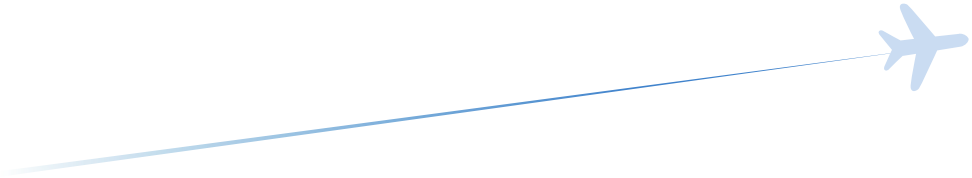

D3.1 Final workshop presentations of wave 1 catalyst-funded projects

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Engage

THE SESAR KNOWLEDGE TRANSFER NETWORK

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Abstract

This deliverable collates the final presentations of catalyst-funded wave 1 projects, given at Engage thematic challenge workshops.

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1 Introduction

1.1 Objectives of this document

The objective of this deliverable is to document the final results of catalyst-funded wave 1 projects, as presented at the second and third series of the Engage KTN's thematic challenge workshops. The overall workshop planning, execution and results are described in the deliverable D2.6 [1].

1.2 Catalyst funding wave 1 projects

Engage catalyst funding is used to support focused projects, where the focus is on maturing exploratory research further towards applications and operational contexts. These catalyst fund (CF) projects were chosen through the *first Call for catalyst funding*. Project proposals could address an Engage thematic challenge or be an 'open' topic. The choice of thematic challenges (TCs) is described in detail in deliverable D3.4 [2]. There are four thematic challenges:

- TC1: Vulnerabilities and global security of the CNS/ATM system,
- TC2: Data-driven trajectory prediction,
- TC3: Efficient provision and use of meteorological information in ATM,
- TC4: Novel and more effective allocation markets in ATM.

The TCs were further fine-tuned through the first series of workshops (described in deliverable D2.5 [3], resulting in the TC descriptions that were included in the *first Call for catalyst funding*. Proposals supporting a thematic challenge needed to clearly state with which challenge the proposal is aligned.

The call documentation can be found here. The call was open from 15 November 2018 to 15 February 2019, receiving 21 proposals. The evaluation process was carried out by the Awards Board and was concluded in April 2019, with notifications of the outcome sent to all proposers. Ten proposals were accepted to receive catalyst funding through the first wave, see Table 1. The project abstract, executive summaries and final technical reports can be found here: engagektn.com/cf-summaries, under 'First wave projects'.

The following sections contain short descriptions of TC workshops, project summaries and the presentations. Final project presentations are available in the PDF format and are attached to this report. The link to the Engage KTN website repository of TC workshop presentations, is also given.

Table 1. Catalyst-funding wave 1 projects, TC relation, end date and final presentation date

Project title	TC	End date	Workshop – final presentation
Authentication and integrity for ADS-B	1	14 May 2020	2nd TC1 workshop 10 November 2020
The drone identity - investigating forensic-readiness of U-Space services	1	30 June 2020	
Data-driven trajectory imitation with reinforcement learning	2	31 May 2020	3rd TC2 workshop 25 January 2021
A Data-drIven approach for dynamic and Adaptive trajectory PredictiON ('DIAPasON')	2	30 June 2020	
An interaction metric for an efficient traffic demand management: requirements for the design of data-driven protection mechanisms ('INTERFACING')	2	31 July 2020	
Probabilistic weather avoidance routes for medium-term storm avoidance ('PSA-Met')	3	30 June 2020	3rd TC3 workshop 27 January 2021
airport-sCAle seveRe weather nowcastinG project ('CARGO')	3	30 November 2020	
Operational alert Products for ATM via SWIM ('OPAS')	3	18 June 2020	
MET enhanced ATFCM	3	19 June 2020	
Exploring future UDPP concepts through computational behavioural economics	4	31 August 2020	27 July 2020*

*Independent final workshop of the project, as a continuity of TC4 activities, as the TC4 did not have dedicated workshop in 2020, the next and final one is planned for June 2021.

2 Thematic challenge 1 catalyst fund projects

The TC1 workshop was held as a virtual event, on 10 November 2020. The workshop had the following objective: "CNS/ATM components (e.g., ADS-B, SWIM, datalink, Asterix) of the current and future air transport system present vulnerabilities that could be used to perform an 'attack'. Further investigations are necessary to mitigate these vulnerabilities, moving towards a cyber-resilient system, fully characterising ATM data, its confidentiality, integrity and availability requirements. A better understanding of the safety-security trade- off is required. Additional security assessments for legacy systems are also needed to identify possible mitigating controls in order to improve cyber-resilience without having to replace and refit. Future systems security by design is essential: a new generation of systems architectures and applications should be explored to ensure confidentiality, cyber-resilience, fault tolerance, scalability, efficiency, flexibility and trust among data owners. Collaborative, security-related information exchange is essential to all actors in aviation. This is specially challenging in a multistakeholder, multi-system environment such as ATM, where confidentiality and trust are key." All workshop presentations can be found, as a zipped file, here: https://innaxis-comm.s3.eu-central-1.amazonaws.com/ENGAGE/Engage.TC1-workshop2-presentations.zip.

2.1 Authentication and integrity for ADS-B

Abstract: The main objective of this project is to provide the means to improve the security of the Automatic Dependent Surveillance-Broadcast (ADS-B), a critical backbone of future surveillance systems. More specifically, we evaluate the data link capabilities of the so-called phase overlay, a backwards-compatible extension to the current implementation of ADS-B. Our results indicate that 8PSK performs best in a realistic radio environment, reliably providing up to 218 additional bits for each ADS-B message at a carrier frequency offset tolerance of about 40 kHz. Based on these insights, we propose a protocol that relies on the phase overlay to authenticate the information provided via the ADS-B.

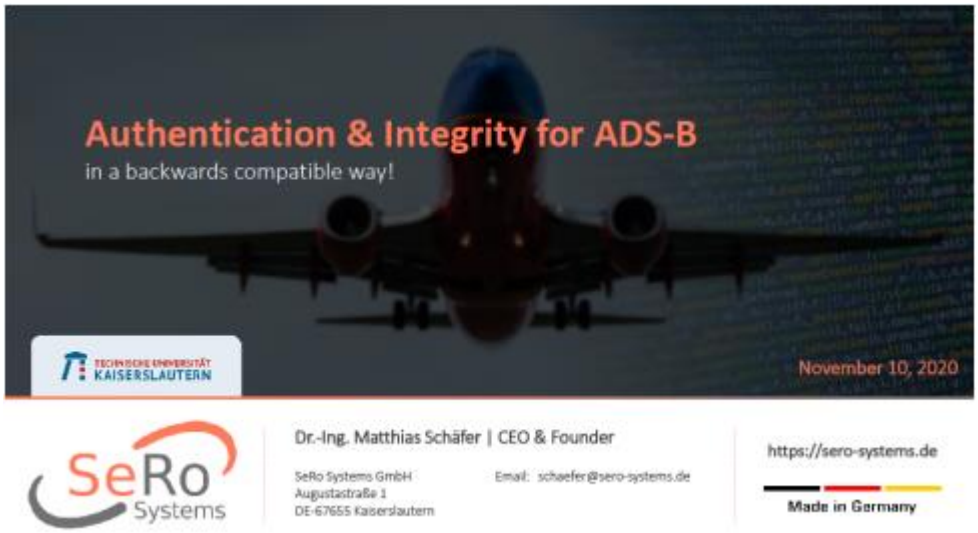

Figure 1. Authentication and integrity for ADS-B – final presentation (click image to open the pdf file)

2.2 The drone identity - investigating forensic-readiness of U-Space services

Abstract: The Drone Identity project investigates forensic-readiness requirements of unmanned aerial systems (UAS), to help identify causes of safety and security related air traffic incidents. It is a collaborative effort between researchers at The Open University (OU) and NATS. The project contributes to addressing the vulnerabilities and global security of communications, navigation, and surveillance systems in air traffic management (CNS/ATM). The collection and use of forensic data associated with drones and surrounding physical contexts is key to effective investigation. The research is conducted in the context of U-Space, focusing on the architecture and concept of operations for European unmanned traffic management (UTM), and the ability to preserve such vital information as evidence for forensic investigations. The goals of such forensic readiness are to ensure that the root causes of incidents can always be analysed, facilitated by evidence collected during operation (drone flight). The project focuses on drone data, examining ways in which key drone characteristics can be determined and recorded soundly, if and when incidents involving the drone(s) occur. In particular, the key attributes that characterise and identify the drones, their operators, and their anomalous behaviours will be investigated. A prototype demonstrator has been developed, including a technical architecture, to illustrate and evaluate the proposed forensic readiness requirements for U-Space services.

Figure 2. The drone identity - investigating forensic-readiness requirements of UAVs – final presentation (click image to open the pdf file)

3 Thematic challenge 2 catalyst fund projects

The workshop was held on 25 January 2021, as a virtual event. The objective of the TC2 is: “Accurate and reliable trajectory prediction (TP) is a fundamental requirement to support trajectory-based operations. Lack of advance information and the mismatch between planned and flown trajectories caused by operational uncertainties from airports, ATC interventions, and ‘hidden’ flight plan data (e.g., cost indexes, take-off weights) are important shortcomings of the present state of the art. New TP approaches, merging and analysing different sources of flight-relevant information, are expected to increase TP robustness and support a seamless transition between tools supporting ATFCM across the planning phases. The exploitation of historical data by means of machine learning, statistical signal processing and causal models could boost TP performance and enhance the TBO paradigm. Specific research domains include machine-learning techniques, the aggregation of probabilistic predictions, and the development of tools for the identification of flow-management ‘hotspots’. These could be integrated into network and trajectory planning tools, leading to enhanced TP.” All workshop presentations can be found, as a zipped file, here: https://innaxis-comm.s3.eu-central-1.amazonaws.com/ENGAGE/TC2+25JAN+2021.zip.

3.1 Data-driven trajectory imitation with reinforcement learning

Abstract: The objective of this project was to present algorithms for data-driven imitation of trajectories, following deep reinforcement learning techniques towards enhancing our trajectory prediction abilities. We aimed at building a data-driven approach in which the learning process is (a) an imitation process, where the algorithm tries to imitate 'expert', demonstrated trajectories, (b) exploiting raw trajectory data, enriched with contextual data (e.g. weather conditions etc) and (c) based on reward models (for producing trajectories in high-fidelity) that are learned during imitation. There are two main project contributions (i) a general framework for the prediction of trajectories in which deep imitation and reinforcement learning methods play a major role, together with methods selecting important features for decision making and future trajectory classification methods; and (ii) a developed and evaluated state of the art deep imitation learning techniques for predicting trajectories in the aviation domain, showing their potential for highly accurate prediction results, especially in long trajectories with multiple patterns / modalities, and in cases where the demonstrated trajectories are few.

Figure 3. Data-driven trajectory imitation with reinforcement learning – final presentation (click image to open the pdf file)

3.2 A Data-drIven approach for dynamic and Adaptive trajectory PredictiON ('DIAPasON')

Abstract: The DIAPasON project focuses on the need of the ATM system to develop tools and methodologies which are able to support traffic and trajectory management functions. For these activities, trajectory and traffic prediction is key, in particular within the context of Trajectory-Based Operations (TBO). While previous research exists addressing these matters, DIAPasON presents a different approach. In particular, the project aims at analysing patterns of flight plan evolution for individual flights, and extract patterns and feature which can be applied in a wide number of operational contexts where this information is available. The main result of the project is the development of a methodology for trajectory prediction and traffic forecasting in a pre-tactical phase (from a few days to a few hours before the operations, when a only limited number of flight plans are available). This can be adjusted to different time scales (planning horizons), considering the level of predictability of each of them and the specific use case to where it should be applied. These results have been explored with support of operational staff to maximise the benefits in the pre-tactical phase.

Figure 4. DIAPasON – final presentation (click image to open the pdf file)

3.3 An interaction metric for an efficient traffic demand management: requirements for the design of data-driven protection mechanisms ('INTERFACING')

Abstract: A major limitation of the current ATM system is the loss of effectiveness due to the limited integration between the layered planning Decision Support Tools (DSTs). While the Trajectory Based Operation concept enables new DSTs that could deal with present demand/capacity, a word of caution at a practical level: ATM stakeholders realise that technological flexibility to regulate flights into a sector is not synonymous of performance, rather several negative effects can arise at the network level due to lack of analysis of interdependencies among regulated sectors. INTERFACING has developed a formal probabilistic framework to detect and characterise at the network level the flight interactions and their interdependencies. New interaction metrics have been implemented to enable the evaluation of regulation efficiency and to pave the way for the design of mitigation measures for a smooth fine-tuning of traffic demand at a micro level that considers the effects at a macro level improving the network performance.

Figure 5. INTERFACING – final presentation (click image to open the pdf file)

4 Thematic challenge 3 catalyst fund projects

The TC3 workshop was held on 27 January 2021, as a virtual event. The objective was the following: "The overall goal of this edition is to streamline the innovation pipeline in the area of efficient provision and use of meteorological/environmental information in the ATM. We start by presenting research results supported by the SESAR's KTN, Engage, through the catalyst funded projects and PhDs, aiming at discussion on finding the ways of bringing the valuable results to the higher TRL levels and foster the collaboration in this research area. The next step is the overview of the newly funded projects in the MET/ENV area, the progress in the European forecast provision, and finally the plans for MET/ENV research in the Strategic Research and Innovation Agenda of future Integrated ATM programme. The overall goal is to discuss and list the kind of information of tools would the climate change and the digitalisation of ATM require from MET/ENV-related research." All workshop presentations can be found, as a zipped file, here: https://innaxis-comm.s3.eu-central-1.amazonaws.com/ENGAGE/Engage-TC3-workshop-3-presentations.zip.

4.1 Probabilistic weather avoidance routes for medium-term storm avoidance ('PSA-Met')

Abstract: PSA-Met integrates new meteorological capabilities in the storm avoidance process, namely, probabilistic nowcasts. These new meteorological products provide not only a forecast of the storm's evolution, but also information about the uncertainty of the convective cells. PSA-Met develops a probabilistic weather-avoidance concept, according to which, the required inputs are a probabilistic nowcast and a risk level, which is an adjustable parameter intended to define the avoidance strategy. The output is a unique avoidance trajectory that takes into account the uncertainty of the convective cells, obtained for the given risk level. Simulation results show that the predictability, the safety and the workload of pilots and air traffic controllers are improved, although with a small loss of flight efficiency. This new weather avoidance concept will be used in a follow-up project, whose objective will be to develop a Medium-Term Storm Avoidance tool intended to enhance air traffic control efficiency.

Figure 6. PSA-Met – final presentation (click image to open the pdf file)

4.2 airport-sCAle seveRe weather nowcastinG project ('CARGO')

Abstract: This project has combined measurements from different instruments to develop a nowcasting algorithm of extreme weather events in a localised area around the Malpensa airport with the aim of improving aviation safety. Radar reflectivity has been used as reference to define and select the extremes; Global Navigation Satellite System (GNSS) zenith total delay, atmospheric parameters from weather stations, and lightning have been used as inputs of a neural network to predict the development of the weather events in the near future (from 30 to 90 minutes before). The results show an accuracy of 0.75 in nowcasting the extreme events when using all the datasets as inputs and decreasing accuracy when excluding one of the inputs. However, there are still several tests that should be performed to understand the optimal setting of the algorithm. This project was the first experiment to collect so many atmospheric sensors in a localised area to nowcast extreme events with ATM purposes and posed the basis to develop a deeper study on this field.

Figure 7. CARGO – final presentation (click image to open the pdf file)

4.3 Operational alert Products for ATM via SWIM ('OPAS')

Abstract: Volcanic emission is a threat to ATM and the safety of flights. Early warnings are an essential source of information for stakeholders. The OPAS project is the development of a SWIM Technical Infrastructure Yellow Profile service providing information (notification & data access) about volcanic SO_2 height. The OPAS service considers observations from three hyperspectral satellite sensors (TROPOMI, IASI-A and IASI-B), respectively operating in the ultraviolet and infrared ranges. These instruments represent the state of the art of satellite SO_2 measurements. The IASI sensor already provides well recognised estimations of SO_2 height, which is available through the SACS early warning system and contributes to the OPAS service. The outcome of the OPAS project is the new algorithmic development (iterative SO_2 optical depth fitting) of TROPOMI SO_2 height retrievals, the creation of alerts and access to tailored information, i.e. SO_2 contamination of flight level and improved mass loading estimates.

Figure 8. OPAS – final presentation (click image to open the pdf file)

4.4 MET enhanced ATFCM

Abstract: The MET Enhanced ATFCM R&D initiative has been launched by MetSafe and France Aviation Civile Services. This one-year project addressed the provision of accurate convection information for ATFCM activities, with the 6 hours' time-horizon as a target. The research approach focused on both technical and operational aspects, as needs identification and concept of operations, assessment of convection models, design and deployment of a model-based R&D convection product. Up-to-date and accurate European thunderstorm forecasts at +6 hours horizon built from a multi weather model algorithm have been delivered as a SWIM webservice for Reims Upper Area Control Centre during technical and operational validation trials. Initial project objectives have been fulfilled: Reims air traffic controllers and FMP operators greatly improved their weather situational awareness and would have been likely to take ATCFM measures based on received information.

Figure 9. MET enhanced ATFCM – final presentation (click image to open the pdf file)

5 Thematic challenge 4 catalyst fund project

As mentioned in Section 1.2, the TC4 did not have a dedicated workshop in 2020. However, the wave 1 CF project in this challenge held its own final workshop, presenting its final results. The TC4 objectives are: “This research explores the design of new allocation markets in ATM, taking into account real stakeholder behaviours. It focuses on designs such as auctions and ‘smart’ contracts for slot and trajectory allocations. It seeks to better predict the actual behaviour of stakeholders, compared with behaviours predicted by normative models, taking into account that decisions are often made in the context of uncertainty. Which mechanisms are more robust against behavioural biases and likely to reach stable and efficient solutions, equitably building on existing SESAR practices? The research will address better modelling and measurement of these effects in ATM, taking account of ‘irrational’ agents such as airline ‘cultures’. A key objective is to contribute to the development of improved tools to better manage the allocation of resources such as slots and trajectories, and incentivising behaviour that benefits the network – for example by investigating the potential of centralised markets and ‘smart’ contract enablers.”

5.1 Exploring future UDPP concepts through computational behavioural economics

Abstract: When the demand of an airspace sector is expected to exceed capacity, flights are delayed and assigned new take-off times through ATFM slots. This delay represents a significant cost for airlines and passengers. The possibility of rearranging flight sequences offers remarkable potential to reduce the impact of ATFM delay. Several prioritisation instruments are proposed in the literature, but their implementation is hindered by the limitations of classical modelling approaches to represent Airspace Users (AUs) behaviour and network effects in a realistic manner. The aim of the project is to overcome these limitations through the combined use of agent-based modelling (ABM) and behavioural economics. The model developed by the project has been used to simulate the performance of a variety of flight prioritisation under different network conditions and AU behaviours, allowing the observation of emergent phenomena and opening the way for a rigorous and comprehensive assessment of innovative approaches to User Driven Prioritisation Process (UDPP).

Figure 10. Exploring future UDPP concepts through computational behavioural economics – final presentation (click image to open the pdf file)

6 Conclusions

This deliverable collates the final presentations of the ten CF wave 1 projects. In some cases, their final reporting was impacted by Covid-19, however all projects have now completed. Their final reports were assessed within the Engage KTN consortium and were of high standard with few clarifications requested. As planned, final technical reports have been published on the Engage website after approval: engagektn.com/cf-summaries.

In addition to final reporting and final presentations at the Engage TC workshops, CF project results have been presented at various events such as the SESAR Innovation Days and other workshops – the results have been positively received by the audiences. Furthermore, the results of several CF projects are being further extended in current Exploratory Research (ER) projects (the following list is not exhaustive):

- CARGO results are being extended in ALARM and SINOPTICA,
- OPAS results are being extended in ALARM,
- PSA-Met results are being extended in FMP-Met,
- MET Enhanced ATFCM results are being exploited by WIPA (wave 2 CF project),
- Exploring future UDPP concepts through computational behavioural economics is being extended through BEACON.

The extension of CF project results into larger, ER projects further testifies to the quality of results produced by the projects.

7 References

[1] Engage project, 2021, “D2.6 Annual combined thematic workshops progress report (series 2), Edition 01.00.00,” February 2021.

[2] Engage project, 2018, “D3.4 Thematic challenges priming report for first workshops, Edition 01.00.00,” June 2018.

[3] Engage project, 2019, “D2.5 Annual combined thematic workshops progress report (priming wave 1), Edition 01.01.00,” January 2019.

[4] Engage project, 2017, “Grant Agreement 783287, Ref. Ares(2017)6114946 - 13/12/2017”.

8 Acronyms

ABM	Agent-based model
ADS-B	Automatic Dependent Surveillance–Broadcast
ATC	Air traffic control
ATFCM	Air traffic flow and capacity management
ATFM	Air traffic flow management
ATM	Air traffic management
AU	Airspace user
CF	Catalyst fund
CNS	Communication, navigation, surveillance
DST	Decision support system
ENV	Environmental
ER	Exploratory Research
FMP	Flow Management Position
GNSS	Global Navigation Satellite System
KTN	Knowledge Transfer Network
MET	Aviation meteorology
R&D	Research and development
SESAR	Single European Sky ATM research
SJU	SESAR Joint Undertaking
SO_2	Sulphur dioxide
SWIM	System Wide Information Management
TBO	Trajectory-based operations
TC	Thematic challenge
TP	Trajectory prediction
TRL	Technology readiness level

UDPP	User driven prioritisation process
UTM	Unmanned traffic management

-END OF DOCUMENT-