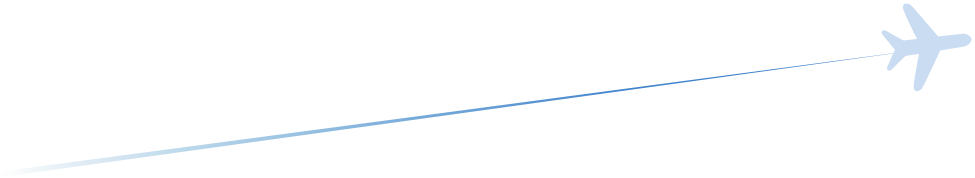

D2.7 Annual combined thematic workshops progress report (series 3)

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Name/Beneficiary	Position/Title	Date
N/A		

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Copyright Statement

Engage

THE SESAR KNOWLEDGE TRANSFER NETWORK

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Abstract

This deliverable reports on the organisation and results obtained from the third and fourth editions of the Engage thematic challenge (TC) workshops held in 2021. Due to the Covid-19 pandemic, the third editions of the TC2 and TC3 workshops, initially scheduled to be held in 2020, were delayed to the beginning of 2021. The TC1 and TC4 workshops reached their third edition in 2021, while TC2 and TC3 closed with the fourth edition. The main lessons learned relate to data availability, collaboration opportunities, machine learning and artificial intelligence methodologies and approaches, and incentives for future ATM implementations.

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1 Introduction

1.1 Objectives of this document

The deliverable reports on the organisation and results obtained from the third and fourth editions of thematic challenge (TC) workshops held in 2021. Due to the Covid pandemic, the third editions of the TC2 and TC3 workshops that were initially scheduled to be held in 2020, were delayed to the beginning of 2021. The TC1 and TC4 workshops reached their third edition in 2021, while TC2 and TC3 closed with the fourth edition.

1.2 The scope

The scope of the deliverable is to report on the activities directly and indirectly linked with the thematic challenge workshops:

- Thematic challenge workshops and future research directions
- Catalyst funding and PhD link
- Related events

The section 2 describes the preparation and execution of third edition of TC workshops, section 3 describes the same for the fourth editions (only TC2 and TC3). Section 4 lists events related to the TC workshops, and papers submitted by catalyst fund projects, related to one of the TCs. Section 5 summarises overall lessons learned from this last year of workshops.

Table 1: List of TC workshops held in 2021

Thematic challenge	Edition	Date and place held
TC1 - Vulnerabilities and global security of the CNS/ATM system	3	15 September 2021, virtual event
TC2 - Data-driven trajectory prediction	3	25 January 2021, virtual event
TC2 - AI, ML and Automation	4	03 September 2021, virtual event
TC3 - Efficient provision and use of meteorological information in ATM	3	27 January 2021, virtual event
TC3 - Efficient provision and use of MET information in ATM	4	09 September 2021, virtual event
TC4 - Economic incentives for future ATM implementation	3	21 June 2021, virtual event

1.2.1 Thematic challenge workshops and future research directions

The goal of the thematic challenges was to address research topics not currently (sufficiently) addressed by SESAR research programme, by providing an initial description of the topics that were expanded through the interaction with interested stakeholders in the dedicated workshops. The call for thematic challenges was open on the Engage website between January and March 2018. The selection process resulted in (described in detail in the deliverable D3.4 [1]) four thematic challenges to pursue:

1. Vulnerabilities and global security of the CNS/ATM system,
2. Data-driven trajectory prediction,
3. Efficient provision and use of meteorological information in ATM,
4. Novel and more effective allocation markets in ATM.

All material from the workshops, namely presentations, descriptions of challenges and workshop conclusions is public and published on the Engage website (engagektn.com/thematic-challenges).

The latest edition of workshops focused on identifying future research directions under each thematic challenge umbrella, the findings of which are reported in this deliverable.

1.2.2 Catalyst funding and PhD links

A strong attribute of the Engage KTN is its focus on the selection of thematic challenges that require further research efforts, but also offering paths to address them:

- Engage catalyst funding:
    - In wave 1, the Engage KTN funded ten projects, completed in 2020 (due to Covid-19 related delays, five projects obtained extensions of varying lengths).
    - In wave2, the Engage KTN funded a further eight projects, that started over the summer of 2020. All the projects are now completed.
- Engage PhDs/theses - the Engage KTN is funding ten PhD students.

The aim of catalyst funding is to further promote cooperation between industry and academia, between exploratory research (ER) and applied research, by funding focused projects, stimulating the transfer of ER results towards ATM application-oriented research. This funding has been awarded to groups (e.g. an industry partner leading a thematic challenge with an academic institution working in an area bringing potential solutions to this thematic challenge) to conduct and fast-track specific activities in support of developing solutions to the challenges and moving closer towards industry goals and objectives, and towards higher technology readiness levels (TRLs).

As the thematic challenges are closely linked with the catalyst funding, the goal of the first round of TC workshops was to collect the conclusions to be included in the material for the catalyst funding calls. The goal of the third round of the TC workshops was to present the results from both the wave 1 and wave 2 catalyst funding (CF) projects. The fourth edition of workshops focused on identification of future research directions.

1.2.3 Related events

The TC3 was introduced and show-cased at the Meteorological Technology World Expo, together with other SESAR MET-related projects. The details are given in Section 4.

2 Thematic challenges workshops - the third edition

This section reports on the third edition of the TC workshops. Each workshop has a dedicated sub-section, listing the organisation details (i.e. introduction), programme, discussions, eventual surveys, and finally lessons learned from the workshop. The workshops are ordered by the thematic challenge (i.e. TC1, TC2, TC3, TC4), and not by the date held.

For the third edition of TC2 and TC3, the post-workshop survey was prepared and shared with participants. The goal was to collect the feedback on quality of the content and organisation. For the TC4, the pre-workshop survey was shared with the participants, the goal being to ask registered participants to share their thoughts and the questions they would like to have answered with the workshop organisers, prior to the workshop.

2.1 Third workshop of thematic challenge 1 'Vulnerabilities and global security of the CNS/ATM systems'

2.1.1 Introduction

The workshop was held on 15th September 2021, as a Zoom meeting. There were 72 registrations for the event, resulting in about 40 participants being present at some point during the workshop. The participation peaked at 30-35 persons present simultaneously. The workshop was moderated by Pablo Hernandez and Paula Lopez-Catala from Innaxis, and Andrew Cook from the University of Westminster. Four presentations were given in Session 1, followed by the discussion on the future of cybersecurity involvement and research directions.

This workshop presented the latest results from the Engage catalyst-fund projects, advancing the state of the art on pentesting platforms, assured telemetry for U-Space and collaborative cybersecurity management frameworks, followed by a discussion on the creation of a cyber-community and its networking needs, as we look towards SESAR 3. Subsequent discussion was dedicated to future cybersecurity work, from research and solution life-cycle perspectives. This was primed by the recommendations on cybersecurity for SESAR 3 produced by the SESAR 2020 Scientific Committee. The overall goal of the workshop was to identify what research infrastructure and future research themes can be proposed for SESAR 3, for example.

2.1.2 Programme

Figure 1: TC1 programme, third edition

Presentations can be found here: engagektn.com/thematic-challenges.

2.1.3 Discussions

2.1.3.1 Session 1

Proof-of-concept: practical, flexible, affordable pentesting platform for ATM/avionics cybersecurity (ATM-cybersec), presented by Andrei Costin (University of Jyväskylä). ADS-B is unencrypted so all the information can be seen. As the information is not digitally signed, it is not easy to determine the origin of the information. Furthermore, it is wireless, and broadcast. The pentesting platform was developed, on different configurations to test different types of attacks on ADS-B, like Denial of Service (DoS) [2] [3], and novel coordinated attack [4].

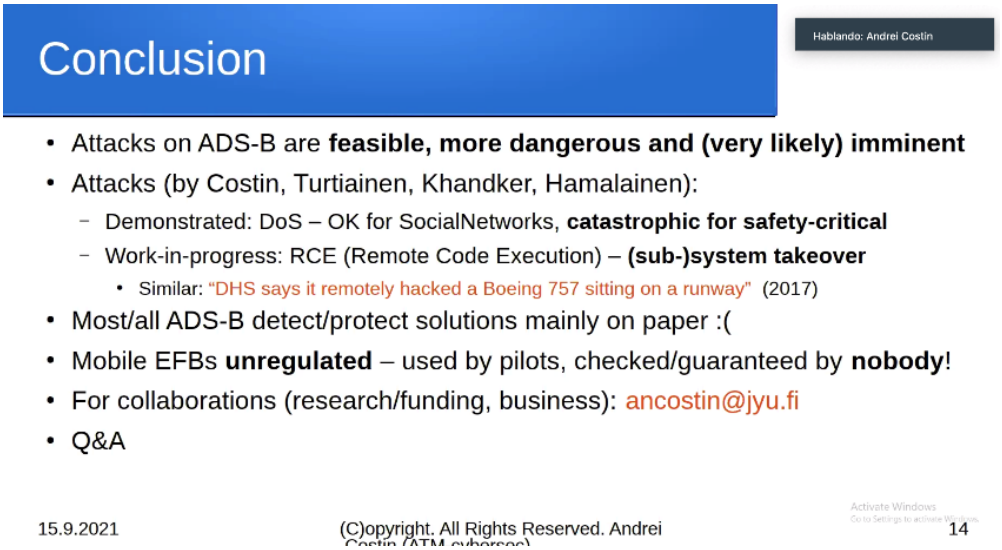


Figure 2: Conclusions, first presentation, TC1

Safe drone flight - assuring telemetry data integrity in U-Space scenarios, presented by Jacob Blamey (NATS). Assessment of different non-nominal scenarios to probe safety risks and security threats.

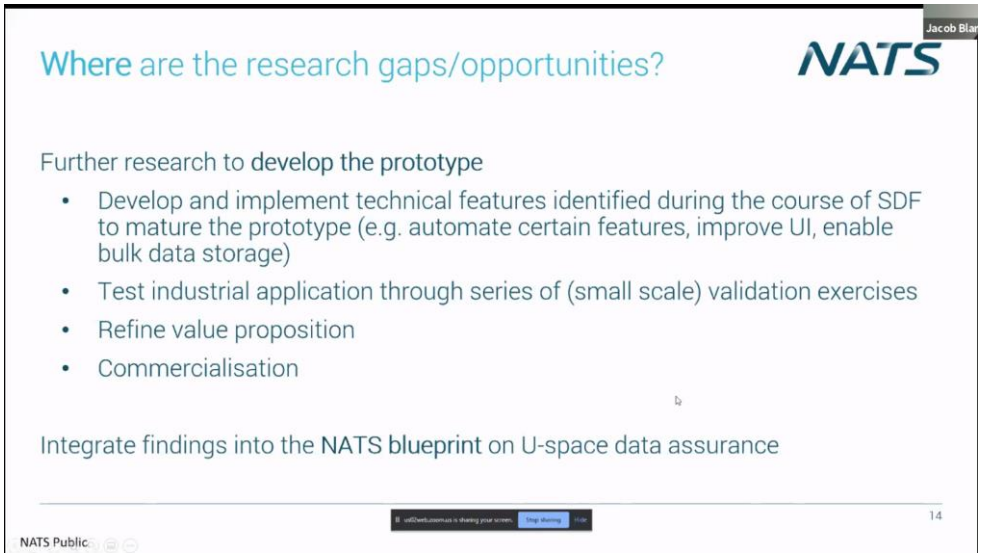


Figure 3:Research gaps and opportunities from Safe Drone Flight project

Collaborative cyber security management framework, presented by Martin Hawley, Winsland Consulting. The project is about management of cybersecurity, which is not very mature, especially when compared to safety management. The project identified how to enhance the collaboration on cybersecurity through productivity tools, and evolved risk methods in ATM from purely qualitative to quantitative methods and identified how to connect risk management to architecture in a simpler, less resource intensive way.

SINAPSE: Software defined networking architecture augmented with Artificial Intelligence to improve aeronautical communications performance, security and efficiency, presented by Muhammad Ali (University of Bradford). Machine learning algorithm selection for cybersecurity. The objective of the project is to have intelligent and secured Aeronautical Datalink Communications network based on Software Defined Network (SDN) augmented with Artificial Intelligence (AI).

Q&A Session

The responsible disclosure mechanisms (in cybersecurity) for the research community are very relevant. These mechanisms are highly bureaucratic and troublesome, should be improved, maybe with incentivisation at the European level. Personal experiences are more on the negative side, mainly due to the highly bureaucratic nature and unresponsiveness of some actors. What makes it even more complex for researchers is that giant tech companies that have large legal teams often make use of cease-and-desist orders. This is a very complex topic in cybersecurity and data privacy in general.

NATS would be happy to share the nominal and non-nominal scenarios for other projects to research. It would be good to coordinate and share them through the Engage website and/or wiki.

In Collaborative cyber security management framework, which areas in particular have you experienced challenges in obtaining appropriate impact (cost) data? Cost-benefit is an opposite of what the project was doing. The project used binomial theorem for figuring out the cost of loss, based on some general statistics.

Could the SINAPSE project tell us a little more about the challenges of using federated learning? Do you see a strong future for this in this domain? (It seems particularly valuable and suited to the cybersecurity context.) When a decentralised model for machine learning (ML) exists, there is a trouble in aggregating them. It is important to know how sparsely located the clients are and what are the temporal lags (i.e. are they an issue), plus how to update the model on the local platforms. The good thing is that only a model is sent, not the data.

2.1.3.2 Session 2

Building a community

The SecRam methodology [5] is envisioned as a minimum means of compliance for security risk assessment, and as the means of easier collaboration and information sharing on security at the SESAR programme level. The tool to enable more efficient data collection and sharing (at appropriate levels of security issues) would be beneficial for all stakeholders.

To compensate for insufficient cybersecurity research in projects and programme, it was recommended that **bringing cybersecurity expertise** becomes a mandatory (e.g. eligibility) requirement, but that might be difficult to apply at the project evaluation stage. However, this expertise can be asked for as a regular call requirement by the consortia, at the evaluation stage (being a requirement, it is lower in importance than eligibility criteria). Applicants/consortia would need to

bring in these resources, but there is still some room for organising initiatives that increase knowledge and skills for these participants, in the form of masterclass sessions, that could be given through the SESAR Digital Academy, or new Knowledge Transfer Network.

Security assessment is linked to the "security by design" requirement. This requirement is the one often cited as a key to raise the awareness on the importance of security inclusion in the early design process. The requirement of needing to complete the Security Risk Assessment is not very meaningful unless it is taken on board seriously. One of the lessons learned from the past efforts on security is that the best way of promoting the importance of the security matters in the projects, and "security by design" is through the Cybersecurity community. The Cybersecurity workshops organised by the Scientific Committee in February 2021, clearly demonstrated the interest for the topic and the "establishment" of the community. Most participants in this workshop expressed that they would be interested in creating and participating in the **SESAR Cybersecurity Community**. Such community might nicely fit in the remit of the next Knowledge Transfer Network, with the caveat to make the participation easier and open to the wider public than in the current workshop.

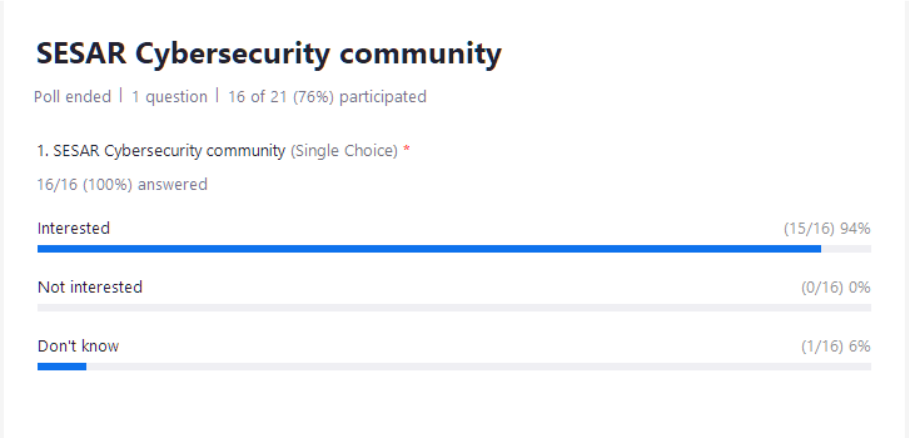


Figure 4: Results of a poll on SESAR Cybersecurity Community interest

Another point linked to both "security by design" and low maturity of security culture in general ATM community is the low awareness of the existence of security problems, the frequency of the attacks and the ensuing effects of attacks (often very costly). The quantification of the problem, in terms of financial impact might be of help to raise security awareness and culture.

Interest on the topic exists, **better exposure and involvement** needs to be achieved. Having an active platform to enable collaboration would be an enabler for this. The Engage wiki (wikiengagektn.com) can help in this purpose, possibly focused on SESAR 3 Call cyber topics to help promote the initiative.

The need for commonality of data sets and comparisons across different implementations. To assess robustness and efficiency – no standard access to data. Maybe going towards the creation of synthesised data sets to be shared across the programme, in order to improve experimental comparability across projects.

Future work

Topics mentioned for the future work related to cybersecurity were:

- Use of AI and investigation of the means of automating certain parts of controllers' work using AI.
- Use of ML and AI penetration testing for industrial prototypes. Apply AI to strengthen systems, make them less subject to cyber attacks. When using ML and AI in operational applications – what are the risks and how do you certify them?
- Considering the ADS-B vulnerabilities and the potential attacks it may suffer, additional effort beyond research activities should be on developing deployable solutions, as the need for the solutions is becoming rather urgent.
- In the past, most resources have been allocated to safety development, and security has been rather neglected. For the future research developments, cybersecurity can leverage on the strong safety management experience.
- 'Responsible disclosure', in particular, and **sharing experimental scenarios**, in general, are challenges in this domain. Engage KTN seeks to report on improvements to both challenges.
- Make sure that cybersecurity considerations are taken into account from the earliest stages of any development, in all the projects, regardless of if the focus is cybersecurity or not.

2.1.4 Lessons learned

General lessons learned are collected in Section 5, where we offer feedback on the format and functioning of the virtual workshops.

Cybersecurity issues are becoming ever more important in many domains, ATM included. Cybersecurity awareness and security culture are still rather immature in ATM research. Even so, there is a lot of interest to address the topic and create a **SESAR Cybersecurity Community**. This interest should be nurtured to keep the good momentum for the cybersecurity community, as there is a risk of losing the momentum in the transition from SESAR 2020 to SESAR 3. The Engage wiki forum on cybersecurity might be one of the tools to bridge this transition gap between the two programmes.

The Engage (website and wiki) could be a tool for sharing **experimental scenarios/use cases**, and **responsible disclosure lessons**.

There is a need for **commonality of data sets** to enable comparisons across different implementations. This is needed to support assessment of robustness and efficiency, as so far there is no standard access to data. A possible solution could lie in moving towards the creation of ***synthesised data sets*** to be shared across the programme, in order to improve experimental comparability across projects.

2.2 Third workshop of thematic challenge 2 'Data-driven trajectory prediction'

2.2.1 Introduction

The third workshop of thematic challenge 2 'Data-driven trajectory prediction' took place as a Zoom-webinar on 25th January 2021. The workshop followed up on the first edition held at Castelldefels in 2018 and the second one held in Athens in 2019. The workshop was moderated by Andrew Cook and Tatjana Bolić from the University of Westminster, and Dirk Schaefer from EUROCONTROL. Twelve presentations were given in three technical sessions; a discussion at the end of the workshop allowed common topics to be revisited.

Since the chosen format was a Zoom webinar the moderators and presenters were invited as panellists and were hence able to activate microphone and camera and share their screens. Other participants were invited as attendees, meaning that they had access to the Q&A and chat functionality but could not activate their microphone or camera. This choice was made as a function of the expected number of participants. The workshop was not video-recorded and was attended by 57 participants.

2.2.2 Programme

1000-1015 **Welcome and overview from the Engage KTN; overview of TC2 and previous workshops -** *Dirk Schaefer (EUROCONTROL), Tatjana Bolić (University of Westminster) and Andrew Cook (University of Westminster)*

SESSION 1 (1015-1155, chair: Dirk Schaefer)

1015-1040 **Uncertainty modelling and data assimilation to propagate aircraft trajectory uncertainties using polynomial chaos expansions -** *Andrés Muñoz (Boeing) and Manuel Soler (University Carlos III Madrid)*

1040-1105 **Prediction of propagation and evolution of delays with machine learning -** *Ramon Dalmau Codina (EUROCONTROL)*

1105-1130 **Trajectory Prediction via Imitation Learning -** *George Vouros (University of Piraeus)*

1130-1155 **Clustering & Complexity measures of European traffic -** *Didier Dohy (NeoMetSys)*

1155-1300 ***Lunch***

SESSION 2 (1300-1440, chair: Tatjana Bolić)

1300-1325 **A Data-drIven approach for dynamic and Adaptive trajectory PredictiON ('DIAPasON') -** *Jose Manuel Cordero (CRIDA)*

1325-1350 **Probabilistic information Integration in Uncertain data processing for Trajectory Prediction -** *Francesco Martone, CIRA*

1350-1415 **An interaction metric for an efficient traffic demand management: requirements for the design of data-driven protection mechanisms -** *Juan José Ramos (Aslogic)*

1415-1540 **PJ18.W2 4DSkyways – Solution 53. Current Research Activities** *Christian Verdonk Gallego (CRIDA)*

1440-1500 ***Coffee break***

1500-1530 **OpenSky: Crowdsourcing Data Collection for ATM Research -** *Martin Strohmeier, University of Oxford*

SESSION 3 (1530-1645, chair Andrew Cook)

1530-1600 **Engage PhD presentations**

- ***Machine Learning Applications to Extend AGENT's conflict resolution capabilities -*** *Ralvi Isufaj (Autonomous University of Barcelona)*
- **Advanced statistical signal processing for next generation trajectory prediction -** *Homeyra Khaledian (Technical University of Catalonia)*
- **Data-based Pre-tactical Trajectory Prediction -** *Manuel Mateos (Nommon)*

1600-1630 **Discussion**

1630-1645 **Wrap-up and close-out -** *Dirk Schaefer (EUROCONTROL) and Andrew Cook (University of Westminster)*

The programme and all presentations are available for download on the Engage website (since 26th January 2021) https://engagektn.com/thematic-challenges/.

2.2.3 Discussions

Engage Announcements

The Engage Knowledge Hub (EngageWiki) was launched recently, and new reports and publications will progressively be added. Access is free and open, user credentials need to be requested and will be granted rapidly. The EngageWiki also contains an ATM concepts roadmap which attempts to collect future research axes in a 2040 timeframe. Inputs are greatly appreciated.

The Engage summer school 2021 was announced, with a hope it could be organised as a physical event in Trieste. Should that not be possible due to Covid, the summer school will be organised as a virtual event.

Collaboration with OpenSky

A collaboration/exchange between Engage and the OpenSky Network was discussed, especially with a view of preparing ***scientific datasets for ATM*** to be driven by Engage KTN and the PhDs' and researchers' needs. Such datasets would be useful since comparability is important – if everyone takes/cleans their own data – often results are not comparable. We may not be able to prepare the data for all use cases but could do it for several. It was stressed that not only *comparability* is desirable

but also *reproducibility* – which means that **availability of code** should be encouraged as well. Reference/standard datasets could be made available by Engage in the EngageWiki. Engage could assist in coordinating CFs and PhDs to come up with the case studies and come back to Martin Strohmeyer from the OpenSky Network.

Trajectory prediction versus trajectory optimisation

How can the good work on trajectory prediction be used for trajectory optimisation, not only for network optimisation by modelling the aircraft behaviour? This has to be seen in the context of SESAR 3 Exploratory Research (ER), where the Strategic Research and Innovation Agenda (SRIA) now envisages an aggressive timeline to research, develop and deploy "better than ATCO" ATC Trajectory Advisories. Must we not stop investing in better predictions and more awareness alerts, and rather focus on computing and proposing the best trajectory? Probably we still need both, trajectory prediction and trajectory optimisation to be able to further mature the ATM tools.

One participant suggested that we have to skip conflict detection in favour of conflict resolution; perhaps even go further – to the trajectory advisories – issue separation and take into account arrival management and similar; this would help avoid overloading the controller. Then add CDO/CDA – trajectory advice that is as good as or even better than what a controller would do. Always keeping the long-term goal of what we want to achieve – the goal being to automate air traffic control.

Flight plan filing

The flight plan filing behaviour is quite different across different airlines, see for example the study by DIAPasON project which compared a legacy and a low-cost carrier in Spain; a legacy carrier often filed flight plans very early but they were significantly revised whilst low-cost carriers filed flights plans later, resulting in actual trajectory being much closer to the last filed flight plan. Whether this is typical or not for legacy vs. low-cost carriers is not the point; there undoubtedly is some pattern in the accuracy or lack thereof of filed flights plans, and of course being aware of that and modelling it can improve the trajectory prediction. It would seem desirable to feed these observations back to the airlines. Overall, a more integrated view including airlines, airport and ANSPs would be very beneficial to obtain a network-wide perspective, and hence permit network-wide optimisation.

MUAC explained that they are typically discussing six hours before the flight when they review filings and discuss with airline dispatchers if they would like to use optimal routes proposed by MUAC. The route proposals come from the MUAC algorithms that use the historical data – similar things exist in NM. This can be seen as a step towards collaborative decision making by involving the airlines.

KPIs

The challenge of tracing the impact of better trajectory prediction through the KPA framework and the existing KPIs was discussed. This would require agreement with all the stakeholders in order to try to find a common approach and show the benefits of the new development. No common approach to KPA/KPI assessment seems to exist presently in the IR and ER projects. The possibility of holding a specific workshop dedicated to performance measurement was suggested.

2.2.4 Post-workshop participant survey

A link to a participant survey was sent to all attendees after the workshop. The survey consisting of four one-choice questions and two free-text fields was filled-in by 13 respondents. Graphs

summarizing the responses to four questions are reported below, while the summary of the free-text comments can be found in the following sub-section.

The respondents appreciated the technical content of the workshop (see Figure 5).

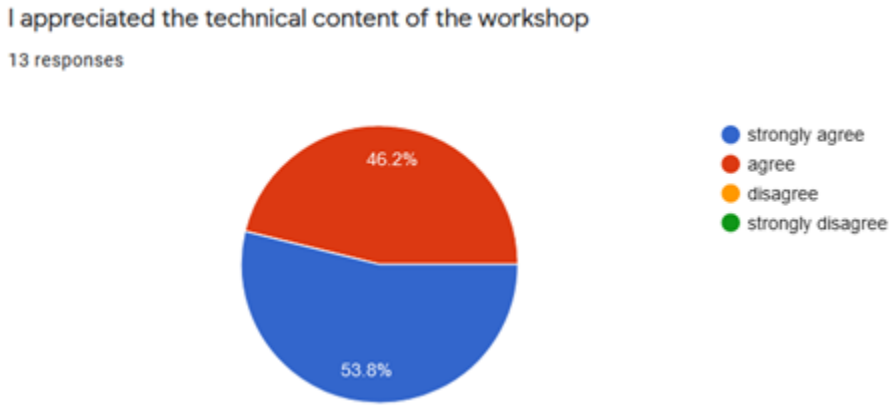


Figure 5: TC2 Workshop - I appreciated the technical content of the workshop

The majority of respondents declared that what they learned at the workshop was generally useful for their work (Figure 6). Respondents had the same opinion on the opportunity for discussion (Figure 7), which does leave some space for improvement (see section 2.2.4.1). Based on the responses, the logistics of the workshop were satisfactory (see Figure 8).

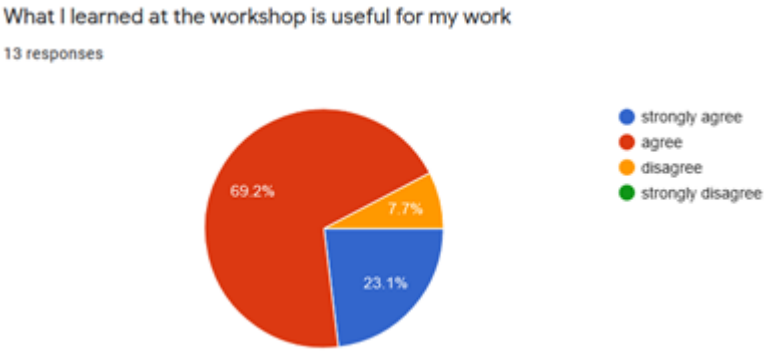


Figure 6: TC2 Workshop - What I learned at the workshop is useful for my work

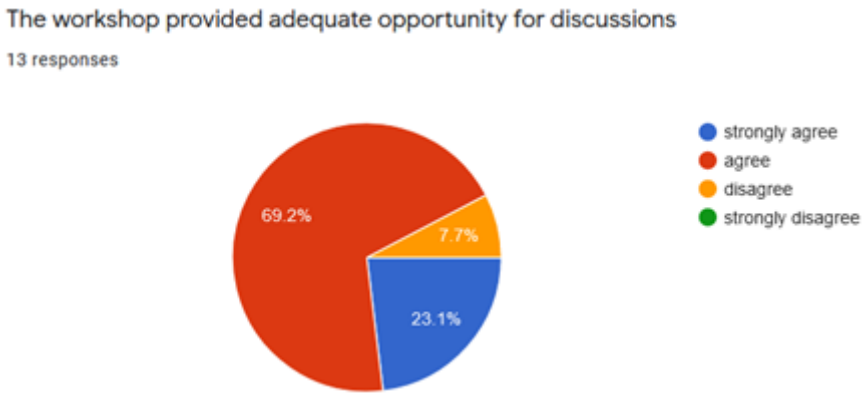


Figure 7: TC2 Workshop - The workshop provided adequate opportunity for discussions

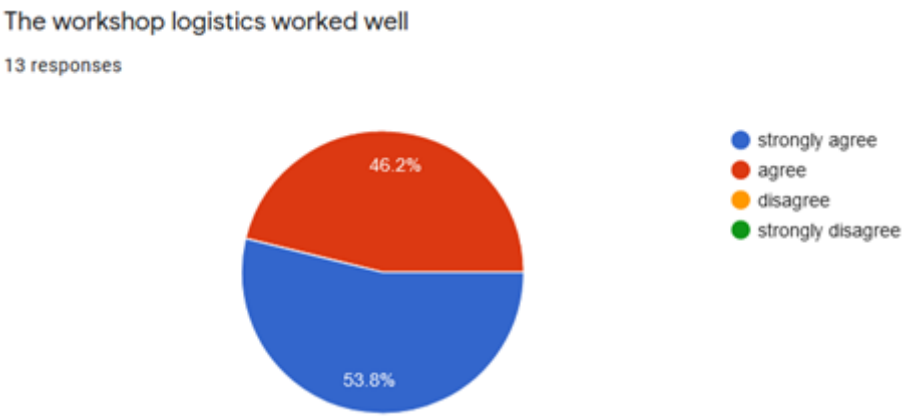


Figure 8: TC2 Workshop - The workshop logistics worked well

2.2.4.1 Comments and suggestions

As already mentioned, the survey included free text fields to allow participants to provide comments and suggestions on two questions:

1. Please let us know what you appreciated and how we can improve future workshops:

   - Organising the workshop during the pandemic situation was appreciated, with the expressed hope of having the opportunity to go back to face-to-face meetings. The possibility of "seeing" who is also participating would be appreciated (note the workshop was held as webinar where the participants could "see" only the presenters and moderators).

   - More opportunities for discussion would be appreciated, and guided discussion may be more productive. Perhaps questionnaires could be sent before the workshop in order to organise the discussion?

- Explaining details of some specific topics, such as OpenSky presentation was a great opportunity, but it would be nice to see also more details about the data files (for example, what is the ground speed, the frequency of it, etc.).

2. Please provide suggestions for future research topics, especially with a view beyond SESAR 3 (2040)

   - Weather impact on new digital solutions (UTM, UAM, Remote Towers, virtual centres).
   - AI and ML topics will likely be hot topics in the coming years. Federated learning or blockchain technologies could have great potential for the industry.
   - UTM, Civil-Military U-space, C-UAS.

2.2.5 Lessons learned

General lessons learned are collected in Section 5, where we offer feedback on the format and functioning of the virtual workshops.

A collaboration/exchange between Engage and the OpenSky Network on preparing ***scientific datasets for ATM*** that could be driven by Engage KTN and the PhDs' and researchers' needs was discussed. It is important to create not only *comparability* but also *reproducibility* – which means that **availability of code** should be encouraged as well. Reference/standard datasets could be made available by Engage in the EngageWiki.

Further work on both trajectory prediction and trajectory optimisation is still needed with regard to integration with maturing automation tools.

Performance assessment of trajectory prediction (e.g. on efficiency) is still to be developed. This would require agreement with all the stakeholders, to try to find a common approach and to demonstrate the benefits of the developments. No common approach to KPA/KPI assessment seems to exist presently in the IR and ER projects, in this domain. The possibility of holding a specific workshop dedicated to performance measurement was suggested.

2.3 Third workshop of thematic challenge 3 'Efficient provision and use of meteorological information in ATM'

2.3.1 Introduction

The workshop was held on 27th January 2021, as a Webex meeting, hosted by the SJU. There were 70 registrations for the event, the attendance oscillating between 35 and 50 participants. The workshop was moderated by Luca Crecco from SJU, and Tatjana Bolić from University of Westminster. Twelve presentations were given, and two discussions held across three sessions.

The overall goal of this edition was to discuss streamlining the innovation pipeline in the area of efficient provision and use of meteorological/environmental information in the ATM. The workshop started 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 was 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 was to discuss and list the kind of information and tools would the climate change and the digitalisation of ATM require from MET/ENV-related research.

2.3.2 Programme

0930-0945 Welcome by SESAR Joint Undertaking and Engage KTN
Welcome by our hosts, SJU and the introduction to the SESAR KTN, Engage, and the day's programme
Tatjana Bolić (University of Westminster), Luca Crecco (SESAR JU)

SESSION 1 Catalyst Funding Wave 1 results

0945-1015 ***Probabilistic weather avoidance routes for medium-term storm avoidance ('PSA-Met')***
Antonio Franco Espin, (University of Seville)

1015-1045 ***airport-sCAle seveRe weather nowcastinG project ('CARGO')***
Riccardo Biondi (University of Padova)

1045-1115 ***Operational alert Products for ATM via SWIM ('OPAS')***
Hugues Brenot (BIRA)

1115-1130 ***Coffee break***

SESSION 2 Catalyst Funding Wave 2 and the Engage PhDs

1130-1210 ***MET enhanced ATFCM and WIPA***
Gladys Mercan (FRACS) and Kamel Rebaï (METSAFE)

1210-1230 **Metsis**
Emmanuel Sunil (NLR)

1230-1245 **Engage PhDs**
"Integrating weather prediction models into ATM planning", Anastasia Lemetti (Linköping University)
"A pilot/dispatcher support tool based on the enhanced provision of thunderstorm forecasts considering its inherent uncertainty ('STORMY')", Eduardo Andrés (UC3M)

1245-1300 **ALARM project**
Manuel Soler (UC3M)

1300-1400 ***Lunch***

SESSION 3 New developments for MET/ENV in ATM

1400-1415 **Integration of dynamic weather cells in collaborative ATFCM - ISOBAR project**
Marta Sánchez Cidoncha (CRIDA)

1415-1445 ***Discussion - Catalyst Funding results and how they can be further exploited***

Moderator: Tatjana Bolić (University of Westminster)

1445-1500 **Overview, *synergies and possibilities for collaboration between new MET/ENV projects***
Luca Crecco (SESAR JU)

1500-1520 ***European weather forecast provision***
Rosalind Lapsley (EUROCONTROL)

1520-1535 ***New SRIA and MET/ENV***
Philippe Lenne (SESAR JU)

1535-1615 ***Discussion - information and tools from MET/ENV related research needed to address the climate change and the digitalisation of ATM***
Moderator: Luca Crecco (SESAR JU)

- Problems and opportunities in climate change and ATM digitalisation.
- MET/ENV performance assessment needs.

1615-1630 ***Wrap-up, conclusions, wider next steps***
Tatjana Bolić, Luca Crecco

The programme and all presentations are available for download on the Engage website https://engagektn.com/thematic-challenges/.

2.3.3 Discussions

2.3.3.1 Session 1 - Catalyst Funding Wave 1 results

Probabilistic weather avoidance routes for medium-term storm avoidance ('PSA-Met'), presented by Antonio Franco Espin, (University of Seville). PSA concept should be capable of generating avoidance rules taking account of uncertainty of storm cells, to improve storm avoidance tools. PSA computes the risk field for each nowcast (slide 11) and defines the risk field isolines as no-fly zones (slide 12). PSA concept includes an implementation based on any deterministic storm avoidance tool; adjustable risk level to define avoidance strategy (slide 8). Storm avoidance is usually based on deterministic nowcasting; PSA concept has made improvements to this. Next steps: include the use of PSA concept in an FMP to improve decision-making when convective weather (slide 19); develop medium-term (MTSA) tool based on PSA concept to warn controllers/give more active role in storm-avoidance process (slide 20); pilot will have the last word (slide 21); brochure presented to stakeholders; good feedback from pilots/controllers (slides 22/23).

At this stage the project used synthetic data for nowcasting, to be able to progress. Further, a large spread in the ensemble forecast could appear. Depending on the avoidance strategy applied by the flight, the risk could be reduced in some regions where this happens. The tool was tested by ATCOs, the tests with airlines should be done at the later stage (i.e. uplink of new routes to the FMS), as the current TRL level is still too low.

airport-sCAle seveRe weather nowcastinG project ('CARGO'), presented by Riccardo Biondi (University of Padova).

CARGO objective to discover optimal temporal & spatial resolution for airport weather nowcasting (looking at 20 minutes, to 2 hours before). Idea of CARGO is to use as many instruments as possible to train nowcasting to identify storm cells. Information currently missing is how quickly the convection is developing locally – this is key to CARGO. MeteoSwiss radar data from 2011-2019 is used for algorithm training; most storm cells are developing south of airport. Different types of ground-based receivers are used (professional and mass-market). Analysis: detect storm cell in vicinity of airport, before it develops. In 2019 test, the following issues were encountered: sensors were not set for this specific purpose, there was not enough time to run all tests, lightning detector was not installed on time. Due to these issues, there was not enough time to connect all the pieces, as was planned. Lessons learned: if different years chosen (from historical test data), results might differ. SINOPTICA and ALARM projects are in touch and are continuing CARGO's research.

Operational alert Products for ATM via SWIM ('OPAS'), presented by Hugues Brenot (BIRA). Motivation – hazard of volcanic emissions to aviation. Areas with occasional and frequent volcanic emissions are shown. Sulphidation can cause corrosion in the engines. Decided to focus on SO_2 height information coming from satellites. Instruments for the observation of SO_2, e.g. TROPOMI[1] (slide 7), with the aim to provide early SO_2 warnings via SWIM. Furthermore, this is a contribution to existing Early Warning System, collecting four types of hazards of which dust/smoke/volcanic are most relevant. Attempted to match observed data with simulation. Here, the IASI algorithm used; v. fast algorithm; accuracy of 1-2 km. Early warning consists of sending an e-mail with SO_2 notification to users, with links to webpage for further information. OPAS provides NetCDF alerts which are easy to read; examples shown of Raikoke volcano in June 2019; SO_2 detection continued after ash cloud had gone. Example of flight GL5T: aircraft could fly over the ash plume, but SO_2 was detected at higher altitude so it flew through SO_2 cloud for 1H. OPAS service will be online soon (Covid-19 delay). Conclusions - future development of API to provide information to stakeholders; complementary data and the work will be continued in the ALARM project. Furthermore, the environmental impact across flight levels will be investigated in ALARM. The use of ground-based observations (i.e. LIDAR) is not planned at this stage, but it is planned to use EARLINET[2] in the future stages. Current principal users of OPAS information are VAACs – they are already aware of eruption but additional OPAS information for them is useful.

2.3.3.2 Session 2 - Catalyst Funding Wave 2 and the Engage PhDs

MET enhanced ATFCM and WIPA, presented by Gladys Mercan and Kamel REBAÏ (METSAFE). Weather has a huge impact on ATM capacity. Mid-2018 there was no tool available for weather related decision making in ATFCM. Video shows a 1H flight, that due to weather diversion, became a 3H flight. Taking the same approach as with weather info for general population, there is a need to provide information about the impact on ATM (that can be automated) – VigiAero tool is developed with that goal. The tool

[1] Satellite.

[2] https://www.earlinet.org/index.php?id=earlinet_homepage

provides information at the sector level per hour for the next 24H (slide 6). *WIPA* (Engage wave 2 catalyst fund project) is about the algorithm, whereas *MET enhanced ATFCM* (Engage wave 1 catalyst fund project) was about data. *MET enhanced ATFCM* took the best of many weather prediction models (involves heavy data processing) and included a Confidence Index. The information is delivered via SWIM, validated as Reims ACC. Quite ambitious project, even before Covid-19 impact. The project introduced the Confidence Index – if both models and observations are available on the MET phenomenon, then confidence score is high. The process is totally automated. Video of such a process (12H forecast), where validation of observed weather and lightning overlaid. Colouration shows Confidence Index. HMI of the tool is provided and was partially validated at Reims. The project took a pragmatic and iterative approach about provision of accurate convection information to FMP with a 6H time horizon. Impact of Covid-19 resulted in low traffic. There is interest for information in cross-border trials. Results: selected 8 days which had 'concrete' results. ATCO situational awareness was increased, and they identified some areas for improvement: HMI is important for this type of product (developed from Reims' own needs). Unforeseen results were found in forecast instability due to significant changes to forecasts, and false alarms and non-detection events due to probabilistic nature – which level can be accepted. In conclusion, some collaboration needs to be put in place with neighbouring sectors (cross-border) to improve ATFCM at European level.

The algorithm uses four different weather prediction models – GSF, ICON, AROME, COSMO – European coverage, with 10 km point for the resolution. The *WIPA* algorithm predicts impact on the capacity only, not the capacity of the specific sector. Looking forward to associating the impact with the loss of capacity. There are no indicators to assess the closeness of predictions and observation. The video shows satellite detection of convection area from a product called RDT (Rapidly Developing Thunderstorm). Lightning detection is also used. So far, validation is mainly visual, not yet developed an automated process to check the validity. Five different weather situations were chosen to calibrate the parameters, mainly five days with specific weather patterns. During last summer, daily visual check was carried out to validate and do some tuning.

METSIS, presented by Emmanuel Sunil (NLR). Relies on Meteo Particle Model (developed by Junzi Sun, TU Delft): from wind measurements to wind field estimate per grid point and applying this method to drones. Low altitude estimates of wind are not very good, and wind is of great importance for optimisation of drone trajectories account of wind (i.e. to extend battery life). This work is a contribution to U-space Weather information Service, and could have applications for other uses, e.g. safety of cranes (slide 12). *METSIS* objectives are: to determine accuracy of the concept (NLR) and determine how low-altitude wind information can be communicated to drone operators within U-space system (AirHub). Experimental validation was performed using drone test flights. AirHub Drone Operations Centre is a real time system. Covid-19 delay affected the delivery of Foxtech Hover 1 Quadcopter required for tests. Drone wind sensor detects vertical and horizontal wind (mounted on a pole sufficiently far from the blades). Configuration of drones to test accuracy (slide 21); wind tunnel tests (slide 22). Drone motion also tested (slide 24); trailer/building/tree obstacles tested (slide 25).

Engage PhDs

"Integrating weather prediction models into ATM planning", presented by Anastasia Lemetti (Linköping University). The work is currently focusing on probabilistic modelling.

"A pilot/dispatcher support tool based on the enhanced provision of thunderstorm forecasts considering its inherent uncertainty ('STORMY')", presented by Eduardo Andrés (University Carlos III

of Madrid). The tool does not make difference in geographic area used; processing time depends on number of storm cells present in the area.

ALARM project, presented by Manuel Soler (University Carlos III of Madrid). Project is dealing with different aviation weather hazards, including volcanic/sand, space weather (radiation), climate impact of aviation, and identification of pollution hotspots. Builds on Early Warning System (EWS), as introduced by OPAS presentation earlier. Goals: dealing with different hazards, so tackling three different temporal domains, different granularities for different hazards and three spatial domains (local/regional/global). Moving from observations to forecasts, sending information in a standardised, coloured format. Overall concept: use ground-based and satellite observations, wrap-up information and distribute it via SWIM. Linked activities: ALARM an umbrella for TC3 projects (e.g. CARGO, OPAS) – synergies exist. Ambitions include integrating forecasts, providing an API (slide 8), alert hosting platform: near real time broadcasting of SO_2 dispersion models, severe weather hazards; synergies with other projects like environmental hotspots, characterised by DLR; weather across borders. Note forthcoming Convective and Volcanic Clouds detection, monitoring and modelling (CVC) summer school, and ALARM stakeholder workshop in May-June 2021.

2.3.3.3 Session 3 - New developments for MET/ENV in ATM

Integration of dynamic weather cells in collaborative ATFCM - ISOBAR project, presented by Marta Sánchez Cidoncha (CRIDA). Eleven partners are involved, addressing enhancement of the pre-tactical capacity flow management through integration of different AI solutions. Learning is accomplished from historical data and operational feedback. *ISOBAR* solution: enhancement of ATFCM operational framework and developing a prototype and demonstrator. Various building blocks are included: ATFCM operational framework, Meteo engine (project consortium includes two MET agencies), data ETL, demand and capacity prediction, various solution blocks.

Overview, synergies and possibilities for collaboration between new MET/ENV projects, presented by Luca Crecco (SJU). There are lots of activities going on at different TRL levels (form PhD to IR). Clearly, there are some synergies and some overlaps. Collaborations are possible – bottom-up approach needs to see which synergies could be achieved (see ER4 MET & ENV mapping slide). There are already links between CF projects and other ER or IR projects. SJU will circulate the slide and ask for input on the links – to have bottom-up approach – to see where different consortia can benefit from one another. The goal is to come up with concept, maybe through bundling different solutions to facilitate the injection of ideas and tools into the IR. Slide of SESAR MET projects (including Engage CF projects). There are other projects that are not presenting today (ER1, ER4, IR – PJ04 29.2 & 29.3; PJ18 Solution 56).

European weather forecast provision, presented by Rosalind Lapsley (EUROCONTROL). An update to the presentation at the 2nd TC3 workshop (5th November 2019). The role of NM is to balance demand with a limited ATM capacity. There was significant decrease in traffic due to Covid-19. Hence, summer 2020 had fewer constraints. The situation was used in a positive way to try out some new things. NM is more concerned with big weather events, over large areas where it is difficult to manage en-route traffic. Airport weather can also have an impact, particularly at large airports (e.g. at Heathrow) or when several large airports are affected at the same time. Other types of disruption (e.g. strikes) can compound the weather effect. NM is not so concerned by single convective cells, but with larger areas with lightning activity. Summer cross-border weather procedure '***CBWP 2020***' [5] (*ISOBAR* referenced it) was trialled. It is not just about having a good weather forecast, but how it is used, where it is important to get the relevant ATCOs to talk to each other. The procedure involved 24H window before

and tactically on the day. The procedure considers re-routing options during convective activities (relaxation of the RAD). CBWP 2020 enhancements: (note: many days had no significant convective actions) a new tactical update was introduced in summer 2020 (previously just pre-tactical). When triggers are met, conference calls involve discussion between ATCOs in affected countries. The trial expanded geographical scope and participants (slide 7), focusing on one piece of information to assist with collaboration. A summary page is presented through the NM, including a snapshot of convective risk during the course of the day. The information is aimed at ATCOs not meteorologists. Key summer 2020 statistics (slide 10), but take with a 'pinch of salt' due to low traffic. Another initiative: '***Airport SMART Wx Task Force***' picking up on impact of airport weather on the network, something that has been of slightly less concern of the NM to date.

New SRIA and MET/ENV, presented by Philippe Lenne (SJU). Overview of the Digital European Sky SRIA [6]. MET topic fits in Section 3.3 – weather impact on delay. Data are difficult to interpret and not always shared, and it is important that the same MET prediction data are used. Section 3.7 aviation green deal: planning the right trajectory includes MET. What is next: investment in what is right at the moment, and currently the focus is on climate impact of aviation. Traffic recovery will come, along with congestion, and we need to include all stakeholders.

Discussion - Catalyst Funding results and how they can be further exploited, moderated by Tatjana Bolić (University of Westminster).

The important points from each project are: what is the main output of each project, (e.g. a tool, a concept), who are the stakeholders in each project (e.g. ANSPs, AUs), what about the data inputs – are there common input? This should be done through talking to projects to find commonalities and differences between projects. The mapping between MET/ENV projects in the ER calls is being completed.

The ER projects would like to know who would be interested in exploiting further the results obtained in the ER phase and are open to possibilities for this maturing process.

Regarding the cross-border weather prediction, there is keen interest in the pre-tactical phase, to start planning for the reactions across borders and NM – to have a 'game plan' for the next day, with relevant up-to-date information on the day. The plan is being developed at the NM level, in some cases states make (made) state-based decisions based on state MET information.

The long look-ahead time of the cross-border cooperation could make it difficult or unreliable to identify individual storm cells to circumvent. This might trigger more research on the topic; *WIPA* tool prediction over the next 24H is becoming more reliable; ML techniques are improving performance of the tool, as is the fine-tuning of algorithms.

From the MET point of view, many projects are spending a lot of effort in collecting data. The main problem is acquiring homogenised data for the entire European airspace (e.g., MET data, GNSS, lightning). It would be helpful if Engage or SJU could work on finding a solution for data sharing, maybe in the form of collaborative datasets. Motivation for some projects (e.g. METSIS) is driven by a lack of appropriate data in general and in future controlled airspace near airports, where drones might one day operate. European Commission and H2020 websites have published guidelines on 'FAIR' data usage (findability, accessibility, interoperability, reusability); all projects are now asked for a data management plan to explain how they will achieve these guidelines, including making datasets available for reuse – this is very important. The guidelines are laudable, but the use of datasets is often hampered by the licensing and non-disclosure agreements linked with the initial input data.

Discussion - information and tools from MET/ENV related research needed to address the climate change and the digitalisation of ATM, moderated by Luca Crecco (SJU).

Two questions were posed to start the discussion:

1. Problems and opportunities in climate change and ATM digitalisation.
2. MET/ENV performance assessment needs.

Climate change has not received much attention in SESAR, as many projects are funded via H2020 but only a couple by SESAR. The climate change impact in aviation so far received less attention for a number of reasons: CO_2 emissions are considered due to fuel burn, but non-CO_2 emissions are not widely considered in aviation. Other studies of non-CO_2 contributions concluded that there is potential for climate impact contribution. The question is, would it be possible to issue regulations triggered by environmental impact? Also how do we aggregate climate impact of individual flights? It is usually negligible for one flight, so focus should probably be on the regions of airspace.

There is importance in the trade-off between CO_2 and non-CO_2 (NO_x, contrails, vapour, etc.) that needs to be considered. Look-ahead time matters, e.g. contrail lasts for a matter of hours while emissions lasting 100 years. Flow of traffic need to be considered over individual flights; 1% of contrails account for 10% of climate change.

There is importance in defining the new environmental indicators. SES II+ package keeps same indicators as before (CO_2) and it is expected CO_2 will drive the behaviour of ANSPs, as they are bound by indicators. The climate is much more complicated, and likely requires additional metrics.

The current climate-related thread might not be enough to come up with more reliable results, it would be valuable to have projects with different approaches. Investigation of re-routing to avoid climate impact should still be mentioned with respect to MET/ENV.

Wrap-up, conclusions, wider next steps, moderated by Tatjana Bolić, Luca Crecco.

The presentations and minutes will be available, as usual, on the Engage website. Short survey on the workshop will be distributed after the workshop to the participants. Participants are informed to request wiki accounts to edit Engage wiki content (wikiengagektn.com); approval is manual, so may take a day or so. A quick run through of some of the wiki features.

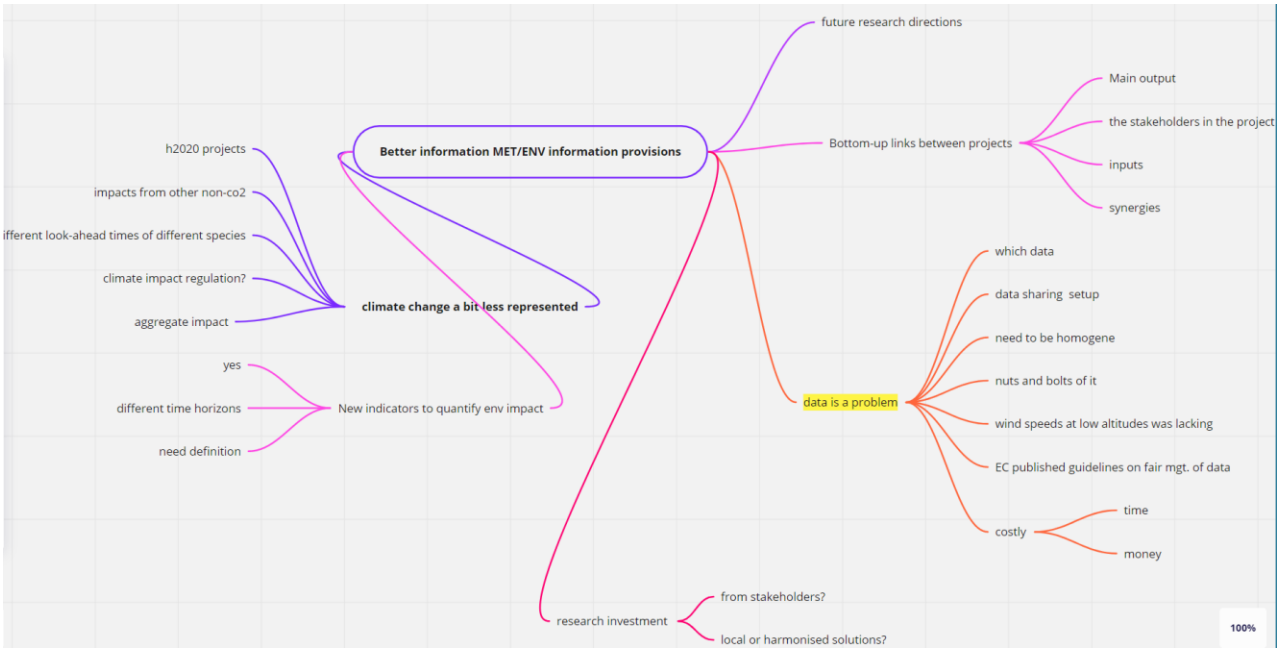


Figure 9: Discussion summary

2.3.4 Post-workshop participant survey

A link to a participant survey was sent to all attendees after the workshop. The survey consisting of four one-choice questions and two free-text fields was filled-in by seven respondents. Graphs summarising the responses to four questions are reported below, while the summary of the free-text comments can be found in the following section.

The respondents appreciated the technical content of the workshop (see Figure 10).

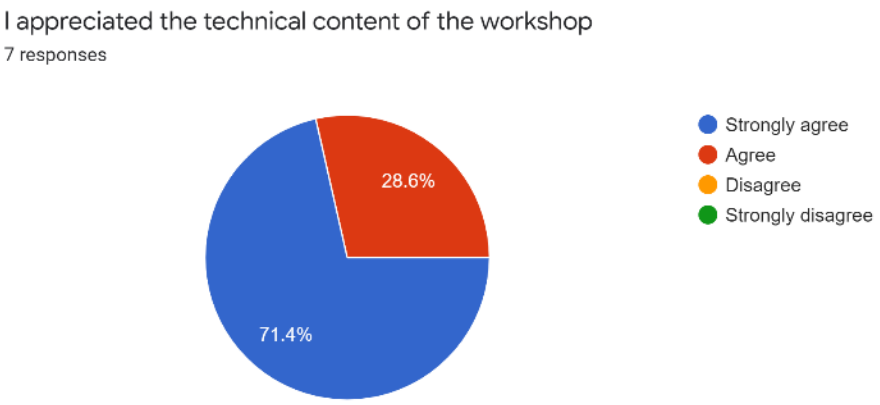


Figure 10: TC3 – I appreciated the technical content of the workshop

The respondents declared that what they learned at the workshop is generally useful in their work (Figure 11). The opportunity for discussion was assessed as adequate by the majority of respondents, but there is space for improvement (Figure 12). Based on the responses, the logistics of the workshop were satisfactory (see Figure 13).

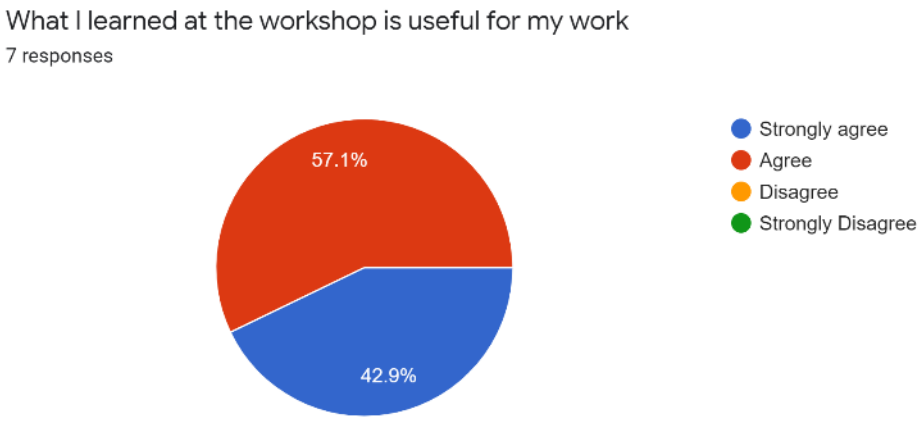


Figure 11: TC3 – What I learned at the workshop is useful for my work

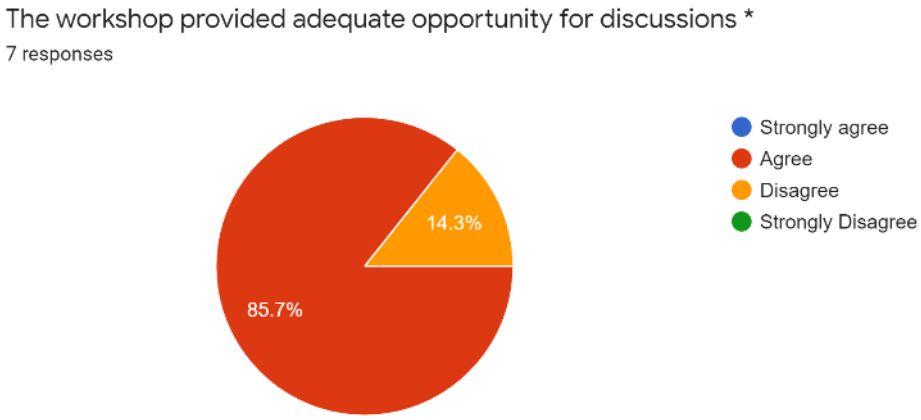


Figure 12: TC3 – The workshop provided adequate opportunities for discussions

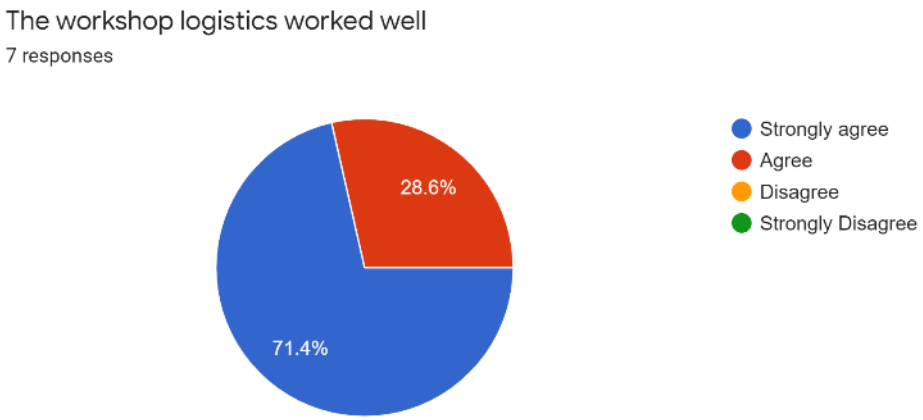


Figure 13: TC3 – The workshop logistics worked well

2.3.4.1 Comments

As already mentioned, the survey included free text fields to allow participants to provide comments and suggestions on two questions:

1. Please let us know what you appreciated and how we can improve future workshops:
   - The variety of attendants and their rich contributions to a solid discussion was appreciated. It would be good to open this forum to weather providers, both public and private entities.
   - The discussions were appreciated. The longer and more interactive discussions would be helpful in the future (e.g. imitating real coffee breaks (breakout rooms?)).
2. Please provide suggestions for future research topics, especially with a view beyond SESAR 3 (2040)
   - To investigate further storm tracking, convection and traffic flow.
   - Further analysis of impact of aerosols on convection development.
   - Integrating weather factor into airport operations.

2.3.5 Lessons learned

General lessons learned are collected in Section 5, where we offer feedback on the format and functioning of the virtual workshops.

A general observation (prompted by the impressive work presented) is that it is very encouraging to see in these presentations the clear use of the Engage funding to support the development of research towards higher TRLs and to catalyse this process. The links with industry are also very impressive in these TC3 activities, which are further picked up by some projects (e.g. ALARM clearly identified the links with past projects and the inspiration coming from the TC3 workshops).

Climate change issues are somewhat less represented in the SESAR programme. The climate change research topic revolves not only around CO_2, but also non-CO_2 impacts. Further, it is important to understand how to assess the climate change impact (e.g. aggregation of impacts at a regional level), and how to then incentivise such inclusion in operations (e.g. climate impact regulation). This links tightly to the importance of defining the new environmental indicators. SES II+ package keeps the same indicators as before (CO_2) and it is expected that CO_2 will drive the behaviour of ANSPs, as they are bound by indicators. However, the climate is much more complicated, and requires additional metrics.

Data access and sharing is a problem. From the MET point of view, many projects are spending a lot of effort in collecting data. The main problem is acquiring homogenised data for the entire European airspace (e.g., MET data, GNSS, lightning). It would be helpful if Engage or SJU could work on finding a solution for data sharing, maybe in the form of collaborative datasets.

2.4 Third workshop of thematic challenge 4 'Economic incentives for future ATM implementation'

2.4.1 Introduction

The workshop was held on 21st June 2021, as a Zoom meeting. There were 67 registrations for the event, the attendance oscillating between 30 and 40 participants. The workshop was moderated by Paul Ravenhill from Think Research, and Andrew Cook from University of Westminster. The focus was on discussions of the various facets of economic incentives for future ATM implementation.

The workshop initially explored how digitalisation and virtualisation are changing the ATM service provision landscape, with a presentation of the RoMiAD CF ('Role of markets in the AAS deployment') project by Think Research, which takes a high-level, holistic view of the economics of ATM virtualisation. This was followed by an industry panel discussion on the practical challenges of increasing digitalisation and virtualisation. Next session widened the context to current exploratory research on ATM incentives, and a second panel tackling how to incentivise positive change in ATM. The workshop concluded by asking the participants to help us define future research needs - what future research can we already propose for SESAR 3, for example?

2.4.2 Programme

1100-1115 **Welcome and introduction to the workshop** – *Andrew Cook (University of Westminster), Paul Ravenhill (Think Research)*

SESSION 1 (1115-1230, Industry view)

1115-1145 **RoMiAD presentation** – *Paul Ravenhill, Maribel Tomas (Think Research)*

1145-1230 **Industry panel: "What are the practical challenges of increasing ATM digitalisation and virtualisation?"**
Moderator: Paul Ravenhill (Think Research)

Panellists: Senior managers of ATM organisations

- *Eduardo Garcia, Manager European ATM Coordination & Safety at CANSO*
- *Klaus Meier, CTO at skyguide*
- *Philippe Bochet, ATC Product Line Director at Thales*

- *Alain Siebert, Chief Economist & Master Planning at SESAR JU*

1230-1330 ***Lunch***

SESSION 2 (1330-1545, Research view)

1330-1345 **Overview of current exploratory research on wider ATM incentives domain –** *Andrew Cook (University of Westminster)*

1345-1430 **Exploratory research panel: "How do we incentivise positive change in ATM?"**
Moderator: Andrew Cook (University of Westminster)

Panellists:

- *Benno Guenther (Salient) for BEACON project*
- *Radosav Jovanović (University of Belgrade) for CADENZA project*
- *Eduard Gringinger (Frequentis) for SlotMachine project*
- *Ruben Alcolea (Nommon) for ITACA project*

1430-1445 ***Coffee break***

SESSION 3 (1445-1530, Defining future research needs)

1445-1530 **Interactive discussion session: "Defining future research needs".**
Moderator: Dirk Schaefer (EUROCONTROL)

1530-1545 **Wrap-up and next steps –** *Andrew Cook (University of Westminster)*

The programme, presentations and material distributed to participants is available for download on the Engage website engagektn.com/thematic-challenges.

2.4.3 Discussions

2.4.3.1 Session 1 – Industry view

Initial questions for the panel members:

- Are we in the right direction?
- How to accelerate?
- How to incentivize?

skyguide opted for a paradigm shift which involves both technological and operational shift. This is changing the way how they manage airspace. They started from engineering and then moved to operational department changes. The question of how to accelerate needs to be tackled at the European level. Covid situation helped to move faster in Switzerland. What they see is that incentives, especially at EU level need to be set correctly. The industry should not be afraid to move forward, as various issues that are usually cited as obstacles can be overcome (e.g. regulation, sovereignty, etc.).

According to the equipment manufacturers, the good technical elements are already available for Air Traffic Services. What is need is a good view of the CONOPS and its harmonisation across EU. More harmonised CONOPS would eliminate different families of systems. We should manage to do this collectively in Europe.

As there is a call for more harmonisation, what is needed from states to have single CONOPS? According to ANSPs the key issue is the need to change the mindset of states. The role of regulators is key to support innovation, to enable innovation, and its pace.

The SJU is bringing its members (across disciplines, and industry segments) together, in order to build consensus and work together on harmonised CONOPS. Types of new businesses that will appear are disruptive. The change will not be only about technological innovation, it will include regulatory, organisational, services evolution. Emphasis is on speed, and we need to be able to help those stakeholders that want to move fast***. A framework that enables progressive forces to move fast is needed.***

How would the data quality and related regulations impact the future virtualisation? In the past decades, the ATC systems were processing (analogue) signals and adding data to it to enrich it. Now we will have more data, but in a digital form, so we do not see the issue with data quality. There might be a ***question of certification of the data providers***. However, we still need to see how far we need to go with this. This is more a regulatory and not data quality issue.

As an ANSP what do you want from ADSP? What will it cost? It is incredible what we pay for providing the service now. Then flexibility – we believe in services – upstream and downstream services. We are now developing an FDP with 300 engineers. In the future, it should be that 2-3 FDPs worldwide provide the basic, low-cost access to all stakeholders. Services would build on top of the basic FDP. For the services, new ideas and competitivity is needed. For that, the market for services needs to be open.

The contestability/competition in the Data layer (ADSP) would help drive innovation. Competition can be good if it would move the innovation in the right direction. The top-down approach of trying to establish now which parts will be open, and which regulated, will inevitably slow down the process. Regulatory framework that provides options to help those that want to go fast.

To what extent ***sovereignty and accountability*** are the slowing factors? These are still an issue, for which we need to find the solution. Transparent and clear division of responsibility is needed. These are difficult issues but can be solved. Research community, and research on these issues is important to steer this part of the conversation.

The Airspace Architecture builds on the idea of horizontal integration, which is cross-border. How do we build trust between different providers in the layer?

The challenge lies in showing that end-to-end solution is satisfactory for the regulator. The resiliency can be shown. The main issue in this type of integration lies in the consolidation of information for the ATCO. ANSPs also agree. For example, they could not do the virtualisation in-house, so they went to the provider of such services. The question arose if the virtualisation provider needs to be certified? After consultation with the regulator, we agreed that there is no need for their certification, but the ANSP needs to confirm that the service they are getting is good enough, so that ANSP can provide the ATS service with the appropriate quality. We should be looking at the qualification, not certification. On the ***sovereignty matter, there is the issues of what data needs to be in the country***. Some ANSPs found a way to continue their collaboration, instituting it as a collaboration as a service, so that can be

a way forward. The EASA intends to amend Regulation 373 [8] to include requirements for data service provision. So, the regulatory developments are happening, and we also need to keep them informed on what is happening in the technology and operational environments.

As closing observations, all the stakeholders should have the courage to move forward. Some of the matters to overcome can be complex and difficult, but are not unsurmountable, as we already have some examples. We also need to develop an enabling framework that would allow the early movers to go in the correct direction and with the appropriate speed.

2.4.3.2 Session 2 – Research view

Initial questions for the panel members:

- How do we incentivise positive change in ATM?
- And what do we intend as positive?

Different stakeholders have different objectives. And the incentives can be very different for different stakeholders. Some behaviours and deployments could be encouraged by economic incentives, while other might need to be mandatory (i.e. if everyone has to do it, then it will be done).

On another point, we are on a path of the positive change with regards to data (data-centric). However, there is still too much focus on the technology – we have to first look at the use case we want to solve and then see what technology to use to solve it. There will be winners and users in these changes, of course. Huge impact on ***how to interact with data and how to use data to bring the benefits*** from that usage. One slowing factor on the road to the digitalisation is the **availability of real data** to validate the system. We still have the issue of making the data available for the research, that has the ultimate goal to design and test new systems (innovations). There should also be a debate on what data really needs to be protected? Is it all of the data? Plenty of "sensitive" data is already publicly available (e.g. FlightRadar). We need to be more open and more specific on which data needs to be protected and which not. It seems that the fear is much higher than the use actually mandates.

Optimising performance of the network working on both demand and supply through the network-centric approach. Cost-efficiency is the main indicator – testing how much more efficient the system could work. Some sort of product differentiation might be helpful as one-size fits all cannot really work for all stakeholders.

ATM is far more advanced with respect to banks for example. Behaviour – it is still early days, but the concept is being talked about in the ATM. As humans, we often behave in a certain way and then we create a story later on why we behaved in that way. ***When we talk about the positive change, we should be a bit broader on what we intend by incentives***. Incentives do not necessarily need to be only economic. For example, ***different social norms,*** e.g. peer-group performance. Behaviour of individuals can be very surprising, sometimes counterintuitive. Take as an example paying money for blood donations, which decreased the number of donations as the donors perceived it as someone profiting from the donation.

2.4.3.3 Session 3 – Discussion "Defining future needs"

The 'Retrospective' dashboard was used to stimulate the discussion. The ideas could be distributed across three columns (notes depicted in Figure 14 below):

- Start doing,
- Continue doing,
- Stop doing.

Start doing

The "start doing" conversation revolved around following topics: incentives to achieve the vision, data availability/flexibility, transition steps, benefits of transition, certification/regulation needed.

The economic incentives are needed to foster the modernisation envisioned, but they should be set up in an appropriate framework that is enabling the early movers to move in the correct direction at appropriate speed. In addition, they could also be taking into account the environmental impact. The incentives do not need to be only economic, but some could be based on broader socio-organisational norms (e.g. peer-group performance).

Data availability and proprietary matters could be barriers to creation of flexible services – if the access to data is limited behind cost and disclosure walls. Linked to this is the question of data privacy and protection. Currently, almost all data in ATM are considered to be in the need of protection, which is not necessarily true. The analysis of what data should be protected and what should be available is needed.

Transition steps towards envisioned modernisation should be investigated, and how to incentivise the needed organisational changes in each step.

Different architecture models may drive different levels of economic benefits. Linked to this, the benefits of harmonised CNS deployment should also be analysed.

The new scenarios should all have clearly defined liability matters and provide assurance of end-to-end provision of ATS. Furthermore, the requirements for ADSPs should be common to all EU states.

Stop doing

Stop using the indicators that are not fit for purpose, in terms that are not measuring what is important for stakeholders. Less proxy indicators, more appropriate ones.

Continue doing

The research to continue on the airspace users' preferences – to establish what they are and ensure they are enabled by the ATM system, maybe even embedding them in the resolution of various ATM constraints.

The implementation should be harmonised across aviation community, in order to allow better flow and use of data.

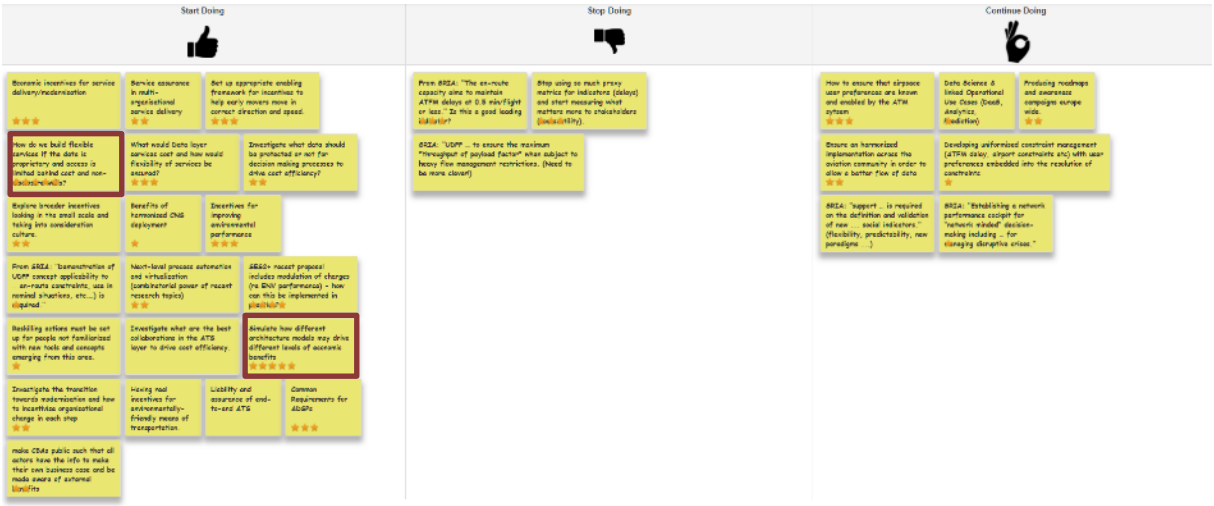


Figure 14: Votes in the discussion (the most voted proposals framed in red)

2.4.4 Pre-workshop participant survey

In the previous edition of workshops, the organisers shared the surveys regarding the workshop organisation (content, discussion, logistics). Here, as the focus of the workshop was on discussion (of various facets of the economic incentives for future ATM implementations), and to make the discussions more interactive, it was decided to ask registered participants to share their thoughts with the workshop organisers, prior to the workshop. The intention was to collect various ideas and pose the questions to the panels and in the open discussion.

Survey questions were the following:

- "How do we incentivise positive change in ATM?" Please type your question for the panel here:
- "Defining future research needs". What hot topics are missing off the agenda? Please type your suggestion for a future research need here:

Unfortunately, only one response was recorded.

2.4.5 Lessons learned

General lessons learned are collected in Section 5, where we offer feedback on the format and functioning of the virtual workshops.

The discussion format of the workshop worked well, with very positive feedback on the panel views. Whilst detailed ideas for future research have been presented in the previous sections, based on the panels and the open discussion, the following key lessons learned and research ideas to pursue in the future are to be highlighted:

- Set up an appropriate enabling framework for incentives to help early movers move in the correct direction and at greater speed. The incentives should not stop only at economic mechanisms but also look into socio-organisational/behavioural ones.
- Data availability and proprietary licencing could be significant barriers to the creation of flexible services – i.e. whereby access to data is limited behind cost and disclosure walls. Currently, almost all data in ATM are considered in need of being protected, which is not necessarily true. Further analysis of what data should be protected and what should be available is needed.
- Liability matters should be clearly defined. How can liability issues impact the assurance of the end-to-end provision of ATS should be analysed. Furthermore, the requirements for ADSPs (i.e. operations and certification) should be created in such a way that they become common across the SES.

Furthermore, reflecting the importance of a number of thematic observations relating to the topic of 'economic incentives for future ATM', these have been synthesised and reported in a dedicated section (Section 5.5), in the general lessons learned, and these are not reproduced here.

3 Thematic challenges workshops – the fourth edition

This section reports on the fourth edition of the TC workshops. Each workshop is reported on in a dedicated sub-section, listing the organisation details (Introduction), programme, discussions, eventual surveys, and finally lessons learned and/or actions stemming from the workshop. The workshops are ordered by the thematic challenge (i.e. TC1, TC2, TC3, TC4), and not by the date held.

3.1 Fourth workshop of thematic challenge 2 'AI, ML and Automation'

3.1.1 Introduction

The fourth workshop of thematic challenge 2 focused on a topic slightly different from the original one (data-driven trajectory prediction) - 'AI, ML and Automation', i.e. the scope was broadened beyond trajectory prediction and extended to include automation. The workshop took place as a Zoom meeting on 3rd September 2021. It was organised and promoted in conjunction with the Engage KTN's summer school, which worked well (see Section 5.1). The workshop was moderated by Andrew Cook and Tatjana Bolić from the University of Westminster and Dirk Schaefer from EUROCONTROL. Eight presentations were given in three technical sessions; a discussion at the end of the workshop allowed to revisit common topics.

Three previous workshops of this thematic challenge (TC2) addressed different approaches to improve trajectory prediction and management through data-driven techniques. Whilst some of these approaches involved probabilistic methods and statistical signal processing, machine learning accounted for the majority of techniques pursued in TC2. At the same time, machine learning approaches are applied in other ATM application areas so that exploiting the synergies between these different application areas seems desirable. The objectives of this workshop were to bring together researchers from different Engage and SESAR exploratory research projects, and a selection of Engage PhDs, applying machine learning for trajectory prediction and also broader application areas, to identify best practices, similarities and synergies.

3.1.2 Programme

1000-1015	**Welcome and overview from the Engage KTN; overview of TC2 and previous workshops –** *Dirk Schaefer (EUROCONTROL), Tatjana Bolić (University of Westminster) and Andrew Cook (University of Westminster)*
1015-1030	**Evolution of Automation, AI and ML research through the SESAR programme –** *Luca Crecco (SESAR JU)*
1030-1145	**SESSION 1** (chair: Andrew Cook)
1030-1055	**Machine learning to improve tactical flight decision making: the case of Pilot3 –** *Luis Delgado (University of Westminster)*
1055-1120	**ARTIMATION –** *Mobyen Uddin Ahmed (MDH)*

1120-1145 **Using machine learning to predict the evolution and propagation of delays: main results and lessons learnt –** *Ramon Dalmau Codina (EUROCONTROL)*

1145-1230 **TECHNICAL PANEL: "What is hot and what is broken in ML research?"** (panellists: Gérald Gurtner (University of Westminster), Jose Manuel Cordero (CRIDA), Brian Hilburn (CHPR), Xavier Olive (ONERA), Ramon Dalmau Codina (EUROCONTROL); moderator: Dirk Schaefer)

1230-1330 ***Lunch***

1330-1510 **SESSION 2** (chair: Tatjana Bolić)

1330-1355 **MAHALO: AI-based conflict detection and resolution tools: Conformity vs. Transparency –** *Brian Hilburn (Center for Human Performance Research) and Tiago Monteiro Nunes (TU Delft)*

1355-1420 **NOSTROMO: Next-generation Open-Source Tools for ATM performance Modelling and Optimisation –** *Maria Teresa Cano Rincon (CRIDA)*

1420-1445 **AISA –** *Tomislav Radisic (University of Zagreb)*

1445-1510 **TAPAS: Unravelling the AI/ML "black box" in ATM –** *Jose Manuel Cordero Garcia (CRIDA)*

1510-1525 ***Coffee break***

1525-1645 **Session 3 PANEL & BRAINSTORMING "Future directions for ML research in ATM"** (moderator: Dirk Schaefer, Tatjana Bolić, Andrew Cook)

- **Brainstorming**
- **Panel** (panellists: Olivia Nunez (SESAR JU), Henk Blom (TU Delft), Benjamin Cramet (EUROCONTROL), Daniel Stecher (IBS Software))

1645-1700 **Wrap-up and close-out**

The programme and all presentations are available for download on the Engage website engagektn.com/thematic-challenges.

3.1.3 Discussions

Evolution of Automation, AI and ML research through the SESAR programme, presented by Luca Crecco (SESAR JU). AI and ML research (linked to automation) in the SESAR 2020 programme was presented. The timeline includes the first call for in the ER-1 call in 2016, the setup of Scientific Committee task force on Automation [7], contributions from PhD and CF projects in Engage, ER4 call in 2018 (X projects) and the inclusion of ML and AI into the SESAR 3 flagship. There are a good number of IR projects applying ML and AI techniques, some took up the results (slide 12) from the ER projects (e.g. MALLORCA and R-WAKE).

3.1.3.1 Session 1

Machine learning to improve tactical flight decision making: the case of Pilot3, presented by Luis Delgado (University of Westminster). Looking into the optimisation of vertical and speed profile, from triggering point along the trajectory, until the descent to FL100. The objective function takes into account cost index (cost of time/cost of fuel). The optimisation takes into account the subsequent flights, investigating if the curfew at the end of the day will be broken or not. The uncertainty of various processes along the trajectory and at the airport are taken into account. Challenges are – the need for distribution (not only average values), prediction horizon (and what information is available at different horizons), multi-model approach (which model, which features), visualisation-interpretability (how to present the information to the end-user), data (availability, and how to extract the useful features).

Complementarity with quantile regression is highlighted.

ARTIMATION, presented by Mobyen Uddin Ahmed (MDH). Project objective is to predict air transportation traffic and optimising traffic flows. AI blackbox concept and various levels of explanatory power for the users. Working on AI models with transparency and explainability – through visualisation, data-driven storytelling and immersive analysis. User-centric AI and lifelong learning – where the system is trying to learn from the human that is involved in the model.

How does life-long learning work if you want to get rid-off some non-useful things? Database will collect all models, and if the new model does not fit, it goes to the old model (weighting applied).

Using machine learning to predict the evolution and propagation of delays: main results and lessons learned, presented by Ramon Dalmau Codina (EUROCONTROL). High-level presentation of two models – evolution of ATFM delay, and delay propagation and night curfews. The objective of the first project was to develop an ML model that trained on historical data can predict the evolution of the current ATFM delay for a regulated flight. The model in hierarchical neural network – it works well but does not provide a measure of uncertainty. The second model looks if it is possible to predict the likelihood that the last flight in the sequence will infringe the night curfew at the last airport of the day. In general, the models lack explainability, may learn from human reactions, a lot of external factors are not considered by the model, and the interaction between flights are not considered.

The cost of delay can be incorporated in the models if the data is available.

TECHNICAL PANEL: "What is hot and what is broken in ML research?"

What is hot and what is broken in ML research? What are the new trends and where are the problems?

Explainability of the models is something that could and should be improved. Economists when they are building the model are focused on the variables (the same as features), and they are trying to focus on the impact the variables on the model, while in the ML is rather the other way around. Should we aim for the more systematic production of ML models in the future? **Data collection** linked to the ML. How to collect data? In the past we had data and we tried to produce the best model to fit the data. Now that we are producing a lot of data, maybe we should aim at having the best possible data for the model.

Technically the kind of research in ML is quite excellent, even with limited capabilities – **difficulties to access data** – improving, but not necessarily the best data. We lack the ground truth in some very basic

concepts, like top of climb, top of descent, which is difficult to explain to people outside ATM and put it into a model. Research is quite good with the material we have. We need to facilitate the uptake of these techniques, in terms of **explainability**, and keep human having a central role.

Generally, things seem to be going ok. However, we should keep in mind challenges in applying ML. In terms of research is the **data problem** – enough, clean and tagged data is always a problem. ML is something that everyone is attracted to, but we need to remember there are some limitations to its application and interpreting data. The explainability has been mentioned. Another example, apply ML to predict weather, but it ignores the underlying physics of weather creation. Important to keep in mind the developments in the area of ethics and the movement called **algorithmic accountability** that we are conscious of where our developments are going.

What is broken. **Data**. The link between the optimisation and the ML models. Usually, we work on the collected data – that is usually "optimised" – someone works on the data (controllers) to achieve the best possible state, and then we work (learn from) on that with ML. Maybe to divide from information extraction, prediction. We forget about optimisation. **Reproducibility** is rather forgotten. When we try to make things better, we cannot always reproduce results, as often data on which the model was done is not shared. **Open data sets** are the things to have – some are available, but not enough. Maybe we should focus on producing clean, labelled data sets that we can all work on.

In other fields of ML, they have benchmarking datasets that other researchers can use, for example to compare models and results. It would be important to also have access to data of what is available at certain time frames – what is available at the beginning of the day, mid-day, end of the day. To have the **dataset that includes the complete daily data**, not only the planned and post-ops data. Otherwise, the risk of creating a model with the "future" data (i.e. post-ops) that might create a problem when running a model (as implementation) and not having that particular data. A lot of data on predicting on optimised data (in supervised learning). Very few works on **reinforcement learning** as very complex optimisation problems can be solved very fast – then the data collection problem – you need a simulator to collect all the data to use in the model. Would be good to organise that, a common simulator. **Graph-neural network** is new hot topic in other domains. New models are cropping up.

Standard data sets were mentioned and it would be good to pose it to the industry panel. Licensing and limitation on data sharing usually becomes a barrier in building such open data sets. Number of initiatives to provide some solutions on these problems. Is this feasible? What properties would you need, how much data – what are the properties such standard data set would need to have?

It is the matter of practice to say that when we publish the paper to publish the data used as well. We should look at our practices as well, not only the industry. We have shared small or large datasets with the community in OpenSky. Publish the datasets with the **DOI** on it for example.

Some initiatives to release the dataset in-house, at the end of the data it **takes a lot of support** in explaining what is there, etc. It is not the dataset itself, also the description. Some of us are not interested in benchmarking, comparison, but in the applications. Sometimes there are too many strong assumptions behind. A lot of times the barriers are artificial. There are ways of releasing data with some **anonymisation**.

Is it interesting to learn from human users? We are training ML models on already optimised data. What would the other way around be?

We use reinforcement learning as a hybrid system. Do you train on the human and just reproduce the human? Reinforcement learning as a part of the hybrid system might be a direction to follow. A conundrum.

In supervised learning we always try to imitate. I am worried that we forget the optimisation. Not just to predict what was done in the past, but to do better than what was done in the past. Not only data, sometimes we need a **simulator to create this data**. Take advantage of ML to improve optimisation data, not to forget it. And there are other optimisation algorithms that work and worked well in the past, we should not forget that.

Imagine you want to introduce a new mechanism in a new process, then you need something else. It is important to predict what the answer of a human would be – behavioural economics (to take into account the actual limitations) might be the answer to emulate the human behaviour (as it is not really optimisation). We do need both, right tools for the right purpose.

If you train on data from reality, and applying new process/thing, then you are changing the environment, which should imply re-training the model. Another topic is the combination of different models.

Using different models has an advantage that you separate the problem into smaller ones. However, a model that focuses on an entire problem could perform better.

Specific experimental setup to define the conformance between the human and the machine to try to optimise around the cost functions in *MAHALO* – we might share this soon.

The problem of using a combination of models lies in the assumptions of the models and the aspect of the causality and correlations. Problem of using many models is that you might treat as causality something that is just a correlation, thus completely departing from the assumptions the models are initially built on. The problem is to keep with the assumptions.

3.1.3.2 Session2

MAHALO: AI-based conflict detection and resolution tools: Conformity vs. Transparency, presented by Brian Hilburn (Center for Human Performance Research) and Tiago Monteiro Nunes (TU Delft). The motivation for the project lies in the fact that some of the most powerful AI techniques are also not particularly explainable – they show good learning performance but are not explainable. Should we build the automation that is transparent (understandable) or conformal (that fits the user) – the relationships and trade-off between the two are the object of investigation. Data sample size is always a problem, we might turn to synthetic generation.

Deterministic conflict resolution (optimisation problem) requires very good specification of the problem while the AI can be a bit less formal.

NOSTROMO: Next-generation Open-Source Tools for ATM performance Modelling and Optimisation, presented by Maria Teresa Cano Rincon (CRIDA) and Francisco Camara (DTU). Main problem being addressed is how to use a simulator to search for policy-relevant values. The aim is to avoid redundant simulation runs and to provide efficient guidance of simulation analysis thus enabling us to predict simulation output values given any input. Initial data used in the metamodel should be representative

enough, thus needing simulation effort. Domain knowledge and expert supervision is recommended. Retraining of the metamodel might be required. Note that the metamodel is approximate in nature.

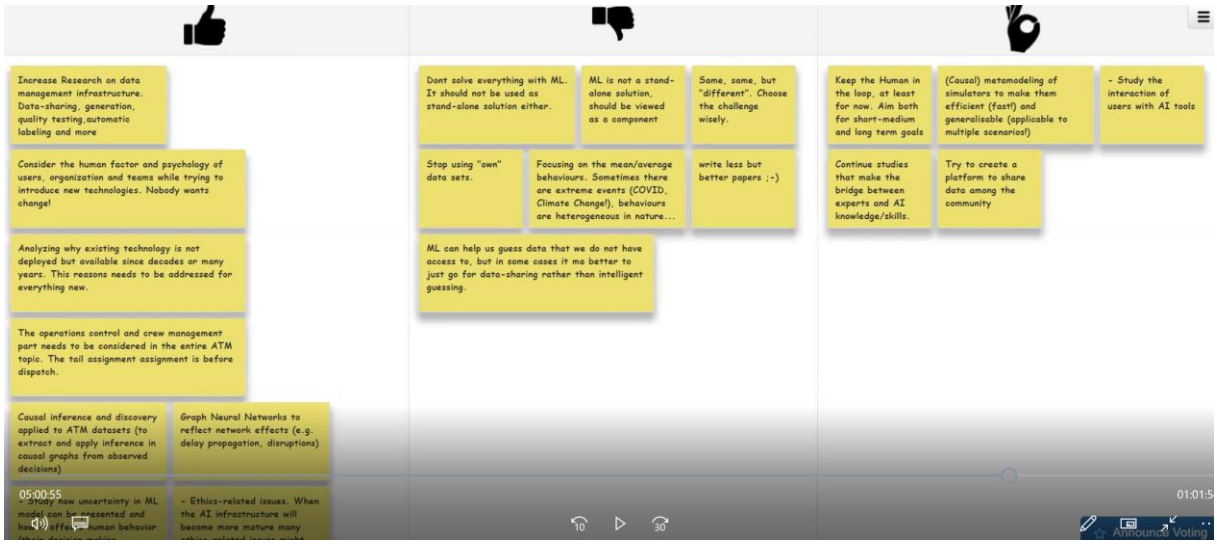
AISA, presented by Tomislav Radisic (University of Zagreb). Trustworthy human centric AI should be the thing of the future. The overall objective of the project is to increase the possibility for introduction of automation in air traffic management, by looking at the effects of human-machine distributed situational awareness, identifying the data needed by the ATCO to ensure that the proposed solution is correct and investigating methods for adaptation of the automated system to changes of the environment ensuring business continuity and safety.

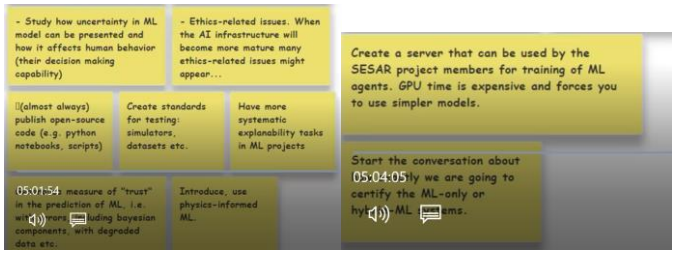
TAPAS: Unravelling the AI/ML "black box" in ATM, presented by Jose Manuel Cordero Garcia (CRIDA). Focuses on transparency of AI/ML models applied in ATM use cases, where highest priority is to enable adoption of these technologies. Care should be taken as ATM is safety-critical domain and operators need to rely on the system. Three levels of explainability: self—explanatory, explainability on demand and explainability by default. The representatives from other projects working on AI and ML are in the each-others advisory boards. Trustworthiness is the best explanation, meaning that in the training a lot of explanation is needed (ensure no biases) and less in actual operations (after the good training). Explainability requirements are different in different phases (system design and certification and operations). Some solutions are too complex for a human to understand in real time, and there the operator needs to trust the system.

3.1.3.3 Session 3 – Brainstorming and panel discussions on Future directions for ML research in ATM

Brainstorming

The 'Retrospective' dashboard used to facilitate the brainstorming. The ideas could be classified under: start doing, stop doing and continue doing categories (see Figure 15 below).





Start doing – continued.

Figure 15: Brainstorming ideas.

Data! The usage of standard reference dataset has been discussed today. The advantages are in comparability, availability, integrity of data sets. The risk is that some of the datasets might need to be very large, and there are also issues with licensing, confidentiality, etc. There was also a suggestion of publishing the data used for papers together with the paper. And there is the question of providing a platform for this.

The data itself are not the problem, but the channels of data distribution. There is also the mind-set barrier. Data is seen to represent a financial asset/value. For this is the reason some stakeholders are reluctant to share it. This might be overcome by imagining a public stakeholder (e.g. group of universities, EUROCONTROL) that store, share and maintain the data. Another way of overcoming the barrier, would be through the sharing the models that can be then run on "private" data. Or provide the cloud-infrastructure to train the models.

The problem is that data exists, but there are obstacles to making it available to "the public", due to confidentiality and similar matters. Many of the projects in SESAR are having problems with the data. Some of the data confidentiality problems are artificial, using convenient excuses.

Life-long retrain topic. When do we need to retrain models? When the environment changes due to interaction with users for example?

At some places there are ways of working with releases. When there is the big gap, the re-training can be triggered, the reasons for the gap should be analysed to see if the retraining is needed. It should be foreseen, and the learning process and performance should be controlled.

We could take an autonomous cars example, they learn from simulating autonomous driving. The tail of uncommon situations is really long, meaning that if even they have that problem, we have it too. What they learned is to have simulations to introduce these uncommon simulations. Thus, we could also work on introduction of simulations to describe better the ATM environment. Finding the strange situations only from data is extremely difficult, simulations can be more helpful on this.

Life-long learning and continuous training is probably a way to go, otherwise the models will not be able to cope as quickly with some changes as humans do.

Uptake of AI tools by industry – barriers and what could be done to overcome them?

We should distinguish between safety critical applications vs safety non-critical applications. The problem of the safety critical application is complex and so far, we have not found the alternatives to the current systems that can be certified for safety. But not all innovation, need to be on the safety-critical applications.

Everything is safety critical at the end in ATM when we look at various combinations of situations. If the machine messes up and you still have time to detect the issue is still ok as humans will be still in the process but if you do not have enough time to resolve the issue and change the decision of the AI tool that is critical. Now AI is a very hot topic but only time will tell us how much AI we need in our processes. The combination of AI and deterministic processes at the very safety critical situations might help in certification process?

If industry wants to apply these ideas, they hire from academia to implement new technology. As idea to consider how to improve the collaborations between industry and academia at the international level on these topics. Collaborations academia-industry should not always remain 'local'.

3.1.4 Lessons learned

General lessons learned are collected in Section 5, where we offer feedback on the format and functioning of the virtual workshops.

An interesting topic raised during the workshop is the fact that advisory systems change the environment in which these advisories are provided, especially if many users use the same advisory system. This effect may be short-term, in the sense that if various controllers use a similar advisory system to solve one conflict this specific conflict may become irrelevant and in the worst case a new conflict may appear; it may also be long-term in the sense that users may change their behaviour on the basis of the advice they receive from an assistant system. Triggered by this observation the question of **retraining ML systems** was discussed; a system trained in the lab will become less and less relevant as the environment for which it was trained evolves and may hence need to be retrained; criteria for deciding when such a retraining is required are not established yet. If ML systems are continuously learning, such retraining is not required anymore, of course, yet the certification process for continuously learning systems will be much more demanding.

Explainability was frequently raised and whilst 'Explainable AI' is now establishing itself as a discipline of Artificial Intelligence some ML algorithms lend themselves more easily to explainability than others. Also, whilst it is easy to claim that all systems should be explainable, the practical value of the explanation for the use should be assessed, especially if there is a trade-off between explainability and performance, for example when two different ML models are compared. The trade-off between conformance and transparency (a concept very related to explainability) will be studies in the MAHALO project.

Training ML systems on datasets where for example human conflict resolution is observed will lead to a **system that mimics human behaviour**; this leads to the question whether ML should be similar to or perhaps better than human decision making. The way ATCOs manage traffic and resolve conflicts depends on some constraints that are irrelevant for machines, for example memory, mental arithmetic and workload. Only mimicking human decision making may introduce a bias in favour of present working patterns rather than fully exploiting the potential of machines.

Any workshop on ML and AI will necessarily lead to a discussion about **data availability and quality** and this workshop was no different. However, two specific aspects seem noteworthy: firstly, the fact that the data mostly used to train advisory systems in air traffic control, for example conflict detection and resolution, are **'too clean real-world traffic data'** in which conflicts have *already* been largely removed, either by pre-tactical or tactical tools (flight planning, slot allocation, MTCD, STCA, etc.) – so the very object of CD&R systems have largely been removed from the data. Secondly, in many cases

the data that can be recorded in experiments or available in real-world observations is not sufficient to satisfy the data-hunger of ML systems and hence **artificial training datasets** may be an option; generating these, e.g. by mirroring existing scenarios or introducing noise comes at a costs of course which needs to be considered.

The next steps and prerequisites of an **uptake by industry** and application of ML systems in real-world applications was discussed and it was suggested to **distinguish** between **safety-critical** and **non-safety-critical** applications as the latter are much more easily certifiable and deployable and allow carrying lessons learned over to the next phase when safety-critical application will be targeted.

3.2 Fourth workshop of thematic challenge 3 'Efficient provision and use of MET information in ATM'

3.2.1 Introduction

The fourth workshop of thematic challenge 3 took place as a Zoom meeting on 9th September 2021. The workshop was moderated by Tatjana Bolić from the University of Westminster and Luca Crecco from SESAR Joint Undertaking. There were 79 registered participants, out of which 63 attended, 54 for more than an hour. The focus was on panel and open discussions.

The workshop explored the MET&ENV topics requiring future research, development or community collaboration. The start was dedicated to the panel discussing the MET&ENV topics requiring future developments from the scientific or technical point of view, intertwining suggestions from the audience. The following panel discussed the paths and time need to cross from the basic research to implementation, and how these can be improved. We concluded the workshop with the participants being invited to help identify the elements needed in the future to facilitate the research (e.g. data sharing, common platform, etc.), collaboration and shortening the time of the innovation pipeline for MET and ENV topics. The discussion was based on a poll taken in advance of the workshop - what research infrastructure and future research can we already propose for SESAR 3, for example?

3.2.2 Programme

1030-1045 Welcome by SESAR Joint Undertaking and Engage KTN
Welcome by SJU and the introduction to the SESAR KTN, Engage, and the day's programme
Tatjana Bolić (University of Westminster), Luca Crecco (SESAR JU)

SESSION 1 **MET&ENV research topics**

1045-1100 ***Overview of MET and ENV topics being researched in SESAR 2020***
Tatjana Bolić (University of Westminster)

1100-1145 ***Panel 1: Future MET&ENV research***
Moderator: Tatjana Bolić (University of Westminster)

Panellists:

- *Alexander Baklanov - World Meteorological Organisation*
- *Sigrun Matthes – DLR (TBC)*
- *Rosalind Lapsley - EUROCONTROL*

- *Damian Rivas - University of Seville*
- *Lauren Donohue - EUMETNET*
- *Emmanuel Sunil - NLR*

1145-1200 ***Coffee break***

SESSION 2 **From research to implementation**

1200-1245 ***Panel 2: Paths and time to MET&ENV products deployment***
Moderator: Luca Crecco (SESAR JU)

Panellists:

- *Kamel Rebai - METSAFE*
- *Andre Weipert - Leonardo Germany*
- *Anton Muscat - metoffice London VAAC*
- *Philipe Lenne - SJU*
- *Chris Peregrine - NMOC*
- *Manuel Soler - UC3M*

1245-1345 **Lunch break**

SESSION 3 **Enabling fast innovation cycles**

1345-1430 **Discussion: research, development and deployment "infrastructure" needed in the future**
Moderators: Tatjana Bolić (University of Westminster), Luca Crecco (SESAR JU)

1430-1445 ***Wrap-up***
Tatjana Bolić (University of Westminster)

The programme is available for download on the Engage website engagektn.com/thematic-challenges.

3.2.3 Discussions

3.2.3.1 Session 1 - MET&ENV research topics

Overview of MET and ENV topics being researched in SESAR, presented by Tatjana Bolić. Evolution of MET and later ENV research in the SESAR research programme was presented. Current SRIA [6], does not contain explicitly directions for MET research, while some ENV matters are mentioned.

Panel 1: Future MET&ENV research

Introduction of expertise in the panel

Forecasting of severe weather events is a key challenge. Great progress has been made with volcanic ash and improvement of methods/models. Integrated atmospheric pollution (sand and dust) has seen great advances and in Europe is lead by Barcelona Supercomputing Center. Issue of wildfires.

Atmosphere. Aviation is making a transition to the sustainable industry, and we need to join the expertise from different disciplines to work together – from ATM stakeholders to atmospheric scientists. The topic of climate is not easy, and we need an interface between the climate science, atmosphere and the ATM.

MET requirements for aviation. It is not easy to elicit the requirements for MET from the stakeholders, if it was easy, it would have been done already. A lot of this particular work is about informing and helping the stakeholders understand how MET can be used to improve their everyday work. There is the need for pro-active communication between experts in different fields (i.e. MET, ATM).

Analysis of aircraft trajectories, including the effects of meteorological uncertainty regarding FMP process and thunderstorms timeframe and trajectory-based operations.

Coordination between various MET services and other stakeholders (such as EUROCONTROL, EASA, EC). The fact of having many states in Europe makes the collaboration on the weather forecasts a bit more complex than in USA for example.

Aerospace engineering, drone integration into airspace, and impact of wind on the drones.

What are the future research needs in MET/ENV?

Forecasting **of extreme weather events** is one of the key issues for aviation. Previously the focus was more on regional (Europe) scale, but we need to move to mesoscale and world scales. Another point is to move from the standard methods of linear nowcasting to new methods. WMO works on similar projects. For volcanic ash there was great progress, after 2010/11. But we need the improvement of methods in VAACs, regarding bettering the models and assimilation of observation data, for ash and SO_2, and source estimation. Forecasting and modelling of dust storms (Barcelona Supercomputing Center is the European centre for this) is constantly developed. Currently it is geared mostly to health issues but could benefit from more research for aviation. The impact of wildfires, and pollution on aviation should also be expanded.

We should focus on the **uncertainties** in various forecasts, and how to deal with them. There are many sources of uncertainty, especially when we are looking at the atmosphere – from observation, forecasting, etc. Then, in particular for the climate impact, there is still the uncertainty on how to measure different impacts (e.g. non-CO_2 impacts) and how the atmosphere is behaving. We need to see how to deal with these uncertainties. Dealing with uncertainties is something that ATM is used to, so we can build on this experience. For climate mitigation intentions, especially when we are talking about the climate-friendly trajectories, we need to find the solutions that are robust within the uncertainties. For this we need the joint multidisciplinary effort.

We are aware that aviation has been severely impacted by Covid. It was difficult to implement new ways of doing things, due to this impact. When we are looking at network impacts of weather, other factors should be included as well. Weather does not happen in isolation. For example, MET interacts with other ATM events (e.g. staff shortages in a sector). So, we cannot think just about the meteorology, but also how is this information used operationally. The real world is very complex, so when you combine the MET impact with other factors, it can easily lead to a bigger impact, so we need to look at the bigger picture. Wider thinking and engaging with industry partners are important. There have been plenty of projects, but the issue we always come against is – what do we do with these results next? **Engaging** with industry partners from early on is another aspect of getting and implementing these tools. If we give nice MET tools/products to ATCOs, what do we expect ATCOs to

do? MET experts may interpret information differently from ATCOs. Focus of all stakeholders should be on **how the tool will be applied** in a real-world environment.

Forecasts for thunderstorms in 8h time horizon contain a lot of uncertainty that is not always easy to interpret by flow management position (FMP) controllers. They might require probabilistic nowcast. There are efforts towards a seamless forecast for use by these positions (8 hours ahead would be enough).

The need of engaging and working with the end-users. Often, we would hear from the users that they need more, better data but the user does not know how to use them. We talked about the deployment previously. In SESAR 1 weather cube was developed. SWIM registry includes new nowcasting products. There is almost **an education** piece that is missing for many of these tools. A gap that needs to be bridged between these different experts, information and how can this be useful to the end user. There is a gap between the available information and how it can be distilled down to be useable. For example, the convection affects the airline. MET service knows the height of it, but controller might just need to know if it will come into their airspace, whereas pilot might be happy to simply fly over it. How to make this multitude of data, observations usable to the users? Could AI and ML be used in these types of services/applications?

When talking about drones, we are just at the beginning of the investigation of the **weather impact on drone operations**. And here the focus is on smaller, light-weight ones that fly in the urban area. These are battery powered, so missions may be very different, and range can be affected by wind (from the safety and efficiency points of view). For example, if faced with the headwind, the range of the possible mission could be very much reduced. Drones come in all sizes, so it is difficult to give a figure on what strength of wind affects them. Drones are more sensitive to changes in the weather compared to aircraft. Suggested four challenges. One is related to measuring weather for drones (resolution and update rate of weather). For example, the wind gust of 15 m/s crashed our small drone, while the 5 m/s that was the mean wind in the same time period could have been easily handled. Two, modelling the weather in the urban environment (urban weather is different compared to the open space one). Three, communicating weather information from the sources to the users. Here, there is the need for strong standards on how this information should be communicated. For example, in Europe we have U-space weather information service, and the WP13 in EASA are looking into how and who can be the provider for this type of information. As drone operators are less trained compared to ATCOs or pilots, these tools need to be extremely easy to use, and need to be extremely transparent on what is possible or not. Weather parameters needed for safe drone flight are: wind, precipitation and temperature. They all effect drone operations. Hopefully SESAR 3 will open a topic on this, as the weather could be a showstopper for this type of applications for small drones. **Engage KTN is a good platform** to draw different communities together (e.g. drone operators with weather forecasters).

3.2.3.2 Session 2 - From research to implementation

It is obvious that climate mitigation and reducing impact of aviation are fundamental, and there is direct link with MET product. We are building SESAR 3, and this is the point when to incorporate the lessons learned. There is the need to link MET product and **sustainability**, not only to stay at the link between the MET and delay and for example volcanic ash. There is a gap between R&D perspective and the operational world. We need to feedback the operational issues to R&D to fill this gap much quicker.

In agreement with this observation from an end-user perspective. There is a huge amount of data, and we need something to make sense/interpret the data, in an operational sense. A MET information

'sweet spot' needs to be found between too-simple and too-complicated! 2021 traffic is at 70%, so weather has not made such an impact, but some of the momentum has been lost. We often have a (cultural) problem of having the FMP position to engage in decision-making in advance. The trust into forecast if often missing, but we need to start planning in advance. Currently, we are firefighting when we are talking about weather, whereas we need to make decisions in advance. We need to get stability and predictability, through the use of all the tools we have at our disposal. There is the need to change from **reactive to proactive approach**.

Regarding the climate change – how aviation affects climate still needs further research. We need to bridge this by applying some sort of catalytic opportunities. There might be two ways of mitigating climate impacts – restrictions or market-based mechanisms. Restrictions could be given in terms of no-access zones. Market-based mechanisms imply rules that allow the system to somehow organises itself around the market rules. We still need to channel products, to translate MET forecast to climate-impact forecast that users can understand.

How to speed up the deployment? From industry point of view: impression that innovation pace of industry is faster than operational implementation (e.g. radar/Lidar). When we implement for example a new meteorological service, a wind product, there is a very complex chain of sensors to create a picture of wind information. The problem is that this example of service has been offered a fair number of years ago, but it is still not being used in operations. There is a chance to improve transition pace from generally validated MET product to tailored MET services (e.g. tailoring to the specific ATC needs). As mentioned earlier, there is the challenge in extracting **user requirements**. Another issue is to make it possible to move from general use to local/regional through more open system. Here, the data standards, policy and automation are needed. Automation should/will increase with availability of data. However, is this usable, transparent to the end-user? Barriers: we are suffering from individual KPIs (e.g. airports think about costs, ATC about safety). So, we end-up having a conflict between the innovation and cost, or between innovation and usability. The innovations should achieve a certain fitness of purpose and sometimes this goes at cross-purposes with the innovation pace. Requirements of different ATM stakeholders are different, which is in contrast of common situational awareness. **Data sharing** is still not what it should be. Data sharing and standards are important for the future.

Regarding the discussion of requirements and prototyping: is the same language spoken between industry and innovation stakeholders? Sometimes we need a long time to come to the same level of comprehension. There are standards, e.g., windshear, glideslopes and they help. Note sometimes it is difficult to understand each other - the customers at different roles have different expectations. The system needs to have flexibility imbedded to allow for tailoring and adaptation, which needs iterations and time.

We are entering a data rich world, and there are demand from users for more data (e.g. for probability). For example, all volcanic ash advisory centres to offer volcanic ash concentration information to wider number of users. At the moment, this is provided to users in Europe, and it is beyond currently mandated ICAO's 'ash yes/no' information. All nine VAACs have now agreed to provide this information but on a much higher resolution (more altitude slices and time frequency and the probabilities). Just in this example, the amount of information is increasing significantly, so we might need to utilise MET advisors to understand the data and advise the users. There is the step change happening in the volcanic ash area. ICAO pathways are often very slow (which could be frustrating) but it is of paramount importance to agree on global regulations, to be applied by all stakeholders. We could all wish for speeding up the ICAO processes, but we should not circumvent

them. Without globally agreed regulations we could easily slip into the 'wild west' of varied information, making it impossible to come to reasoned decisions!

Two en-route control centres deployed a tool within the three years, which was the goal of the centres. Small, agile teams included the ATCOs in the prototyping. When collecting requirements, needed to make it a more 'fun' process with ATCOs. The goal was to make it simple and focus on one problem, e.g. weather impact for next 24H. MET experts need to understand the difficulties faced by ATCOs interpreting the data, and ATCOs need to understand the information from MET. There is also **sociological/educational challenge**, especially linked to explaining the element of uncertainty. What is also interesting, the sensibility of controllers to the weather of one centre was completely different from the other one. There is also a need for "soft skills" of researchers/developers – sociology for example. There should be some level of regulation on data and services. However, is the **regulation** good for innovation? Often the regulation is blocking the fast pace of innovation.

Lots of data out there – AI usage in MET is slightly slower than other areas of aviation (e.g. capacity) – is AI and ML a way forward that would enable expediting the deployment?

We were told 30 years ago that: "machines would soon take over forecasting! Machines are getting faster, machine learning is being developed. There will come a time when there is no point having a person involved in the process." We are still not there.

In this case the group started to use AI and neutral networks – it works. It can work providing a better result temporally and for tailored products (e.g., for an airport). France MET service has an ML team, but there are barriers slowing down the pace. Product depends on **regulation**. ML not to substitute the MET person – will still need the MET expert. What we are applying the models on are complex, so we will still need experts involved int eh process.

3.2.3.3 Session 3 - Enabling fast innovation cycles

Room 1: Data and data infrastructure

Moderator: Tatjana Bolić

The discussion around data offered interesting views on what should be stopped, what should be started and what we should continue working on (see Figure 16 below).

The only point in the "stop doing" category refers to "losing" time on acquiring the data. Roughly 6-12 months of each project are spent on finding, acquiring and cleaning data.

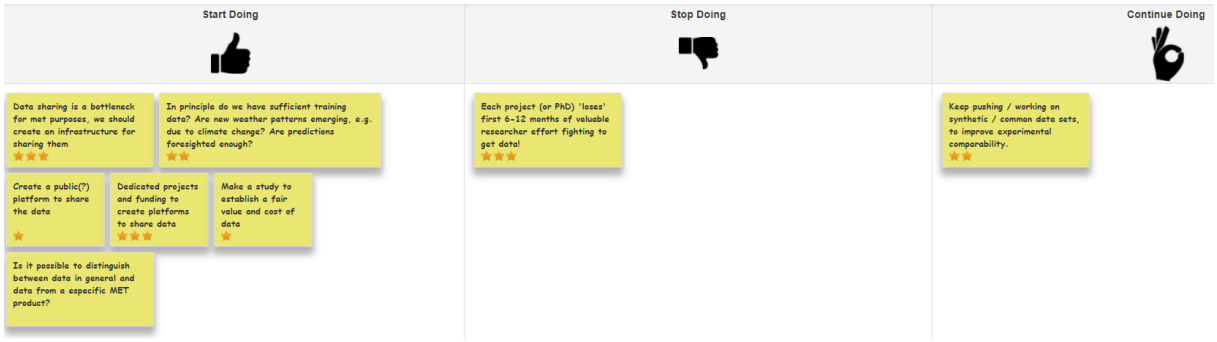


Figure 16: TC3 - brainstorming on data and data infrastructure

The discussion in the “start doing” category revolved around investigation of the requirements and costs for the data sharing platform, for research purposes. This is important as often in the MET the data is available through the local MET providers and makes obtaining European-level data complex. The two most voted ideas in this category can be summed up as: Maybe an infrastructure for data sharing is needed. It should be investigated what is the fair value and cost of data.

An important mention in the “continue doing” category is to continue requesting and working on either synthetic or common data sets, to improve the experimental comparability, which is currently lacking in the ATM domain.

Room 2: Research collaboration for faster deployment

Moderator: Luca Crecco

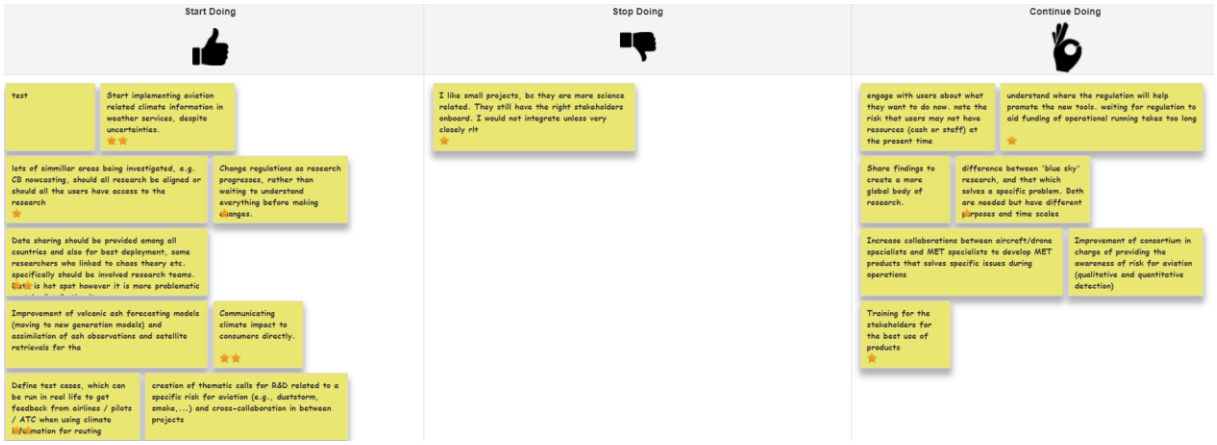


Figure 17: TC3 - brainstorming on research collaboration for faster deployment

The important thing in this area is that some research was performed, products defined, but until someone pays for them it is hard to get them out into the world. Regulation comes at the very end.

Change regulations as research progresses. We need to make sure everyone has an overview of what is going on; one person cannot do everything.

Data sharing is very important; distributing the data. Team members might help people to understand.

Volcanic ash forecasting now has much more comprehensive models. Sand and dust forecasting is well-researched in Europe, mainly for health concerns rather than aviation (e.g. engines). End-user has needs for such models, tools and services.

It is important to have reasons for changing regulations, e.g. body pushing for changes. Highlight airlines taking better routes. Public opinion is often overlooked.

Discussion

Moderators: Tatjana Bolić, Luca Crecco

Incentives for airlines to fly better trajectories? Identification of green trajectories, looking at the trade-off between the costs and benefits.

There are a couple of possibilities – test cases to get feedback; type of information provided, then we see the gaps.

We are receiving mixed messages from EC: EU Green Aviation offers incentives for green trajectories and on other side we have an amendment to Regulation 261 with a greater penalty on airlines for missed connections (in most instances encouraging accelerated fuel burn). There is a bit of conflict in terms of signalling, and it would be good to get some feedback from airlines on this.

Maybe we could use market dynamics. If we inform consumers about sustainability of individual flights so they can choose between them. To use competition principles to force airlines to become more sustainable. Big data could be used to make estimations on this. Some websites already give this type of information (like Skyscanner).

Recap of room 2 board: Communicating climate impact to consumers directly is important. Early involvement of the regulator in research is encouraged (i.e. from the design phase). Involve all the stakeholders in the process. Recommendation to keep the existing research in the programme but try to consolidate various bits and pieces to move towards the services.

Recap of room 1 board: data is a bottleneck; difficult to obtain; cannot use same dataset in multiple projects. Maybe create public platform to share MET and ATM data to give easier access without having multiple agreements in place. Each PhD loses approx. 6-12 months trying to get the data. This is a recurring theme throughout different workshops. Keep pushing the work on synthetic datasets. Another negative impact is that we cannot really compare results between projects due to use of different data sources. EUMETNET access – can these be extended to cover more datasets?

The challenge of extending the access to data often depends on how it is paid for, in in the case of many MET data providers it is cost recovery. If it is cost-recovery, then there are very specific rules on how data can be used. IATA turbulence dataset is brilliant but expensive. It is important to know what type of data is of interest to researchers. The advice is to build relationship with local MET provider.

3.2.4 Pre-workshop participant survey

“Future MET and ENV research panel” What topics need further research? Please type your suggestion for future research, and for the panel discussion here: “Future MET and ENV research panel” What topics need further research? Please type your suggestion for future research, and for the panel discussion here:”

Environment-related questions:

- How certain we are that climate friendly routes are concentrating on the correct factors, when the confidence levels in different results vary so much?
- Verification of forecasts, i.e. contrail forecasts, environmental impact models. Costs to airlines and society, like movement restrictions due to potential flight restrictions, need to be quantified, as well as the potential beneficial effects of consideration of environmental impact reduction measures.

Forecasts:

- Future research is needed to improve short-range and very-short range forecast of severe meteo-hydrological phenomena, in a warming climate, potentially impacting ATM activities.
- Acceptance and management of MET uncertainty in ATM community. Methods to digest/use/present weather information that build trust in the end user to break the "we do not know anything for certain in the Wx department with 100% certainty" wall.

Tool development and interpretability of results:

- "In line with example idea from Edition 3, December 2019 of Paper (Forecasters and end-users (e.g. controllers and pilots) co-developing products that are easy to interpret in terms of the impact weather will have on such users (e.g. airspace, flights): As a continuation of work being done in SESAR2020 Wave 2 PJ.18-w2-53, on integration of Adverse Weather Areas (areas with thunderstorm activity) into controllers Conflict Detection and Resolution tool, there is an opportunity to integrate this AWA concept on aircraft systems for in-flight assessment and optimization. It is seen as logical next step in the final aim for all stakeholders to have same information and shared situational awareness which contributes to more efficient and safer ATM."

Integrated solutions:

- Safety and security assessments in integrated solutions.
- Research on i) more synergies for different applications (e.g. wake turbulence and glide slope information); ii) collaborative common situational awareness (not following individual KPI's); iii) using digital transformation pace for an enhanced automation of MET Services.

Drones:

- Hyperlocal weather service for drones.

"Paths and time to MET and ENV products deployment." Different paths of the product development can be envisioned - in close cooperation with end-user, or stand-alone development, and anything in between. These paths might require different time periods for the full development aimed at implementation, and might need to follow MET standards and/or regulations. Please type your question or suggestion for the panel here:

End-user involvement:

- Trust and usability of MET based products by ATM professionals are severely lacking in many departments of ATM. It seems that this is partly due to difference in goals and expectations between the ATM and MET communities. This would call for joint treatment of Wx related issues by both communities. Various local initiatives show that this is possible. Can we scale up this approach without very significant time penalty?
- To what extent can products be integrated globally to allow a more international approach to long haul flights?
- The product development should happen in close cooperation with end-user.

Other:

- Including different solutions with different time periods.
- Very pertinent topic. Of course, in global aviation, we would be looking for globally applicable procedures based on globally available data (consistent, authoritative etc. ...). That could well be an ENV extension of the WAFS. As the timeframe for such an undertaking is 5 years, as an absolute, fastest track minimum, work towards this should begin.... as soon as the relevant parameters (atmospheric composition like moisture content...) are identified.
- It is all about operational requirements and KPIs - experience shows that the innovation pace of industry is faster in comparison to the operational implementation pace.

"Research, development and deployment "infrastructure" needed in the future for fast innovation cycles in MET." Please type your suggestion here:

Focused on online data of AWOS.

Infrastructure needs data standards and policy with a high degree of usability, also incorporating smart concepts for the implementation and validation of new services. Its all about data sharing and policy. Technology will come.

Perhaps, the WMO-based institutions have a role to play, perhaps, it´s the private sector. Suggest to do a transparent, if possible, competition / bidding process , that should include free or very low fee access to the results to all who are interested to enable wide and fast adoption of new systems and technology.

It is recommended to support and strengthen the dialogue with research centres expert in the development of e-Infrastructure looking for the convergence between big data, high-performance, and cloud-computing concepts thus enabling fast innovation cycles in MET.

Do all bodies involved (weather agencies, climate modellers, airspace regulators, airlines) meet regularly with an agreed agenda for improvements or are there still pockets of research that have not been considered across all of these groups?

To what extent is the same approach used and understood by all interested parties?

People working with weather and climate research are all right with their innovation cycle. The problem lies more with MET in ATM and is a by-product of the way the ATM innovations are developed. There are also examples of relatively quick local innovation cycles that are possible despite the glacial pace of the global ATM-MET innovation. What we need is a way to efficiently identify, promote and introduce innovation. One could imagine introducing something like DTC (https://dtcenter.org/about) but for the benefit of ATM community where a lot of improvements would be quickly evaluated in a near-operational environment on a regular basis.

3.2.5 Lessons learned

General lessons learned are collected in Section 5, where we offer feedback on the format and functioning of the virtual workshops.

Future research needs

Whilst various research topics have been discussed, here we list the most emphasised ones during the workshop (for detailed discussion, see Section 3.2.3.1):

- Forecasting **of extreme weather events** is one of the key issues for aviation.
- To focus on the **uncertainties** in both weather forecast and the climate research, especially on how to deal with them. Here we need joint multidisciplinary effort.
- A sociological/educational component in both the scoping for tool requirements and the implementation and use of the MET tools or services is required.
- The weather impact on (small) drone operations needs further investigation:
    - Measuring weather for drones (resolution and update rate of weather).
    - Modelling the weather in the urban environment (urban weather is different compared with open space).
    - Communicating weather information from the sources to the users that needs for strong standards on how this information should be communicated.
    - Drone operators are less trained compared to ATCOs or pilots, so these tools need to be extremely easy to use.

From research to implementation

Several issues were shared across the needs for future research and on speeding up the time from research to implementation:

- The need to address sustainability. What would be the best way: through regulatory or market-based mechanisms?
- Need to have the proactive approach in addressing the weather that should involve all the stakeholders, especially in creating the joint effort in addressing the problem to make best decisions on the available data and services: the sociological/educational component needs to be included.
- Work on extracting user requirements to be able to best tailor and adapt general MET services to local situations.
- Data sharing is still not what it should be. Data sharing and standards are important for the future.

- The ICAO pathway is very slow, but it is really important to have global regulations. It should be faster, but without global regulations it will become the 'wild west' with information making it impossible to come to reasoned decisions!

Climate impact and mitigation

This is a hot topic, and there are different facets that still need to be researched and require multidisciplinary effort. In particular, for the climate impact there is still the uncertainty in how to measure the impact and how to measure the way the atmosphere is behaving. The way of addressing these uncertainties needs to be addressed. The ATM community is used to dealing with uncertainty modelling, which should help ease these efforts. We need to find climate mitigation solutions that are robust within the uncertainties.

Data

Data is a bottleneck. It is difficult to obtain, and the same dataset often cannot be used in multiple projects. Maybe the answer would be in a creation of **public platform** to share MET and ATM data to give easier access without having multiple agreements in place. Each PhD loses approx. 6-12 months trying to get the data. This is a recurring theme throughout different workshops. We need to keep pushing the work on synthetic datasets. One cannot compare results between projects due to use of different data sources. EUMETNET access – can these be extended to cover more datasets?

4 Related events

This section describes other events related to the thematic challenges and lists the publications initiated by the CF projects.

4.1 Events

4.1.1 Meteorological Technology World EXPO

The event took place on 24th March 2021, in the virtual environment. The goal of the event was to bring together aviation meteorologists, airline and airport operators, air navigation services and other key stakeholders to discuss next generation of MET systems, solutions and services for aviation.

The event was showcasing the SESAR JU's MET contributions in general, part of which was composed of Engage's TC3 CF participants and mentors. The session was hosted and moderated by Luca Crecco, Philippe Lenne (SJU) and Tatjana Bolić (UoW). The programme can be found below[3]:

Introduction: overview of the SESAR programme and its MET-related activities

- Luca Crecco, SESAR JU - ATM Expert
- Tatjana (Tanja) Bolić, University of Westminster - Senior Research Fellow - Vice-Chair of the SESAR JU Scientific Committee

Panel discussion 1: Weather impact prediction for Air Traffic Flow and Capacity Management Services

- Kamel Rebai, CEO, MetSafe
- Gladys Mercan, Project Manager, France Aviation Civile Services
- Tatjana (Tanja) Bolić, Vice-Chair of the SESAR JU Scientific Committee and Senior Research Fellow, University of Westminster
- Christopher Peregrine, Head of Operations Analysis Service, Network Manager
- Thierry Durigneux, FMP Manager Reims, DSNA

Moderated by Philippe Lenne, Sustainability Programme Manager, SESAR JU

Panel discussion 2: MET services for enhanced safety and sustainable aviation

- Manuel Soler, Associate Professor, University Carlos III de Madrid

[3] Adapted from https://www.meteorologicaltechnologyworldexpovirtuallive.com/en/conference-programme.php

- Sigrun Matthes, Researcher, DLR
- Martin Gazak, CEO, Microstep-Mis
- Tatjana (Tanja) Bolić, Vice-Chair of the SESAR JU Scientific Committee and Senior Research Fellow, University of Westminster
- Riccardo Biondi, Researcher, University of Padova – Researcher
- Hugues Brenot, Researcher, Royal Belgian Institute for Space Aeronomy

Moderated by Luca Crecco, ATM Expert, SESAR JU

Conclusion and wrap up

- Luca Crecco, ATM Expert, SESAR JU
- Tatjana (Tanja) Bolić, Vice-Chair of the SESAR JU Scientific Committee and Senior Research Fellow, University of Westminster

The event was recorded and can be viewed at: https://www.sesarju.eu/node/3779

4.1.2 Convective and Volcanic Clouds detection, monitoring and modelling (CVC) training school, 6th edition

The purpose of the school[4] is to train students with outstanding research interest in the techniques allowing to detect, monitor, and model convective and volcanic clouds, to gain knowledge of the instruments and satellite missions (present and future) and to be able to support such kind of studies. Furthermore, the extreme atmospheric event cloud detection is a high multidisciplinary and challenging topic since the same techniques and instruments can be used for meteorology, volcanic monitoring, atmospheric physics and climate purposes. The school, in its six editions, has been organised by researchers from Università degli Studi di Padova and the Istituto Nazionale di Geofisica e Vulcanologia. One of the organisers, Riccardo Biondi, coordinated a wave 1 catalyst fund project.

The Engage KTN, and the TC3 have been represented in the lecture given by Tatjana Bolić on the "Convective weather decision support tools".

4.2 Publications

The following papers have been submitted for publications and are currently under review:

[4] http://www.cvctrainingschool.org/school/

- Costin *et al.*, “Practical denial-of-service and combined high-level attacks on real-world ADS-B, ATC, ATM hardware and software”, ACM TOPS, 2021 (under review).
- Costin *et al.*, “Cybersecurity attacks against software logic and error handling within ADS-B implementations: systematic testing of resilience, and implementation of some countermeasures”, IEEE TAES, 2021 (under review).
- Costin *et al.*, “Fuzzing 'GDL-90 Data Interface Specification within aviation software and avionics devices - a cybersecurity perspective”, Elsevier COSE, 2021 (under review).

5 Lessons learned

The lessons learned as they apply to individual workshops can be found in the sections dedicated to the workshops. This section reports on the generic lessons learned across the workshops.

5.1 Format and implementation of virtual workshops

Due to the Covid-19 pandemic, all of the workshops reported in this deliverable were operated as virtual events. This naturally reduces the degree of personal interactions that are otherwise enabled through physical meetings, whilst, in contrast, it generally allows higher participation from both presenters and delegates, since the additional constraints of travel are removed. Nevertheless, there is some reporting of user 'saturation' with such virtual events in general, the number of which has grown over the past year, and this may contribute to some attrition in numbers going forward, such that these types of event need to genuinely offer and communicate something new and of value to participants, it is suggested, in order to maintain reasonably healthy participation numbers.

Other, general observations on the implementation of virtual workshops, include the following:

- Full-day events place too much burden on participants, such that it is preferable to run workshops for somewhere between half- and three-quarter- (at most) day formats, ensuring sufficient screen breaks.
- Where thematically sensible, co-locating such workshops with another event works well and can help to drive up the attendance and range of participation at *both* events (a specific example is the virtual co-location of the Engage summer school and the fourth workshop of thematic challenge 2: 'AI, ML and Automation' (see also Appendix B).
- Loading workshops with too many presentations is not inspiring for participants; it is better to have a smaller number of presentations, which are well aligned with clear objectives of the workshop, and referring participants to further material, as and when required. More discussion time was often requested by participants.
- It is important to secure expert discussants for panel and plenary session moderation; it inspires lower audience participation if the discussant/moderator is not able to maintain a sufficiently high level of technical interaction with delegates and participants.
- Mixing the content between highly specific material (e.g. a specialist area of cybersecurity) and very low TRL exploratory research is difficult to manage; careful alignment of the content of the workshop, the likely participants, and the objectives needs to be closely maintained.
- Circulating questionnaires in advance of a workshop met with mixed results, working well for some audiences and less well for others. A limited number of technical questions circulated to a technical audience seemed to work best.
- Mixing the internal format of workshops works well, for example between presentations, panel discussions and plenaries. *Simple* interactive boards (such as Retrospective) and in-line (*ad hoc*) polls work well with no pre-emptive training for participants required, and help to

maintain diversity across the workshop, in addition to offering an inclusive means of participation (e.g. for those who are more reticent to contribute orally).

- There was sometimes quite a diversity of participant numbers across similar events (e.g. Engage and non-Engage) organised over the period (e.g. regarding similar topics but divergent audiences). GDPR constraints permitting, it would be useful in SESAR 3 to consider a closer collaboration between projects and other (e.g. SJU) participant lists, to mutually drive attendance and support consistency of participation and homogenised learning and development across similar events, rather than separated streams of participants.

- The strong support from SJU regarding promotion of events through the SESAR *e-news* communications was much welcomed and highly beneficial. Communication of such events well in advance is advisable, with workshop organisers mindful of months whereby no *e-news* is to be issued.

- Across a number of platforms investigated, Zoom was the preferred option overall, giving a good range of functionality choices between its 'meeting' and 'webinar' modes, for example with regard to launching Q&As, *ad hoc* polls, and controlling webcam and microphone engagement. (It is to be noted, however, that *some* institutional firewalls may block Zoom access.)

- Applications (such as Zoom) that support (semi-)automated registration are also recommended, as this allows estimation of the number and demographics of likely participants and the management of (further) targeted invitations.

5.2 Data

Data is a bottleneck in exploratory research. It is difficult to obtain, and the same dataset often cannot be used in multiple projects. Maybe the answer would be in a creation of **public platform** to share MET and ATM data to give easier access without having multiple agreements in place. Each project and/or PhD loses approximately 6-12 months trying to obtain (and consolidate and clean) data. This is a recurring theme throughout the thematic challenge workshops.

There is a need for commonality of data sets to enable comparisons across different implementations. This is needed to support assessment of robustness and efficiency, as so far there is no standard access to data. A possible solution could lie in moving towards the creation of synthetic data sets to be shared across the programme, in order to improve experimental comparability across projects.

For example, a collaboration/exchange between Engage and the OpenSky Network on preparing ***scientific datasets for ATM*** to be driven by Engage KTN and the PhDs' and researchers' needs was discussed. It is important to create not only *comparability* but also *reproducibility* – which means that **availability of code** should be encouraged as well. Reference/standard datasets could be made available through the Engage wiki (wikiengagektn.com). It was suggested that it would be helpful if Engage or the SJU could work on finding a solution for data sharing, maybe in the form of collaborative datasets.

5.2.1 Barriers

Different types of data are requested in the ER work. Some of the data can be obtained freely (e.g. the R&D archive data by EUROCONTROL, ADS-B from OpenSky Network), some need to be paid for (e.g. schedule data, air fares), some need to be acquired from multiple sources if a greater geographical area is being researched (e.g. MET lightning or radar observations), which complicates and prolongs the data acquisition. In most of mentioned cases, some sort of licencing and non-disclosure agreement is put in place. In practice, this prevents data sharing, even if the input data used is just a small subset of obtained data. In some cases, the results of the research can be shared, but without the input data used, it is difficult to achieve comparability and reproducibility. Sometimes, non-disclosure agreements are linked to the confidentiality/privacy issues, but this could be resolved through anonymisation, or even non-disclosure clauses.

5.2.2 Opportunities

A creation of a **public platform** to share MET and ATM data (and code) to give easier access to funded research projects, thus circumventing multiple agreements between myriad of stakeholders. The analysis of the feasibility of such a venture would be required, covering the storage needs, related costs, and the design of the appropriate licensing agreements with data providers and data users.

5.3 Collaboration

Throughout all the workshops, the need for, and benefits of collaborations (on different topics) continue to appear. Here we mention the topics of collaboration identified in various TCs:

- There is a lot of interest to get involved into cybersecurity and create a **SESAR Cybersecurity Community**. This interest should be nurtured and keep the good momentum for the cybersecurity community, as there is a risk of losing the momentum in the transition from SESAR 2020 to SESAR 3. The Engage wiki forum on cybersecurity might be one of the tools to bridge this transition gap between the two programmes.

- **Performance assessment and metric development** within various topics and domains, such as trajectory prediction (e.g. on efficiency), or environmental (climate)) impacts, require further development. This would need agreement with all the stakeholders in order to try to find a common approach and show the benefits of the new methods and approaches.

- Climate change issues are somewhat less represented in the SESAR programme when compared to wider European research. Climate change research topics and measurements rely not only on CO_2, but also **non-CO_2 impacts**. Further, it is important to understand how to assess climate change impact (e.g. aggregation of impacts at the regional level), and how to then incentivise inclusion of such measurement and assessment in operations (e.g. through climate impact regulations).

An important observation is that it was very encouraging to see across the thematic challenges, the use of Engage funding to support the development of research towards higher TRLs and to catalyse this process. The links with industry are also very impressive in these activities, which are further picked up by some projects (e.g. ALARM clearly identified the links with past projects and the inspiration coming from the TC3 workshops).

5.4 AI and ML

Explainability of the models is something that could and should be improved. When economists are building the model, they focus on the variables (the same as features), and they are trying to focus on the impact the variables on the model, while in the ML is rather the other way around – the model fits the data. Should we aim for the more systematic production of ML models in the future?

Data collection linked to the ML. How to collect data? In the past we had data and we tried to produce the best model to fit the data. Now that we are producing a lot of data, maybe we should aim at having the best possible data for the model.

In supervised learning we always try to imitate, and we might be forgetting the optimisation already incorporated in the data we are working with. We should strive not just to predict what was done in the past, but to do better than what was done in the past. To avoid this trap, sometimes we need a **simulator to create the data** that does not already contain the 'optimisations'. We should take advantage of ML to improve optimisation data, not to forget it. There are other optimisation algorithms, non-ML, that still work well and are well suited to many on-going research contexts.

It is likely that many ML and AI models will need re-training. When there is a large service gap in a released product or tool, retraining can be swiftly triggered, whereas the *reasons* for the gap should be analysed to see if the retraining is needed. This should be foreseen and planned into the research programme, and the learning process and performance should be controlled.

5.5 Economic incentives for future ATM

The planned changes in ATM will not only be about technological innovation. The change will include regulatory, organisational, and service evolution. To achieve the largest benefits for the system, the emphasis should be on speed of uptake, and those stakeholders that want to move quickly should be supported**. A framework that enables progressive forces to move quickly is needed. When we talk about positive change, we should adopt a broader view regarding incentives**. Incentives do not necessarily need to be only economic. For example, **different social norms,** e.g., peer-group performance. The behaviour of individuals can often be surprising, sometimes counterintuitive, but often can help in speeding up the adoption of innovations.

A **question of certification of the data providers** might arise. This may precipitate questions on what to certify, and possibly even sovereignty matters. **The challenge lies in showing that end-to-end solution is satisfactory for the regulator,** thus demonstrating resilience. The main issue in this type of integration lies in the consolidation of information for the ATCO. Does the virtualisation provider need to be certified, or would it be enough that ANSPs confirm that the service is appropriate? Service is appropriate when ANSPs can provide the ATS service with the appropriate quality. Maybe we should be looking at the qualification, not certification? On the **sovereignty matter, there is the issue of what data needs to be within a given State.** Some ANSPs already found ways and means to collaborate, instituting this collaboration as a service, as a way forward.

Further data related issues centre around **how to interact with data and how to use data to deliver benefits** from such usage. It seems, currently, that the fear of misuse and similar issues is much higher than the use actually requires. Data availability and proprietary licencing could be significant barriers

to the creation of flexible services – i.e. whereby access to data is limited behind cost and disclosure walls. Currently, almost all data in ATM are considered in need of being protected, which is not necessarily true. The analysis of what data should be protected and what should be available is needed, as this is one of the cornerstones of the airspace architecture study.

6 Next steps

The next steps for this deliverable, reporting at the end of a chain of delivery on the Engage thematic workshop events, is to:

- Post this deliverable (on approval from the SJU) on the Engage website, along with the other thematic challenge conclusion and outlook summaries, presentations, programmes and various supporting materials, to pave the way as a consultation document for potentially affiliated and follow-up work in SESAR 3, e.g. by a potential successor KTN.

- Reflect on the key findings herein, in Engage D3.6 ('Opportunities for innovative ATM research'), since the latter is a consolidated look ahead to future research opportunities, such that it makes sense to include key reflections from the thematic challenges therein.

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8 Acronyms

ADS-B	Automatic Dependent Surveillance–Broadcast
ADSP	air data services provider
AI	Artificial intelligence
ANSP	air navigation service provider
API	application programming interface
AROME	small scale numerical weather prediction mode
ATC	air traffic control
ATCO	air traffic controller
ATFCM	air traffic flow and capacity management
ATM	air traffic management
ATS	air traffic services
AU	airspace user
AWA	adverse weather areas
AWOS	automated weather observing system
CDO	continuous descent operations
CDA	continuous descent arrival
CF	catalyst funding
CNS	communication navigation surveillance
CONOPS	concept of operations
DCB	demand capacity balancing
DOI	digital object identifier
DoS	Denial of service
ENV	environmental
ER	exploratory research
EWS	early warning system
FDP	flight data processing

FL	flight level
FMP	flight management position
FMS	flight management systems
GDPR	(EU) General Data Protection Regulation
GNSS	global navigation satellite system
GFS	global forecast system (weather prediction model)
HMI	human machine interface
ICON	Icosahedral Nonhydrostatis weather prediction model
IR	industrial research
KPA	key performance area
KPI	key performance indicator
KTN	knowledge transfer network
LIDAR	Light Detection and Ranging
MET	aviation meteorology
ML	machine learning
MTSA	medium-term storm avoidance
MUAC	Maastricht Upper Area Control Centre
NetCDF	Network Common Data Form
NM	network manager
R&D	research and development
RAD	route availability document
RDT	rapidly developing thunderstorm
SDN	Software Defined Network
SES II+	second regulatory package on Single European Sky
SESAR	Single European Sky ATM research
SJU	SESAR Joint Undertaking
SRIA	Strategic Research and Innovation Agenda
SWIM	system wide information management

TRL	technology readiness level
UAS	unmanned aircraft system
UTM	UAS traffic management
VAAC	volcanic ash advisory centre
WMO	World Meteorological Organisation

Appendix A How to incentivise innovation in ATM?

For the TC4 workshop, RoMiAD project prepared a white paper that was shared with the audience. The paper's abstract is below, while the paper can be downloaded together with the presentations of the TC4, from https://engagektn.com/thematic-challenges/.

Abstract

The Airspace Architecture Study (AAS) proposed a transition to a distributed architecture enabling significant performance increases in the European Air Traffic Management (ATM) system. Successful transition requires service providers to adopt new technologies, operational concept, and business models.

The proposed architecture is based on three operational layers including the notion of a new form of service provider– the ATM Data Services Provider (ADSP) - which would enable certain services currently provided within an area control centre to be provided remotely.

This white paper is a summary of the findings of Project RoMiAD (Role of Markets in AAS Deployment) – catalyst fund project of SESAR's Engage Knowledge Transfer Network, which considered how ATM cost efficiency can be increased through adoption of the AAS architecture and how the necessary transition can be incentivised.

Appendix B Engage 2021 summer school programme

The Engage 2021 summer school programme, below, shows how the fourth workshop of thematic challenge 2 ('AI, ML and Automation') was organised and promoted in conjunction therewith. This was communicated in promotional messages for both events, and drove up mutual audiences, thanks to the thematic overlap between a number of the PhD presentations and the content of the workshop.

Engage 3rd Summer School Programme, 30 August – 02 September 2021

(Programme v1.5; all times CEST; virtual event)

	09.45-10.00	10.00-11.15	11.30-12.30		13.30-14.10	14.10-14.45	15.00-15.30	
MON 30AUG	Opening *Andrew Cook (UoW) & Lorenzo Castelli (University of Trieste)*	Airline and airport operations centres *Jonas Langner (TU Braunschweig), Sashiko Shirai Reyna (Amsterdam UAS/ENAC)*	Panel discussion Moderator: *Bojana Mirkovic (University of Belgrade-FTTE)*	Lunch break	Signal processing for trajectory prediction *Homeyra Khaledian (UPC Barcelona)*	Panel discussion Moderator: *Junzi Sun (TU Delft)*	SESAR Young Scientist Award *Junzi Sun (TU Delft)*	
TUE 31AUG		11.15-12.00 The Engage wiki *Pablo Hernandez (Innaxis)*	12.00-12.30 Teaching resources in the wiki *(University of Belgrade-FTTE*)*	Lunch break	13.30-14.45 DCB hotspot detection and machine learning for traffic demand prediction *Sergi Mas Pujol (UPC Barcelona), Manuel Mateos (Nommon/UPC Barcelona)*	15.00-16.00 Panel discussion Moderator: *Lorenzo Castelli (Uni. of Trieste)*		
WED 01SEP		10.00-11.15 Machine learning and traffic deconfliction *Alevizos Bastas (University of Piraeus), Ralvi Isufaj (UAB Barcelona)*	11.30-12.30 Panel discussion Moderator: *Fedja Netjasov (Belgrade-FTTE)*	Lunch break	13.30-15.30 Shaping a future European ATM Academy *SESAR Scientific Committee*	15.30-16.00 Engage PhDs Q&A *UoW*		
THU 02SEP		10.00-11.15 Weather prediction / forecasting models *Anastasia Lemetti (Linköping University), Eduardo Andrés (Universidad Carlos III Madrid)*	11.30-12.30 Panel discussion Moderator: *Tatjana Bolic (University of Westminster)*	Lunch break	13.30-14.45 Flight prioritisation, UDPP and route charging *Jan Evler (TU Dresden), Andrea Gasparin (University of Trieste), Natalia Solčianska, (University of Trieste)*	15.00-16.00 Panel discussion Moderator: *Andrew Cook (University of Westminster)*	16.15-17.00 Future research horizons *Dirk Schaefer (EUROCONTROL)*	17.00-17.15 Close and what's coming next *Andrew Cook (UoW)*

**Bojana Mirkovic, Fedja Netjasov, Danica Babić*

Friday 03 September, follow-on workshop: Machine learning, AI and automation in ATM Registration details for all events here.

PhD sessions

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