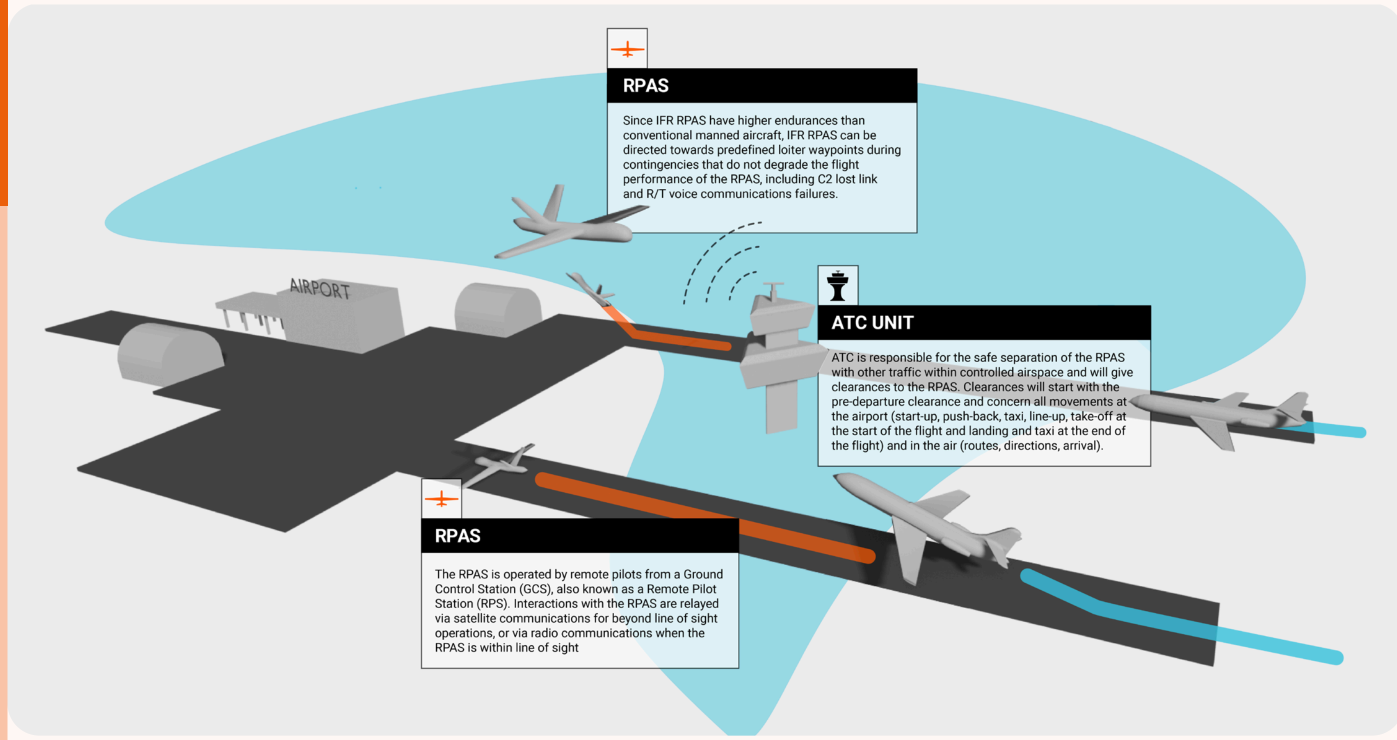
Real Time Simulations Impressions

WHAT'S IN IT FOR AVIATION?

INVIRCAT contributes to the ATM Master Plan, which foresees full integration of RPAS and other unmanned aircraft systems by 2035 in controlled and uncontrolled airspace. The market for civil and military applications involving RPAS is growing, and the potential use cases are numerous. While passenger transport with unpiloted aircraft might be in the far future, cargo transport is already performed using RPAS. INVIRCAT paves the way towards a full integration of such RPAS.

WHAT'S NEXT?

INVIRCAT as an Exploratory Research project could be followed by future SESAR activities. One topic to be investigated more closely is **the full RPAS integration in TMA and surface operations** by validating a full IFR RPAS flight, designing the required additions to human machine interfaces, detailing, and validating the handover process in real flight trials, etc.
A second topic for next steps in research is the **ATM-U-space interaction**, including aspects related to the design of vertiport operations, their interaction with AM and the intermodal transport model that may derive from the coexistence of a vertiport within the airport.



The INVIRCAT concept

CONTACTS

Project Coordinator	**Gunnar Schwoch - *DLR* -** gunnar.schwoch@dlr.de
Communication Manager	**Paola Lanzi - *Deep Blue* -** paola.lanzi@dblue.it

Invircat.eu | Sesarju.eu/projects/invircat | Invircat-project | InvircatProject

SAFE LANDing through enhanced ground support

Project duration: July 2020 - December 2022

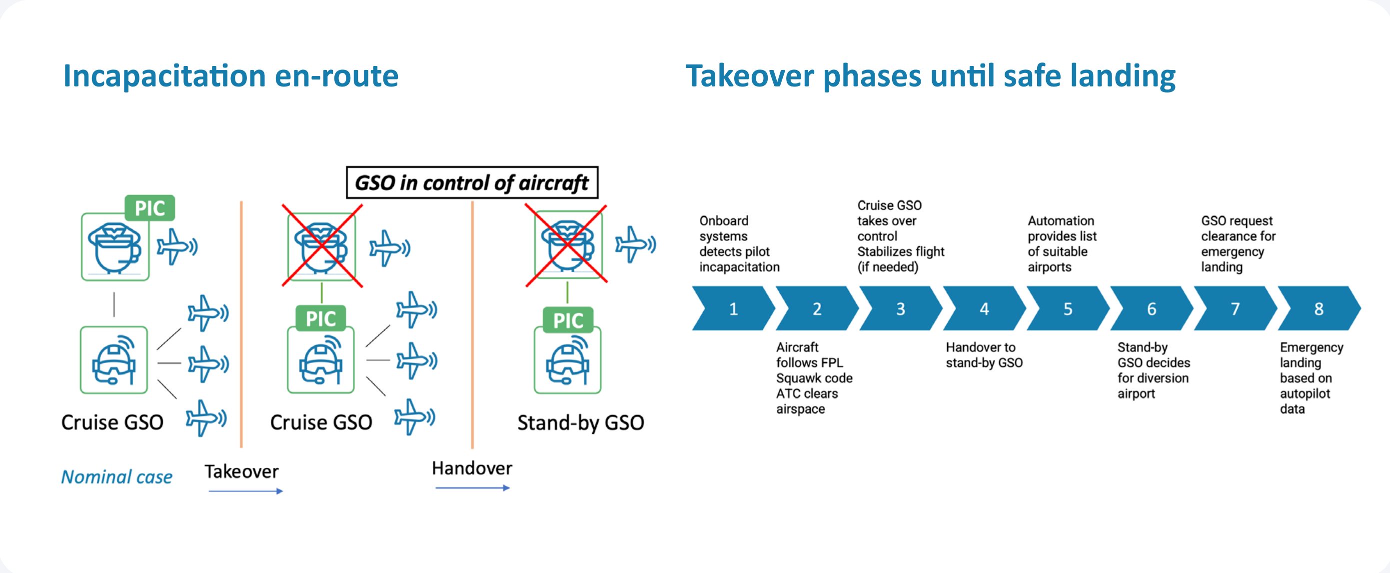
2
simulation campaigns

17
participants in the simulations

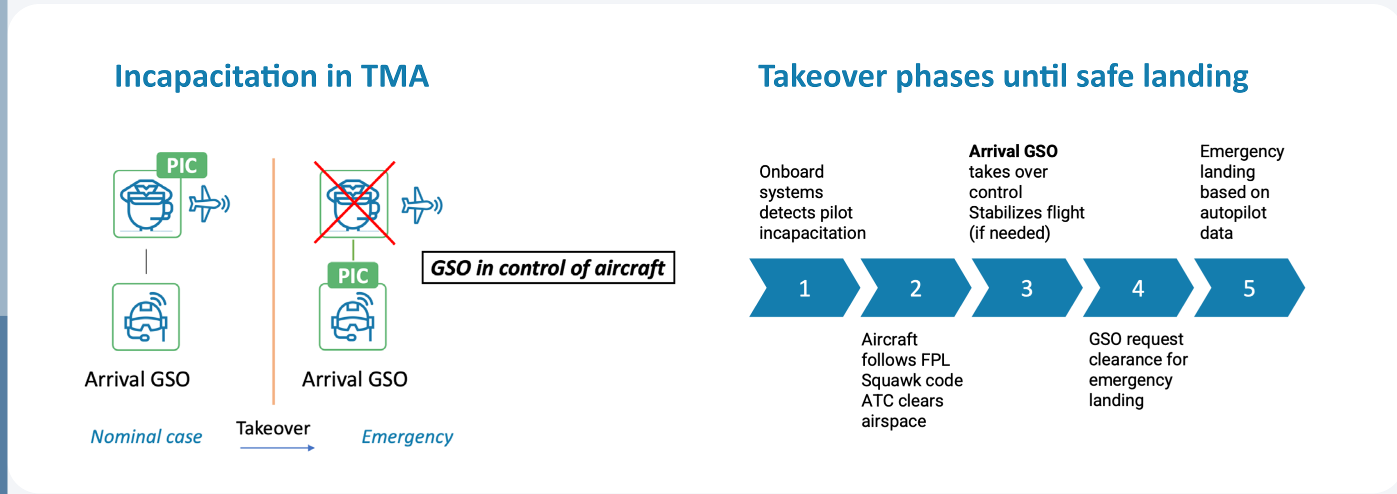
5
projects SAFELAND collaborated strictly with

WHAT IS THE PROJECT FOCUS?

A major challenge for the implementation of Single Pilot Operations (SPO) in commercial aviation is to ***maintain safety levels*** *as in current operations and* ***guarantee a safe return to land in case of pilot incapacitation****. To tackle this issue, SAFELAND developed a concept of operations relying on Ground Station positions being manned by remote pilots who can monitor the SP aircraft and take over control in case of incapacitation; once incapacitation is declared, the remote pilot becomes the pilot in command (PIC) and the aircraft "becomes" an RPAS.*



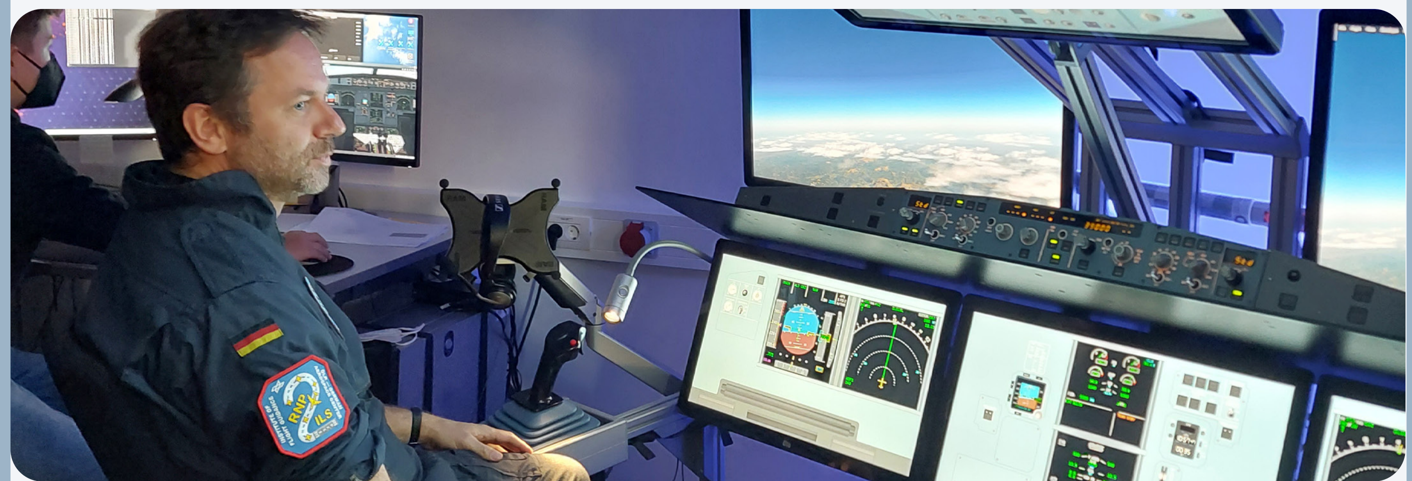
Infographic - SAFELAND CONOPS and takeover phases when the incapacitation happens en-route



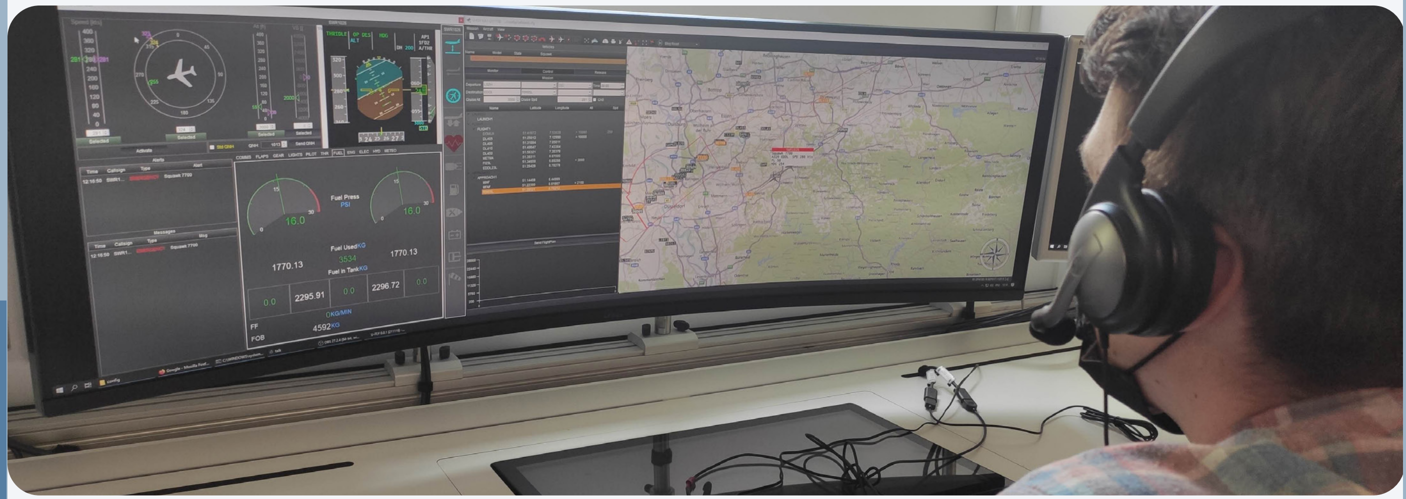
Infographic - SAFELAND CONOPS and takeover phases when the incapacitation happens in Terminal Manoeuvring Area (TMA)

WHAT DID THE PROJECT DO?

Following a human-centered design approach, a series of iterative activities were executed to design and evaluate the SAFELAND CONOPS from the operational ATM perspective. The first part of the project was fully dedicated to the generation of the concept, taking into consideration different implementation options, and their operational and technical requirements. Once defined, the final CONOPS was validated through two human-in-the-loop simulation campaigns. The first simulation, at a lower level of fidelity, allowed to preliminary evaluate the acceptability of the procedures and the dynamics between actors, and served to refine the concept (e.g., role, tasks, procedures) and better design the next campaign. Following, a more realistic real time simulation was conducted at DLR facilities involving pilots (in the role of remote pilots) and air traffic controllers. The concept was assessed exploring its potential impact in terms of operational feasibility, human performance, and safety. To complement its assessment, an analysis of the legal, regulatory, and economical implication of the final concept was carried out, together with a safety and cyber-security assessment. The results were further evaluated with the support of an external Advisory Board.



A321 cockpit simulator based on X-Plane 11 software



Ground Station Operator (GSO) and the Ground Station (GS) interface (U-FLY) during the SAFELAND RTS - Institute of Flight Guidance @ German Aerospace Center (DLR), Germany

WHAT DID THE PROJECT ACHIEVE?

The evaluation activities performed within the project suggests that the SAFELAND concept could be a robust proposal to address single pilot incapacitation. Specifically, the operating procedures implied by the concept and the dynamic of interactions between the different actors were positively evaluated by the participants involved in the simulation campaigns. Also, no major showstoppers have been identified from the legal and regulatory point of view. Moreover, the SAFELAND project made explicit the key technological, infrastructural, and procedural enablers that shall contribute to maintain SPO safety levels as in current dual pilot operations.

WHAT'S IN IT FOR AVIATION?

Estimates lead to a high demand of new pilots when taking traditional two-manned cockpits as a baseline. With the implementation of new technologies, SPO can be seen as the next disruptive aviation innovation to encounter pilot shortages in the future. The SAFELAND project is an important step in the route to achieve this disruptive innovation, bringing alive a CONOPS and the operational requirements needed to address the risk of single pilot incapacitation in SPO.

WHAT'S NEXT?

The SAFELAND project addressed a specific safety issue related to an operational concept that is still under development (SPO for commercial aviation). Therefore, as a first step, effort should be allocated to the generation of a reference SPO CONOPS, to provide a coherent framework for future work on single-pilot incapacitation. In parallel, research will be dedicated to progress the development and deployment of the technological enablers needed to ensure safe SPO (e.g., a pilot health monitoring system, autoland capabilities, back-up systems). From a regulatory point of view, some amendments to soft rules (Acceptable Means of Compliance and Guidance Material to European Regulation) by revision of several RuleMaking Tasks (RMTs) may fill the current gap. Finally, the social and ethical implications of SPO should be explored, with a focus on trust and acceptability from end-users and the public.

CONTACTS

Project Coordinator

Stefano Bonelli - *Deep Blue* - stefano.bonelli@dblue.it

Project Partners

Aurora De Bortoli Vizioli - *Deep Blue* - aurora.vizioli@dblue.it

Teemu Joonas Lieb - *DLR* - teemu.lieb@dlr.de

Safeland-project.eu | Sesarju.eu/projects/safeland | SAFELAND project | SafelandP

SAFELAND Real Time Simulations

SafeOPS

From Prediction To Decision Support - Strengthening Safe And Scalable ATM Services Through Automated Risk Analytics Based On Operational Data From Aviation Stakeholders

Project duration: January 2020 - December 2022

+600.000

real world approaches

+1.850

real world go-arounds used to train a go-around prediction

WHAT IS THE PROJECT FOCUS?

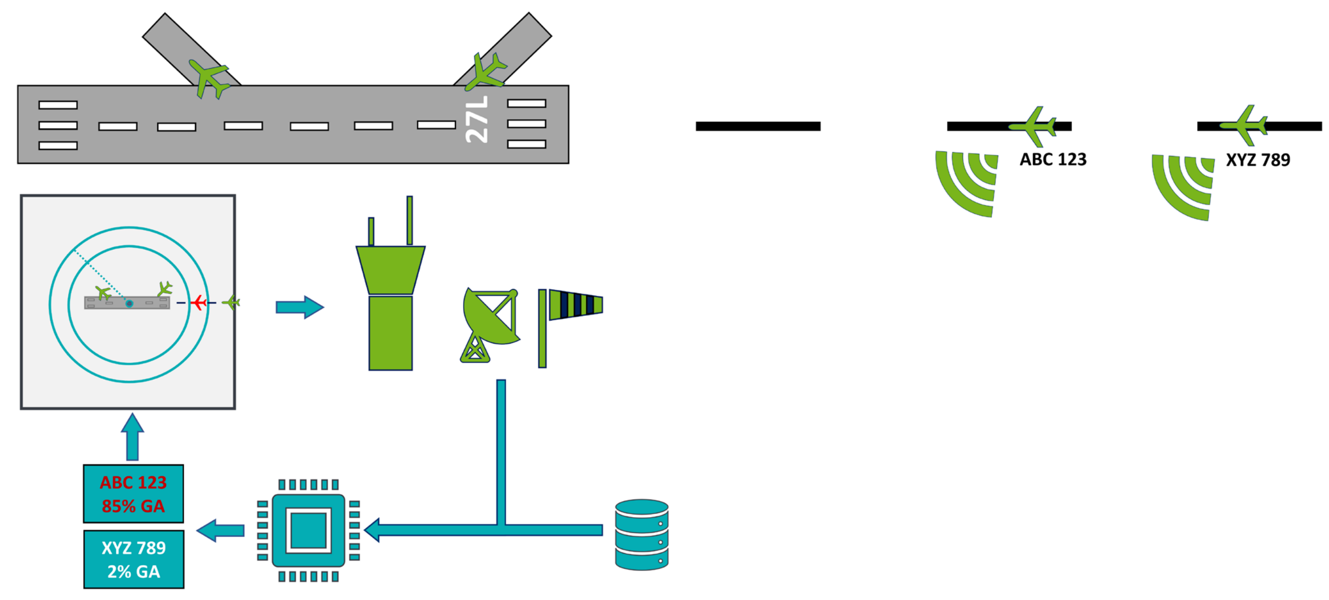
SafeOPS investigates an AI-base; decision support tool for Air Traffic Control in the context of go-arounds. The project researches how Air Traffic Controllers handling go-arounds could use the predictive information to adapt their strategies, avoiding knock-on effects that can accompany go-arounds; and thereby increasing safety and resilience.

WHAT DID THE PROJECT DO?

The project employs a three-layered approach that, *includes an operational layer, a predictive layer, and a risk framework*. In workshops with Air Traffic Controllers, the *operational layer* developed scenarios in which a go-around prediction could provide benefits for Air Traffic Management. This led to an initial concept of operations and the definition of use cases and requirements in the initial phase of SafeOPS.
Based on this, the *predictive layer* developed an initial machine learning model for go-around predictions, yielding insights in achievable accuracies and the transparency of the predictions. In parallel, the *risk framework* assessed the risks and benefits of the foreseen decision support concept in terms of operational safety, including also human factors considerations.
In the final phase of the project, the *operational layer*, designed a simulation exercise based on the *risk framework's* and the *predictive layer's* findings, to investigate the impact of the SafeOPS concept on safety and resilience. Thus, SafeOPS focused on separation challenges, workload, and capacity of the Tower operations in the initially defined scenarios.

WHAT DID THE PROJECT ACHIEVE?

SafeOPS developed an AI-model, which can predict go-arounds, based on publicly available data sources. Based on this, it investigated risks and benefits of a decision support concept for Air Traffic Management in a complementary evaluation, consisting of a risk framework and simulation exercises. With this impact evaluation, SafeOPS could demonstrate that the envisioned concept can provide benefits in terms of safety and resilience. Even false predictions do not have negative effects on safety, which is an important finding; however, false predictions can negatively affect the capacity of airports.



SafeOPS Concept visualization on a high-level basis. Aircraft transmit performance data, which is received by ANSPs' radar. Together with weather information, the SafeOPS concept predicts the likelihood of a go-around for each approach and provides this information to the Controller via the radar screen.

WHAT'S IN IT FOR AVIATION?

The next generation Air Traffic Management systems are driven by two goals that are hard to combine:, the increasing demand for capacity and cost-efficiency, as well as for safety and resilience. SafeOPS proposes a proactive approach for safety management, capable of predicting safety hazards in real-time. Also, the probabilistic nature of the concept will contribute to the introduction of new liability models, regulations, processes, and risk assessment methodologies in the aviation community.

WHAT'S NEXT?

Based on its results, SafeOPS identified some topics for future research. First, the AI-based prediction tool must be enhanced to become an online capable tool, based on ANSP radar data, and to meet the EASA guidelines for AI in aviation.
Second, the safety and resilience vs. capacity trade-off must be[1] investigated. With the potential effects on safety, resilience, and capacity now explored, a cost analysis including capacity losses is necessary to find the minimum acceptable accuracies for the machine learning component.
Lastly, the concept must be investigated for wider operational spectrum, using Monte Carlo methods complementary to the simulation exercises.

CONTACTS

Project Manager — **Lukas Beller - *TUM*** - lukas.beller@tum.de

Project Partners — **Carlo Abate - *Deep Blue*** - carlo.abate@dblue.it
Elizabeth Humm - *Deep Blue* - elizabeth.humm@dblue.it

Pablo Hernandez - *Innaxis* - ph@innaxis.aero

Philipp Kurth - *DFS* - philipp.kurth@dfs.de

safeops.eu | Sesarju.eu/projects/safeops

[1] EASA Concept Paper: First usable guidance for Level 1 machine learning applications (www.easa.europa.eu/en/downloads/134357/en).

MAHALO

Modern ATM via Human/Automation Learning Optimisation

Project duration: July 2020 - December 2022

34 real en-route ATCOs involved

2 main simulations performed, in Italy and Sweden

18 different scenarios per each controller played

WHAT IS THE PROJECT FOCUS?

*Artificial Intelligence (AI) provides both **opportunities and considerable challenges** to the continued growth of Air Traffic Control (ATC) services. The MAHALO project focused on two constructs thought to underlie human-AI interaction. The first is **conformance**, which the project has defined as the apparent strategy match between human and AI systems. The second construct, **transparency**, refers to the degree to which the system makes its internal processes apparent to the operator. MAHALO set out to experimentally manipulate these two constructs, and to explore their main and interactive effects on a broad number of **human performance measurements**, including conflict detection performance, automation acceptance, and rated workload.*

WHAT DID THE PROJECT DO?

MAHALO conducted two field simulations at two sites, with 34 participants, **to evaluate the impact of conformance and transparency manipulations on controller** acceptance, agreement, workload, and general subjective feedback, among other measures. Each simulation consisted of two phases. First was a training pre-test in which controllers interacted with scripted traffic scenarios that presented two-aircraft closing conflicts, and which recorded controllers' resolution strategies. Second was a main experiment phase, in which the same controllers interacted with Machine Learning (ML) solved analogues of the pre-test scenarios.

Conformance of advisories had an impact on controllers' response, but not in a uniform direction. Although personalized advisories received more favourable responses

in many cases, there were also cases when the optimal or group advisories were favoured. There was no strong effect of transparency on controllers' responses.
An in-depth analysis was made dividing participants in two groups depending on how close their separation distance preference was to the target separation distance aimed for by the optimal model's advisory. The analysis revealed a reoccurring pattern emerging where the group of participants, whose average separation distance measured in the training pre-test was closer to the separation distance aimed for by the optimal advisory, showed unchanged or more positive responses to the advisory with increasing transparency. That is, **their acceptance of advisories and ratings of agreement, conformance, and understanding was higher** compared with the other group.

WHAT DID THE PROJECT ACHIEVE?

Over the project runtime the MAHALO project has achieved several results:

- Conducted a state-of-the-art review of Machine Learning (ML) advances.
- Developed and demonstrated a ML capability.
- Designed an experimental user interface and simulation capability.
- Conducted human-in-the-loop validation trials of the user interface.
- Integrated ML capabilities with the simulator and experimental interface.
- Conducted a first full simulation to demonstrate the entire test platform.
- Specified experimental design for the final simulation sessions.
- Defined some guidelines on how to incorporate conformance and transparent mechanisms of AI solutions to conflict detection and resolution

PUBLICATIONS:

Westin, C., Hilburn, B., Borst, C., Kampen, E. Van, Bang, M., (2020), Building Transparent and Personalized AI Support in Air Traffic Control, Digital Avionics Systems Conference, 2020

Westin, C., Nunes Monteiro, T., Borst, C., Bonelli, S., (2020), Balancing transparency and conformance of an AI conflict detection and resolution support system, Proceedings of the Tenth SESAR Innovation Days, 2020.

Nunes Monteiro, T., Borst, C., Kampen, E. Van, Hilburn, B., & Westin, C. (2021), Human-interpretable Input for Machine Learning in Tactical Air Traffic Control. Proceedings of the Eleventh SESAR Innovation Days, 92, 1--6. + presentation (WP3 & WP4).

Bonelli, S., Borst, C., Brambati, F., Cocchioni, M., Hilburn, B. & Monteiro-Nunes, T., (2022), Transparent and Personalised AI Support in Air Traffic Control: First Empirical Results, The International Conference on Cognitive Aircraft Systems, 2022.

A participant interacting with the Simulator. The monitor shows a frozen scenario with the highest level of transparency

WHAT'S IN IT FOR AVIATION?

An implicit assumption going into research was that **transparency fosters understanding, acceptance** and **agreement**. As a thought experiment, however, consider the case where poorly functional automation is outputting advisories. In this case, transparency might have the opposite effect and lower controllers' agreement and acceptance of the system. The notion here is that if transparency involves making clear to the operator the inner workings of the algorithm, it does not necessarily increase agreement and acceptance, but should optimize them. Transparency and explainability should **increase acceptance and agreement for an optimal algorithm, which should also decrease acceptance and agreement for a sub optimal algorithm.**

WHAT'S NEXT?

Results of the MAHALO project, while valuable in themselves, suggest clear avenues of exploration for future research. One avenue is the potential utility of **personalisation**, or tuneable parameters that might allow for a hybrid of the optimal and personal model view, such that controllers could tune certain parameters within the confines of an optimal advisory system. Second is the potential benefit of an **adaptive systems approach**, to automate that tuning such that parameters can be adjusted in step with learning performance.

Third is the **potential hybridisation of machine learning together with adaptive systems**, both for task performance but also as a trigger for task reallocation. Finally, future research is required to explore **potential benefits of advisory transparency** on advisory acceptance and system trust. In contrast to expectations, measures of acceptance, agreement and workload did not benefit overall from increased transparency. This suggests that transparency alone may not be suitable as a measure for increasing operators' acceptance.

CONTACTS

Project Coordinator

Stefano Bonelli - *Deep Blue* - stefano.bonelli@dblue.it

Project Partners

Matteo Cocchioni - *Deep Blue* - matteo.cocchioni@dblue.it

Clark Borst - *TUD* - C.Borst@tudelft.nl
Erik-Jan van Kampen - *TUD* - E.vanKampen@tudelft.nl

Carl Westin - *LiU* - carl.westin@liu.se

Brian Hilburn - *CHPR* - brian@chpr.nl

Supathida Boonsong - *LFV* - supathida.boonsong@lfv.se

Mahalo.eu | Sesarju.eu/projects/mahalo | Mahalo project | H2020_MAHALO

ARTIMATION

Transparent Artificial Intelligence and Automation to Air Traffic Management Systems

Project duration: July 2020 - December 2022

2 use cases developed

3 dimensions for immersive analytics

0 cables used by the EEG helmet to gather neurophysiological data

WHAT IS THE PROJECT FOCUS?

The project assessed the impact of both different visualisation techniques for AI algorithms to provide explainability to the ATC task of Conflict Detection and Resolution, and the impact of an Explainable AI (XAI) tool on Air Traffic Controllers' trust to optimise the use of runways, supporting the task of Delay Prediction.

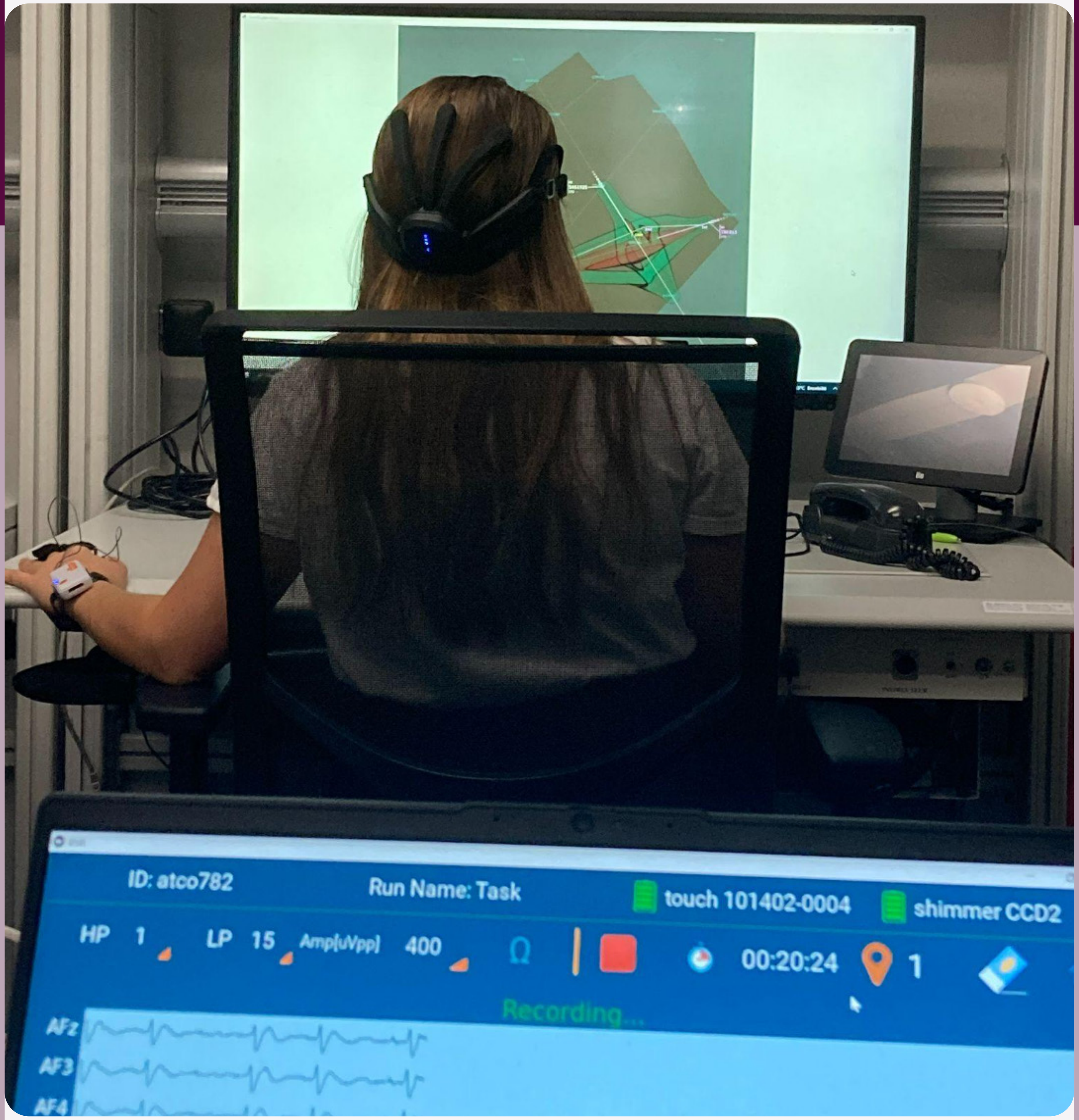
WHAT DID THE PROJECT DO?

ARTIMATION gathered information about 3 different kind of visualisation techniques to represent an AI outcome for the task of Conflict Detection and Resolution. It then, tested them with two different experimental groups, i.e., ATC experts and ATC students. Differences in human factors indexes (e.g., stress, workload, approach-withdrawal, acceptance, trust) were assessed both with neurophysiological measures, and traditional self-report questionnaires and semi-structured debriefing interviews. Moreover, 3 different algorithms have been trained to support the task of Delay Prediction to optimise the runway use. The 3 algorithms select different parameters to show to Tower Air Traffic Controllers to understand what selection provides the higher trust level and the higher agency towards the delay.

19

WHAT DID THE PROJECT ACHIEVE?

As far as the Conflict Detection and Resolution visualisation use case, ARTIMATION assessed the human performance differences between ATC experts and students. The project explored the feasibility of introducing Explainable AI tools in training sessions for ATC students, to always provide a different point of view and a tool to compare the students' own decision-making process with an optimal solution designed considering several parameters.
The Delay Prediction use case aims at optimising the runway use introducing explainability through the visualisation of parameters influencing an aircraft delay. Preliminary results will be illustrated during the conference.



ARTIMATION Conflict Detection and Resolution visualisation (picture taken during validation activities)

WHAT'S IN IT FOR AVIATION?

Aviation will benefit from ARTIMATION from both use cases. The Conflict Detection and Resolution use case will introduce the concept of Explainable AI in training, assessing the feasibility of different kinds of visualisations to have a better mental picture of a possible optimal resolution.
The Delay Prediction use case will realise a proof-of-concept of the introduction of Explainable AI in Control Towers to optimise the use of runways.

WHAT'S NEXT?

Nowadays, explainable AI is not made for high-complexity tasks, such as Conflict Detection and Resolution. An environment that could benefit from the introduction of XAI can be the remote digital tower: this new environment will be conditioned more and more from digitalisation and the introduction of Artificial Intelligence. ARTIMATION's next steps involve understanding and assessing how to provide trust to Air Traffic Controllers dealing everyday with AIs.

CONTACTS

Project Coordinator — **Mobyen Uddin Ahmed - *Malardalens University***

Project Partners — **Shaibal Barua - *Malardalens University***
Mir Riyanul Islam - *Malardalens University*

Stefano Bonelli - *Deep Blue*
Ana Ferreira - *Deep Blue*
Nicola Cavagnetto - *Deep Blue*

Fabio Babiloni - *La Sapienza University*
Pietro Aricò - *La Sapienza University*
Giulia Cartocci - *La Sapienza University*

Christophe Hurter - *Ecole Nationale de l'Aviatione Civile*
Augustin Degas - *Ecole Nationale de l'Aviatione Civile*

artimation.eu | Sesarju.eu/projects/artimation | Artimation Project | ArtimationAI

These projects have received funding from the SESAR Joint Undertaking under the European Union's Horizon 2020 research and innovation program under the grant agreement: INVIRCAT N° 893375, SAFEOPS N° 892919, ARTIMATION N° 699381, URCLEARED N° 892440, MAHALO N° 892970, SAFELAND N° 890599.

SUPPORTED BY sesar JOINT UNDERTAKING

PRINTED IN OCTOBER 2022