

ATM sector changes

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Abstract

The aviation industry is rapidly evolving, driving increased demand for skilled professionals in Air Traffic Management (ATM). Engage 2 focuses on attracting individuals to ATM careers while ensuring academia prepares competent professionals. Our approach involves analysing recent developments, projecting them into the future, and identifying essential skills. Insights from research and industry partners inform a comprehensive list of trends, guiding follow-on activities within this project and beyond.

It is recommended that readers also refer to the parallel and independent activities of the ongoing Master Plan development, for example regarding trends in the sector and SESAR programme (a draft from June 2024 was available at the time of writing).

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Engage 2

THE SESAR 3 KNOWLEDGE TRANSFER NETWORK

Engage 2

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1 Introduction

1.1 Background and context

This deliverable analyses trends in the field of Air Traffic Management (ATM). In this context, the term trend refers to a general direction or pattern in which the industry will be moving and could include technological advancements, operational strategies, regulatory changes, or other factors that may influence how air traffic is managed. The trend analysis is accomplished by examining recent developments and projecting these into the future, considering both near-term and mid-term perspectives.

The findings outlined in this report, a collection of trends, serve as the foundation for two follow-up tasks in Engage 2. These include Task T4.2, which focuses on “Study pathways for skills and career developments”, and Task T5.1, which is responsible for producing an “ATM concepts roadmap”.

The identification of trends includes several distinct steps. Two surveys have been conducted with separate audiences: we asked universities about changes in, and adaptations to, their curricula, in order to be able to identify trends they are trying to reflect with those changes. In parallel, we gathered information from industry through a survey, providing them an opportunity to outline their views on future trends and developments.

During the activity, there was also the opportunity to network with parallel activities outside the project, which were concerned with surveying user groups on related topics. Preliminary results from these surveys conducted by CANSO and EUROCAE WG-125/EASA were also taken into account in our analysis.

Another independent activity looked at recent research output published at the SESAR Innovation Days (specifically in the years 2021 - 2023) and at the Air Traffic Management Research and Development Seminar (held in 2021 and 2023) and identified especially those results that have been achieved outside the known framework of SESAR, as per the scope of this task and other activities (such as the concepts roadmap) of Engage 2. This literature survey helped us to extend our view on trends that have already been established in the earlier Engage KTN, which was then limited to documents published up to mid-2021. Moreover, we also analysed national funding schemes in a number of countries including those of the project partners involved in the activity to see whether there are specific national focus topics that could also point out important trends from other industries not seen in ATM yet.

Mindful of the very fast development in generative AI, we also decided to include a trend analysis on research literature using this technology as a complementary approach against which to compare our results from earlier steps in our trend analysis.

The outputs from these activities are consolidated into a comprehensive list of trends in ATM. This list will be accompanied by an analysis of the expected impact of these trends on the skills required from the ATM workforce, with a specific focus on future researchers active in the field.

This comprehensive approach supports a thorough understanding of the current landscape and future directions of the field of ATM, providing valuable insights for stakeholders and contributing to the development of a skilled and adaptable workforce.

The authors of this document acknowledge the ongoing development of a new edition of the SESAR ATM Master Plan, with a draft available for internal review as of June 2024 [13].

1.2 Research objectives

The primary objectives of this research are threefold:

The first objective is to conduct a comprehensive analysis of recent developments and trends in the ATM sector. This involves a detailed study of the research results and market dynamics influencing the ATM sector. The aim is to gain a deep understanding of the current state of the sector and the factors driving its evolution.

The second objective is to project these developments and trends into the future. This involves forecasting how the identified trends and developments might evolve over time, considering various factors such as technological advancements, changing consumer behaviour, regulatory shifts, and market forces. The goal is to provide a forward-looking perspective on the ATM sector.

The third objective is to assess the expected impact of these developments on the skills required from the ATM workforce, with a specific focus on likely future researchers in this field. This will involve identifying the key skills and competencies that will be in demand in the future, understanding how the role of researchers in the ATM sector might change, and outlining the implications for workforce development and training programmes.

By achieving these objectives, this research aims to provide valuable insights that can guide strategic decision-making for stakeholders in the ATM sector, including businesses, policymakers, educators, and researchers. It also seeks to contribute to the broader academic discourse on the future of the ATM sector.

1.3 Scope and limitations

The **time horizon** for the trend analysis in this document was set to cover near- and mid-term perspectives. Some of the approaches taken by the work, i.e. questionnaires developed specifically to gather information from various stakeholders, captured trends within the next 10 years, whereas the AI based trend analysis covers trends with a horizon of 30 years. With a longer period to look at, more variables and unknowns come into play and factors outside technological advancements, such as economic cycles, political changes and societal shifts will have increased impact.

Throughout this document, we must recognize the substantial foundation established by our predecessor project, KTN Engage³ in the years 2018-2022. For clarity, this project will be referred to as “Engage 1 KTN” or simply “Engage 1” in the rest of this document. This project undertook a thorough

³ <https://cordis.europa.eu/project/id/783287>

and comprehensive review of the existing literature up until mid-2021. This exhaustive survey encompassed a wide array of research papers, articles, and publications relevant to our field of study.

Given the breadth and depth of this prior review, our current project has been strategically positioned to build upon this foundation. Our focus has been primarily directed towards the exploration and analysis of new research work published after the cut-off date of the predecessor project. This approach has allowed us to stay abreast of the most recent developments and findings in our field, ensuring that our work is at the cutting edge of research.

By concentrating on the latest research results, we have been able to incorporate fresh perspectives, innovative methodologies, and novel findings into our project. This has not only enriched our understanding of the subject matter but has also opened new avenues for exploration and discovery.

Despite concerted efforts to boost the response rate (via newsletters, LinkedIn postings, cards with QR codes distributed at events, personal emails sent out by project members) for **two distinct questionnaires**, we have received only a **limited number of responses**⁴. As a result, each individual response is treated as a qualitative input rather than a quantitative measure. Furthermore, due to the limited number of responses, the collected data set does not possess the statistical representativeness necessary for a comprehensive analysis. Therefore, while the responses provide valuable insights, they cannot be considered statistically representative of the larger population.

While the number of responses to our questionnaires was limited, we have expanded our perspective by aligning with **two other initiatives** (CANSO [1] and EUROCAE WG125 together with EASA [2]). These initiatives engaged with similar stakeholder groups but with different objectives. The insights gained from these collaborations have been invaluable, and we have successfully integrated a summary of their findings into our work. This additional data has enhanced our analysis, offering a more holistic view of the situation, even with the constraint of limited direct responses.

Given that some contributors and reviewers of this deliverable are members of the scientific review board of the upcoming ATM Master Plan 2024 [13], there has been an implicit alignment during the editing process. Should any further alignment become necessary, this will be reflected in the upcoming deliverable D5.1, the initial version of the ATM Concept Map.

⁴ For each of the two surveys conducted, we received approximately 20 responses.

2 Methodology

The Description of the Action (DoA) [3] outlines the task developing the content of this document as follows:

As a starting point Task 4.1 will identify trends by analysing recent developments in the field and by projecting these developments into the future, considering near-term and mid-term perspectives. As in the two-pronged approach, the identification of trends will involve three distinct steps: i) a systematic literature survey conducted by identifying relevant publications and reports (including relevant deliverables from Engage KTN), ii) collection of insights from research partners identifying how adaptations in curricula reflect expected trends in the ATM sector, iii) collection of input from industry partners through a survey that gives them the opportunity to outline their view on future trends and developments. All inputs from activities (i), (ii) and (iii) will then be consolidated into a list of trends along with an analysis of their expected impact on the skills required from ATM workforce with a specific focus on future researchers active in that field. The literature survey in activity (i) will benefit from an initial list of trends that can be derived from the SRIA, that includes e.g., human-AI teaming, explainable AI, and safety precursors.

The goal of this deliverable is, therefore, to create a shortlist of trends that will inform downstream activities of the Engage 2 project and that could impact the SESAR programme. Moreover, further analysing these trends, the deliverable will highlight how identified trends will have a potential impact on the future ATM workforce.

Figure 1 outlines the overall process and methodology applied to reach these goals: **questionnaires** are developed and used as means to solicit inputs from key stakeholders. This step also benefits from other surveys being run independently of our project; relevant results will also be considered in our work. The **literature survey** is based on results from the Engage (1) KTN, specifically deliverables D3.9 and D3.10. These early results are complemented by analyses made for research papers published after the Engage (1) KTN cut-off date in order to identify potential contributions in recent research work. Moreover, for papers acknowledging funding sources outside SESAR we investigated these funding sources for further pointers towards unknown trends based on funding schemes indicated at their respective web sites. Finally, a further step, complementary to the literature survey - and an extension to the original scope of the work - applies artificial intelligence to independently explore the scope of future trends in ATM and their potential impacts.

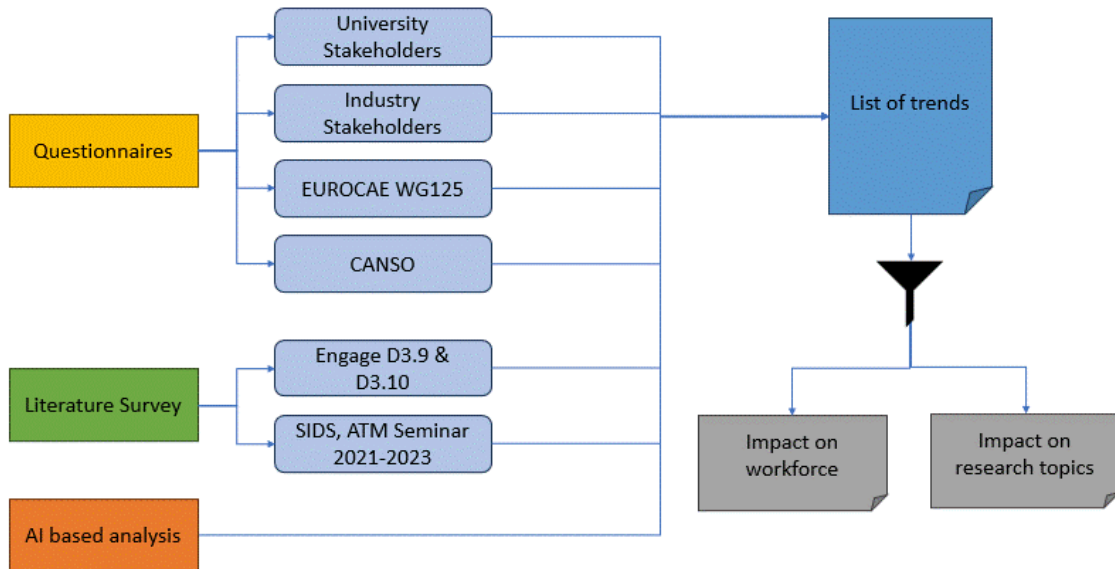


Figure 1: Methodology for trend analysis

3 Trend Analysis

The field of Air Traffic Management (ATM) is perpetually evolving. On one side, this evolution is driven by ongoing optimizations and improved processes for the critical workflows. On the other side, it is propelled by the relentless advancement in technology and significant technological breakthroughs pertaining to the tools utilised.

This chapter is dedicated to the execution of a trend analysis, with the objective to understand and predict the future direction of a phenomenon by examining its historical patterns. The focus is on three distinct methodologies, each considering different modes of analysing pertinent information sources: Questionnaires, Literature Survey, and an Artificial Intelligence (AI) based trend analysis.

Questionnaires to **capture stakeholder inputs** serve as a direct channel to trend analysis. By formulating specific inquiries to a chosen demographic, primary data about their behaviours, perspectives, and predictions can be gathered. This technique enables the capture of the intricacies of human behaviour and societal trends that may not be discernible in academic literature.

Subsequent to questionnaires, the **Literature Survey** is scrutinised. This technique constitutes the cornerstone of any trend analysis. It entails a systematic perusal of extant scholarly articles to collect information about historical and current trends. This strategy offers a comprehensive understanding of the subject matter and aids in identifying gaps in the existing knowledge, thus laying the groundwork for future research.

Lastly, the advanced realm of **AI-Based Trend Analysis** is explored. The emergence of artificial intelligence has enabled the analysis of extensive volumes of data with unparalleled speed and precision. AI-based trend analysis can uncover hidden patterns and predict future trends with a level of accuracy that was previously unattainable.

In combination, these three methodologies present a comprehensive approach to trend analysis, each with its unique benefits and limitations. By comprehending and integrating these methods, profound insights into the trends that shape our domain can be gained, and this knowledge can be utilised to make informed decisions for the future.

3.1 Stakeholder Inputs

This section presents a summary of the findings derived from four distinct surveys. Two of these surveys were conducted by our project team, while the remaining two were executed by external entities, more specifically EUROCAE WG125 with EASA and CANSO.

The first part of this section delves into the insights gathered from our project's questionnaires. These questionnaires were specifically designed to capture valuable data pertinent to our project's objectives. The analysis of the responses has yielded significant findings that have furthered our understanding and shaped the direction of our project.

Following this, we turn our attention to the surveys conducted by external bodies. Despite being external, these surveys provide a broader context and enrich our data pool. The findings from these

surveys offer a different perspective, allowing us to compare, contrast, and integrate these external insights with our own.

Together, these four surveys provide a broad overview of our research landscape. The subsequent sections will detail the specific findings and their implications.

3.1.1 Engage 2 Industry Questionnaire

To explore the views of stakeholders in the aviation industry on future trends and developments, Engage 2 has developed a questionnaire to be circulated online (see Section 7.3 Appendix: Industry Questionnaire). Respondents were asked to indicate the sector of aviation within which they are working, their role, their age group, their perceptions on relevant technical and operational trends as well as their perceptions on the key challenges of the aviation industry within the next ten years. The questionnaire was promoted through various channels, including direct email invitations, QR codes presented at events and posts on LinkedIn. The questionnaire was launched at the SESAR Annual Conference in October 2023 and was available online until February 2024.

A total of 20 respondents answered all the questions⁵. The majority of the respondents were from Air Navigation Service Providers (ANSPs) (22.7%) and the Manufacturer/ (service) supplier sectors (22.7%) and identified their role as “Research & development” (45%). Regarding their age, respondents mostly represented the age groups of 35-44 (25%), 45-54 (30%) and 55-64 (30%). Although the sample size did not allow the quantitative analysis of the variables included in the survey, it provides useful qualitative inputs on the perceptions of trends and challenges that are worth to be introduced.

When asked about what **technical trends** they consider as relevant in the upcoming next ten years, respondents suggested the importance of:

- opportunities related to **virtual/augmented reality**,
- integration of **drones** into the airspace ATM/UTM,
- **data communication** (air-air; air-ground),
- general **automation** as well as the management of **AI and ML**,
- **sustainability** and green propulsion systems,
- **information security** and cybersecurity, and,
- flying above **stratospheric altitudes**.

When asked about what **operational trends** they consider as relevant in the upcoming next ten years, respondents were focused mainly on the importance of:

- **climate change** and better predictions for **weather forecasts**,
- more **data based steered operations** and flight execution,
- **passenger experience** (reliable information provided to passengers),
- administrative and **bureaucratic burden** to manage future air traffic,
- ATM concepts in **highly automated environments** (e.g. automation of tasks and controls),
- **competition with other industries** to talents,

⁵ Country was not requested.

- **social attitudes** towards aviation.

When asked about what **major challenges** they expect regarding current and future workforce, respondents highlighted:

- the challenge of **hiring and retaining** technical staff (need for attracting young Engineering talents),
- the importance of reaching out to the **new generation**,
- the importance of **training and reskilling** existing staff in a more interactive and reinforced way,
- the **financial burden** being the result of the increasing number of personnel.

3.1.2 Engage 2 University Questionnaire

Engage 2 initiated a second survey to delve into the perspectives of universities on upcoming trends and advancements (refer to Section 7.4 Appendix: University Questionnaire for details). The survey, which was distributed online, asked participants to specify details on their university, their role, age group, and their views on pertinent technical and operational trends. They were also asked about what they perceive to be the major challenges facing the aviation industry in the coming decade. The survey was disseminated through a variety of means, including direct email invitations, QR codes displayed at events, and LinkedIn posts. It was first introduced at the SESAR Innovation Days in November 2023 and remained accessible online until February 2024.

A total of 18 respondents completed the entire survey. Responses were received from 12 countries, mainly from Europe plus one response from Africa, with multiple respondents only received from four countries. In terms of age demographics, the respondents were mostly balanced across all age groups. Despite the sample size being too small for a quantitative analysis of the survey variables, it still offers valuable qualitative insights into perceptions of current trends and challenges that are worth exploring.

When questioned about the **technical trends** they deem significant for the forthcoming decade, the emphasis of the respondents was primarily on the significance of:

- Human Factors and HMI.
- New design methods for aircraft components and structures (e.g. eco-driven and sustainability-driven approaches).
- Digital Twin for all Life Cycle aspects.
- Development of new functional materials.
- New computing techniques, e.g. quantum.
- Eco- and Sustainable Design.
- Open Science/Open Source software and knowledge transfer - especially from institutions funded by governments.
- Digital communication navigation and surveillance, New Space and Satellite-based CNS.
- Green aviation and transition.

When asked about what **operational trends** they consider as relevant in the upcoming next ten years, respondents were focused mainly on the importance of:

- Increased automation, increased machine to machine communication, increased dependency on GNSS and satellite-based services. Increased use of internet-based protocols, increased resource virtualization, increased dependency on services based architectures (ground and airborne).
- Flexibility to adapt to requirements.
- Free routes and TBO.
- Ground and airborne high level of automation.
- Civil-military coordination.

Here are some items that were highlighted when the respondents were asked about **other significant trends**:

- Human role in an environment with an increasing level of complexity and automation. User and social acceptance.
- Infrastructure development.
- Multimodal regulation.
- Evolution of the Societal point of view: needs and constraints.
- Policy & regulatory.

Respondents highlighted the following major challenges with **future workforce**:

- High level of exchanges and interactions between industry and academics. Ensuring seamless transition between academic programmes and the advanced technical and scientific expertise required by industry. Making the workforce highly adaptive and proactive to contribute to innovation acceleration.
- Environmental protection.
- Proper dialogue with specific industries and sectors (e.g. ANSPs) to understand their needs and to reflect those in a balanced way in the curriculum.
- Digitalization should not lead to reduced chances of being employed.
- Adaptability to change.
- Less human resources in ATM due to automatization and AI.

3.1.3 EUROCAE WG125 and EASA

The EUROCAE Working Group 125 (WG125) in cooperation with EASA is focused on the Next Generation of Aviation Professionals (NGAP). This group is composed of industry leaders, educators, and subject matter experts who are working together to create a roadmap for the future of aviation education and training. Their work includes developing best practices, identifying key competencies and skills needed for future aviation professionals, and creating a mentoring programme.

As part of their initiative, WG125 launched a survey open from November 2023 to January 2024 to collect first-hand inputs from those who have insights to share and can directly benefit from the group's efforts. The survey covered various target groups, including young people, students, aviation professionals, educators, and others.

This initiative by WG125 is a significant step towards addressing the potential shortage of aviation professionals in the European aviation system. It aims to engage, attract, and maintain the Next Generation of Aviation Professionals.

By looking at future trends in the industry, the report [2] aims to explore ways to attract and retain aviation professionals to address the shortage of qualified staff. It highlights the need for research in employee lifecycle issues, upskilling, knowledge transfer, and the impact of the regulatory environment on recruitment and deployment.

While the subject of the report does not directly look more detailed into future trends, it mentions a number of these that are also considered here for pointing towards new directions:

- Sustainability, digitalisation, Artificial Intelligence (AI) and cybersecurity
- Unmanned aviation, electric vertical take-off and landing aircraft (eVTOLs), Urban Air Mobility (UAM) and Advanced Air Mobility (AAM)
- Shift towards low-carbon economy
- Trust into the aviation industry as a whole and its key players

3.1.4 CANSO

In April 2024, CANSO, in cooperation with Firstfruits Services, issued a survey report [1] reflecting a global survey of those 28 and under working in the aviation industry and those currently studying with the intention of entering the industry, as presented at the 'Future Skies: Tomorrow's Voices' day at Airspace World, March 2024, Geneva, organised by CANSO, Engage 2 and Firstfruits Services. The impetus for the event was the rising concern regarding the difficulty in attracting the right talent and retain a workforce able to deliver the future vision of aviation. As follow-up to the survey, a focus group was held to review and discuss the findings. Some of the participants presented these findings in Geneva, across two sessions.

The survey itself focused on the factors that influence the attraction and retention of young professionals (18-28) in aviation. Drawing on prior research from McKinsey and the World Economic Forum, eight factors were chosen to explore next generation perspectives: total compensation, career development and advancement, meaningfulness of work, workplace flexibility, support for health and wellbeing, inspiring and caring leaders, inclusivity and diversity, and reliable and supportive people. Below, the Engage team has selected and reflected a key finding from the report on each dimension.

(1) Total compensation

For students, this factor remains important in choosing a job, ranking third in the list of influencing factors, with 94% seeing it as influential.

(2) Career development and advancement

Of the eight factors, career development and advancement gave the lowest satisfaction score. McKinsey's research into these factors across multiple industries concluded that career development and advancement is the most influential in choosing and remaining in a job. Forming clear, accessible and well-supported pathways is therefore crucial to retain talent, and is something the ATM industry must look at more closely.

(3) Meaningfulness of work

For students this factor ranked first, with 96% agreeing it is an important factor when choosing a job (and 71% strongly agreeing).

(4) Workplace flexibility

For students, this factor ranked eighth in importance, with 78% agreeing it is an important factor when choosing a job.

(5) Support for health and wellbeing

For students this factor ranked fourth, with 91% agreeing it is an important factor when choosing a job.

(6) Inspiring and caring leaders

There is an appetite within the younger generation to be involved in shaping the industry and their organisations; however, there was a mixed response regarding leadership's openness to innovation and new ideas. 52% of respondents agreed that their new ideas and innovation are valued, however 28% disagreed.

(7) Inclusivity and diversity

Most respondents are positive about inclusivity and diversity in their organisation, with 74% agreeing they personally feel included and comfortable, and 75% perceiving their organisation as inclusive and diverse.

(8) Reliable and supportive people

Maintaining a healthy culture is crucial, as McKinsey's data highlights that a lack of reliable and support people is the second most common reason for a young professional to leave a job. For students this factor ranked second, with 93% agreeing it is an important factor when choosing a job.

A notable demographic trend was the correlation between the overall optimism and satisfaction score and time spent in the industry [1]:

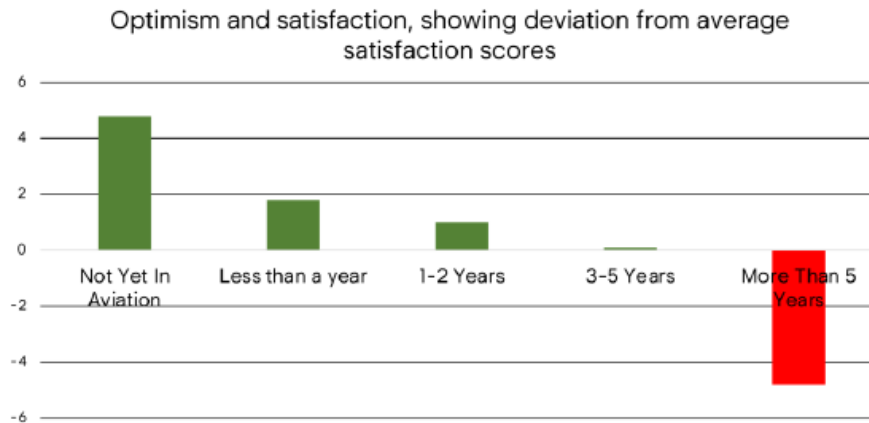


Figure 2: Workplace optimism and satisfaction as a function of time spent in aviation [1]

Environmental impact, corporate responsibility and the public image of the aviation industry is clearly a factor that is increasingly in the spotlight. 12% of respondents joined the industry to make a difference in this domain, whilst 69% were concerned, but it hadn't influenced their decision to join the organisation. 19% were not concerned about the environmental impact of the organisation.

Respondents selected organisational strategies, which they believed would improve talent attraction and retention. The top-selected options were:

1. Offer higher wages
2. Improve talent progression and promotion processes
3. Provide effective reskilling and upskilling

Respondents also selected industrial policies, which they believed would make a significant difference to attraction and retention. The top-selected options were:

1. Funding for reskilling and upskilling, particularly in digital and data literacy
2. Tax and other incentives for companies to improve wages
3. Improvement to school systems

In response to free-response questions, highest perceived attraction and retention factors were as indicated below.

Attraction

1. Passion
2. Excitement/challenges
3. Salary/pay
4. Work environment
5. Career advancement

Barriers

1. Salary/pay
2. Environmental concerns
3. Lack of awareness of the industry
4. Training costs
5. Work-life balance

The report makes the following insightful conclusions (with our text emboldening):

*The **frequent mentions of passion** were intriguing. Despite the many issues raised across this survey, the young professionals in aviation are passionate about the industry with 98% expecting to still be working in the industry in 5 years - an extraordinary figure. The reasons for this passion and its impact on our industry require further investigation.*

*The findings raise questions about how wide a pool of talent is being brought into the industry. Will we have the right talent for the future if we only attract people who are passionate about aviation? **What about those with the skills and competencies required, but who don't carry a specific passion for the industry?** Are we creating different pathways for that talent pool?*

*The findings of this survey, alongside the many perspectives shared through the focus groups, CEOs breakfast and panel sessions, makes a clear case that our **organisational attractiveness needs to be addressed**. Whilst much work is underway in collaborative discussions in global fora, there is a need for organisations and their leaders to assess how they can better incorporate the voices of the young people in their ranks and redesign organisations to be fit for the future, putting pathways in place to co-develop the workforce of tomorrow.*

3.2 Literature Survey

3.2.1 Baseline from Engage 1 KTN

This section summarises the future research opportunities for ATM, published in 2022 as one of the 'legacy' deliverables (D3.10 Research and innovation insights [4]) of the earlier Engage 1 KTN. The basic framework of this work was structured around three research pillars (see Table 1). Each research pillar has a dedicated section. SESAR's Strategic Research and Innovation Agenda (SRIA), Digital European Sky was the focal point of comparison. Detailed proposals for future research, plus research enablers and platforms were suggested for SESAR 3.

Research pillar	Summary of pillar
Gap analysis	A two-phase approach, firstly using a data-driven analysis of SESAR projects in the repository of the Engage wiki, using machine learning and multi-dimensional vectors to identify gaps in the existing research corpus, relative to the SRIA. The second phase deployed expert judgement to interpret and comment on the data-driven phase, to filter and focus on key findings.

Research pillar	Summary of pillar
Thematic challenges	The goal of Engage thematic challenges was to address research topics which were not (sufficiently) addressed by the SESAR research programme. The Call for thematic challenges was open to the research community on the Engage website from January 2018. This predated the SRIA. Four challenges were devised and matured during the lifetime of the KTN using a series of dedicated workshops and catalyst fund projects.
Horizon flagships	These set out to advance the definition of future research concepts beyond what is published in the SRIA. ‘Horizon’ reflects the familiar concept of horizon scanning in research, identifying future concepts. ‘Flagship’ is used as a complementary term to the SRIA ‘flagship activities’. These ideas were conceived and developed by the consortium experts. The concepts are futuristic in the sense that they have not already been (fully) researched in the ATM domain, either through omission and/or because the underpinning principles are still at a very low TRL.

Table 1: Engage 1 KTN’s three research pillars

These activities were conducted at different stages of the Engage 1 KTN. Thematic challenges were launched initially, followed by gap analysis and horizon flagship development. Overlaps in outputs were expected due to the asynchronous nature of these efforts.

3.2.1.1 Gap analysis – examining previous research

The process to identify potential research gaps, identifying future research directions, deployed a phased combination of quantitative and qualitative analysis. An auto-encoder model was used to extract key statistical information from SESAR deliverable texts to identify areas potentially poorly covered in the SRIA and yet with remaining potential interest to the research community. This information included keyword analysis, semantic similarity indices, and outlier detection. The results were then interpreted by ATM experts within the Engage consortium.

The analysis incorporated data from 426 SESAR 1 and SESAR 2020 projects. A total of 1873 deliverables and Solution data packs were sourced (up to mid-2021), however there were gaps in coverage, particularly with later SESAR 2020 Calls and missing SESAR 1 metadata. In parallel, 653 conference papers presented at the SESAR Innovation Days (2011-2020) and the USA/Europe ATM Research and Development Seminars (2011-2019) were collated with the assistance of EUROCONTROL. Associations between these papers and SESAR projects were also identified.

3.2.1.2 Engage 1 KTN thematic challenges

The goal of the Engage 1 KTN’s thematic challenges was to address research topics not (sufficiently) addressed by the SESAR research programme. Four thematic challenges (TCs) were selected following an open call for suggestions from the research community:

TC1 Vulnerabilities and global security of the CNS/ATM system;

- TC2 Data-driven trajectory prediction;
- TC3 Efficient provision and use of meteorological information in ATM;
- TC4 Novel and more effective allocation markets in ATM.

A series of workshops were organised for each thematic challenge, with the final round focused on identifying future research directions under each thematic challenge umbrella, the findings of which are reported in detail in Engage D2.7 [5].

The aim of catalyst funding was 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 was awarded 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).

The thematic challenge workshops were closely linked with catalyst funding. The goal of the first round of TC workshops was to collect conclusions to be included in the material for the catalyst funding Calls. The second round of workshops presented the catalyst funding (CF) projects from wave 1, and other appropriate research from the same thematic challenge areas. The goal of the third round of the TC workshops was to present the results from both the wave 1 and wave 2 CF projects. The fourth edition of workshops focused on identification of future research directions.

Taking the results obtained from the fourth TC2 workshop held in 2021 as an example, this focused on a topic slightly different from earlier workshops (data-driven trajectory prediction) – ‘AI, ML and Automation’, i.e. the scope was broadened beyond trajectory prediction and extended to include automation. 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 have been applied in other ATM application areas so that exploiting the synergies between these different application areas seemed 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.

3.2.1.3 ‘Horizon’ flagships

Looking further ahead, the Engage 1 KTN set out to advance the definition of future research concepts and directions beyond what is already published in the SRIA. The nomenclature ‘horizon’ flagship activities was used. ‘Horizon’ reflects the familiar concept of horizon scanning in research, identifying future concepts. ‘Flagship activities’ was used as a complementary term to the SRIA ‘flagship activities’. These ideas were conceived and developed by the consortium. The concepts had to be futuristic in the sense that they had not already been (fully) researched in the ATM domain, either through omission and/or because the underpinning principles (e.g. for quantum computing) still remain at a very low TRL (level 0 or 1). These concepts did, however, at least have to map to some

extent onto existing ATM activities in the SRIA: if they connected to none of these at all, it was difficult to justify their relevance to ATM, considering the relatively broad scope and maturity of the SRIA. The timeline of 2040 was somewhat illustrative, in that some ideas could be partially developed at higher TRLs sooner, others later. The six horizon flagship activities proposed for seeding the ATM concepts roadmap are presented in the following sub-sections, in no implied order of priority.

3.2.1.3.1 Quantum computing

Quantum computers use quantum physics properties to enable certain types of computations to be performed vastly quicker than classical computers. At the time, approximately fifty countries were engaged in national and (especially) international quantum research and development projects, with private capital investment and multidisciplinary cooperation being prevalent.

Whilst stability issues for quantum computers need to be resolved, quantum computing is likely to bring particular opportunities for simulation, especially when coupled with machine learning and AI. These are expected to include higher-precision weather forecasting and improved (in detail, lookahead and scope) environmental impact models, for example. Applications involving very much faster (and some currently infeasible) solutions to search space and combinatorial problems, may offer vastly improved capabilities both for operational/tactical searches of improved solutions to complex capacity constraints in ATM. In the SESAR exploratory research context, in particular, much larger numbers of future scenario simulations and hitherto infeasibly complex models are likely to be enabled to be run.

3.2.1.3.2 Strong AI

Strong AI is also known as general AI or artificial general intelligence. It usually refers to a currently theoretical form of AI whereby a computer will have an intelligence comparable to that of humans, with the ability to solve problems, learn, and plan future contingencies. Current forms of AI, and ML algorithms, are dependent on (often biased) training data used as inputs, to the extent that truly predictive capabilities have not currently been developed (one has to wait for a particular type of event to occur and then re-train the model). Whilst some argue that strong AI is not achievable, others, such as DeepMind⁶, argue that reinforcement learning (which comprises an environment, agents, and rewards) is a sufficient basis for strong AI, and see as key the inclusion of agents that learn through interaction with the environment, which could be through operational sensors. Such tools, even if not attaining the full specification of strong AI (however that may be defined), may bring greatly superior capabilities to ATM both through improved forecasts and predictive capabilities, strategically and tactically, and also underpinning stronger metamodels for performance assessment and with 'strong emergence' foresight capabilities, including improved human behavioural models, e.g. for future policy generation, whereby a host of new possibilities may well be proposed through vastly increased modelling power and utility.

3.2.1.3.3 Integrated ticketing and virtual interlining

Europe is not alone in being caught in a fragmented modal service culture. Nevertheless, a comprehensive review of existing single-ticketing solutions and identification of the benefits, barriers and lessons learned is needed. Single ticketing and virtual interlining already exist in various formats,

⁶ <https://venturebeat.com/2021/06/09/deepmind-says-reinforcement-learning-is-enough-to-reach-general-ai/>

such as specific rail-air collaborations (Lufthansa, Deutsche Bahn) and much wider schemes (AccesRail⁷ is an example of an IATA Travel Partner).

Overcoming the regulatory, accountability, revenue sharing, and insurance barriers would open up the opportunities for new businesses, offering real Mobility as a Service (MaaS), not just ‘ticketing as an app’ approach, as currently available (e.g. giving information on traffic jams, delays, cancellations, and enabling the booking of a train or bus ticket to the airport). Travel operators may be envisaged selling seats offered by transport operators of all modes, for a certain level of service, building on more limited integration currently in place (e.g. with certain guarantees when connecting across different low-cost carriers at an airport, or joint air-rail tickets). These could act as the travel organisers, also covering needs in case of disruption, throughout the booked travel in a door-to-door context and based on the chosen service level and priorities (e.g. cost, flexibility, environmental impact). It would be interesting to explore passenger expectations and willingness to pay for such integrated services.

3.2.1.3.4 European risk register for ATM and air transport resilience

“Resilience” is mentioned often in the SRIA, mostly with reference to cybersecurity, but also flagging climate/meteorological resilience and passenger journey resilience. However, the need may be suggested for a higher-level, European risk register for ATM and air transport, taking account of space weather, pandemics and more disperse ATM service outages (by whichever means, e.g., climate, higher levels of automation, cyber attacks, etc.), and also potentially broader adversarial attacks aimed at destabilisation. This should also include potential degradation of energy supply in the air transport chain, as a result of the situation in Ukraine.

Learning from the past experience of the European Aviation Crisis Coordination Cell (EACCC) could indicate which type of risks to include in the register, how to best use it, to monitor the emerging strategic and (pre-)tactical situations, and being overall proactive in calling up the crisis cell and/or other stakeholders and units.

Complexity science and complex network theory have already proven in ATM to be well-suited tools with a range of metrics particularly adept at measuring network resilience, and these could be brought to bear to assess the absorptive, adaptative and restorative forms of resilience currently in place, to identify key vulnerabilities and develop cost-benefit trade-offs for mitigations. Further, development and use of novel techniques based on machine learning to support risk (any risk from the register) intelligence services in aviation/ATM could be encouraged, to support network resilience. Regarding such resilience, it would also be informative to explore what lessons have been learned from the Covid-19 pandemic, for example, in terms of the sustainability of current financial, business and performance assessment models for airspace users and ANSPs.

3.2.1.3.5 Improved route emissions metrics and policies

The need to cut back on aviation’s climate impact is generally accepted and emissions capping and a Trading System⁸ have been put in place in Europe (focusing on CO₂ emissions in aviation). However, environmental impacts are manifold and difficult to model, and more importantly monitor, beyond

⁷ <https://accesrail.com/>

⁸ https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets_en

simple CO₂ emissions. Non-CO₂ emissions are responsible for roughly 75% of aviation's global net effective radiative forcing. Among them, NO_x emissions depend on pressure ratios and the combustion temperatures of jet engines, so that more efficient engines ironically may lead to greater NO_x emissions. The climate impact of NO_x emissions and contrails depend on many factors, including flight level, atmospheric conditions, time of day and year, and geographic latitude, and is to date not perfectly well understood. Contrail-optimised flight routes may hence increase the fuel burn and hence also CO₂ emissions, leading to the necessity to trade-off various climate impacts. Sustainable aviation fuels (SAFs) may mitigate some of these climate impacts, but SAFs are not presently available in sufficient quantity and their total life-cycle climate impact needs to be considered.

Despite the introduction of the SES Performance and Charging Scheme⁹, the present air traffic route charging system is mainly based on a cost recovery method, leading to differences in route charges. In some cases, especially when direct routes lead through airspace with higher route charges, the total cost of a flight, including the cost of fuel, and route charges, can be reduced by flying a longer route through cheaper airspace. Following a recent reform, now the flown rather than the filed flight plan is the basis for route charging; this is desirable from a service provider's point of view but may ironically have aggravated the problem of emissions, as longer, but overall cheaper routes result in higher emissions.

Many governments are proposing or implementing flight taxes to off-set aviation's environmental impact. If implemented correctly, this could provide new possibilities for more sustainable flight operations. The challenge is how to create a system that gives policymakers the ability to measure and monitor emissions and the possibility to propose and implement environmentally beneficial emission trading or even tax policies that fundamentally affect how airlines operate. A full cost model that establishes a realistic price for the transportation and makes the environmental impact of travelling choices more transparent to customers may influence their decisions; this could include the aspect of inter-modality, i.e. planning and executing trip planning across competing or complementary flight modes.

3.2.1.3.6 ATM-U-space coordination; UAM access mechanisms

U-space is a crucial building block for the successful deployment of unmanned aerial systems and urban air mobility. Since these new market entrants (including police and other surveillance operations, urgent delivery of medical supplies, air taxi operations, delivery operations) are presently not sufficiently covered by existing flight rules and airspace management developed to serve 'traditional' aviation, concepts have been developed and regulations drafted in the recent past. The SESAR project CORUS-XUAM¹⁰ developed a concept of operations for Urban Air Mobility and demonstrated its feasibility in a series of Very Large-scale Demonstrations in a number of European countries. Despite these efforts, a number of open questions remain. ATM-U-space coordination, the structure of U-space airspace (present concepts distinguish between categories X, Y and Z) and segregation (free route airspace, layers, tunnels in the sky); the operation of vertiports; and priority rules are amongst such questions.

⁹ https://eu-single-sky.transport.ec.europa.eu/ses-performance-and-charging-scheme_en

¹⁰ <https://cordis.europa.eu/project/id/101017682>

In controlled airspace, demand-capacity balancing is performed principally through the Network Manager by applying restrictions and encouraging re-routings in case demand exceeds the capacity of certain airspace elements at peak times. The use of U-space and UAM airspace through a plethora of actors with heterogenous operating patterns and vehicles, as well as the more on-demand nature of UAS traffic, as compared to scheduled flight operations, make it questionable whether such an approach is applicable to U-space and UAM. Apart from applying priority rules, and in case demand exceeds capacity of access to airspace and vertiports, one approach is to investigate whether economic approaches, such as auctioning, selective pricing or different service levels are practical, whilst at the same time attempting to maintain principles of equity, and avoiding market dominance of specific operators of types of operations.

3.2.1.4 Concluding reflections on the horizon flagships and the SRIA


By definition, the research ideas discussed previously are not strongly aligned with the SRIA. However, in Table 2, the top three semantic similarities between the six horizon flagships (Engage 1 KTN threads) and the SRIA flagships have been indicated. The blue text refers to the SRIA flagship names and numbers. The black bold captures the horizon flagship names. One of the strongest relationships in the table can thus be seen to be that between “strong AI” (Engage 1 KTN horizon flagship) and “Artificial intelligence (AI) for aviation” (SRIA flagship), with a similarity of 0.66. This is a logical association, adding validatory weight to the approach, as do the other relationships in the table. It is also worth noting that most (4/6) of the highest similarities are reflected through *transversal* SRIA flagships (7 and 8).



Thread	SRIA flagships (cosine semantic similarity)	Engage research threads and aligned SRIA flagships
1		Quantum computing
	8 (0.36)	Artificial intelligence (AI) for aviation
	1 (0.29)	Connected and automated ATM
2	5 (0.25)	Virtualisation and cyber-secure data sharing
		Strong AI
	8 (0.66)	Artificial intelligence (AI) for aviation
3	1 (0.48)	Connected and automated ATM
	7 (0.39)	Aviation Green Deal
		Integrated ticketing and virtual interlining
4	6 (0.64)	Multimodality and passenger experience
	7 (0.37)	Aviation Green Deal
	3 (0.34)	Capacity-on-demand and dynamic airspace
4		European risk register for ATM and air transport resilience
	8 (0.41)	Artificial intelligence (AI) for aviation
	7 (0.39)	Aviation Green Deal
	6 (0.36)	Multimodality and passenger experience



5		Improved route emissions metrics and policies
	7 (0.62)	Aviation Green Deal
	6 (0.47)	Multimodality and passenger experience
	3 (0.44)	Capacity-on-demand and dynamic airspace
6		ATM-U-space coordination; UAM access mechanisms
	4 (0.73)	U-space and urban air mobility
	2 (0.53)	Air-ground integration and autonomy
	1 (0.49)	Connected and automated ATM

Table 2: Semantic similarities between SRIA flagships and Engage horizon flagships

The horizon flagships pillars shown in Table 3 are indicated alongside the best aligned SRIA flagship activities (albeit this time drawing on the quantification of Table 2, flagging up to two flagships with semantic similarities > 0.40), and some commentary is presented on the key relationships between the Engage 1 KTN threads and the SRIA flagships. Text in black relates to the Engage 1 KTN thread (with the corresponding names in bold); text in light blue relates to the SRIA flagship(s) (names likewise in bold). The table is intended to initially point the reader to some main points of association and complementarity between the research directions highlighted by the Engage 1 KTN thread and one or two key flagships in the SRIA, as a starting point for further engagement.

Thread	SRIA flagship(s)	Summary
1		Quantum computing: Quantum computers use quantum physics properties to enable certain types of computations to be performed vastly quicker than classical computers. A fundamental advantage of quantum computers is the ability to consider large numbers of combinations simultaneously. Quantum computing could expose cybersecurity vulnerabilities, through solving integer factorisation problems, which underpin many public key cryptographic systems, including blockchain applications, thus already generating improved cybersecurity research. Quantum computing is likely to bring particular opportunities for simulation, especially when coupled with machine learning and AI.
	8 	Artificial intelligence (AI) for aviation: whilst the strongest correspondence of quantum computing is unsurprisingly with the 'AI' flagship, the wider implications for this new technology are very broad and deep, considering the applications of much faster solutions to search space and combinatorial problems, potentially offering vastly improved capabilities both for operational/tactical searches of improved solutions to complex capacity constraints in ATM, and e.g. (safety) validation. Exposing cybersecurity vulnerabilities and supporting public key cryptographic systems are clearly important in the ATM context regarding not only CNS, but also in the context wider of information exchange over

Thread	SRIA flagship(s)	Summary
		networks, supporting SWIM and privileged data exchange (e.g. for UDPP).
2		Strong AI: this is also known as general AI or artificial general intelligence, usually referring to a form of AI whereby a computer has intelligence comparable to that of humans, with the ability to solve problems, learn, and plan future contingencies. Reinforcement learning is arguably a sufficient basis for strong AI, e.g. with the inclusion of agents that learn through interaction with the environment through operational sensors. Coupled with deep neural networks, more powerful dimension reduction and polynomial classification, such technologies could help to build better predictive models from specific aircraft and component safety profiles through to full socio-technical system models at the design stage.
	<p>8, 1</p>  	Artificial intelligence (AI) for aviation: the strongest correspondence of strong AI is not unexpectedly with the 'AI' flagship, which cites "AI for prescriptive aviation". Whilst strong AI represents a step-shift in the state of the art, it builds on the current science, for example, whereby the coupling of advanced sensor technologies with ML/AI techniques, could support system development in multiple contexts, such as risk mitigation, system diagnoses, performance assessment, forecasting, predictive support and design. Connected and automated ATM: may be supported specifically through more efficient resource allocation for humans and machines, although this is just one of many other SRIA flagships potentially impacted strategically and tactically e.g. through strong AI's foresight capabilities, 'strong emergence' and policy generation.
3		Integrated ticketing and virtual interlining: Europe remains largely in a fragmented modal service culture. Importantly, single ticketing and virtual interlining already exist in some formats, such as specific rail-air collaborations, and some wider schemes (e.g. through IATA). A comprehensive review of existing single-ticketing solutions and identification of the benefits, barriers and lessons learned is needed in order to build upon and extend these models in an integrated manner with ATM. Overcoming the regulatory, accountability, revenue sharing, and insurance barriers would open up the opportunities for new businesses, offering real Mobility as a Service (MaaS), not just 'ticketing as an app' approach, as currently available.
	6	Multimodality and passenger experience: fully logically, this represents the strongest SRIA flagship correspondence with integrated ticketing and virtual interlining. An examination of existing virtual interlining models

Thread	SRIA flagship(s)	Summary
		<p>and online travel agencies would give better insights into the implications for airspace users, airport infrastructure requirements and other modal travel service providers (e.g. rail). Operationally, the impacts on holding flights for delayed trains, and <i>vice versa</i>, could be significant – further metric development and scenario simulations are required. Future travel operators should offer appropriate connection guarantees and passenger needs in case of disruption, throughout the booked travel in a door-to-door context. The SRIA discusses ticketing, integration and crisis management.</p>
4		<p>European risk register for ATM and air transport resilience: a higher-level, European risk register is suggested, taking account of space weather, pandemics and more disperse ATM service outages (by whichever means, e.g., climate, higher levels of automation, cyber attacks, etc.), and also potentially broader adversarial attacks aimed at destabilisation. This should also include potential degradation of energy supply in the air transport chain, as a result of the situation in Ukraine. Learning from the past experience of the European Aviation Crisis Coordination Cell and various broader, national risk registers, could indicate which type of risks to include, how best to monitor the emerging strategic and (pre-)tactical situations, and being overall proactive in calling up crisis cells.</p>
	<p>8</p> 	<p>Artificial intelligence (AI) for aviation: “resilience” is mentioned often in the SRIA, mostly with reference to cybersecurity, but also flagging climate/meteorological resilience (Aviation Green Deal) and passenger journey resilience (Multimodality and passenger experience). Comparably strong associations for the risk register thread from Engage with the SRIA ‘AI’ flagship result from common references to resilience, machine learning, complexity and networks. Complexity science and complex network theory have already proven in ATM to be well-suited tools and metrics for network resilience. It would be informative to explore lessons learned from the Covid-19 pandemic, e.g. in terms of the sustainability of current financial, business and performance assessment models for airspace users and ANSPs.</p>
5		<p>Improved route emissions metrics and policies: non-CO₂ emissions are responsible for roughly 75% of aviation’s global net effective radiative forcing. The impact of NO_x and contrails depend on many factors, including flight level, atmospheric conditions, time of day and year, and geographic latitude, and is to date not fully understood. Contrail-optimised flight routes may increase the fuel burn and hence also CO₂ emissions, leading to the necessity to trade-off various climate</p>





Thread	SRIA flagship(s)	Summary
		<p>impacts. Environmentally friendly (e.g. contrail- or NO_x-optimised) routes might well be longer, increase fuel burn, related costs and flight times. Since the <i>flown</i> flight plan is now the basis for route charging, this may also result in longer but overall cheaper routes resulting in higher emissions.</p>
	<p>7, 6</p>  	<p>Aviation Green Deal: regarding the need for improved route emissions metrics and policies, this flagship addresses the specific high-level R&I needs/challenges of ‘Optimum green trajectories’ and ‘Non-CO₂ impacts of aviation’, in addition to an ‘environmental dashboard’ relating to metric development and implementation, impact assessment trade-offs, and incentivisation considerations. Regarding links with the Multimodality and passenger experience SRIA flagship, the Engage thread stresses the current relatively passive role of passengers in flight sustainability, whereas strengthened national and international policy (taxes) and data transparency may generate a stronger passenger link with airline decision-making and business models, also in the multimodal context.</p>
6		<p>ATM-U-space coordination; UAM access mechanisms: U-space is a crucial building block for the deployment of unmanned aerial systems and UAM. Notwithstanding on-going implementation research, including VLDs, open questions remain regarding ATM-U-space coordination, e.g. regarding the structure of U-space airspace and segregation, and the operation of vertiports. Furthermore, different vehicles and types of operations will exist in U-Space (especially for UAM), including police/surveillance operations, delivery of (e.g.) medical supplies, and air taxi operations. Studies on societal acceptance and with ATCOs suggest different degrees of willingness to prioritise these different operations, further complicated when piloted flights are admitted to U-Space/UAM.</p>
	<p>4, 2</p>  	<p>U-space and urban air mobility and Air-ground integration and autonomy: the correspondence between these two SRIA flagships and research directions flagged by Engage is self-evident. The latter notes that manned aviation may well be present in VLL airspace, with drones: equipage requirements, management of non-nominal/emergency situations and common services need to be developed. The vicinity of airports, in which different vehicle types will operate, with infringement risks, is of particular interest. There is a strong link with the Smart City concept. Access to U-space and UAM airspace will have to be based on equipage requirements and respect principles of equity, whilst applying yet-to-be-defined priority rules, e.g. for emergency and security flights. DCB raises further challenges in this context.</p>

Table 3: Research threads for the horizon flagships pillar & relationships with SRIA flagships

3.2.1.5 Practicalities and enablers of supporting future research directions

In addition to identifying new and continuing areas for research in future, the practicalities and ‘enablers’ of such research were considered by the Engage 1 KTN. Some of these enablers are distinct mechanisms (such as catalyst fund projects, community collaboration), whilst some others have a higher research content *per se*, such as the development of broader performance metrics, but were included here more as horizontal / supporting activities, which immediately relate to the wider corpus of research work previously discussed. Others, such as synthesising and sharing data collaboratively, lie some in between the two.

3.2.1.5.1 Lessons learned from the Engage 1 KTN catalyst fund projects

The previous KTN funded 18 catalyst fund (CF) projects. The focus of these was on maturing exploratory research further towards applications and operational contexts. The projects were able to address the corresponding thematic challenges (plus one ‘open’ project), move solutions closer towards industry goals and objectives, and towards higher TRLs.

The catalyst funding scheme (EUR 60k maximum budget allowed through the Horizon 2020 ‘cascade’ funding mechanism) supported projects for an intended 12 months’ duration. This approach was very well received by all the CF projects, for a variety of reasons. Most obviously, it overcame the commonly faced barrier for such activity whereby other funding schemes were not available, or set at too high an access bar (e.g. larger projects let through SESAR 2020 ER Calls). In addition, the low administrative burden was appreciated as it cut unnecessary overheads and left enough room for the researchers to focus on the actual research.

The CF funding scheme was considered, by the Engage 1 KTN consortium and the catalyst project leads, to be a good instrument for a variety of TRL projects, from initial idea exploration, to focused, agile development of ATM solutions. The projects at all TRL levels highlighted the importance of early and continuous collaboration with their targeted stakeholders. Various forms of collaboration were applied by projects – from direct collaboration with the end-users (as a project partner), through individual interviews, to the extensive use of advisory and/or focus groups. This potential barrier was thus generally perceived as being well managed.

Regarding stakeholder involvement, having an Engage 1 KTN network of contacts in key organisations (such as EASA, EUROCONTROL, certain ANSPs, etc.) to whom to turn for specific questions, was highlighted as a positive provision, which could be enhanced further in future.

Overall, the CF funding scheme was positively evaluated by the projects. CF recipients requested the retention of such a scheme in the SESAR 3 programme. One suggestion was to allow project durations longer than one year, to allow more time for publication and dissemination (as in many areas of ATM it is often impossible to publish a paper in less than a year). This would have to be assessed against the principle of refreshing the thematic challenges during the lifecycle of the KTN, as was part of the executed plan, although all the original challenges in wave 1 were ultimately retained in wave 2 of the funding Engage 1 KTN D2.7 [5]. Although slightly larger next stage funding rounds (e.g. EUR 150k), aimed at conducting small-scale validation exercises, were suggested by some projects, this is currently not permissible under EU framework rules.

3.2.1.6 Research enablers

3.2.1.6.1 Open access to scientific publications and research data¹¹

Research results obtained in the SESAR programme are of broad interest and based on public funding; they should hence be made freely available to the research community as well as industrial or institutional stakeholders. The principles of open access to Horizon publications and data are laid out by the European Commission¹².

In contrast to open publication standards, many journals and conferences are commercially oriented, selling access to research publications such as conference papers and journal articles. This leads to the somewhat ironic situation that authors have to acquire the ‘privilege’ to distribute articles they have written and submitted to a journal, often paying four-digit amounts per article. This clearly is an impediment to open access to research results and should be (largely) discouraged. A number of vehicles for open access publication are available. We suggest that the following recommendations are made to research projects involving public funding, including SESAR 3.

(a) Open access to publications

Each beneficiary ensures open access to all peer-reviewed scientific publications relating to the results of the research project. The main mechanism for this will be ‘green’ open access (self-archiving), where the beneficiaries deposit an electronic copy of the peer-reviewed and accepted manuscript in an online repository, typically no later than one month after its publication. To this end:

- all scientific publications should be available for download from the project website;
- the project should publish results in scientific conferences with an established policy of making all articles freely available for download on the conference website;
- project members are encouraged to publish articles they have authored or co-authored on appropriate archiving platforms, such as ResearchGate¹³ and ZENODO¹⁴;
- publications being hosted by a KTN repository are also encouraged.

In other cases, the project may budget for ‘gold’ open access publications and project results may be submitted to scientific journals that (otherwise) charge the research community for these articles either on a per-access basis (or by selling gold open access). This includes regular journal submissions as well as articles in special issues. In this case, the project should acquire gold open access for the articles it produces, but this option should be reserved for particular cases, with clearly allocated

¹¹ It should be noted that Engage 2 has further elaborated on these results of the Engage 1 KTN and has already delivered in April 2024 a dedicated deliverable on that subject: D5.24 “Engage 2 Open Science Strategy”.

¹² For example, https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/open-science/open-access_en

¹³ <https://www.researchgate.net/>

¹⁴ <https://zenodo.org/>

budgets at the proposal stage, rather than being the norm. It is noted that academic institutions may have special relationships with publishers and specific journals, and/or national requirements for research publication may drive more material through one pathway (such as gold open access) than another. Gold open access may sometimes be complicated by cost ineligibility after project closure, since publication processes can be protracted.

(b) Open access to research data

Research data is information (particularly facts or numbers) collected to be examined and considered, and to serve as a basis for reasoning, discussion or calculation, especially with a view to reproducing the results and conclusions in peer-reviewed scientific publications. Upon publication of a peer-reviewed scientific article the underlying datasets should be examined with a view to the possibility of making them available to the research community, either through the project website or using appropriate vehicles such as OpenAIRE¹⁵, or the publishing journal itself. Mindful of the need to avoid resource duplication, vehicles such as the Engage wiki may also be valuable for deposits of data and/or code.

3.2.1.6.2 Data and code issues

Further to the preceding discussion, data availability is a well-recognised bottleneck in exploratory research. It is often difficult to obtain, and the same dataset often cannot be used in multiple projects. This is a barrier to improving experimental comparability across projects. Many projects and/or PhDs lose approximately 6-12 months (or more) in trying to obtain (and consolidate and clean) data, and this was a recurring theme throughout the Engage 1 KTN thematic challenge workshops.

Different types of data are required across ER work. Some of the data can be obtained freely (e.g. from the relatively new, and extensive, EUROCONTROL archive of Aviation Data for Research¹⁶, launched at the 2020 Engage summer school; ADS-B data from the OpenSky Network¹⁷), some need to be paid for (e.g. schedule data, passenger itineraries and fares), and 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 data acquisition. In most cases, some sort of licensing and non-disclosure agreement is required. In practice, this prevents data sharing, even if the input data used is just a small subset of the full set of obtained data. In some cases, the results of the research can be shared, but without the input data used, such that it is difficult to achieve comparability and reproducibility. Sometimes, non-disclosure agreements are linked to confidentiality/privacy issues, but this could be resolved through anonymisation, or even non-disclosure clauses.

One solution may be the creation of a framework to share ATM-relevant data (including MET data), to afford easier access without having multiple agreements in place. This would require the provision of centralised licencing for certain commercial data (and/or the creation of synthetic datasets for the

¹⁵ <https://www.openaire.eu/>

¹⁶ <https://www.eurocontrol.int/dashboard/rnd-data-archive>

¹⁷ <https://opensky-network.org/>

ATM community). Any such activity should be coordinated with EUROCONTROL, and considered in conjunction with its data archive. Centralised commercial data licencing, e.g. across the SESAR 3 ER programme, could be a very effective and time-saving device for researchers, although likely to present several challenges in implementation.

(a) Synthetic training data for ML models

Synthetic data is a particular issue for ML models. These require large data sets for training, testing and validation. In many instances, existing datasets are insufficient to satisfy this data hunger, especially when rare events, such as air traffic conflicts are studied. An additional problem lies in the fact that often real-life (or simulated) data are not clean. Identifying conflict geometries based on aircraft positions derived from SSR or ADS-B data is hindered by the fact that flight planning, flow restrictions and ATC interventions have already eliminated the overwhelming majority of conflicts, the very object of observation. For these and other reasons, the use of artificial datasets for the training of machine learning systems holds some promise, especially since datasets of almost unlimited size may be produced. Different ways of generating such artificial training datasets may be imagined, including cloning, rotating existing data, introducing white noise or generating traffic data with fast-time simulators. Admittedly, these methods have their specific risks as the data so generated differ from ‘real’ observations in a systematic or stochastic way, which may lead to a bias or lower statistical power due to ‘noisy’ data. Approaches regarding how to augment the dataset for the training of ML systems and guidelines for understanding the benefits and disadvantages of the different approaches would be useful.

(b) Common European Mobility Data Space

It is also worth flagging in this context the joint initiative of DG MOVE and DG CNECT, regarding the Common European Mobility Data Space. This initiative aims at unlocking the potential of mobility data for both passengers and cargo. The goal is to create a common European data space for mobility, that would “facilitate access, pooling and sharing of transport and mobility data, building on existing and future initiatives” [6]. The first Call for European Digital Innovation Hubs was launched on 17 November 2021 as a preparatory action for the common European mobility data space (through a Coordinated and Support Action (CSA)), to identify mobility data sharing initiatives, gaps, overlaps and potential common building blocks. The Common European Mobility Data Space will also have an impact on air traffic mobility data management, and could open up new research, mobility and business possibilities.

3.2.1.6.3 Community collaboration

Throughout all the Engage 1 KTN workshops, the need for, and benefits of collaborations (on different topics) continued to appear. The following topics of collaboration were identified in various TC workshops:

- There was considerable interest to get involved in, and create, a **SESAR cybersecurity community**. This interest should be nurtured and used to maintain the good momentum for the cybersecurity community, as there is a risk of losing this 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, required further development. This would need agreement with all the stakeholders in order to find common approaches and show the benefits of new methods and approaches. A dedicated community spanning ER and IR research would be particularly appropriate in this context, thus building links between the SESAR Performance Framework development and Exploratory Research.
- Climate change issues have been somewhat less represented in the SESAR programme when compared to wider European research. Climate change research topics and measurements rely not only on CO₂, but also non-CO₂ 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). This could also form the basis of a dedicated community for collaboration across disciplines.

3.2.1.7 Building further in SESAR 3: conclusions

3.2.1.7.1 Research directions

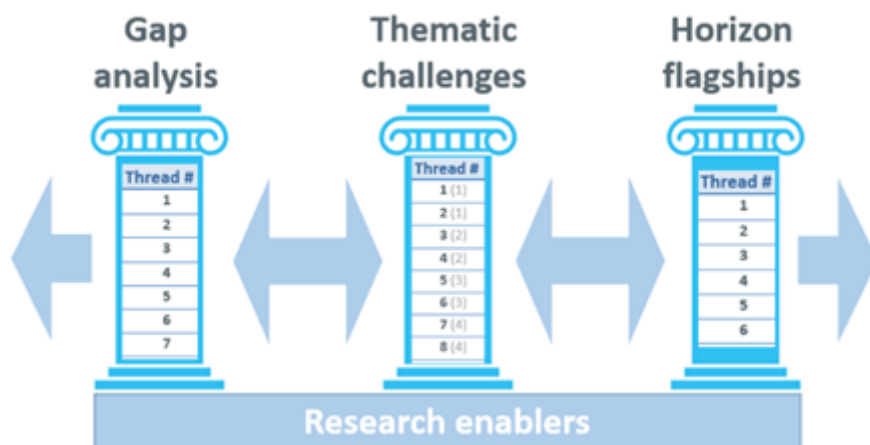


Figure 3: Research pillars, threads and enablers

Figure 3 shows the Engage 1 KTN’s three research pillars. Each pillar may be conceived of as comprising various ‘threads’, i.e. their key component research ideas, and these threads are summarised in the Appendix in Section 7.5. The pillars are shown in 2D, although they conceptually lie along three non-orthogonal axes. There are many relationships between the threads that may be explored further, using a mixture of qualitative (expert-led) and quantitative (data-driven) approaches.

Engage found that an initial qualitative analysis was likely to bring new insights and synergies. (Note that many of the threads in the gap analysis and thematic challenge pillars, for example, are related

to even just the first two threads of the horizon flagships, *viz.* quantum computing and strong AI). It was expected, and suggested, that other interdisciplinary insights and technical advances be brought into this landscape, both to help navigate and shape it, and to provide the tools for its development through new R&I.

From the data-driven perspective, the search space that the axes define is a rich environment for exploring future research, for example using the multi-dimensional vectorisation approach for the gap analysis, using an auto-encoder (unsupervised ML) model. This environment and such activities may be supported by the research enablers described in the previous section (several of which themselves require further research activity and development), and of course by other enablers. Table 9 summarizes the research threads for the gap analysis pillar and the relationships with SRIA flagships. Table 10 puts the research threads for the thematic challenges pillar in relation with SRIA flagships.

Having set the scene and furnished a wealth of ideas for follow-on research, the Engage 1 KTN recommended that such priorities could be best assessed with an expert-led parallel review of projects funded through the SESAR 2020 ER4 and SESAR 3 ER1 Calls. On-going work such as the Innovation Hub initiative from EUROCONTROL should also be consulted for potential collaborative opportunities and inspiration.

Through the Engage wiki, the research community has at its disposal ready-made fora for supporting such future ideation and knowledge exchange, a repository in which to store data and code, and a roadmap into which future results may be integrated. The wiki's interactive research map may also be used as a preliminary tool to search the research space. New work initiatives could be taken up through Engage 2's new thematic challenges, with supporting catalyst fund projects and PhDs, and matured through a further series of workshops. Table 11 relates the research threads for the horizon flagships pillar (as introduced in Section 3.2.1.3) to the SRIA flagships.

Some of the practicalities for taking such work forward, and our recommendations for the supporting platforms, are presented in the next section.

3.2.1.7.2 Research platforms

Sources of project data – consolidation and recency

The value of a single source of regularly updated data, with analytical functionality, also embracing the wider ATM research environment received strong endorsement from the user community. Such data should, in future, include not only catching up with SESAR 2020 (e.g. ER4), but move forward to projects funded through SESAR 3 Calls, and material from other non-SESAR industrial research programmes, and maintain the main conference materials already encompassed. Other open access papers could also be added. Such data could be incorporated into the Engage wiki's interactive research map and ATM concepts roadmap.

Underpinning this, extended periods of time were needed by the Engage 1 KTN to complete the task of sourcing and preparing materials, to resolve underlying data provision issues (e.g. resolving initial legal constraints on accessing SESAR 1 deliverables). The preparation of corresponding metadata was largely a manual task (see D3.9 [7] Sections 2-4); and GDPR affected how information from the wiki

tools could be displayed (e.g. ensuring the removal of personal names from keywords) as well as the publication of deliverables in the wiki's repository. This took up a huge amount of effort and resources for the Engage 1 KTN consortium in particular, and for SJU colleagues in support.

In D3.9 [7] Section 3, the Engage 1 KTN also discussed a number of issues relating to processing the (SESAR) PDF documents. These variously related to header, footer, cover pages, font formats, text information in images, proper names being mistaken as keywords by automated tools, and lists of references placed through the deliverable content, rather than at the end of deliverables. Future work, in SESAR 3, could define an improved reporting format, including systematic key word indexing, to achieve a compromise between convenience of reporting and automated analyses, with a shift more towards the latter, thus better enabling future analyses, similar to those presented herein.

Further challenges identified to be overcome include obtaining such deliverables in a timely fashion (sometimes there is a significant period between initial submissions (which themselves are often delayed) and final approval, thus permitting public release), and the incentive or requirement for projects to make such deliverables available directly to a third party (such as a KTN). This means that there were currently some inevitable gaps in the analysis of Section 3.2.1.1, for example, due to the incomplete set of data directly available as inputs into the process. Whilst the Engage 1 KTN's repository contains materials as recent as 2021, most of the identified weakest links in the gap analysis related to work delivered around 2016. This was of course aligned with the objective of looking at retrospective gaps, whilst underlining the need for expert interpretation of the algorithmic outputs.

Wiki registration and security

Deliverable D3.9 [7] presented lessons learned relating to wiki user registration and participation, plus protection from external (bot) attack and the secure, remote storage of files on Amazon Web Services. Complementarily to this, the Engage wiki hosting and domain were both secured with sufficient longevity to hand over all licensing and access control to Engage 2 in SESAR 3.

Wiki discussion fora

Through several activities described in D3.9 [7], it was recommended that the wiki discussion fora be further deployed to gather sufficient momentum to become hubs for various communications and discussions in SESAR 3. Examples mentioned are hosting discussions around specific technical sessions of the SESAR Innovation Days or to encourage inter-project researcher collaboration across a SESAR 3 research topic (e.g. multimodality), even integrating across ER-IR on specific issues.

Format and implementation of virtual workshops

Due to the Covid-19 pandemic, many of the Engage 1 KTN's workshops were operated as virtual events. Virtual activities naturally reduce 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 was some reporting of user 'saturation' with such virtual events in general, 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 Engage 1 KTN 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 1 KTN summer school and the fourth workshop of thematic challenge 2: ‘AI, ML and Automation’ in September 2021).
- 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 1 KTN 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. S3JU) 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 by the Engage 1 KTN 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.

3.2.2 Trends from non-SESAR research

The Engage 1 KTN has conducted a targeted review of research papers from diverse origins, encompassing deliverables from EU projects, and contributions to SESAR Innovation Days and FAA & Eurocontrol ATM Seminars, all prior to the cut-off date (mid-2021). These results have been presented in the previous section.

This deliverable takes previous work further by looking at research articles published at the SIDS from 2021 to 2023 and the ATM Seminar in 2021 and 2023. These conferences published a total set of 225 papers that were filtered for relevance.

The filtering step followed the goal to narrow down the scope to articles specifically relevant to our research focus of identifying new trends, which lead to the exclusion of reports from ongoing (Exploratory) SESAR research projects, as these are considered following a well established roadmap that is well understood and will most likely not point out new trends.

The resulting set of the research articles (133) was mainly characterised by their acknowledged funding sources either being national funding agencies within the EU not connected to SESAR or funding sources outside the EU. Table 4 gives an overview of the number of papers being analysed.

Conference	Total number of papers in the conference	Candidate papers	Papers with new trends
SIDS 2021	37	16	1 (#87)
SIDS 2022	51	19	5 (#76, #77, #90, #98, #106)
SIDS 2023	42	25	3 (#39, #64, #76)
ATM Seminar 2021	54	41	0
ATM Seminar 2023	41	32	0
<i>Total</i>	<i>225</i>	<i>133</i>	<i>9</i>

Table 4: Research papers in 2021 - 2023 analysed for trends

The candidate set of papers and related observations are shown in more detail in the Annex in Section 7.2. The main observations are listed below, also citing the reference to the paper and the conference:

- Virtualization & virtual centres (SIDS-2021-87)
- Cooperative conflict resolution (SIDS-2022-76)
- Climate optimal routing and contrail avoidance (SIDS-2022-77)
- Vigilance and skill retention (SIDS-2022-90)
- Non-CO2 emissions and contrail avoidance (SIDS-2022-98)
- Emission reduction (SIDS-2022-106)
- Explainability of AI based automated systems (SIDS-2023-39)
- Floating sectors (SIDS-2023-64)
- Space traffic (SIDS-2023-76)

These trends are taken over to the Annex in Section 7.1 that captures all trends identified by the different analysis sources.

3.2.3 Trends identified in national funding schemes

In the vast landscape of scientific research and innovation, a limited view on a few selected national funding schemes (AT, CH, UK) can provide an alternative angle on research initiatives outside ATM:

- One such topic is the **circular economy**, an economic system aimed at eliminating waste and the continual use of resources. This model is designed to benefit businesses, society, and the environment. It is underpinned by a transition to renewable energy sources, the maximisation of the usage of a variety of resources, and the redefinition of products and services to minimise waste.
- Another area of focus is **zero-emissions mobility**, a concept that aims to reduce the environmental impact of transportation. This involves the development of vehicles that emit no exhaust gases from the onboard source of power, contributing to cleaner air and a healthier planet.
- In the realm of computing, **quantum computing** is a rapidly emerging field. Quantum computers leverage the principles of quantum mechanics to process information. They hold the promise of solving complex problems that are currently beyond the reach of classical computers. Research programmes related to quantum computing are further differentiated into sub-domains, e.g.:
 - The concept of a quantum-enabled economy explores an economy that harnesses the power of quantum technologies across various sectors. This includes everything from quantum computing to quantum sensing and quantum cryptography.
 - Researchers are already looking beyond quantum computing, exploring post-quantum cryptography and other technologies that could potentially outperform quantum computers.
 - Finally, the intersection of quantum and space research is another exciting frontier. This involves the application of quantum technologies to space exploration and astronomy, potentially leading to breakthroughs in our understanding of the universe.

- The field of transportation is also set to be revolutionised with **hypersonic transport**, a type of travel where vehicles move at speeds significantly faster than the speed of sound. This could drastically reduce travel times, making it possible to reach any destination in the world in just a few hours.

These topics represent just a snapshot of the exciting developments being funded and explored today.

3.3 AI-based Trend Analysis

3.3.1 Background and generative AI capabilities

AI of different forms has been gaining more and more traction in the last 20 years, but the popularity of 'generative AI' ('GenAI') grew rapidly in November 2022 when OpenAI released their new version of a chat AI called 'ChatGPT 3.0'. Its popularity immediately pushed other companies to release their own version of a chat AI, in particular Google and Amazon. Even if several concerns have been raised since then, in particular in terms of reliability, the datasets involved in training, etc, this technology has been flagged as the most promising path to general artificial intelligence (see also Section 3.2.1.3.2 Strong AI), and has found many applications. Moreover, in just a year and half, several new features have been added to the tools, including image recognition and generation, text and speech recognition, information retrieval etc.

These AIs are all using pre-trained transformers for their models, a new architecture for artificial neural networks that shows great promise. These models are statistical in nature, trying to predict, bit by bit (token by token) the text that they need to print in order to answer to a prompt. This prediction is made based on a larger dataset of texts and prompts, produced beforehand. Hence, the model itself does not have any kind of logic engine and has one natural limitation: it can produce unreliable information, also known as 'hallucinations'.

However, by nature, these models are good at communicating in natural languages (and other types of languages, like programming languages...), and are particularly suitable at synthesising text, extracting particular strands of information for the users. This makes them useful for many academic applications, in particular when researchers try to summarise information based on previously published academic papers, i.e. performing a literature review.

Because basic generative models are limited in their access to outside information, in particular information coming from academic papers, some degree of specialisation is needed before using them for this purpose. There is typically two ways to specialise a GenAI:

- Fine-tuning: in this case, the user can partially retrain the AI to better answer some specific questions.
- Information retrieval: in this case, the AI is able to use another piece of software when it needs to retrieve information.

The first one requires a major effort, because the user has to produce some dataset, in general in the forms of 'prompts->answers' format in order to retrain the model. This can be very time intensive,

and is usually used for ‘superalignment’, i.e. to change behaviour of the model. For instance, an AI trained school teaching should not produce any violent output.

The second possibility is in general more light-touch, in particular because the information retrieval piece of software itself is provided by the company developing the GenAI, e.g. OpenAI. An example of that is Microsoft using an information retrieval system on top of ChatGPT to power its Bing search engine: the user can ask a question to ChatGPT when they are using Bing, which processes it and uses the information retrieval system to look for answers on indexed web pages.

This information retrieval system can also be much simpler, and the mainstream version of ChatGPT allows the uploading of different types of text-based files, after which the user can ask the AI some questions about the text. The AI is also able to pinpoint the file and the exact location in the file in which it retrieved some pieces of information. This opens the way to more reliable information retrieval with GenAI, while keeping the “creative” aspect of the AI, which may be able to extrapolate and synthesise ideas better than human experts would do.

Based on this notion, some GenAI have been specialised for academic purposes. One of these tools, SciSpace, is the one that we are going to use. It is based on a ChatGPT engine, with a powerful information retrieval system that is able to look into a massive database of academic articles (and patents).

In this deliverable, we want to leverage the power of GenAI to see if we are able to forecast the main trends in air transportation in the next decades, based on findings and information from academic papers and other general documents.

3.3.2 Objectives for the AI-based trend analysis

Our goal is thus the following:

- To test the ‘forecasting’ capabilities of GenAI for air transportation.
- To see how much the predictions can be back-linked to academic papers and other references.

In order to do this, we selected **ChatGPT** as our general purpose GenAI model, and **SciSpace**¹⁸ for our literature review specific needs. The results obtained and shown in Section 3.3.3 have been obtained either with ChatGPT 4¹⁹ or 3.5-turbo²⁰ (the best ones available at the time of the analysis). ChatGPT 3.5-turbo (that will be called 3.5 in this deliverable) is far cheaper than the 4.0 version and was thus used when high numbers of prompts were required. Note that we also checked other models at the beginning of the analysis, in particular the paid-for version of Google’s Gemini AI, and Claude 2.

¹⁸ <https://typeset.io/>

¹⁹ <https://openai.com/index/gpt-4/>

²⁰ <https://help.openai.com/en/articles/8555514-gpt-3-5-turbo-updates>

ChatGPT was selected for its ease of use with uploaded documents. We used the web-based premium account as well as the API version.

SciSpace was selected across a few other similar tools for its perceived reliability in the results it gave, based on preliminary tests. SciSpace is powered by ChatGPT, although it is not clear which version is used, even with the premium account (that allows more requests).

In this deliverable we will refer to the web-based or API based model as ChatGPT and to the specialised model as SciSpace.

In order to use the creative power of ChatGPT and the academic information retrieval power of SciSpace, we used the following workflow:

1. Ask ChatGPT about technological trends in air transportation in the next 30 years.
2. Ask ChatGPT to put a likeliness of appearance of each technology.
3. For each technology, ask ChatGPT which stakeholder would be impacted, positively and negatively.
4. For each technology, each stakeholder, and each impact, ask SciSpace to back up ChatGPT's claims with academic papers.

We then asked ChatGPT to consolidate the information. In particular, in this deliverable, we show three type of results:

- a consolidated list of technology trends for the future (in Section 3.3.3.1),
- a consolidated literature review on one technology, encompassing all the impact on stakeholders (in Sections 3.3.3.2 et seq.).
- A consolidated Excel file showing ALL results from the extensive literature review made with ChatGPT and SciSpace (further details provided in Section 7.6).

Added to this analysis, we used ChatGPT to consolidate another list of technological trends for the future, based on other documents. Indeed, after the analysis, ChatGPT released a new version of their information retrieval system where the user could upload up to 10000 documents (compared to 20 before). Hence, we were interested in uploading documents that contain important information on the potential future of air transportation, in particular regarding the single sky initiative.

For this list, we transformed 311 pdf documents which have been published since the gap analysis conducted by the Engage 1 KTN (see Section 3.2.1.1) into text-based files and uploaded these to a ChatGPT Assistant, an instance of ChatGPT that can be used with an API, datasets, and be deployed afterwards if needed. The files we uploaded consisted of:

- SJU master plan (2020 edition, [10])
- Deliverables from SESAR (89)
- Articles from the SIDs (130)
- Articles from ATM Seminars (92).

We then asked exactly the same question (regarding trends) to this assistant. The answer is presented and discussed below.

Note that in this deliverable, our goal was not to provide the ‘best’ AI-based trend analysis, but to see if the tools were able to produce interesting results without too much editing. One could in principle go further and have better quality results by:

- Using prompt engineering to have better results overall, in particular when the AI gives generic answers.
- Producing several answers with the same prompts and asking for consolidated results.
- discuss the answers with the AI, asking for the logic behind this and reprompting it.
- Adjusting the hyper parameters of the models.
- Having more tailored questions for some prompts²¹.
- Using memory features from AI to carry information across conversations.

3.3.3 Results from the AI-based trend analysis

3.3.3.1 Technology Trends

When prompted without any context, ChatGPT listed the following technologies to be important in the next 30 years²², with the likelihoods shown in parentheses after each entry:

- **Electric Aircraft (80-90%):** the push for greener and more sustainable aviation solutions is driving the development of electric aircraft. These aircraft promise reduced carbon emissions, lower operating costs, and quieter flights, addressing environmental concerns and regulatory pressures.
- **Autonomous Aircraft (70-80%):** Autonomous technology can increase safety, reduce human error, and improve operational efficiency. With advancements in AI and machine learning, autonomous aircraft could revolutionize cargo transport and eventually passenger travel.
- **Supersonic Jets (60-70%):** Supersonic jets can drastically reduce travel times, making long-distance travel more convenient. Advances in materials and aerodynamics are overcoming previous limitations related to noise and fuel efficiency.
- **Drones (90-95%):** Drones are already transforming cargo and logistics, providing cost-effective solutions for last-mile delivery. Their use in surveillance, infrastructure inspection, and even passenger transport is expected to grow.
- **3D Printing (80-90%):** 3D printing allows for rapid prototyping, customized manufacturing, and the creation of complex parts with reduced waste. This technology can lead to more efficient production processes and lighter, stronger aircraft components.
- **Advanced Air Traffic Management Systems (85-95%):** As air traffic increases, advanced management systems will be crucial for maintaining safety and efficiency. These systems can optimize flight paths, reduce delays, and manage autonomous and traditional aircraft in shared airspace.

²¹ For instance, we were asking ChatGPT the stakeholders that would be impacted by “Quantum Computing”. But without previous context, the AI doesn’t know that it is related to air transportation anymore and lists irrelevant stakeholders. This can be easily fixed by providing some context for every prompt.

²² Slightly edited answer from ChatGPT, only merging the likelihood question with the first question on technologies.

- **Virtual Reality (VR) (80-90%):** VR can enhance pilot training, providing immersive and realistic simulation environments. It also has potential applications in passenger entertainment and remote maintenance support.
- **Quantum Computing (50-60%):** Quantum computing offers unprecedented computational power, enabling complex simulations, optimization of flight routes, and advancements in material science. It could revolutionize problem-solving in aerodynamics and logistics.
- **Blockchain (70-80%):** Blockchain technology ensures secure and transparent data sharing across the aviation industry. It can enhance supply chain management, improve maintenance record-keeping, and streamline passenger identity verification.
- **Internet of Things (IoT) (90-95%):** enables real-time monitoring and communication between aircraft systems, ground control, and maintenance teams. This connectivity can improve predictive maintenance, enhance passenger experiences, and optimize operations.
- **Hyperloop (40-50%):** While primarily a ground transportation concept, the hyperloop could complement air travel by offering ultra-fast connections between airports and city centers. It can reduce congestion and integrate seamlessly with air transportation networks.
- **Space Travel (50-60%):** The commercialization of space travel could lead to new opportunities for long-distance travel and even point-to-point suborbital flights. Advancements in space technology can also trickle down to benefit traditional aviation.
- **Advanced Materials (80-90%):** Development of advanced materials such as carbon composites and meta-materials can lead to lighter, stronger, and more efficient aircraft. These materials can improve fuel efficiency, reduce maintenance costs, and enhance overall performance.

3.3.3.2 Stakeholders impacted (example)

ChatGTP can list the stakeholders that would be impacted by each technology. Below is an example for the Electric Aircraft technology²³:

1. **Aircraft Manufacturers:** They are directly involved in the design and production of electric aircraft, requiring adaptation to new technologies, materials, and manufacturing processes.
2. **Airlines:** Airlines are key customers of electric aircraft, and they must consider factors such as operating costs, range, and infrastructure support when incorporating these new aircraft into their fleets.
3. **Passengers:** Passengers may benefit from potentially lower airfares and reduced noise pollution, but they might also experience changes in flight routes, durations, and overall travel experience.
4. **Airports:** Airports need to update their infrastructure to support electric aircraft, including charging stations and maintenance facilities, which can involve significant investment.
5. **Aircraft Maintenance Companies:** Maintenance protocols and skills need to adapt to new electric propulsion systems, battery maintenance, and other unique features of electric aircraft.

²³ This answer has not been edited, except for removing the introductory and conclusion sentence.

6. **Electric Battery Manufacturers:** They play a crucial role in developing high-density, reliable, and safe batteries to power electric aircraft, driving advancements in battery technology.
7. **Electric Motor Manufacturers:** Electric aircraft require advanced electric motors, prompting manufacturers to innovate and improve efficiency, power-to-weight ratios, and reliability.
8. **Aviation Fuel Suppliers:** They may face reduced demand as electric aircraft reduce reliance on traditional aviation fuels, necessitating a strategic shift or diversification.
9. **Air Traffic Control:** Air traffic controllers need to adapt to new flight characteristics of electric aircraft, including different performance metrics and potentially altered flight patterns.
10. **Government Regulatory Bodies:** Regulatory bodies must establish new certification standards, safety protocols, and regulations specific to electric aircraft operations and maintenance.
11. **Environmental Agencies:** These agencies are interested in the potential environmental benefits of electric aircraft, such as reduced carbon emissions and noise pollution, supporting sustainability goals.
12. **Local Communities near Airports:** Local residents may benefit from reduced noise pollution and improved air quality, but they may also be concerned about changes in airport operations and infrastructure.
13. **Tourism Industry:** Electric aircraft could affect tourism by potentially lowering travel costs and reducing the environmental impact of air travel, making destinations more attractive to eco-conscious travellers.
14. **Freight and Cargo Companies:** These companies need to evaluate the feasibility of electric aircraft for cargo transport, considering factors like range, payload capacity, and operational costs.
15. **Pilot and Crew Unions:** Unions need to address the training and certification requirements for pilots and crew to operate electric aircraft, as well as potential changes in job roles and conditions.
16. **Aerospace Engineers:** Engineers are at the forefront of developing and optimizing electric aircraft technology, including aerodynamics, propulsion, and materials science.
17. **Renewable Energy Providers:** They may see increased demand for renewable energy sources to power electric aircraft and associated airport infrastructure, fostering growth in this sector.
18. **Investors and Shareholders in Aviation Industry:** Investors need to consider the financial implications and opportunities of transitioning to electric aircraft, including potential returns and risks.
19. **Insurance Companies:** They must develop new risk assessment models and insurance products tailored to the unique characteristics and potential risks associated with electric aircraft.
20. **Research and Development Institutions:** R&D institutions are crucial for advancing electric aircraft technology, conducting research on batteries, electric motors, aerodynamics, and other key areas.
21. **Aviation Training Institutes:** These institutes must update their curricula and training programs to prepare the next generation of pilots, engineers, and maintenance personnel for electric aircraft technology.

3.3.3.3 Examples of positive/negative impacts

ChatGPT is also able to explain why it includes the stakeholders in the list. For instance, when prompted to explain the positive and negative impact of Electric Aircraft on Freight and Cargo Companies, the following output was obtained²⁴:

Positive impacts:

- This could also improve their public image and attract customers who value environmentally friendly practices.
- This could allow for more flexible flight schedules, including at night, which could improve efficiency for freight and cargo companies.
- Maintenance: Electric aircraft have fewer moving parts than traditional aircraft, which could potentially lead to lower maintenance costs and less downtime.

Negative impacts:

- This could limit their usefulness for long-haul freight and cargo flights.
- Freight and cargo companies would need to invest in this infrastructure or rely on third parties to provide it.
- This could limit the amount of cargo that can be transported on each flight, potentially increasing costs.
- There may be unforeseen technical challenges or regulatory hurdles that could delay or prevent the widespread adoption of electric aircraft by freight and cargo companies.
- This could be a significant barrier to entry for some companies.

3.3.3.4 Examples of literature review

After positive and negative impacts have been listed by ChatGPT, SciSpace can produce a literature review of each of them. What follows is an example of literature review on the impact of Electric Aircraft on the Freight and Cargo Companies stakeholders. The references can be found in the supplement as described in the annex in Section 7.6. The following text has been generated with SciSpace independently for each impact, and collated together with ChatGTP, with minor edits.

Electric aircraft offer significant benefits for freight and cargo companies. They provide a more sustainable and environmentally friendly transportation option, reducing greenhouse gas emissions and noise pollution [5695²⁵] [5696]. The integration of electric aircraft in regional air mobility can enhance efficiency, affordability, and community-friendly transportation, especially for short-distance routes served by smaller local airports [5697]. Additionally, the use of electric aircraft can lead to cost savings, as they operate from short runways and can leverage renewable energy sources like solar

²⁴ The bullet points are unedited, except for the introductory and conclusion sentences.

²⁵ The reference numbers in this section refer to source documents as listed in the Excel supplement. For further details please refer to Section 7.6.

power for charging, potentially reducing operational costs for freight and cargo companies [5698]. Despite facing technical challenges, the development of electric aircraft is progressing, offering the potential for freight and cargo companies to benefit from cleaner and more sustainable transportation solutions in the future [5699].

Electric aircraft offer numerous benefits for freight and cargo companies, positively impacting their public image and attracting environmentally conscious customers. By transitioning to electric propulsion systems, these companies can significantly reduce emissions, noise pollution, and operating costs, while enhancing safety and maintenance efficiency [5700] [5701]. The adoption of electric aircraft technology can lead to substantial environmental improvements, aligning with global sustainability goals and showcasing a commitment to eco-friendly practices. Moreover, the use of electric propulsion systems can potentially revolutionize ground operations, such as implementing electric landing gear drive systems, further reducing fuel consumption and emissions during taxiing and ground handling processes [5702]. This shift towards electric aircraft not only benefits the environment but also enhances the overall sustainability and attractiveness of freight and cargo companies to environmentally conscious consumers.

Electric aircraft offer several positive impacts for freight and cargo companies, including the potential for more flexible flight schedules, especially at night, leading to improved operational efficiency. By transitioning to electric propulsion systems, aircraft can operate with reduced noise levels, benefiting both the environment and communities around airports [5703]. Additionally, the adoption of electric aircraft can significantly decrease greenhouse gas emissions, contributing to a cleaner and more sustainable transportation sector [5704] [5705]. Moreover, the advancements in power electronics and electric machines play a crucial role in enhancing safety, efficiency, power density, and power quality of electric airplanes, ensuring reliable and cost-effective operations for freight and cargo companies [5706] [5707].

Electric aircraft offer significant benefits in terms of maintenance for freight and cargo companies. By transitioning to electric propulsion, these companies can reduce maintenance costs associated with traditional fuel-powered engines, as electric motors have fewer moving parts and require less maintenance overall [5708] [5709]. Additionally, electric aircraft produce lower noise levels, which can lead to reduced wear and tear on components, further decreasing maintenance needs [5710]. Moreover, the integration of electric/hybrid-electric aircraft in regional air mobility (RAM) services can enhance the efficiency and affordability of transportation, potentially transforming regional airports into zero-emission hubs that support various modes of electric vehicles, including freight and cargo operations, with renewable electricity [5711]. This shift towards electric aviation not only benefits the environment but also offers tangible advantages in terms of maintenance for freight and cargo companies.

The transition to electric aircraft in the aviation industry presents challenges that could limit their usefulness for long-haul freight and cargo flights for freight and cargo companies. Electric airplanes face technical hurdles such as electric power increase, voltage bus increase, and the need for wide bandgap devices to overcome these challenges [5712] [5713]. While advancements are being made, the current limitations in battery technology may restrict the range of electric aircraft, making them less suitable for long-haul flights, especially in the near future [5714]. Additionally, the efficiency and

power density of electric airplanes are crucial factors that need to be optimized to meet the demanding requirements of long-haul freight and cargo operations [5715] [5716].

Electric aircraft adoption in the freight and cargo industry may pose challenges for companies in terms of infrastructure investment. As the aviation sector transitions towards electrification to reduce greenhouse gas emissions, freight and cargo companies would need to invest in the necessary electrical infrastructure to support electrified aviation [5717]. This includes onsite distributed energy resources like solar photovoltaics and battery energy storage systems. Additionally, the shift to electric aircraft requires advancements in technology, such as improved battery specific energy, to increase aircraft range [5718]. The electrification of aircraft, whether through more-electric, hybrid electric, or all-electric frameworks, necessitates efficient generation, distribution, and consumption of electric power, highlighting the importance of power electronics and electrical machines in ensuring aviation safety [5719][5720]. Freight and cargo companies may need to adapt to these changes by either investing in their infrastructure or relying on third parties for support in the electrified aviation era.

The transition to electric aircraft could potentially limit the amount of cargo that can be transported on each flight, leading to increased costs for freight and cargo companies. This limitation arises due to the challenges associated with electric airplane electrification, such as the need to overcome technical hurdles like electric power increase and voltage bus increase [5721] [5722]. Additionally, the electrification of aircraft systems, including propulsion and secondary systems, can impact the overall cargo capacity and efficiency of electric airplanes [5723] [5724]. As advancements in electric aircraft technology progress, the trade-off between passenger capacity and cargo capacity may become a critical factor for freight and cargo companies to consider when adopting electric aircraft for their operations [5725].

The adoption of electric aircraft in freight and cargo companies may face challenges that could hinder widespread implementation. Technical hurdles such as the increase in electric power demand and voltage bus requirements, as discussed in [5726] [5727], pose significant obstacles. Additionally, the integration of wide bandgap (WBG) devices and power electronics, highlighted in [5728] [5729], is crucial yet complex. Regulatory barriers and safety concerns related to power electronics, efficiency, and power quality, as emphasized in [5730], further complicate the transition to electric aircraft for freight and cargo operations. Overcoming these challenges will be essential to ensure the successful and timely adoption of electric aviation in the freight and cargo industry.

The transition to Electric Aircraft could pose significant barriers for Freight and Cargo Companies due to several reasons. Firstly, the current limitations in battery technology may restrict the range of all-electric aircraft, limiting their capacity for long-haul cargo transportation [5731]. Additionally, the high requirements of aviation safety in terms of power generation, distribution, and consumption necessitate efficient power electronics and electrical machines, which can be challenging to implement in electric aircraft systems [5732] [5733]. Moreover, the need for advancements in electric power increase and voltage bus increase, along with overcoming technical challenges like noise pollution and safety concerns, may further complicate the adoption of electric aircraft for freight and cargo operations [5734]. These factors collectively highlight the potential obstacles faced by companies in the freight and cargo industry looking to transition to Electric Aircraft.

3.3.3.5 Comparison with ChatGPT fed with SESAR documents

In this case, we asked ChatGPT to provide 15 technologies, but this time using the documents uploaded, related to SESAR in general. The output was as per the following²⁶:

1. **Urban Air Mobility Technologies:** Including VTOL and PATS categories, and particularly eVTOL technology, are considered crucial for Urban Air Mobility【4:0†source】²⁷.
2. **Electric Propulsion:** Essential for achieving zero emission goals by 2050 and will be applied to various modes of transport, including air transportation【4:0†source】.
3. **Automation:** Important for increasing the efficiency and flexibility of public mass transport systems【4:0†source】.
4. **Multimodal Transport:** Enabling integration and coordination of different modes of transport through data exchange for improved efficiency and sustainability【4:0†source】.
5. **Autonomous Transport:** Requiring communication as an enabler for integration and coordination between different modes of transport for efficiency and sustainability【4:0†source】.
6. **Digitalization:** Key enabler for sustainable and efficient future transportation systems, allowing for optimization at the ecosystem level【4:1†source】.
7. **Infrastructures Integration:** Supporting seamless door-to-door mobility in urban and suburban environments through evolutionary approaches【4:2†source】.
8. **Passenger-Centric Approach:** Putting passenger needs and desires at the center of future solutions, introducing the concept of passenger trajectory【4:2†source】.
9. **Ground Surveillance Service:** Utilizing vehicle reports such as ADS-B and eID for position reporting using cellular networks【4:3†source】.
10. **Artificial Intelligence:** Necessary for the operational concept of ATM service for passengers in intermodal transport, making mobility safer, more ecological, and more efficient【4:3†source】.
11. **LTE/4G and 5G Networks:** Providing essential connectivity for future air transportation systems, with 5G introducing new service classes and capabilities like network slicing【4:3†source】.
12. **mmWave Radar:** Future research is recommended for deployment at airports and further enhancement of machine learning algorithms for classification to improve radar performances【4:4†source】.
13. **Network Slicing:** Significant for dividing networks into virtual slices with different features, which will aid in enhancing connectivity and services for air transportation systems【4:3†source】.
14. **Edge Computing:** Allowing for lower latency and increased computational capacity, crucial for future air transport applications requiring real-time data processing【4:3†source】.

²⁶ This answer has not been edited, except for removing the introductory and conclusion sentence.

²⁷ † sources:

4:0: 891061-X-TEAM_D2D-D1.2-export.txt
4:1: 891061-X-TEAM_D2D-D1.2-export.txt
4:2: 891061-X-TEAM_D2D-D1.2-export.txt
4:3: 894616-FACT-D1.3-export.txt
4:4: 893917-NewSense-D6.2-export.txt

15. **U-space Integration:** The role of UTM (U-space) will increase to support D2D mobility and reach a mature state by 2050, crucial for integrating air mobility means into urban and suburban mobility solutions【4:2†source】.

In this case, ChatGPT is more specific in terms of technology, and is able to give sources directly from the SESAR documents that we uploaded. However, it is less able to capture big trends and new technologies (such as quantum computing). Moreover, it cites only five sources, which seem fairly marginal compared to the general goal of the question.

Sources:

- 【4:0†source】: 891061-X-TEAM_D2D-D1.2-export.txt
- 【4:1†source】: 891061-X-TEAM_D2D-D1.2-export.txt
- 【4:2†source】: 891061-X-TEAM_D2D-D1.2-export.txt
- 【4:3†source】: 894616-FACT-D1.3-export.txt
- 【4:4†source】: 893917-NewSense-D6.2-export.txt

4 Results

In the previous section we have detailed the process to identify candidate trends from various sources. Now we will put these different sets together and reduce the results into a short list. This section is split into two sub-sections. The first, "Synthesis of Findings", compiles all the data we gathered into understandable results. The second, "Critique and Evaluation", examines these results in detail. It verifies their accuracy and dependability and discusses what they signify in the larger context.

4.1 Synthesis of Findings

Through a variety of sources, we have compiled a comprehensive list of 86 potential trends. A detailed enumeration of these candidates can be found in the Appendix, specifically in Table 7 (refer to Section 7.1). As outlined in the Methodology section (see Section 2), we implemented a filtering process that correlates these trend candidates with prominent research activities, as delineated in key strategic documents (SESAR SRIA 2020 [11], Clean Aviation SRIA [12]). A synopsis of this correlation is presented in Table 5.

Strategic research activities	Number of trends
SRIA Flagship #1	11
SRIA Flagship #2	6
SRIA Flagship #3	9
SRIA Flagship #4	3
SRIA Flagship #5	5
SRIA Flagship #6	5
SRIA Flagship #7	6
SRIA Flagship #8	8
SRIA Flagship #9	1
Other activities identified in SRIA	5
Clean Aviation	5

Table 5: Mapping trend candidates to strategic research activities

The filtering process²⁸ reduced the total number of trend candidates from 86 to 27. These 27 will be looked at more closely in the next sections. Out of the 59 trend candidates that were successfully mapped, 54 were linked to existing research streams in the SESAR 2020 SRIA [11]. The other 5 trend candidates were linked to activities in Clean Aviation [12].

4.1.1 Common themes and trends

Following the mapping process, which resulted in the elimination of 59 trend candidates, the remaining 27 trend candidates underwent a clustering process. Based on an interpretation of their brief identification text, the trend candidates were grouped together to pinpoint prevalent themes and patterns.

This step led to the definition of five distinct trend clusters:

- Talent Management & Development Challenges
- Societal Perspectives & Evolving Attitudes to Aviation
- Academia-Industry: Transition & Adaptations
- Aviation Industry & Workforce Transformation
- Broader Technological Trends

The first trend cluster primarily focuses on strategies to enhance the sector’s appeal as a workplace. The second cluster concentrates on the public’s perception of the sector. The interaction between academia and industry and its impact on the sector is the focus of the third clusters. Cluster four groups trends in the area of transformations within the sector’s industry. The final cluster, the fifth, encapsulates a wide range of both group and individual technology trends.

Table 6 presents information on the different trend clusters and enumerates the potential trends identified in the initial stages of trend analysis.

Cluster ID	Trend Cluster	Trend Identification
C-1	Talent Management & Development Challenges	<ul style="list-style-type: none"> ● Competition for talent (with other sectors) ● Hiring and retaining staff ● Reaching out to new generation ● Training and reskilling ● Financial burden for sector specific education
C-2	Societal Perspectives & Evolving Attitudes to Aviation	<ul style="list-style-type: none"> ● Social attitudes to aviation ● Evolution of the societal point of view (needs, constraints)

²⁸ Please note that some of the trend candidates have been mapped to multiple SRIA flagships.

Cluster ID	Trend Cluster	Trend Identification
C-3	Academia-Industry: Transition & Adaptations	<ul style="list-style-type: none"> ● Interaction between industry and academia ● Staff transition between industry and academia ● Curriculum adaptation for sector needs
C-4	Aviation Industry & Workforce Transformation	<ul style="list-style-type: none"> ● Policy & regulation ● Workforce preparation for contributions to innovation acceleration ● Digitalisation vs. workforce reduction ● Adaptability to change ● Vigilance and skill retention vs. higher levels of automation ● Hypersonic transport ● CNS innovations (mmWave Radar, Network Slicing)
C-5	Broader Technological Trends	<ul style="list-style-type: none"> ● New computing techniques, e.g. quantum computing²⁹, edge computing ● Open science & open source SW & knowledge transfer ● Virtual reality (VR) ● Circular economy ● 3D printing ● Eco and sustainable design

Table 6: Trend Clusters

The process of identifying potential trends and their corresponding designations often results in a broad range of interpretations. This is due to the inherent subjectivity and complexity involved in trend analysis, especially when merging inputs from many different sources and streams. The deliverable produced, therefore, provides a preliminary understanding of these trends, serving as a springboard for further exploration. It intentionally leaves room for subsequent activities to delve deeper into these interpretations, fostering a more comprehensive and nuanced understanding of the trends in question. This approach ensures a dynamic and evolving comprehension of trends, accommodating the diverse perspectives that may arise in the process. We also note that the clusters are not entirely mutually exclusive, i.e. with some overlap between them, although we have tried to minimise this as much as practicable.

²⁹ Quantum computing was the only trend candidate that appeared in three different sources.

4.1.2 New research topics derived from trends

The trend analysis resulted in two clusters, namely C-4 “Aviation Industry & Workforce Transformation” and C-5 “Broader Technological Trends”, that captured inputs that have some potential to lead to new research topics. As indicated earlier capturing only headlines with a few words during the analysis stage leaves a high degree of interpretation which also has the potential that later stages in the Engage 2 project will deliver these interpretations where appropriate.

In C-4 we grouped the following trends:

- a) Policy & regulation
- b) Workforce preparation for contributions to innovation acceleration
- c) Digitalisation vs. workforce reduction
- d) Adaptability to change
- e) Vigilance and skill retention vs. higher levels of automation
- f) Hypersonic transport
- g) CNS innovations (mmWave Radar, Network Slicing)

C-5 contains these trends:

- a) New computing techniques, e.g. quantum computing, edge computing
- b) Open science & open source software & knowledge transfer
- c) Virtual reality (VR)
- d) Circular economy
- e) 3D printing
- f) Eco and sustainable design

4.1.3 Implications on workforce derived from trends

This section gives a first interpretation of the trends captured during the trend analysis phase.

Based on the trends captured in the trend cluster C-1 titled “Talent Management & Development Challenges”, we can derive several implications on the workforce in the sector:

- a) Based on the demographic development, the competition for human resources will become more intense and therefore career paths for employees must be presented more clearly than before. This can best be achieved if there is cooperation in this regard that spans the entire sector and also includes training institutions to the same extent as industrial companies and professional associations.
- b) Fluctuating personnel requirements in the past and the resulting job insecurity have shown that unfavourable working conditions in the sector (e.g. shift work) can have an impact to the extent that employees move to other areas at the first sign of a deterioration in the situation.
- c) A joint effort is needed to attract the younger generations to work in the sector. This starts early on in school education and must also include the further stages of education and training.

- d) Due to the transformation in the sector, employees need to be continuously trained and familiarised with new processes and technologies.
- e) Some work profiles of the sector require intensive training programmes and certification, and the resulting financial burden can turn interested parties away to other sectors.

The implications above already limit the numbers of individuals interested in the sector. However, additional challenges are outlined in cluster C-2, which provides a societal perspective:

- a) The general public views the aviation sector with some scepticism because, on the one hand, the popularity of air travel is on the rise, but at the same time negative environmental effects are being perceived.
- b) Alternative travel options are increasingly desired and the social pressure to avoid air travel is growing.

When looking at job profiles that require an academic education, cluster C-3 summarizes some aspects that highlight implications on future workforce:

- a) Better institutional support is needed to enable training that is as practice-orientated as possible in cooperations between academic institutions and industrial partners.
- b) The transition of staff between academic institutions and the industry, particularly in the air traffic management sector, is desirable as it fosters a symbiotic relationship where academia can provide innovative, research-based solutions to real-world challenges, while industry experience can offer practical insights and applications to enrich academic learning and research.
- c) An exchange between academia and industry is necessary to ensure that the training programmes are adapted to new operational and technical developments in a timely manner.

4.2 Critique and Evaluation

One of the strengths of our approach is the wide-ranging analysis of different sources in order to identify trends that could be highly relevant to the air traffic management sector. We analysed structured surveys conducted both directly by the project and by other initiatives in the sector. It also built on results that had already been compiled in the predecessor project KTN 'Engage 1'. The part of the scientific publications that was published after the end of the predecessor project was analysed for new trends in a further activity. Particular attention was paid to identifying those research activities that were conducted outside of the European SESAR programme, as a measure to avoid a certain European bias. In addition, new methods of trend analysis were used, which created a complementary list of trends based on the same source materials with the help of artificial intelligence.

4.2.1 Methodological limitations and biases

As defined in the Description of the Action, we used questionnaires as tools to capture inputs from stakeholders. It turned out that despite various efforts to improve response rates only few responses could be captured within the available time span. We understand the accuracy of survey data is heavily dependent on the sample size, and generalizations can be dangerous:

Firstly, a small sample size may not be representative of the larger population. This is because it's less likely to capture the full range of variability within the relevant stakeholders. Secondly, results from small surveys are more susceptible to random error. This means that the results could be influenced by chance factors that aren't representative of the larger population. And lastly, small surveys can be more vulnerable to bias. As the stakeholder groups contacted by our project to respond will most likely share common characteristics, the results may be skewed in a particular direction.

In conclusion we must assume that our results have certain limitations and need to be used with care in the downstream activities.

4.2.2 AI-based trend analysis

The work performed with ChatGPT and SciSpace in Section 3.3 allows us to compare this approach, and the outputs, with the traditional survey and literature review described in Section 3.1 and 3.2.

4.2.2.1 Limitations

Overall, the technologies and trends highlighted by the first version (without SESAR documents uploaded) make sense, even if they are somewhat generic. We are in particular interested to see that it flagged technologies such as quantum computing which only few reports have so far linked to air transportation. This proves that AI may be a valuable tool to generate ideas about what the future.

It has been shown also that AI is able to go deeper into the analysis, not only acting as an automatic tool that lists keywords but can also explain in this instance who would be impacted by the technology and why. We would also argue that the likelihood of appearance given by the AI makes sense qualitatively but did not add much information. These likelihoods are thus more indicative in nature, and would be of more value in future if combined with expert views, for example, thus drawing together some of the methodologies of this deliverable (generative AI and expert opinion).

The SciSpace tool is definitely a nice addition but is insufficient. Indeed, it is not able to cite seminal papers and gets focused on details rather than trying to present the bigger picture. On top of this, SciSpace cites only 5 articles maximum per abstract, even if it also gives a list of references that can be a lot bigger (see the main Excel file, Section 7.6). We would argue that the tool is better at acting like a discovery for new articles rather than to draw a good picture of the state of the art.

When uploading SESAR documents, ChatGPT may be able to go through them quite efficiently. It is able to extract main information from documents, even though we believe it gets too focused on marginal topics, like 'LTE/4G and 5G Networks'. Moreover, it seems sometimes a bit more focused on actual specific technologies rather than on big trends, even though it is able to cite Urban Air Mobility and Passenger-Centric Approach. Interestingly, it did not mention quantum computing in this case, probably because no documents mentioned it. Hence, a limitation we see in this case is that when prompted to take into account some documents, it might be hard for the AI to also take into account other general knowledge like the one it exhibited in the instance.

Moreover, although the answers make sense, the citation process seems flawed, with only a handful of sources cited for technologies. The citations are also highly inconsistent when asked the same question several times, posing the question of the reliability of the citation process. It looks like the tool actually processes the documents but struggles to link back to them properly.

Finally, we highlight an important issue when using LLMs: the output is stochastic, i.e. different answers can be obtained from the same prompts. This can be modified by adjusting the model's parameters, the temperature and the 'nucleus sampling' ('top-p'). Both are interrelated and linked to the randomness and the creativity of the model. For instance, a low temperature will make the model more coherent, while a low top-p will make the model less creative. In this deliverable we haven't changed the default parameters, but we believe that they could be chosen more carefully, for instance:

- Using high top-p with low temperature for trend forecasting might be useful for having good creativity for future trends, while keeping coherence high.
- Once the technologies are set, it might be useful to experiment with smaller top-p values in order to have more reliable and deterministic assessment of the impact on each stakeholder.

4.2.2.2 Possible improvements

The methodology presented here is quite crude. First, some of the stakeholders listed by the AI were unrelated to air transportation (but related to the technology) because of the way some prompts were constructed, and the fact that we used memory-less models (i.e. they didn't remember the previous questions, in particular the one regarding the technology). Some simple fixes to the prompts could avoid most of these issues.

The automatic process of asking SciSpace for a literature review is also quite inefficient, for instance because some stakeholders are clearly the same across technologies, but their names differ slightly. To fix this, we could ask ChatGPT to review the list of stakeholders, consolidate it, and link them back to the corresponding technologies. This is not so easy because of the high number of stakeholders but should be feasible.

In this methodology, there is no back and forth between ChatGPT and SciSpace. Indeed, one could in principle automatically download some references presented by SciSpace, upload them to ChatGPT, then ask ChatGPT to review its answer for each impact.

In this deliverable we used SciSpace on the answer from the ChatGPT that didn't know anything about the SESAR documents³⁰. We would like to perform a comparative analysis to see if SciSpace would be able to complement the initial sources, or even overlap with them. We then use the iterative process explained above on top of that.

4.2.2.3 Further notes

In this deliverable we have used existing tools to see if we could leverage easily (and quickly) the LLMs that already exist for literature review and trend analysis. Another possibility is to use more low-level tools, for instance clustering techniques combined with transformers to make automatic text analysis. This requires more effort but could lead to more robust trend forecasting for instance.

Another side product of the generative AI-based trend analysis is that ChatGPT instances with memory and databases can be used and deployed afterwards (for instance the one we used for this deliverable), which means that anybody could query them to dive deeper into the references, the

³⁰ This is because OpenAI allowed only 20 files to be uploaded until around mid-May, which was not suitable for the amount of SESAR documents we wanted to use.

stakeholders, etc. This could prove a great tool to interface with a common knowledge database in the future. However, we would advise against this currently, because the models of this generation are not objective-led, i.e. they have no problem answering *any* kind of question. For instance, the AI we used for listing the stakeholders can also be used for any other task, such as debugging a code in Python. This problem is called ‘super-alignment’ and is an on-going research domain in AI. We thus recommend ‘re-using’ such outputs only in a future context whereby the tools have improved, whilst noting again that this is a very rapidly maturing domain.

4.3 Next steps

The key next steps for this activity include:

- Complementing results from Task 3.1, this deliverable serves as an input to the skills transformation map being developed within Task 4.2: *Study pathways for skills and career development*.
- These results also feed activities in WP5. The AI-based trend analysis has prepared the groundwork for Task 5.1: *ATM concepts roadmap*. The trends and findings will feed the second selection cycle of Task 5.2: *Thematic challenges*. Later reporting in D5.1 will also include a discussion on how the identified trends relate to the updated thematic challenges.

5 References

- [1] CANSO in cooperation with Firstfruits, 2024. Future Skies: Tomorrow's Voices, survey report, Unpublished Draft, April 2024, personal communication.
- [2] EUROCAE WG125 & EASA, 2024. White Paper NGAP Connectors, Unpublished Draft, April 2024, personal communication.
- [3] Engage 2 project, 2023. Description of the Action (DoA) Part A, Edition 8.0, May 2023.
- [4] Engage project, 2022. D3.10 Research and innovation insights, Edition 01.00.00, August 2022.
- [5] Engage project, 2021. D2.7 Annual combined thematic workshops progress report (series 3), Edition 01.01.00, November 2021.
- [6] European Commission, 2021. European Commission, DG MOVE and DG CNECT, Workshop on a common European mobility data space, organised by the European Commission, November 2021.
<https://digital-strategy.ec.europa.eu/en/activities/work-programmes-digital>
- [7] Engage project, 2022. D3.9 The Engage wiki - an update on the KTN's knowledge hub functionality, research maps and repository, Edition 01.01.00, August 2022.
- [8] PJ19 (Content Integration), 2018. D4.0.050 Guidance to Apply SESAR Safety Reference Material, Edition 00.03.01, December 2018.
[https://www.sesarju.eu/sites/default/files/documents/transversal/SESAR_2020 - Guidance to Apply the SESAR2020 Safety Reference Material.pdf](https://www.sesarju.eu/sites/default/files/documents/transversal/SESAR_2020_-_Guidance_to_Apply_the_SESAR2020_Safety_Reference_Material.pdf)
- [9] SESAR Joint Undertaking, 2019. A proposal for the future architecture of the European airspace, February 2019.
https://www.sesarju.eu/sites/default/files/2019-05/AAS_FINAL.pdf
- [10] Single European Sky ATM Research 3 Joint Undertaking, European ATM master plan – Digitalising Europe's aviation infrastructure – Executive view – 2020 edition, Publications Office, 2019, <https://data.europa.eu/doi/10.2829/10044>
- [11] Single European Sky ATM Research 3 Joint Undertaking, Strategic Research and Innovation Agenda Digital European Sky, September 2020,
https://www.sesarju.eu/sites/default/files/documents/reports/SRIA_Final.pdf
- [12] Clean Aviation Joint Undertaking, Strategic Research and Innovation Agenda, December 2021,
https://www.clean-aviation.eu/sites/default/files/2022-01/CAJU-GB-2021-12-16-SRIA_en.pdf
- [13] [Single European Sky ATM Research 3 Joint Undertaking, European ATM Master Plan – 2024 edition, June 2024 draft.](#)

6 List of acronyms

Acronym	Description
AAM	Advanced Air Mobility
ADS-B	Automatic dependent surveillance – broadcast
AI	Artificial intelligence
ANSP	Air navigation service provider
ATM	Air traffic management
CANSO	Civil Aviation Navigation Services Organisation
CF	Catalyst fund
CNS	Communication navigation surveillance
CSA	Coordinated and Support Action
DoA	Description of the Action
EACCC	European Aviation Crisis Coordination Cell
EASA	European Union Aviation Safety Agency
ER	Exploratory research
EU	European Union
eVTOL	Electric Vertical Take-Off and Landing
FAA	Federal Aviation Administration
FCFS	First-Come First-Served
GDPR	General Data Protection Regulation
IATA	International Air Transport Association
IR	Industrial research
KPI	Key performance indicator
KTN	Knowledge Transfer Network
MaaS	Mobility as a Service
MET	Meteorology
ML	Machine learning
NGAP	Next Generation of Aviation Professionals
R&I	Research and innovation
S3JU	SESAR 3 Joint Undertaking

SAF	Sustainable Aviation Fuel
SES	Single European Sky
SESAR	Single European Sky ATM Research Programme
SIDS	SESAR Innovation Days
SJU	SESAR Joint Undertaking
SRIA	Strategic Research and Innovation Agenda
SSR	Secondary Surveillance Radar
TC	Thematic challenge
TRL	Technology readiness level
UAM	Urban air mobility
UAS	Unmanned aircraft system
UTM	UAS traffic management

7 Appendix

7.1 Table of Trends

According to our approach, we have gathered potential trends from a variety of sources for this task. The document text includes a summarization and grouping of these trends. We utilize the appendix to present an exhaustive list of all potential trends, along with links to sections that offer further details about their origins.

Trend	Description	Source section	Filtering / Comment
T-01	Virtual/augmented reality	3.1.1	covered by SRIA flagship #8
T-02	Integration of drones	3.1.1	covered by SRIA flagship #4
T-03	Data communication	3.1.1	covered by SRIA flagship #1
T-04	Automation as well as AI&ML	3.1.1	covered by SRIA flagship #1, #8
T-05	Sustainability and green propulsion systems	3.1.1	covered by SRIA flagship #1
T-06	Information security	3.1.1	Security covered as transversal topic in SRIA
T-07	Flying above stratospheric altitudes	3.1.1	Covered by SRIA flagship #3 (“HAO”)
T-08	Climate change and weather forecasts	3.1.1	covered by SRIA flagship #7
T-09	Data-based operations and flight execution	3.1.1	covered by SRIA flagship #5
T-10	Passenger experience	3.1.1	covered by SRIA flagship #6
T-11	Administrative and bureaucratic burden to manage future air traffic	3.1.1	Covered by SRIA “Better regulations”
T-12	Highly automated environments	3.1.1	covered by SRIA flagship #1
T-13	Competition for talents	3.1.1	Cluster C-1
T-14	Social attitudes towards aviation	3.1.1	Cluster C-2

T-15	Hiring and retaining staff	3.1.1	Cluster C-1
T-16	Reaching out to new generation	3.1.1	Cluster C-1
T-17	Training and reskilling	3.1.1	Cluster C-1
T-18	Financial burden for sector specific education	3.1.1	Cluster C-1
T-19	Human factors and HMI	3.1.2	covered by SRIA flagship #8
T-20	New aircraft designs	3.1.2	Covered by Clean Aviation JU
T-21	Digital twin for all life cycle aspects	3.1.2	covered by SRIA flagship #2
T-22	New materials	3.1.2	Covered by Clean Aviation JU
T-23	New computing techniques, e.g. quantum	3.1.2	Cluster C-5
T-24	Eco- and sustainable design	3.1.2	Cluster C-6
T-25	Open science & open source SW & knowledge transfer	3.1.2	Cluster C-5
T-26	Digital communication	3.1.2	covered by SRIA flagship #1
T-27	Green aviation & transition	3.1.2	covered by SRIA flagship #7
T-28	Increased automation, increased machine to machine communication, increased dependency on GNSS and satellite-based services	3.1.2	covered by SRIA flagship #1, #2
T-29	Flexibility to adapt to requirements	3.1.2	Partially covered by SRIA flagship #3
T-30	Free routes and TBO	3.1.2	covered by SRIA flagship #3
T-31	Ground and airborne high level of automation	3.1.2	covered by SRIA flagship #1, #2
T-32	Civil-military coordination	3.1.2	covered by SRIA flagship #9

T-33	Human role in environment with an increasing level of complexity and automation	3.1.2	Partially covered by SRIA flagship #8
T-34	Infrastructure development	3.1.2	covered by SRIA flagship #1, #2
T-35	Multi-modal regulation	3.1.2	Partially covered by SRIA flagship #6
T-36	Evolution of the societal point of view, needs and constraints	3.1.2	Cluster C-2
T-37	Policy & regulatory	3.1.2	Cluster C-4
T-38	Interaction between industry and academics	3.1.2	Cluster C-3
T-39	Transition between academic programs and industry	3.1.2	Cluster C-3
T-40	Workforce preparation for contributions to innovation acceleration	3.1.2	Cluster C-4
T-41	Environmental protection	3.1.2	covered by SRIA flagship #7
T-42	Curriculum adaptation to sector needs	3.1.2	Cluster C-3
T-43	Digitalization vs workforce reduction	3.1.2	Cluster C-4
T-44	Adaptability to change	3.1.2	Cluster C-4
T-45	Less human resources in ATM due to automatization and AI	3.1.2	covered by SRIA flagship #8
T-46	Virtualization & virtual centres (SIDS-2021-87)	3.2.2	covered by SRIA flagship #5
T-47	Cooperative conflict resolution (SIDS-2022-76)	3.2.2	covered by SRIA flagship #3
T-48	Climate optimal routing and contrail avoidance (SIDS-2022-77)	3.2.2	covered by SRIA flagship #7
T-49	Vigilance and skill retention (SIDS-2022-90)	3.2.2	Cluster C-4

T-50	Non-CO2 emissions and contrail avoidance (SIDS-2022-98)	3.2.2	covered by SRIA flagship #7
T-51	Emission reduction (SIDS-2022-106)	3.2.2	covered by SRIA flagship #7
T-52	Explainability of AI based automated systems (SIDS-2023-39)	3.2.2	covered by SRIA flagship #8
T-53	Floating sectors (SIDS-2023-64)	3.2.2	covered by SRIA flagship #3
T-54	Space traffic (SIDS-2023-76)	3.2.2	covered by SRIA flagship #3 ("HAO")
T-55	Circular economy	3.2.3	Cluster C-6
T-56	Zero-emissions mobility	3.2.3	covered by SRIA flagship #7
T-57	Quantum computing	3.2.3	Cluster C-5
T-58	Hypersonic transport	3.2.3	Cluster C-5
T-59	Electric Aircraft	3.3.3.1	Covered by Clean Aviation JU
T-60	Autonomous Aircraft	3.3.3.1	covered by SRIA flagship #2
T-61	Supersonic Jets	3.3.3.1	Mentioned in SRIA flagships
T-62	Drones	3.3.3.1	covered by SRIA flagship #4
T-63	3D Printing	3.3.3.1	Cluster C-6
T-64	Advanced Air Traffic Management Systems	3.3.3.1	Covered by SRIA
T-65	Virtual Reality (VR)	3.3.3.1	Cluster C-5
T-66	Quantum Computing	3.3.3.1	Cluster C-5
T-67	Blockchain	3.3.3.1	covered by SRIA flagship #5
T-68	Internet of Things	3.3.3.1	Mentioned in SRIA but without further details
T-69	Hyperloop	3.3.3.1	covered by SRIA flagship #3 & #6

T-70	Space Travel	3.3.3.1	covered by SRIA flagship #3
T-71	Advanced Materials	3.3.3.1	Covered by Clean Aviation JU
T-72	Urban Air Mobility Technologies	3.3.3.5	covered by SRIA flagship #3
T-73	Electric Propulsion	3.3.3.5	Covered by Clean Aviation JU
T-74	Automation	3.3.3.5	covered by SRIA flagship #1
T-75	Multimodal Transport	3.3.3.5	covered by SRIA flagship #6
T-76	Autonomous Transport	3.3.3.5	covered by SRIA flagship #2
T-77	Digitalization	3.3.3.5	covered by SRIA flagship #5
T-78	Infrastructures Integration	3.3.3.5	covered by SRIA flagship #5
T-79	Passenger-Centric Approach	3.3.3.5	covered by SRIA flagship #6
T-80	Ground Surveillance Service	3.3.3.5	covered by SRIA flagship #1
T-81	Artificial Intelligence	3.3.3.5	covered by SRIA flagship #8
T-82	LTE/4G and 5G Networks	3.3.3.5	covered by SRIA flagship #1
T-83	mmWave Radar	3.3.3.5	Cluster C-5
T-84	Network Slicing	3.3.3.5	Cluster C-5
T-85	Edge Computing	3.3.3.5	Cluster C-5
T-86	U-Space Integration	3.3.3.5	covered by SRIA flagship #4

Table 7: Summary of trends identified within the document

7.2 Table of Research Documents

This table lists research documents from the SIDs and the USA/Europe ATM Research and Development Seminar in the time span from 2021 to 2023 that have been published after the end of Engage 1. Based on the acknowledged funding institution, papers citing non-SESAR funds have been analysed for future trends. The resulting shortlist is described in more detail in Section 3.2.2 above.

Document Identifier	Document Title	Funding acknowledged (or Engage 2 assumption)	Identified trend (unexpected, outside range of usual topics)
SIDS-2021-72	ANSP Measures of Flight Descent Performance	Airservices Australia (self-funded)	–
SIDS-2023-25	Investigating Transparency Needs for Supervising Unmanned Air Traffic Management Systems	China Scholarship Council	–
SIDS-2021-56	Modeling the European Air Transportation Network considering inter-airport coordination	EUROCONTROL contract	–
SIDS-2021-64	Are All the Requested Air Traffic Flow Management Regulations Actually Indispensable?	EUROCONTROL (self-funded)	–
SIDS-2021-65	Prediction of Flight Departure and Arrival Routes with Gradient Boosted Decision Trees	EUROCONTROL (self-funded)	–
SIDS-2021-87	Capacity sharing within Virtual Centre	EUROCONTROL contract	Virtual Centres / Virtualization
SIDS-2022-082	Predicting Airport ATFM Regulations using Deep Convolutional Neural Networks	SESAR 2020 and EUROCONTROL	–
SIDS-2022-101	Agent-based modeling to support collaborative decision making in predictable airport ground operations	EUROCONTROL contract	–

SIDS-2023-01	Modelling the Likelihood of Air Traffic Management Regulations due to Weather at Airports	EUROCONTROL (self-funded)	–
SIDS-2023-53	PETA: Combining Machine Learning Models to Improve Estimated Time of Arrival Predictions	EUROCONTROL (self-funded)	–
SIDS-2021-04	Improved Sensing and Positioning via 5G and mmWave radar for Airport Surveillance	SESAR 2020 and Academy of Finland	–
SIDS-2022-061	Use of 5G and mmWave radar for positioning, sensing, and line-of-sight detection in airport areas	SESAR 2020 and Academy of Finland	–
SIDS-2023-28	LTE Mobile Network Technical Feasibility for Unmanned Aerial Vehicle BVLOS operations in a Rural Test Area	Academy of Finland and ERDF	–
SIDS-2023-39	Bringing Explainability to Autoencoding Neural Networks Encoding Aircraft Trajectories	French partners	Explainability of AI based automated systems
SIDS-2021-69	Maximum total range of eVTOL under consideration of realistic operational scenarios	German partners	–
SIDS-2022-022	Apron Controller Support by Integration of Automatic Speech Recognition with an Advanced Surface Movement Guidance and Control System	SESAR 2020 and German Federal Ministry of Education and Research	–
SIDS-2022-081	Take-off Support Lights: A Pilot Support System for Super Close Runway Operations (SupeRO)	DLR (self-funded)	–
SIDS-2022-098	When do contrails cool the atmosphere?	TU Dresden (self-funded)	non-CO2-emissions, contrails
SIDS-2023-32	Arrival Time Management in real weather conditions	German Research Foundation contract	–

SIDS-2021-63	Qualitative and quantitative risk assessment of urban airspace operations	SESAR 2020 and Horizon 2020	–
SIDS-2021-91	BADA eVTOL Performance Model for UTM Traffic Simulation and Analysis	Horizon 2020	–
SIDS-2022-068	Grammar Based Speaker Role Identification for Air Traffic Control Speech Recognition	SESAR 2020 and Clean Sky 2	–
SIDS-2022-074	Speech and Natural Language Processing Technologies for Pseudo-Pilot Simulator	SESAR 2020 and Clean Sky 2	–
SIDS-2022-092	Autonomous Drones to Ensure Safety in Transport: Concept and Implementations	Horizon 2020	–
SIDS-2023-73	Evaluating Transatlantic Flight Emissions and Inefficiencies Using Space-Based ADS-B Data	Horizon Europe	–
SIDS-2023-15	Time-Minimal Aircraft Trajectory in the Presence of Unsteady Wind by Shape Optimization	Hong Kong University Grant Council	–
SIDS-2023-62	Urban Perspectives on UAVs Infrastructure Development	Italian partners	–
SIDS-2021-47	Safety Optimization of a Layered Airspace Structure with Supervised Learning	TU Delft (self-funded)	–
SIDS-2021-70	Quantifying Accuracy and Uncertainty in Data-Driven Flight Trajectory Predictions with Gaussian Process Regression	TU Delft (self-funded)	–
SIDS-2022-067	A Tactical Conflict Resolution Method for UAVs in Geovectored Airspace	TU Delft (self-funded)	–
SIDS-2022-076	Lateral and Vertical Air Traffic Control Under Uncertainty Using Reinforcement Learning	TU Delft (self-funded)	cooperative conflict resolution

SIDS-2022-077	Examining Contrail Formation Models with Open Flight and Remote Sensing Data	TU Delft (self-funded)	climate optimal routing - contrail
SIDS-2022-090	Gamification for Increased Vigilance and Skill Retention in Highly Automated Air Traffic Control	TU Delft (self-funded)	Vigilance and Skill Retention
SIDS-2022-106	Evaluating Aviation Emission Inefficiencies and Reduction Challenges with Electric Flights	Dutch Ministry of Foreign Affairs and Dutch Research Council	emission reduction
SIDS-2022-107	Preliminary Design and Capacity Study of Automatic Dependent Surveillance for Drones	TU Delft (self-funded)	–
SIDS-2023-04	Using Relative State Transformer Models for Multi-Agent Reinforcement Learning in Air Traffic Control	TU Delft (self-funded)	–
SIDS-2023-05	Policy Analysis of Safe Vertical Manoeuvring using Reinforcement Learning: Identifying when to Act and when to stay Idle	TU Delft (self-funded)	–
SIDS-2023-10	Contrail Altitude Estimation Based on Shadows Detected in Landsat Imagery	TU Delft (Climate Action Seed Fund Grant)	–
SIDS-2023-21	Sector Traffic Balancing Using Tactical Demand Tailoring	Dutch partners	–
SIDS-2022-050	How European Travellers Make Decisions Regarding Airport Access Mode Choice	SESAR 2020 and Serbian Ministry of Education, Science and Technological Development	–
SIDS-2021-85	A Machine Learning Framework for Predicting ATC Conflict Resolution Strategies for Conformal Automation	National Research Foundation and Civil Aviation	–

		Authority of Singapore	
SIDS-2021-100	Regulating arrival UAV flows between the AirMatrix and the droneport using a dynamic carousel circuit	Civil Aviation Authority of Singapore	–
SIDS-2022-087	Air Traffic Flow Representation and Prediction using Transformer in Flow-centric Airspace	National Research Foundation and Civil Aviation Authority of Singapore	–
SIDS-2023-12	Aircraft Landing Time Prediction with Deep Learning on Trajectory Images	National Research Foundation and Civil Aviation Authority of Singapore	–
SIDS-2023-56	A Machine Learned Traffic Flow Coordination Framework for Flow-Centric Airspace	National Research Foundation and Civil Aviation Authority of Singapore	–
SIDS-2023-60	Enhancing Airside Monitoring: A Multi-Camera View Approach for Aircraft Position Estimation for Digital Control Towers	National Research Foundation and Civil Aviation Authority of Singapore	–
SIDS-2023-64	Introduction of moving sectors for flow-centric airspace management	National Research Foundation and Civil Aviation Authority of Singapore	Floating sectors
SIDS-2023-76	Integrated Air and Space Traffic Management: An Agent-Based	Singaporean National	space traffic

	Simulation for Analysis of Space-Launch Impact on Air Traffic	Research Foundation	
SIDS-2021-66	A Tree-based Machine Learning Model for Go-around Detection and Prediction	Saab-NTU Joint Lab (self-funded) and Saab AB	–
SIDS-2021-78	Variable Taxi-Out Time Prediction Using Graph Neural Networks	Saab-NTU Joint Lab (self-funded) and Saab AB	–
SIDS-2023-22	Impact of USSPs performance in shared U-space volumes	Spanish Ministry of Science and Innovation	–
SIDS-2023-27	Use of Convective Indices to Improve the Prediction of Departure Delays	Spanish Ministry of Science and Innovation	–
SIDS-2023-67	A machine learning approach for predicting airport passenger flows	Spanish Ministry of Economic Affairs and Digital Transformation and NGEU	–
SIDS-2021-101	Towards a Comprehensive Characterization of the Arrival Operations in the Terminal Area	Swedish Transport Administration and Swedish Transport Agency	–
SIDS-2022-080	Mapping the Decision-Making Process of Conflict Detection and Resolution in En-Route Control: An Eye-tracking based approach	Swedish Transport Administration	–
SIDS-2022-085	Digital Tower Assistant Functionality and Design - Planning, Analysis and Operative Interfaces based on Workshops with ATCOs	Swedish Transport Administration	–
SIDS-2023-58	Arrival Optimization with Point Merge in a Dual-runway Environment	Swedish Transport Administration	–

SIDS-2023-66	Mercury: an open source platform for the evaluation of air transport mobility	UoW (self-funded)	–
SIDS-2023-40	Weather-Aware Integrated Air Traffic Management Technology Development	MIT and NAV CANADA	–
SIDS-2023-68	Systematic Approach to Assessing the Readiness of a Technology for Safe and Effective Human Use: Opportunities to Integrate Human Readiness Levels (HRLs) in Federal Aviation Administration (FAA) Research, Acquisition, and System Development Processes	Federal Aviation Administration and NextGen	–
ATM-2021-085	Measuring the resilience of airline operation networks	National Natural Science Foundation of China	–
ATM-2023-029	STL combining LSTM for long-term predicting airport traffic flow	National Natural Science Foundation of China	–
ATM-2023-062	Slot allocation for a Multiple Airport System: Equity and Efficiency	National Natural Science Foundation of China	–
ATM-2021-024	Mid-air collisions with drones: Assessment of collision scenarios and of drone operation risks in urban areas	Horizon 2020	–
ATM-2021-014	A Machine Learning Approach to Predict the Evolution of Air Traffic Flow Management Delay	EUROCONTROL (self-funded)	–
ATM-2021-015	Early Detection of Night Curfew Infringements by Delay Propagation with Neural Networks	EUROCONTROL (self-funded)	–

ATM-2021-058	Predicting arrival delays in the terminal area five hours in advance with machine learning	EUROCONTROL (self-funded)	–
ATM-2023-018	Looking for the best flight efficiency indicators for arrivals	EUROCONTROL (self-funded)	–
ATM-2021-042	Learning Uncertainty Parameters for Tactical Conflict Resolution	ENAC (self-funded)	–
ATM-2023-038	The Curse of the Time Horizon in Detect & Avoid Algorithms	ENAC (self-funded)	–
ATM-2023-019	Quantitative air risk assessment for a drone inspection mission along fast-train lines	DGAC and Swedish Transport Administration (via Swedish ANSP)	–
ATM-2021-012	Flight Prioritization and Turnaround Recovery	German Federal Ministry of Economic Affairs and Energy	–
ATM-2021-026	Estimating stochastic air transport process times using the Fuzzy Critical Path Method: Determination of the Estimated aircraft Total Turnaround Time (ETTT)	German Federal Ministry of Economic Affairs and Energy	–
ATM-2021-027	Air taxi flight performance and application	TU Dresden (self-funded)	–
ATM-2021-047	Robust CDO Trajectory Planning under Uncertainties in Weather Prediction	German Research Foundation (DFG)	–
ATM-2021-065	Aircraft Performance-optimized Departure Flights Using Traffic Flow Funnels	TU Dresden (self-funded)	–
ATM-2023-048	Time of the day-dependent impact of Contrail Avoidance Strategies on Airline Delay Costs	German Research Foundation (DFG)	–

ATM-2023-058	Multiple Aircraft in a multi-criteria Trajectory Optimization	German Research Foundation (DFG)	–
ATM-2021-044	A Fast and Flexible Emergency Trajectory Generator - Enhancing Emergency Geometric Planning with Aircraft Dynamics	SESAR 2020 and Clean Sky 2	–
ATM-2023-023	Operational Live-Trial for Contrail Prevention at the Maastricht Upper Area Control during 2021 - Can persistent contrails be avoided in the real world?	Horizon 2020	–
ATM-2021-023	Feasibility Study of Free routing Airspace Operation over the North Pacific Airspace	Tokyo Metropolitan University (self-funded)	–
ATM-2021-039	Modeling of Flight Time Prediction Uncertainty for Four-Dimensional Descent Trajectory Management	Tokyo Metropolitan University (self-funded)	–
ATM-2021-046	Data-Driven Analysis Method for Calculated Time Over in Air Traffic Flow Management	Electronic Navigation Research Institute (self-funded)	–
ATM-2023-013	Airspace Design Proposal for Efficient Flight Operations in North Pacific Oceanic Airspace	Tokyo Metropolitan University (self-funded)	–
ATM-2023-031	Designing a Framework of Integrated Aircraft Departure and Surface Traffic Operation via Queuing Network Models	Civil Aviation Bureau (JCAB)	–
ATM-2021-004	Development and Testing of a Collaborative Display for UAV Traffic Management and Tower Control	TU Delft (self-funded)	–

ATM-2021-066	Safety risk posed to persons on the ground by commercial UAS-based services - Learning from airports and hazardous installations	TU Delft (self-funded)	–
ATM-2021-069	Modeling and Detecting Anomalous Safety Events in Approach Flights Using ADS-B Data	TU Delft (self-funded)	–
ATM-2023-042	Optimizing Global Flight Altitudes for Contrail Reduction: Insights from Open Flight and Weather Balloon Data	TU Delft (self-funded)	–
ATM-2023-049	Contributing Factors to Flight-Centric Complexity in En-Route Air Traffic Control	TU Delft (self-funded)	–
ATM-2023-051	Estimating Wind Fields Using Physically Inspired Neural Networks With Aircraft Surveillance Data	TU Delft (self-funded)	–
ATM-2021-040	Embodied Multimodal Interaction with a Portable Mixed Reality-based Digital Tower	Saab-NTU Joint Lab, Saab AB and Air Traffic Management Research Institute (ATMRI), Singapore	–
ATM-2021-052	A Machine Learning-Based Framework for Aircraft Maneuver Detection and Classification	National Research Foundation and Civil Aviation Authority of Singapore	–
ATM-2021-062	Real-time Departure Slotting in Mixed-Mode Operations using Deep Reinforcement Learning: A Case study of Zurich Airport	National Research Foundation and Civil Aviation Authority of Singapore	–

ATM-2023-045	Dynamic Air Traffic Flow Coordination for Flow-centric Airspace Management	National Research Foundation and Civil Aviation Authority of Singapore	–
ATM-2023-059	Airside Surveillance by Computer Vision in Low-Visibility and Low-Fidelity Environment	Saab-NTU Joint Lab and Saab AB	–
ATM-2023-069	Cleared to Land - A Multi-view Vision-based Deep Learning Approach for Distance-to-Touch Down Prediction	National Research Foundation and Civil Aviation Authority of Singapore	–
ATM-2023-037	Area Navigation Terminal Airspace Complexity Estimation for Arrivals	Korea Agency for Infrastructure Technology Advancement (KAIA)	–
ATM-2021-021	Wind Profile Estimation from Aircraft Derived Data Using Kalman Filters and Gaussian Process Regression	Spanish Government	–
ATM-2021-049	Fuel-based flight inefficiency through the lens of different airlines and route characteristics. A post-operational analysis for one day of traffic at the ECAC area.	UPC (self-funded)	–
ATM-2021-054	On-line platform for the short-term prediction of risk of expansion of epidemics	Spanish Government	–
ATM-2023-021	Towards Multi-Aircraft Transfer Learning for Trajectory Tracking	Spanish Government	–
ATM-2021-001	Ground risk vs. Efficiency in Urban Drone Operations	Swedish Transport Administration	–

		and Swedish Research Council	
ATM-2021-031	Towards AI-based Air Traffic Control	Swedish Transport Administration	–
ATM-2023-057	Performance Characterization of Arrival Operations with Point Merge at Oslo Gardermoen Airport	Swedish Transport Administration	–
ATM-2023-016	Collision Risk Assessment in Terminal Manoeuvring Areas based on Trajectory Generation Methods	Swiss Federal Office of Civil Aviation	–
ATM-2023-030	Data-Driven Airborne Collision Risk Modelling using a Probability Density Function	Swiss Federal Office of Civil Aviation	–
ATM-2021-005	Shortfall Analysis of Departure Throughput During Convective Weather in Complex Airport Regions	Federal Aviation Administration	–
ATM-2021-006	Evaluation of Aircraft Speed and Wind Modeling Accuracy in Automation for Trajectory Based Operations	United States Air Force	–
ATM-2021-016	Recommending Strategic Air Traffic Management Initiatives in Convective Weather	Federal Aviation Administration and United States Air Force	–
ATM-2021-017	Trajectory Planning for Mission Survivability of Autonomous Vehicles in Moderately to Extremely Uncertain Environments	NASA	–
ATM-2021-018	Modeling Impacts of Aviation Mitigations & ATC Delay on Passenger COVID-19 Infection Risk	United States Air Force	–
ATM-2021-032	Spatial Modeling of Airport Surface Fuel Burn for Environmental Impact Analyses	MIT (self-funded)	–

ATM-2021-033	Shadow Evaluation of the ATD-2 Phase 3 Trajectory Option Set Reroute Capability in the North Texas Metroplex	US partners	–
ATM-2021-034	Evaluation of UTM Strategic Deconfliction Through End-to-End Simulation	US partners	–
ATM-2021-041	Reinforcement Learning for Traffic Flow Management Decision Support	USA Government	–
ATM-2021-059	Fusion and analysis of data sources for assessing aircraft braking performance on non-dry runways	Federal Aviation Administration	–
ATM-2021-078	Leveraging local ADS-B transmissions to assess the performance of air traffic at general aviation airports	Federal Aviation Administration	–
ATM-2021-079	Having a Bad Day? Predicting High Delay Days in the National Airspace System	Federal Aviation Administration	–
ATM-2021-080	Miles-in-Trail Restrictions and Aviation System Performance: Chicago O’Hare Case Study	Federal Aviation Administration	–
ATM-2021-083	Airport Ground Holding with Hierarchical Control Objectives	NASA	–
ATM-2021-084	Quantifying the Impact of Air Travel on Growth of COVID-19 Pandemic in the United States	UC Berkeley (self-funded)	–
ATM-2023-020	Estimating the impact of increasing Pilot-Applied Separation on Approach	Federal Aviation Administration	–
ATM-2023-025	Teaching Artificial Intelligence Good Air Traffic Flow Management	USA Government	–
ATM-2023-026	Risk-Adjusted Traffic Management Strategies for Convective Weather Conditions	United States Air Force	–

ATM-2023-027	Market Structures for Service Providers in Advanced Air Mobility	NASA	–
ATM-2023-033	Implementation of Long-Range Air Traffic Flow Management at Large Hub Airports: An International Perspective	United States Air Force	–
ATM-2023-034	Evaluation of Convective Weather Impacts on US and European Airports	Federal Aviation Administration	–
ATM-2023-055	Data-Driven Approach for Runway Braking Condition Assessment with Forecasting Capability	Federal Aviation Administration	–
ATM-2023-063	Remote Identification Trajectory Coverage in Urban Air Mobility Applications	National Science Foundation	–
ATM-2023-064	Debuffering Timestamped ADS-B Records for Kinematic Applications	Federal Aviation Administration	–
ATM-2023-068	Strategic Planning of Aerial Assets for Disaster Response: Enabling Efficient and Equitable Access to Drone-Based Search Resources	NASA and MIT	–
ATM-2023-070	UAV Scheduling Strategies in Multi-modal Last-Mile Urban Parcel Delivery	National Institute for Congestion Reduction and Robert P. Wadell Endowed Fellowship	–

Table 8: Summary of research documents analysed for trends

7.3 Appendix: Industry Questionnaire

Engage 2 - Future trends & developments in aviation industry

The goal of this questionnaire is the collection of aviation industry stakeholders' views on future trends and developments.

Estimated time to complete: from 5 minutes (13 questions)

* Indicates required question

Aviation sector

1. Which sector of the aviation industry are you working in? *

Mark only one oval.

- Air Navigation Service Provider (ANSP)
- Civil Aviation Authority (CAA)
- Manufacturer / (service) supplier
- Airport
- Airline
- Not working in aviation industry *Skip to question 11*
- Other: _____

Job role

2. Which role characterizes your job best? *

Mark only one oval.

- Operational
- Technical
- Managerial
- Sales/marketing
- Research & development
- Consulting
- Other: _____

TECHNICAL trends

3. Please rate the relevance of the following **technical trends** over the next **10 years**; provide your own trends in the next question if missing in the list. *
- By 'relevance', we mean in terms of likely impact on the way operations will be performed in 10 years' time.

Mark only one oval per row.

	Not relevant	Quite relevant	Relevant	Highly relevant
Automation using Artificial Intelligence (AI) and Machine Learning (ML)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Virtualization and Cloud Computing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Data Sharing / Data Platforms / Data Markets	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

4. What other **TECHNICAL** trends do you consider relevant or highly relevant?

OPERATIONAL trends

5. Please rate the relevance of the following operational trends over the next **10 years**; provide your own trends in the next question if missing in the list. *

By 'relevance', we mean in terms of likely impact on the way operations will be performed in 10 years' time.

Mark only one oval per row.

	Not relevant	Quite relevant	Relevant	Highly relevant
Increase in airspace complexity (more traffic and new airspace users)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Increased contingencies for / regulatory consideration of disruption (e.g. pandemic, volcanic eruption)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Improved weather models and forecasts	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
New and more robust cyber security measures	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Increasing shift toward sustainable aviation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Increasing shift toward an integrated	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

transport
system

6. What other OPERATIONAL trends do you consider relevant?

7. Is there any **other relevant trend** apart from operational and technical that you want to highlight?

8. The above mentioned trends may have an **impact on the current and future workforce**. What are the major challenges you are expecting in that respect?

Key challenges

9. What are the key challenges that you expect in the coming decade? Please select up to three that are the most desirable, but difficult to deliver. *

Please select at most 3 options. Challenges as identified by [project HAIKU](#).

Check all that apply.

<p>HIGH LEVEL SAFETY STANDARDS Developing new resilient, flexible and proportionate safety procedures and approaches for risk management to anticipate and manage emerging risks</p>	<p>STRONG SAFETY CULTURE Maintaining a strong safety culture across the entire aviation system, in particular extending it to new entrants</p>
<input type="checkbox"/> High level safety standards	<input type="checkbox"/> Strong safety culture
<p>ADAPTIVE REGULATION Enabling regulations to progress in step with the evolution of operations to avoid the risk of regulatory lag or gaps that could undermine the safety of operations, specifically for UATM</p>	<p>FROM SEGREGATION TO INTEGRATION Developing a robust global architecture for fully-inclusive traffic management, integrating ATM and UATM systems</p>
<input type="checkbox"/> Adaptive regulation	<input type="checkbox"/> From segregation to integration
<p>MINIMAL CARBON FOOTPRINT Enabling the aviation system to sustain traffic demand, while minimising the carbon footprint to a level acceptable to society</p>	<p>SUSTAINABLE FUEL SOURCES Producing Sustainable Aviation Fuel, battery and hydrogen fuelled gas turbine engines</p>
<input type="checkbox"/> Minimal carbon footprint	<input type="checkbox"/> Sustainable fuel sources

<p>ADAPTATION TO EXTREME WEATHER EVENTS Developing the capability to adapt to and operate in more extreme and severe weather conditions due to climate change</p>	<p>MULTIMODAL TRANSPORT SERVICES Enhancing connectivity of transport hubs and integrating their systems to allow mixed traffic interoperability. Developing multimodal services, platforms and apps to ensure smooth journeys for passengers and simple usage of UATM delivery services to customers</p>
<input type="checkbox"/> Adaptation to extreme weather events	<input type="checkbox"/> Multimodal transport services
<p>SYSTEM INTEGRATION Effectively integrating new tools and technologies with existing legacy systems</p>	<p>CYBER-RESILIENCE Developing robust security measures to prevent and neutralise attacks and ensure the safety of operations and critical supporting infrastructure</p>
<input type="checkbox"/> System integration	<input type="checkbox"/> Cyber-resilience
<input type="checkbox"/> Other: _____	

10. When reflecting on your previous answers, please indicate the areas where you see the **highest potential for improved cooperation between industry and academics** in joint research projects.

Privacy sheet

Engage 2 is a collaborative project involving Deep Blue Srl, University of Westminster, Technische Universitaet Braunschweig, Univerzitet U Beogradu, Fundacion Instituto de Investigacion Innaxis, Frequentis, EASN Technology Innovation Services, Eurocontrol, and Università degli Studi di Trieste.

The project has received funding from the SESAR 3 Joint Undertaking under the European Union's Horizon Europe research and innovation programme under grant agreement No 101114648.

Participants' personal data (first name, last name, organization name, country, email address) will only be used by Engage 2 for the purposes of the project. Only in case specific permission is given, they may also be used to invite the participants to take part in future research activities and commercial initiatives.

Personal data will be collected, processed and protected according to the General Data Protection Regulation (GDPR) (EU) 2016/679. Participants will have the right to request access to and rectification or erasure of personal data or restriction of processing concerning the data or to object to processing as well as the right to data portability just by sending an email to the person responsible of data treatment listed hereafter. They will also have the right to lodge a complaint with a supervisory authority.

RESPONSIBLE FOR DATA TREATMENT IN ACCORDANCE TO THE GDPR (CONTROLLER)

Deep Blue S.r.l., Via Daniele Manin, 53 - 00185 Rome RM (Italy)

CONTROLLER'S REPRESENTATIVE IN THE SPECIFIC PROJECT

Micol Biscotto - Project Coordinator

11. After reading the information sheet above *

Check all that apply.

- I hereby give my consent to the processing of my personal data needed for the the submission of the "Future trends & developments in aviation industry" questionnaire.
- I understand that my personal data will be held and processed in confidence and in accordance with the principles laid out by GDPR.

I also provide my consent

12. to be contacted by the Engage 2's consortium in the next 4 years for matters related to project activities *

Mark only one oval.

Yes

No

13. to be contacted by the Engage 2's consortium members for matters related to scientific research *

Mark only one oval.

Yes

No

14. E-mail address *

Please leave your e-mail address in case some clarification of your free text inputs is needed. You can also request to receive a copy of the results below. Your e-mail address will only be used to clarify questions with you and to send you a copy of the results if you request that.

15. What is your age group? *

Mark only one oval.

younger than 25

25-34

35-44

45-54

55-64

older than 64

16. Would you like to receive a copy of the results? *

Mark only one oval.

Yes

No

7.4 Appendix: University Questionnaire

Engage 2 | The impact of ATM Innovation on Academic Programmes

The goal of this questionnaire is the collection of insights from universities/colleges identifying how adaptations in curricula reflect expected trends in the ATM sector.

* Indicates required question

Section 1

1. Which of the following describe(s) your current role? Please select all that apply. *

Check all that apply.

- Researcher
- Lecturer
- Early career researcher
- Senior researcher
- Professor
- Other: _____

2. Please indicate the study programmes offered by your university/college. *

Mark only one oval per row.

	Undergraduate studies	Postgraduate studies	Both undergraduate and postgraduate	Not offered
Professional staff programme (e.g. Flight Training; Professional Pilot degree)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Air transport engineering programmes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Aviation management programmes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Aeronautical/aerospace engineering	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Joint programmes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

3. If you have indicated you are offering studies for "other" programmes in the question above, please provide the name of the study programme.

4. Of these study programmes, please indicate in which one you are spending most of your time. *
(We would like you to respond to the remaining questions with this one in mind.)

Mark only one oval.

- Professional staff programme (e.g. Flight Training; Professional Pilot degree)
- Air transport engineering programmes
- Aviation management programmes
- Aeronautical/aerospace engineering.
- Joint programmes
- Other

5. What is the interval used by your university/college to **formally change** (with validation) the courses/lectures of its **aviation-related curriculum**? *

Mark only one oval.

- Every year
- Every 1-2 years
- Every 3 years
- Less often
- Don't know

6. How often do you make **significant changes**, such as adding a new topic or revising part **of a module**, but **without requiring formal validation**? *

Mark only one oval.

- Every year
- Every 1-2 years
- Every 3 years
- Less often
- Don't know

7. Please rank the following statements in order of preference (agreement) by selecting one item per column. *

Mark only one oval per row.

	First	Second	Third
Regular modernization of curricula is an important differentiator.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Solid basic education shall not be compromised by concentrating too early and too much on new technology and trends.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Degrees have a higher reputation when granted by an institution that is well known for adopting new trends and technologies early.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Section 2

Your view on trends

8. Please rate the importance of having **further information on the exact skills required by employers** in the aviation industry regarding the following **TECHNICAL** trends within the next 10 years. *

(You can provide your own trends in the next question, if missing from the list)

Note: the same three items are also used in a survey with industry, which will allow us to compare the responses, but you can add your own choice(s) in the next question.

Mark only one oval per row.

	Not important	Quite important	Important	Highly important
Automation using Artificial Intelligence (AI) and Machine Learning (ML)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Virtualization and Cloud Computing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Data Sharing / Data Platforms / Data Markets	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

9. What other TECHNICAL trend(s) do you consider (highly) important? (We welcome any topic.)

10. Please rate the relevance from your point of view of the following OPERATIONAL trends within the next 10 years. *

(You can provide your own trends in the next question, if missing from the list)

Note: By 'relevance', we mean in terms of likely impact on the way operations will be performed in 10 years' time.

Mark only one oval per row.

	Not relevant	Quite relevant	Relevant	Highly relevant
Increase in airspace complexity (more traffic and new airspace users)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Increased contingencies for / regulatory consideration of disruption (e.g. pandemic, volcanic eruption)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Improved weather models and forecasts	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
New and more robust cyber security measures	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Increasing shift toward sustainable	<input type="radio"/>	EUROPEAN PARTNERSHIP		

aviation

11. What other OPERATIONAL trend(s) do you consider (highly) relevant?

12. Is there any other trend, apart from operational or technical, that you want to highlight?

13. The above mentioned trends may have an **impact on the current and future workforce**. What are the major challenges you are expecting in that respect? Please describe.

Privacy sheet

Engage 2 is a collaborative project involving Deep Blue Srl, University of Westminster, Technische Universitaet Braunschweig, Univerzitet U Beogradu, Fundacion Instituto de Investigacion Innaxis, Frequentis, EASN Technology Innovation Services, Eurocontrol, and Università degli Studi di Trieste.

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RESPONSIBLE FOR DATA TREATMENT IN ACCORDANCE TO THE GDPR (CONTROLLER)

Deep Blue S.r.l., Via Daniele Manin, 53 - 00185 Rome RM (Italy)

CONTROLLER'S REPRESENTATIVE IN THE SPECIFIC PROJECT

Micol Biscotto - Project Coordinator

14. After reading the information sheet above *

Check all that apply.

I hereby give my consent to the processing of my personal data needed for the the submission of the "Future trends & developments in aviation industry" questionnaire.

I understand that my personal data will be held and processed in confidence and in accordance with the principles laid out by GDPR.

I also provide my consent

EUROPEAN PARTNERSHIP



Co-funded by
the European Union

15. to be contacted by the Engage 2's consortium in the next 4 years for matters related to project activities *

Mark only one oval.

Yes

No

16. to be contacted by the Engage 2's consortium members for matters related to scientific research *

Mark only one oval.

Yes

No

E-mail address

Please leave your e-mail address in case some clarification of your free text inputs is needed. You can also request to receive a copy of the results below. Your e-mail address will only be used to clarify questions with you and to send you a copy of the results if you request that.

17. Please insert your email.

18. Please indicate the country where your institution is located.

19. What is your age group?

Mark only one oval.






- younger than 25
- 25-34
- 35-44
- 45-54
- 55-64
- older than 64

20. Would you like to receive a copy of the results? *

Mark only one oval.

- Yes
- No

7.5 Appendix: Research threads by Engage 1

Thread	SRIA flagship(s)	Summary
Additional focus on safety performance	1 	Connected and automated ATM: The SRIA has not allocated safety as an area of specific work <i>per se</i> , but rather as a horizontal performance criterion forcing safety evaluations to be undertaken in each area. However, the foreseen contributions of the nine flagship activities to the safety dimension seem to be quite modest, from “maintaining” to “maintained if not improved”, falling rather short, it seems, of earlier ACARE/SES objectives of a ten-fold safety improvement. This flagship (connected and automated ATM) aims at higher levels of automation and specific tools for safety improvement in higher levels of automation. It would be of value to stress even more the need for a well-designed and executed safety assessment, as that is usually the stepping stone for faster development and deployment, especially for safety-critical innovations. Approaches to safety assessment developed since SESAR 1 could add value here.
Developing techniques for dynamic risk modelling	1, 2  	Connected and automated ATM; Air-ground integration and autonomy: These two flagships propose research into safety-critical areas, which require rigorous safety assessments. It would be of value to stress the need for well-designed and executed safety assessments for research performed in these flagships (also for other flagships, but the link to these two is more critical). However, it is readily acknowledged that material on the application of dynamic risk modelling is included in the <i>Guidance to Apply SESAR Safety Reference Material</i> [8], whereas it would be endorsed that actual safety assessments should deploy tools specific to the safety requirements in question.
Enhanced surface/vehicle driver guidance and airport DCB	1 	Connected and automated ATM: The SRIA formulation addresses airports in two areas: “connected and automated ATM” and “multimodal and passenger experience”. Enhanced surface/vehicle driver guidance and airport DCB might further be developed particularly under the high-level R&I need/challenge of “Airport automation including runway and surface movement assistance for more predictable ground operations” outlined within the former flagship.
Ideation and ER in airports (performance) domain	8 	Artificial intelligence (AI) for aviation: Whilst the SRIA seems to attach rather less importance to the role of airports in this flagship, some of the airport-related work lends itself very well to ML approaches. The topic covering the airports (performance) domain is not necessarily linked to AI, but many applications, especially digitalisation, can be achieved using AI and ML techniques to build innovative and more advanced performance frameworks.










Thread	SRIA flagship(s)	Summary
Market-uptake and incentivising airspace users, with performance simulations	2 	Air-ground integration and autonomy: Market-uptake and incentivising airspace users, for example for TBS (time-based separation) systems could loosely fit in the flagship on air-ground integration and autonomy, developing further the assessments needed for TBS (or other similar) business cases. Such research requires deeper economic and market mechanisms investigations, as well as network-level performance simulations.
Advanced AI/ML to predict loads and propose sector configurations	8 	Artificial intelligence (AI) for aviation: Research into advanced AI/ML techniques to predict sector loads and propose sector configurations would seem to be potentially accommodated in the capacity-on-demand and dynamic airspace flagship, but would in fact most likely fit better in the artificial intelligence (AI) for aviation flagship if the goal were to be to develop and use advanced AI/ML-based techniques predictively.
Extended UDPP research	3 	Capacity-on-demand and dynamic airspace: UDPP research is contained within this flagship, aiming at extending the concept, but not mentioning explicitly inter-airline slot swaps or specific indicators to explore. Definitions of equity and fairness across all stakeholders, and analyses of the corresponding trade-offs, would clearly bring important added value to the research in this flagship.

Table 9: Research threads for the gap analysis pillar & relationships with SRIA flagships

Thread	SRIA flagship(s)	Summary
Establish and develop a SESAR 3 cybersecurity community	5 	Virtualisation and cyber-secure data sharing: This flagship addresses several high-level R&I needs/challenges, with that of ‘cyber resilience’ describing the need for monitoring and adapting to the changing threat landscape and emergence of new actors, aiming at the development of cyber-resilience guidelines and procedures tailored to ATM. However, a large and positive impact could be obtained through continuous collaboration and updates within a dedicated SESAR 3 cybersecurity community. This flagship is the place for setting up such guidelines and procedures, although not necessarily the best place for the establishment and nurturing of a cyber community, which might be developed through the SESAR 3 KTN or Digital Academy, overarching the flagship and its corresponding work components and actors.

Thread	SRIA flagship(s)	Summary
<p>Support a culture of responsible disclosure & sharing experimental scenarios</p>	<p>5</p> 	<p>Virtualisation and cyber-secure data sharing: A major high-level R&I need/challenge in this flagship, where responsible disclosure and sharing experimental scenarios could bring added value, is “Free flow of data among trusted users across borders”, which foresees: “The sharing of data through interoperable platforms and, the exchange of open data between trusted partners, combined with open architecture policies [...]”. This added value should be flagged explicitly, i.e. to add responsible disclosure between trusted partners. Additionally, sharing experimental scenarios (and experimental data) applies to all the areas of SESAR 3 programme, and each flagship would benefit from this.</p>
<p>Explainable AI: explore trade-offs between explainability and performance</p>	<p>8</p> 	<p>Artificial intelligence (AI) for aviation: This flagship focuses on research and development of AI for aviation, aiming to develop new “methodologies for the validation and certification of advanced automation that ensure transparency, legal aspects, robustness and stability”, to foster higher automation and use of AI in all phases of planning and execution. The exploration of trade-offs between explainability and performance should bring new knowledge to the flagship, possibly enabling faster development and implementation of AI algorithms in certain areas (most probably non safety-critical ones).</p>
<p>Artificial datasets for ML: avoiding training on already-cleaned scenarios</p>	<p>8</p> 	<p>Artificial intelligence (AI) for aviation: Different aspects of AI and ML algorithm development are discussed in the SRIA, among them the high-level R&I need/challenge “AI Improved datasets for better airborne operations”, which mainly describes the possibilities from fitting new sensors and higher volumes of communication between air and ground. This flagship would benefit from taking into account the two key aspects of datasets for ML identified through the KTN’s investigations: a need for data not including pre-intervention by other entities and having sufficient data points for training ML algorithms, e.g. through artificial training datasets.</p>
<p>Climate impact: mitigation and metrics</p>	<p>7</p> 	<p>Aviation Green Deal: This SRIA flagship refers to non-CO₂ impacts on the climate. The flagship would, however, benefit from further description and focus on defining the measurement for all components of aviation emissions, which would help to assess the impact of new technologies, such as aircraft with electric or hydrogen propulsion, and (on-going) SESAR Solutions. This aligns closely with defining new environmental indicators, which would support the development of the SESAR 3 Performance Framework.</p>
<p>Further modelling of uncertainty in weather forecasts and climate impacts</p>	<p>1, 7</p> 	<p>Aviation Green Deal: This flagship specifically mentions the need for the development of an environmental impact assessment methodology and new metrics, to be able to take climate impact into account properly. Inclusion of uncertainty is of paramount importance in this area. Connected and automated ATM: Improved weather forecasts are mentioned in this flagship, with the aim of improving trajectory advisories by taking into account various uncertainties. The inclusion and explanation of uncertainties in the forecasts would improve the tools for trajectory prediction and thus network performance in general.</p>








Thread	SRIA flagship(s)	Summary
Incentivising early adopters: economic and behavioural mechanisms	5 	Virtualisation and cyber-secure data sharing: This SRIA flagship addresses virtualisation and some aspects of regulatory and service evolution needed. The flagship would benefit from the assessment of incentivisation of various stakeholders, linked to different business models, that would be appropriate in the European ATM market, to expedite this transition. 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 to do so.
Creating flexible services: ops data licencing, sovereignty and accessibility	5 	Virtualisation and cyber-secure data sharing: This flagship acknowledges the importance of data and data sharing, planning work on these aspects. Currently, almost all data in ATM are considered in need of being protected, which is not necessarily true. The flagship would benefit from a more detailed approach to the development, and licencing of new business models, including data certification, needed in the transformation towards the Airspace Architecture Study [9] vision, also tackling the issue of data sovereignty and cross-State sharing.

Table 10: Research threads for the thematic challenges pillar & relationships with SRIA flagships

Thread	SRIA flagship(s)	Summary
Quantum computing	8 	Artificial intelligence (AI) for aviation: whilst the strongest correspondence of quantum computing is unsurprisingly with the 'AI' flagship, the wider implications for this new technology are very broad and deep, considering the applications of much faster solutions to search space and combinatorial problems, potentially offering vastly improved capabilities both for operational/tactical searches of improved solutions to complex capacity constraints in ATM, and e.g. (safety) validation. Exposing cybersecurity vulnerabilities and supporting public key cryptographic systems are clearly important in the ATM context regarding not only CNS, but also in the context wider of information exchange over networks, supporting SWIM and privileged data exchange (e.g. for UDPP).

Thread	SRIA flagship(s)	Summary
Strong AI	<p>8, 1</p>  	<p>Artificial intelligence (AI) for aviation: the strongest correspondence of strong AI is not unexpectedly with the ‘AI’ flagship, which cites “AI for prescriptive aviation”. Whilst strong AI represents a step-shift in the state of the art, it builds on the current science, for example, whereby the coupling of advanced sensor technologies with ML/AI techniques, could support system development in multiple contexts, such as risk mitigation, system diagnoses, performance assessment, forecasting, predictive support and design. Connected and automated ATM: may be supported specifically through more efficient resource allocation for humans and machines, although this is just one of many other SRIA flagships potentially impacted strategically and tactically e.g. through strong AI’s foresight capabilities, ‘strong emergence’ and policy generation.</p>
Integrated ticketing and virtual interlining	<p>6</p> 	<p>Multimodality and passenger experience: fully logically, this represents the strongest SRIA flagship correspondence with integrated ticketing and virtual interlining. An examination of existing virtual interlining models and online travel agencies would give better insights into the implications for airspace users, airport infrastructure requirements and other modal travel service providers (e.g. rail). Operationally, the impacts on holding flights for delayed trains, and <i>vice versa</i>, could be significant – further metric development and scenario simulations are required. Future travel operators should offer appropriate connection guarantees and passenger needs in case of disruption, throughout the booked travel in a door-to-door context. The SRIA discusses ticketing, integration and crisis management.</p>
European risk register for ATM and air transport resilience	<p>8</p> 	<p>Artificial intelligence (AI) for aviation: “resilience” is mentioned often in the SRIA, mostly with reference to cybersecurity, but also flagging climate/meteorological resilience (Aviation Green Deal) and passenger journey resilience (Multimodality and passenger experience). Comparably strong associations for the risk register thread from Engage with the SRIA ‘AI’ flagship result from common references to resilience, machine learning, complexity and networks. Complexity science and complex network theory have already proven in ATM to be well-suited tools and metrics for network resilience. It would be informative to explore lessons learned from the Covid-19 pandemic, e.g. in terms of the sustainability of current financial, business and performance assessment models for airspace users and ANSPs.</p>





Thread	SRIA flagship(s)	Summary
<p>Improved route emissions metrics and policies</p>	<p>7, 6</p>  	<p>Aviation Green Deal: regarding the need for improved route emissions metrics and policies, this flagship addresses the specific high-level R&I needs/challenges of ‘Optimum green trajectories’ and ‘Non-CO₂ impacts of aviation’, in addition to an ‘environmental dashboard’ relating to metric development and implementation, impact assessment trade-offs, and incentivisation considerations. Regarding links with the Multimodality and passenger experience SRIA flagship, the Engage thread stresses the current relatively passive role of passengers in flight sustainability, whereas strengthened national and international policy (taxes) and data transparency may generate a stronger passenger link with airline decision-making and business models, also in the multimodal context.</p>
<p>ATM-U-space coordination; UAM access mechanisms</p>	<p>4, 2</p>  	<p>U-space and urban air mobility and Air-ground integration and autonomy: the correspondence between these two SRIA flagships and research directions flagged by Engage is self-evident. The latter notes that manned aviation may well be present in VLL airspace, with drones: equipage requirements, management of non-nominal/emergency situations and common services need to be developed. The vicinity of airports, in which different vehicle types will operate, with infringement risks, is of particular interest. There is a strong link with the Smart City concept. Access to U-space and UAM airspace will have to be based on equipage requirements and respect principles of equity, whilst applying yet-to-be-defined priority rules, e.g. for emergency and security flights. DCB raises further challenges in this context.</p>

Table 11: Research threads for the horizon flagships pillar & relationships with SRIA flagships

7.6 Supplement – AI based analysis data and results

The results of the AI-based trend analysis are provided in a separate file named “Engage_2_D4.1_Supplement.xlsx” that may be accessed [here](#). It contains the consolidated literature review that has been generated with GPT-4.