EASA

European Union Aviation Safety Agency

EASA Scientific Committee

ANNUAL REPORT 2023

EASA
European Union Aviation Safety Agency

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An agency of the European Union

Acronyms and Terminology

MSCA	Marie Skłodowska-Curie Actions
SciComm	Scientific Committee
TF	Task Force
EASA	European Union Aviation Safety Agency
PhD	Doctor of Philosophy

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1 Executive Summary

The EASA Scientific Committee was established and became fully operational in 2022 with the objective to provide advice to the EASA Executive Director on scientific issues. Primary focus of advice are areas with the potential to influence the future development of the EASA expertise in scientific and technical domains linked to research, innovation, and disruptive technologies. The committee consists of a small number of internationally recognized experts covering relevant areas of expertise and having direct access to relevant academic stakeholders.

After its first successful year of operation and delivery of the first annual report spring 2023 the present document covers the reporting on the second operational year. The report provides evidence of the activities undertaken, the respective outcome and recommendations regarding future activities.

In 2023 the Scientific Committee continued its operation along the established working arrangements and provided support via efficient and lean processes following the agreed annual working cycle. According to the recommendations delivered in 2022 the 2023 cycle maintained the existing thematic areas addressing

- the development of schemes connecting the Scientific Community with EASA,
- the state of research regarding the impact of climate change on aviation, and
- application perspectives of artificial intelligence level 2 in the air transport system.

The respective Task Forces were adjusted in terms of membership and continued delivering results relevant for short term actions as well as for long term strategic considerations.

For connecting the Scientific Community with EASA, the committee has proposed measures to establishing strong networks between academia, EASA and further relevant stakeholders. On short term, the first edition of the "EASA PhD Conference" has been held successfully and excellent PhD students were presented with an award, recognising the quality and pertinence of their work. A bilateral engagement with EASA experts has been carried out allowing EASA to gain insights on certain aspects of new technologies and new challenges, while students got an opportunity to get feedback on the operational application of their research work.

The Task Force on impact of climate change has consolidated the review of scientific works on the trends regarding severe thunderstorms, hail and clear air turbulence published in 2022. In addition, they have extended their investigations to dust storms, airborne icing, and to high temperature events. For each type of weather hazard, they have reviewed the state of knowledge regarding past and future trends, and identified whether there are agreements between research works, and what are the main uncertainties and uncovered aspects. Their recommendations regarding possible future research are based on this in-depth review.

The Task Force on Artificial Intelligence contributed to preparing and launching the survey 'Ethics for AI in Aviation'. This survey, preparing the next steps of guidance development, also enabled the consolidation of the concepts from the Human-AI teaming guidance laid down in the Proposed Issue

02 of the EASA Concept Paper on Artificial Intelligence. In addition, anticipatory work on the design principles for advanced automation (Level 3 AI) paved the way for a finer grain classification of 'non-supervised advanced automation' operations and confirmed the notion of autonomy for systems capable of setting their own intended domain of use or goal without external oversight. Moreover, a mapping to other domains automation schemes confirmed the genericity of the EASA AI Levels classification scheme. Overall, valuable inspiration has been provided for the development of EASA guidance for Level 3 AI in the upcoming Issue 03 of the EASA AI Concept Paper.

In light of the third activity cycle in the year 2024, recommendations regarding the way forward on the current topics have been elaborated by the committee. Further potential thematic focus has been identified in the topics of climate impact on aviation, AI in aviation and academic networks.

The presented report describes the activities, key findings and recommendations issued by the Scientific Committee. A comprehensive appendix provides more detailed insights into the findings.

2 Introduction

The document summarizes the activities undertaken by the EASA Scientific Committee in its second operational year 2023. It briefly recaps the background and motivation of setting up the committee, its composition, the internal procedures and the working arrangements as defined in 2022. The main focus of the report lies on the three relevant organisational and scientific topics carried over and continued from the first year. These topics cover the following areas:

1. topic #1: PhD Scheme Development
2. topic #2: Impact of climate change
3. topic #3: Artificial Intelligence

The document describes for each of these topics the applied methodology as well as the work plan, its implementation and the results achieved so far. In addition, recommendations are provided covering two different time scales: Short term “quick wins” will be presented providing options of immediate consideration and implementation in order to leverage existing opportunities. Longer term recommendations will be presented which may support strategic considerations of EASA. In addition, the way forward on the three initial topics is proposed as well as taking up further relevant topics in the next cycles.

The present report shall preserve the findings of the SciComm and build a basis for its future work. It may provide guidance to EASA on certain topics and may serve the scientific community as basis for considering future research directions. Finally, the state of the art in the selected research topics and the need of further research is elaborated to a good extent.

Finally, the report is intended to be the second in a series of annual reports recording the activities undertaken by the Scientific Committee members. It may provide evidence of the value of the committee’s contributions on the short-term scale as well as on the strategic level.

3 Mission, Composition and Organization of the EASA Scientific Committee

3.1 Mission

The EASA Scientific Committee (SciComm) was established in 2021 with the objective to provide advice to the EASA Executive Director on scientific issues that may influence the future development of the EASA expertise in scientific and technical domains linked to research, innovation, and disruptive technologies. Furthermore, the scientific committee members should advise the Executive Director as regards processes in aviation that may impact Aviation Safety, Environmental Protection, Security, and Aviation Health Safety.

The Committee and its members shall in particular advise the Executive Director on:

- how to best address the technical and scientific challenges EASA may be faced with through emerging concepts and innovative / disruptive technologies
- the digital evolutions and their potential mid-term impact on the EASA oversight processes
- scientific related matters concerning knowledge gaps, assessment of research results and new threats to aviation
- how to best address new societal evolutions in the aviation sector (of a nature affecting either technical developments or its business models)
- the seriousness of potential new risks/threats in Environmental protection
- the seriousness of potential new risks/threats in aviation health safety
- the effectiveness of technologies in reducing/mitigating these risks
- how to help promoting appropriate innovative processes and technological evolution (in or alongside the EASA EPAS)
- the directions of the Research activities that EASA could support, both in the domains of Excellence Science & Outreach and of Application Oriented Research
- how to facilitate the transfer of the EASA activities to the EASA regulatory, knowledge management, and implementation processes
- any other topic brought to the Committee by the EASA Executive Director

In order to fulfil this mission, an initial but not exclusive list of relevant scientific areas has been defined by EASA and the members of the SciComm have been selected through an open process ensuring an appropriate coverage of these areas.

The background of founding the committee, its general mission, its tasks as well as relevant formal arrangements are described in further detail in the document “Terms of Reference”.

3.2 Composition

The members of the Scientific Committee have been appointed by the EASA Executive Director based on the list of independent external experts maintained by EASA as a result of Call for Expression of

Interest EASA.2019.CEI.14. Members were chosen for their expertise, being mostly of academic nature, with direct access to universities, Academia and PhD networks.

EASA evaluated their competences to ensure commitment to the furthering of safety, environmental protection, security, research, innovation and aviation health safety activities through an adequate coverage and balance in terms of:

- Academic and/or Industrial expertise;
- Range of views and competencies within the scientific community (i.e. coverage of the most relevant scientific fields linked to the needs of the EASA activities);
- Experience in a range of relevant research and innovation activities with publications and/or public appearances, or PhD schemes

In December 2021, EASA appointed the chairman and members for the Committee for a duration of three years (2022-2024) in their personal capacity. As two of the initially eleven members decided at the end of 2022 to retire from the Committee for private reasons, the following experts carried on the activities in 2023:

Prof. Dr. Peter Hecker, Chairman	Vice President TU Braunschweig
Dr. Nicholas Asher	Director of the Artificial and natural Intelligence Toulouse Institutes
Prof. Frances Brazier	Professor at TU Delft in Intelligent systems
Prof. Marianna Jacyna	Dean of the Faculty of Transport, Warsaw University of Technology
Prof. Martin Kaltschmitt	Head of the Institute of Environmental technology and Energy economics
Dr. Christiane Schmidt	Senior Associate Professor, Communications and Transport Systems Division at the Department of Science and Technology (ITN) at Linköping University
Prof. Nicole Viola	Professor of Aerospace Systems at Politecnico di Torino and Affiliate Professor at Concordia University, Montreal
Prof. Marco Lovera	Leading the research laboratory of the Aerospace Systems and Control Laboratory at the University Politecnico di Milano advanced systems
Dr. Torben Hovald	Analysis and Monitoring Unit Team Leader, European Union Agency for Railways

Table 1: Members of the Scientific Committee in 2023

3.3 Organization and Formation of Task Forces

In 2022 the SciComm had developed and implemented an internal process for organizing its workflow, i.e. the structuring, prioritizing and managing of activities along the Terms of Reference. This process had proven its suitability over the first year successfully supporting an efficient operation delivering maximum support to EASA in the first operational year. Therefore, it was maintained for 2023.

According to the recommendations provided in the 2022 report, the Committee decided to maintain and further develop the thematic focus on three topics also for 2023:

1. topic #1: PhD Scheme Development
2. topic #2: Impact of climate change
3. topic #3: Artificial Intelligence

In order to further evolve on these topics in an efficient manner, the existing Task Forces have been maintained and the membership has been adjusted according to the further evolution of the topics. An assignment list for 2023 is provided in table 2.

	Taskforce #1 PhD Scheme Development	**Taskforce #2 Impact of climate change**	**Taskforce #3 Artificial Intelligence**
EASA PoC	Emmanuel Isambert	Guillaume Aigoin	Guillaume Soudain
Further EASA support	Kirsti Reinartz-Krott		
Prof. Dr. Peter Hecker	X		X
Dr. Nicholas Asher			X
Prof. Frances Brazier			X
Prof. Marianna Jacyna	X		X
Prof. Martin Kaltschmitt	X		
Dr. Christiane Schmidt		X	
Prof. Nicole Viola		X	
Prof. Marco Lovera			X
Dr. Torben Hovald			

Table 2: Composition of Task Forces

Operation of Task Forces

The Task Forces defined individually their objectives for 2023. In addition, the mode of operation, an appropriate schedule, as well as the workshare among the members were developed. The Task Forces organized their activities typically via email exchanges, collaborative online working spaces and virtual meetings. They kept in contact with their EASA PoC, who provided relevant material and involved additional EASA members as required (see table 2). The TFs reported briefly the progress during the SciComm meetings over the consultation period. This allowed a general awareness across the whole SciComm and ensured a regular update and involvement of all SciComm members.

At the end of the consultation period the Task Forces summarized their activities and provided input to annual report, which is requested according to the SciComm's Terms of Reference. In general, the reporting was a joint effort among all SciComm members specifically supported by the chairpersons of the SciComm and TF.

4 Report of Task Force #1: PhD Scheme Development

4.1 Introduction and Scope

Since the creation of the SciComm in 2021, the Agency has begun to develop a structured collaboration with European Aerospace Universities and Academia, which are continuously involved in research at various stages, be it exploratory, applied or industrial research. EASA has witnessed through the exchanges with students, that PhD programmes can contribute in identifying and understanding the impact of technological (r)evolutions, including knowledge gaps and disruptive elements with respect to aviation standards, in supporting the maturation of new standards and in transferring scientific knowledge to Aviation Authorities. The Agency has also realised the benefits and opportunities to advise ongoing and upcoming research in order to allow a smooth transition towards the regulated activities linked to the implementation, exploitation and deployment of new products, work processes or services in aviation. Scientific networks can effectively support this new role of the Agency, and at the same time help developing competences of aviation professionals, thus improving and smoothing out the innovation cycle.

Under the lead of the 'PhD Task Force' (in short TF) , the Scientific Committee has begun implementing its task to connect European Universities and Academia with EASA, by holding the first European_Academia@EASA conference in March 2023, which enabled an exchange between Academia and the EU aviation regulator on R&I topics that will, in the not so far future, change the aviation world, pose new regulatory challenges for the aviation authorities, contribute to future editions of the European Plan for Aviation Safety (EPAS) and steer the European Research agenda. Furthermore, it has investigated further potential connection solutions like networks, associations, PhD funding schemes and other means of communication and dissemination. The main intention is to strengthen ties with the European academic world and raise awareness of important research topics from a regulatory perspective.

An important aspect of the PhD Task Force is the promotion and inclusion of critical technological issues that are of interest to the other EASA Scientific Committee Task Forces in future doctoral education programmes.

4.2 Work Plan and Methodology

The first quarter of 2023 was dedicated to the preparations for the European_Academia@EASA conference held on 23-24 March. The workplan of the TF mainly consisted of the following action items:

- Defining the roles of the SciComm members at the conference
- Defining the invitation list, including keynote speakers, pitch makers and sending out invitations

- Drafting the conference agenda and programme of the conference (it was decided not to have a poster session at the conference due to limited time and space and to enable the promotion of the best ideas through personal presentation)
- Setting up a light networking scheme with an exchange to be offered to 4 of the 'winning PhD students whose presentations were voted best by the selection committees
- Organising a post conference survey or questionnaire
- Organising the exchanges/visits of the 4 'winning' PhD students

At each plenary meeting the TF/the Agency asked for guidance from those members who have the experience of organising similar events. Members of the Scientific committee volunteered as keynote speakers or as session committee members at the conference.

Following the successful conference, and parallel to some of the PhD students' visits at the Agency, the TF concentrated on enhancing further networking options such as the SESAR 3 ENGAGE2 project or the EU Maria Skłodowska-Curie actions:

- Clarifying internally with EASA experts the interest(s) to participate in such networks, and
- Meeting the focal points of the actions to define the involvement of the Agency/the SciComm therein.

The Task Force implemented the work plan sequentially as indicated. The work was organized via few dedicated Task Force meetings but also discussing preparations at the plenary to involve all members in order to use the maximum of expertise and know-how on organising past similar events.

4.3 Key Findings in 2023

The following main outcomes were achieved:

The short-term strategy developed in 2022 for connecting academia with EASA was successfully implemented firstly with the 2 days European_Academia@EASA, hosting around 100 participants, of those about 40 PhD students (20 of whom presented their topics).

The agenda of the conference[1] was built around topic sessions and Q&A sessions thereafter.

The PhD TF issued an opinion on further directions of work, particularly the continuation of current forms of interaction between EASA and the academic community.

The first day of the conference saw the morning session with its welcome and keynote speeches, followed by the 3 main sessions, including an opening pitch and series of presentations, addressing:

- the impact of climate change and extreme weather phenomena on the air transport system' (three student presentations), and

[1] https://www.easa.europa.eu/en/newsroom-and-events/events/europeanacademia-easa-conference-2023

- two sessions on Artificial Intelligence (six students' presentations), as this had generated the biggest interest among the applicants for presentations.

The first day of the event was then wrapped up and finished off with a social event taking place at the Agency.

The second day of the event included:

- the final session on Artificial Intelligence (three student presentations),
- the session on Environmental Sustainability of Air Transport (four student presentations), and
- the session on New Approaches and Methods for Safety Risk Management in aviation (four student presentations).

To end the conference, the conclusions were given and an award ceremony was held to formalise the selection of the four 'winning' students, who could then exchange/visit EASA in the course of their further PhD studies during 2023.

As a follow-up, and as was recommended in the 2022 report, a post-conference survey was circulated shortly after the conference, receiving some useful feedback:

- Primary objectives of the conference were networking, bilateral discussion and sharing of experience.
- Event met the objectives expectations with a score of 4.1 out of possible 5 and with 4.5 out of 5 for the set-up.
- The vast majority of responders said they would be interested in similar future events.

The conference presentations were disseminated upon request among the conference participants.

The second part of the short-term strategy to connect EASA and academia was achieved with the exchanges of the four 'winning' PhD students, whose visits in the May - November 2023 period at EASA provided deeper understanding on topics and solutions of interest having an impact on the aviation system.

Practical knowledge from a regulator's perspective, which is needed once a product/solution reaches a higher maturity level and is to be certified/approved, was shared. At the same time, EASA experts were acquainted with new know-how and methodologies developed by the students.

The concerned students were:

- Gabriele Luzzani, Politecnico di Torino, 'Study and development of a real-time pilot monitoring system' - visit in May/June and also participation in the 'EASA AI Days';
- Suzanne Salles, CERFACS ISAE-SUPAERO, 'Modelling the impact of atmospheric variables on the performance of an aircraft during take-off: Towards the Adaptation of air traffic operations to global warming' - visit October/ November 2023;

- Lidia Serrano Mira, Universidad Politécnica de Madrid (UPM), 'Definition of a methodology for the determination and application of a variable separation minima between aircraft in flight in an en-route environment' - visit October 2023;
- Rebekka van der Grift, TU Delft, 'Measurement driven aircraft noise modelling' - visit October 2023, participation as panellist in EU Green Week 2023 in June.

As future options for developing the exchange between EASA and academia, several **longer-term developments** such as sponsorship of university chairs can be envisaged, in case funding becomes available. Alternatively, the establishment of an association of universities linked to EASA will continue to be considered.

Furthermore, at **short term**, participation to the EU Marie-Curie actions, in particular the two networks 'TRACES' and 'eVTOL' were discussed and EASA experts' interest thereto sought. At a meeting with the focal points of the DeepBlue lead of the ENGAGE2 consortium, it was clarified by the Agency that any involvement would be undertaken via an EASA-SESAR service level agreement.

4.4 Recommendations

The work carried out by the Task Force has resulted in implementation of parts of the **short-term strategy** with the first conference cycle and the first student exchange cycle.

Post-conference it is recommended to:

- Build connections with permanent academics, not just PhD students (this is part of the network idea in general),
- Bring Industry and other players like the national research organisations into the loop,
- Publish the presentations and provide an inventory of related material to interested parties (at least the registered participants),
- Re-visit the communication options related to the conference (developing it as a brand, increasing visibility, using it for marketing and communication purposes, etc.), and
- Consider continuing the conference on an annual / biennial schedule.

Post exchange cycle with students it is recommended to:

- Establish a clear EASA-PhD exchange procedure, with objectives, means (such as budget distribution), programme and 'code of conduct' to achieve quality monitoring.

In parallel the **long-term options** should be investigated. Options for sponsorship of university chairs should be investigated as well as the establishment of an association of universities linked to EASA. In addition, further potential instruments should be developed on the basis of a survey among universities and EASA stakeholders.

Finally, since two consortia involved in Marie Skłodowska-Curie Actions (MSCA) for creating PhD networks have contacted EASA (i.e., ‘TRACES’ (in flight icing) and ‘eVTOL and Drones Flight Physics’), the Task Force should develop means of involving these networks in an appropriate manner.

5 Report of Task Force #2: Impact of climate change

5.1 Introduction and Scope

In its sixth assessment report[2], the Intergovernmental Panel on Climate Change (IPCC) reported that the global mean air surface temperature has increased by 1.1°C in 2020 compared to pre-industrial levels. They also foresee a very likely further increase to 1.5°C before 2040 and 2.0°C before 2060. In addition, regardless of the scenario, temperatures will likely rise in Europe faster than the global average.

This IPCC report states that every incremental increase of the global mean air surface temperature increases the impacts of severe and extreme weather events, such as storms and hurricanes, heatwaves, heavy precipitations, flooding, droughts, etc.

This increasing impact can manifest itself in numerous ways, including:

1. increased magnitude of the severe and extreme weather events;
2. increased frequency of the severe and extreme weather events;
3. severe and extreme weather events occurring in new regions;
4. variability of the occurrences of severe and extreme weather events (for example, occurring either earlier or later in the year than they have in the past); and
5. more frequent combinations of severe and/or extreme weather events.

Hence, climate change affects trends related to hazardous weather phenomena for aviation (e.g., changes to storm patterns, changes to airborne icing conditions, changing wind patterns, changing precipitation, etc.), which may significantly magnify some safety risks and create new ones.

For this reason, since 2023 the European Plan for Aviation Safety (EPAS) includes a strategic priority to manage the impact of climate change on aviation safety[3], and since 2024 a research action to review scientific works on the past and future trends regarding weather-related hazards for commercial air transport aeroplanes, and on the impact of climate change on these trends[4]. For future trends, the interest is on the projected changes associated with different emission scenarios from the IPCC. The typical economical lifecycle of large aeroplanes and associated ground infrastructure and ground communication, navigation and surveillance systems puts the major focus on changes until the middle of the century.

More specifically, EASA expressed an interest in investigating the trends regarding these potential hazards and safety risks:

- Severe turbulence (within cloud and in clear air) during climb, cruise and descent,

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[2] Refer to Assessment report 6 (Climate Change 2021, the physical science basis), August 2021.

[3] Refer to EPAS 2023-2025 Volume I, Strategic priorities (European Plan for Aviation Safety (EPAS) 2023-2025 | EASA (europa.eu)), section 3.1.1.

[4] Refer to EPAS 2023-2025 Volume II, EPAS actions, 2024 edition (European Plan for Aviation Safety (EPAS) 2023-2025 | EASA (europa.eu)), research action RES.0059.

- Hail during the flight,
- Lightning strike during the flight,
- Wind hazards associated with severe convective weather (e.g. low-level windshear during approach, take-off or initial climb, updrafts, tornado, etc).
- Contaminated or flooded runway and fog during landing,
- Severe airborne icing during the flight,
- Sand and dust damage during the flight,
- Mass diversion of flights caused by a large-scale weather event,
- Surface weather conditions affecting take-off safety, and
- Bird strike during take-off or landing.

The Task Force #2 was formed in the SC meeting in March 2022. In 2022, it consisted of three scientific members (Vincent-Henri Peuch, Christiane Schmidt, and Nicole Viola) and two EASA members (Guillaume Aigoin and Filippos Tymvios); in 2023, it consisted of two scientific members (Christiane Schmidt and Nicole Viola) and two EASA staff members (Guillaume Aigoin, Senior Flight Data Expert and Filippos Tymvios, Meteorology Expert), as well as a temporary scientific member (Suzanne Salles, PhD student).

Task Force #2 deliverables are expected to become an important information source for EASA activities to manage the impact of climate change on aviation safety (such as the European Network on Impact of Climate Change on Aviation[5]) and for the European Safety Risk Management process[6].

5.2 Work Plan and Methodology

The work plan of the Task Force focused on the investigation of a selected number of hazards, namely severe convective storms and hail, clear air turbulence, sand and dust damage during flight, airborne icing, and rising air temperatures and their effects on take-off performance. In addition, a preliminary analysis of lightning was performed.

In 2023, the work of the Task Force was organised as follows:

- Christiane Schmidt was responsible for convective weather and associated hazards,
- Nicole Viola was responsible for clear air turbulence and airborne icing,
- Filippos Tymvios was responsible for sand and dust damage,
- Suzanne Salles was responsible for rising temperatures and effect on take-off performance, and
- Guillaume Aigoin was responsible for the coordination of the Task Force activities.

The scientific members reviewed the state-of-the-art knowledge (review of more than 100 scientific papers) of the chosen hazards and deepened open issues with international experts in the fields,

[5] Refer to EASA launches new initiative to tackle impact of climate change on flight safety | EASA (europa.eu)
[6] Refer to Safety Risk Management | EASA (europa.eu)

namely in 2022: Prof. Michael Kunz, Dr. Susanna Mohr (both from the Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology, Germany) and Dr. Timothy Raupach (Climate Change Research Centre, University of New South Wales, Australia) for hail, John T. Allen (Associate Professor of Meteorology, Central Michigan University, USA) for hail and severe convective storms, and Paul Williams (Professor of Atmospheric Science, University of Reading, UK) and CERFACS, Laurent Terray (Director of the Climate modelling and Global change (GLOBC) Team at CERFACS and PhD Students of the GLOBC Team at CERFACS) for clear air turbulence. In 2023: again, with Paul Williams and CERFACS (Christian Pagé and Mohamed Foudad), moreover, with Pieter Groenemeijer and Francesco Battaglioli (both from the European Severe Storms Laboratory) on hail and convective storms, and with Victor Gensini (from the Northern Illinois University, USA) on dynamical downscaling.

Specific virtual meetings were scheduled with these international experts to further discuss their latest findings.

All members of the Task Force, i.e., the scientific members and the EASA members, regularly met through biweekly virtual meetings during which the scientific members presented the progresses of their research. The meetings were also useful to further elaborate together the information of the experts in climate change and to prepare the presentations for the meetings of the EASA Scientific Committee.

5.3 Key Findings in 2023

5.3.1 Severe Convective Storms and Hail

For details of the development of convective weather and associated phenomena, definitions, observations, proxies[7] for projections, projections, as well as knowledge gaps and uncertainties, we refer to the appendix. Most projections are based on proxies, but also projections using dynamical downscaling are reviewed.

Hail.

- Any observational data for hail is sparse.
- For ***Europe***, past trends on hail show little agreement, though a recent analysis indicates a **strong and significant increase in hail frequency in parts of Europe, e.g., in Northern Italy**.
- For ***Europe*** an **increase of the frequency of environments that are favourable for hail** (with low significance and some contradictions, e.g., the UK) **is projected**—even for the middle of the century. For the end of the century and RCP8.5 this includes increases of up to 160%. Changes are attributed to more convective instability because of low-level moisture and an increasing melting level height.

[7] For most weather phenomena, the phenomenon itself cannot be projected. Hence, researchers use variables that they can measure/project—so called proxies—to infer information on the actually interesting variable, e.g., the frequency or intensity of hail. For example, for hail, proxies for convective instability, for the microphysical processes and for vertical wind shear are used—and different proxies exist for all of these.

- For ***North America***, past trends do not show clear trends.
- For ***North America***, projections of hail intensity (hail sizes/damaging hail stones) and frequency are consistent between approaches based on different climate models, and an **increase of days favouring severe convective storms within most regions and seasons is projected**. The increase in environments is particularly projected for warm seasons and warm and humid regions, the increase in intensity/severity is projected for dry and cool regions, but with fewer events. Altogether a shift to larger hail (on the ground) is projected. The number of studies with projections for the **middle of the century are limited**.
- For ***Oceania***, the only past trends exist for Sydney, with a negative trend for severe hail.
- For ***Oceania***, projections are scarce, but the existing studies agree in trends: **an increase in frequency, severity, and favourable environments**, but also large inter-decadal variability. The only projection for the middle century is for the Sydney Basin, also with an increase in frequency and intensity of hailstorms.

For a detailed description on the existing past- and future-trend studies (results, methods used, considered time frame etc.), please see the appendix.

Knowledge gaps:

- Hardly projections for regions outside of Europe and North America exist, because the same proxies cannot be used for different world regions.
- New proxies must be developed for other regions.
- Observational data are spatially limited.
- Few future-trend studies of the middle of the century exist—not because methods are lacking, but because results for end of century are more statistically significant.
- Data for 500 hPa (about 5000-6000 meters altitude) is lacking.

Uncertainties in the analyses stem from a variety of factors:

- Trigger mechanisms/initiation for hail are not considered in many studies—and even if the atmosphere is prone to produce hail, this still hardly happens.
- The microphysical processes of hail are still associated with high uncertainties.
- Hail events have high variability.
- Proxy-based studies have a low resolution in space and time, while for the actual formation of hail a high resolution is needed, which in turn is very computationally expensive.

For a detailed description of the reasons and consequences of the knowledge gaps and uncertainties, please see the appendix.

Severe Convective Storms (Thunderstorms).

- There do **not exist reliable, long-term records of severe thunderstorms**. The largest set of records exists for the US. However, a recent study indicated that the **occurrences of thunderstorm environments have significantly increased across most of Europe during the past 72 years.**
- For ***Europe***, an **increase in frequency of favourable environments for severe thunderstorms and the number of days with such environmental conditions is projected**—with varying magnitude. However, for **southwestern and southeastern Europe and northwest Ireland, a slight decrease in thunderstorms** is projected. For certain regions (Iberian Peninsula), the increase is most pronounced in summer and fall. The **cleanest upward trends** can be described for **Southern Germany, Italy and Southern France**. The driving factor for the increases is **that thunderstorms are more likely to produce more severe weather hazards in future climates.**
- For ***North America***, an **increase in frequency of favourable environments for severe thunderstorms and the number of days with such environmental conditions is projected** for several regions in the US. For spring and fall and increase of severe thunderstorm environments is already projected before a global warming of 2°C for the Eastern US. The **largest increase** in the number of days with severe thunderstorm environmental conditions is projected for **summer and spring**—with largest increases for **regions close to the Gulf of Mexico and the Atlantic**. An **increase in the frequency and intensity of supercells**[8] is projected for the **eastern contiguous US**, they will be less frequent in parts of the Great Plains. The **season for hazardous convective weather** is projected to become **longer**.
- For ***Oceania***, an **increase in severe thunderstorm environments is projected for northern and eastern Australia**, but only a single study exists.
- For ***Japan***, a doubling of the frequency of strong tornadoes is projected for spring and (geographically limited) for summer.
- For the ***world***, a **frequency increase in environments favourable to convective storms of 5-20 percent per °C of global warming is projected.**

For a detailed description on the existing past- and future-trend studies (results, methods used, considered time frame etc.), please see the appendix.

Knowledge gaps/Problems:

1. Projecting the initiation of convective storms is still very imprecise.
2. No good proxies are known for regions not in the USA or in Europe.
3. Few future-trend studies for the middle of the century exist—not because methods are lacking, but because results for end of century are more statistically significant.

[8] intense, long-lived thunderstorms, responsible for most damaging hail and deadly tornadoes

4. Existing global climate models and severe convective storms have different scales; hence, many severe storms cannot be detected by the current generation of global climate models.

5. When projections are made for severe convective storms, different phenomena (wind, hail, tornadoes) are aggregated; however, these are not favoured by the same environmental conditions, and considering them as a unified set of hazards is problematic.
6. Environments that are favourable for severe convective storms must not result in a storm, the likelihood for initiation is very local (which is not well reflected in global climate models).

Uncertainties:

- In climate models, proxies are used to project conditions favourable for severe convective storms—this does not mean that a severe convective storm actually forms.
- Many phenomena have large interannual natural variability and discriminating between climate change and this natural variability is problematic.

For a detailed description of the reasons and consequences of the knowledge gaps and uncertainties, please see the appendix.

Problems 4 and 6 (and in parts the first listed uncertainty) may be overcome by dynamical downscaling: in global climate models, convective processes are parameterized instead of simulating storms directly. Thus, the resolution on severe convective storms is significantly larger than that used in operational weather forecasting. To achieve that granularity even for projections, comparable to high-resolution regional climate models, dynamical downscaling is needed: in areas of interest high resolution is nested with the general low-resolution global climate model. That is, the scale is reduced, but dynamically only in those locations that are of interest for severe convective storms. This approach is detailed in the appendix. However, currently dynamical downscaling is associated with various obstacles, for example the very high computational cost and the very large output data sets. For a detailed description on the concept, existing future-trend studies and current limitations, pleases see the appendix.

Lightning.
The following are preliminary results on lightning: a conclusive literature review was not performed in 2023.Various researchers used lightning as an indicator for the occurrence of severe convective storms, hence, while their main goal was not to project changes in the hazard lightning, these are projections for that hazard. Because of the importance of lightning as a hazard for aviation, these preliminary results are summarized. The researchers considered cloud-to-ground lightning.

- ***Across most of Europe***, the **occurrence of lightning has significantly increased during the past 72 years,** with the largest absolute increase in the Alpine and Caucasus Mountains, and the largest relative increase in Scandinavia. **The increases** appear throughout the year, but **particularly during summer**. Across Russia, a significant decrease in lightning occurred.

- For ***Europe***, an **increase in lightning cases for central and eastern Europe are projected** both for the middle and the end of the century and all different representative concentration pathways, for the end of the century, increases in lightning counts over **the southern Nordic countries, the British Isles and parts of the Atlantic Ocean** are projected (with an increase by a factor of 2.6 over Scandinavia). Decreases of lightning counts are projected over various parts of Europe, except for higher terrain—the projected **lightning increases are strongly correlated with elevation**. **During summer, increases are projected for northern and a decrease in central Europe**—this decrease is accompanied with a reduction in mean cloud ice which **yields fewer lightning strikes/thunderstorm**.
- For ***the US***, the strongest positive lightning trends occurred in the southern States over the past 72 years, significant negative trends were found across the Colorado Plateau and the Great Basin.

For a detailed description of the considered studies, please see the appendix.

5.3.2 Clear air turbulence

An important source of Clear Air Turbulence, CAT, is strong vertical wind shear, which is prevalent within the atmospheric jet streams. The investigation here reported has focused on CAT due to jet streams. Effects due to mountain waves and convection have been disregarded. Please refer to the appendix for more details.

The difficulty of long-term CAT prediction is due in large part to the fact that, from the meteorological perspective, turbulence is a “multi-scale” phenomenon. In the atmosphere, turbulent “eddies” are contained in a spectrum of sizes, from 100s of kilometres down to centimetres. The effect of the turbulence eddies on aircraft acceleration and trajectory are more pronounced when the size of the eddies is about the size of the aircraft. While large scale eddies can be forecasted, small scale eddies cannot. However, it appears that most of the energy associated with turbulent eddies on the aircraft scale cascade down from the larger scales of atmospheric motion. Assuming the large-scale predictions are sufficiently accurate, the turbulence prediction problem is then one of identifying large-scale features that are conducive to the formation of aircraft-scale eddies. Therefore, diagnostic indices from numerical weather prediction models are used to identify and predict regions likely to contain CAT. The diagnostics indices are mathematical models that generally assume that the smaller-scale turbulence is formed as a result of conditions set by the large-scale flow. Then the clear-air turbulence diagnostics are converted into eddy dissipation rates (EDR). The eddy dissipation rate is a natural measure for quantifying the strength of turbulence.

Globally, results of two independent research teams on historical patterns and trends of CAT in the recent four decades (1979–2019/2020) show that high frequencies of MOG CAT occurred on the northern side of the jet in the winter period (DJF) and three maxima patterns were found over the East Asia, Northern Pacific, and North-western Atlantic regions (and continental United States for one research team). There is substantial agreement between these scientists on hotspots for MOG CAT in

past trends and on their geographical locations. However, there is no agreement on which is the region most affected by MOG CAT, being East Asia for one team and North Atlantic for the other.
Current results of CAT future trends span typically over 30 years (2050-2080) and reveal that the busiest international airspace around the middle and high latitudes (North Atlantic, North America, North Pacific, Europe, and Asia) experiences larger increases in CAT than the global average, with the frequency of severe CAT approximately doubling at 200 hPa (12 000 m above sea level) over North America (+113%), the North Pacific (+92%), and Europe (+161%). The less congested skies around the tropics (Africa, South America, and Australia) generally experience smaller increases. Whereas globally, it is light turbulence that experiences the largest relative increase, locally, it can be severe turbulence (e.g., over Europe). For each strength category and geographic region, the increase in frequency is larger at 200 hPa than 250 hPa (10 000 m above sea level). The increase in frequency generally displays relatively little seasonality.
The same future trends for CAT is confirmed by various multi-model climate projections, which indicate that the positive trend will continue in the future with the global warming. Results reveal that North Africa, East Asia and Middle East are MOG (Medium or Greater) CAT hotspots with high agreement amongst the climate models and the CAT diagnostics. In general, models project a MOG-CAT increase within the 20-40°N latitudinal band and a weak decrease northward. The projected increases in MOG-CAT frequency over these regions are greater when the global mean air surface temperature is higher. Even though the results of different research teams are consistent in some cases (i.e. the increase of frequency of occurrence of MOG CAT with global warming scenarios for certain hotspots), complete agreement amongst scientists has not been reached yet for all geographical areas and all seasons. Contrary to previous studies, some recent research results show in fact a slight decrease in MOG-CAT frequency over the North Atlantic and a MOG CAT frequency increase over North Africa and Middle East.

Uncertainties mainly relate to:

- **diagnostics**. Most of the uncertainties stems from the turbulence diagnostics rather than the climate models. The limiting factor that is preventing the reduction of uncertainty in projections of future CAT does not lie with climate models, but with CAT diagnostics. Therefore, to reduce these uncertainties, further research is needed to improve and refine the diagnostics. Considering specific set of diagnostics, particularly weighted average of set of diagnostics, instead of simple average, could be an interesting approach to increase accuracy of results. Weighted average allows in fact to make more skilful diagnostics count more. The skill of a diagnostic is considered higher if there is higher agreement with observation data. Weighted linear combinations of the clear-air turbulence diagnostics calculated from numerical weather prediction models have been found to have significant skill when verified against pilot reports (PIREPs), and these combinations are currently being used for operational turbulence forecasting. In addition, gaining further insights into the circumstances in which each individual diagnostic does (and does not) add useful information to the assessment of CAT intensity level could be crucial, so that a diagnostic may be down-weighted or eliminated from the ensemble on those occasions when it is merely adding noise. Reaching these insights will likely require further improvements in our fundamental understanding of the sources and dynamics of CAT. These could lead to consider different set of skilful diagnostic indexes to best represent CAT due to diverse physical phenomena in different geographical areas. This specific

- issue appears to be extremely challenging. Aircraft measurements may be very useful to push the limits of current research. However, aircraft measurements may not be directly available.
- **Future radiative forcing scenarios**. The future radiative forcing scenarios depend on socioeconomic and political factors. These estimations are of course affected by uncertainties.

Limitations of current analyses mainly relate to:

- the altitude under consideration. In the state-of-the-art literature only 200 hPa and 250 hPa, corresponding to 10 000 and 12 000 m above sea level, have been investigated so far. Investigating lower and higher altitudes to cover a wider range of civil passenger aircraft may be of interest in future analyses. Moreover, the current typical cruise altitudes of medium-large subsonic civil passenger aircraft of 10000 to 12000 m above sea level may also change in the future, depending on the rise of the tropopause and consequently the rise of the jet streams due to an increasingly warming environment, notwithstanding the optimal aircraft performance and the propulsive technology requirements.
- The sources of CAT under consideration. Present results do not generally include all possible sources of CAT but focus mostly on CAT due to jet streams.

5.3.3 Rising Air Temperatures and Effects on Take-Off Performance

According to the IPCC's sixth Assessment report, compared to the pre-industrial period 1850–1900, the average global surface temperature is expected to rise by 1.2 to 3.0°C depending on the socio-economic scenario over the period 2041-2061 and by 1° C to 5.7° C over the period 2080–2100. More details on socio-economic scenarios, future projections and climate models are found in the appendix. Following are the main takeaways of the literature review on the impact of rising air temperature on take-off performance of large airplanes (for more details, please see the appendix):

- The review has shown that according to the cited studies, the intensity and duration of heatwaves linked to climate change have a degrading impact on take-off performance of large airplanes. The overall trends of rising temperatures in past and future periods are translatable in trends of lower performance for aircrafts.
- For past trends, studies on some selected airports show a steady and significant decrease of the average MTOW allowed by performance that result from rising temperatures and changes to wind patterns.
- For future trends, projections show an increase in restrictions between reference historical periods and an even sharper increase between mid-century and end of century periods which depend on aircrafts, airports and projected socio-economic scenario for the future.

- Studies show that airports most impacted are airports where daily temperatures are high with restrictive conditions like high altitude and short runways being additionally limiting factors. The severity of impact depends on degree of temperature of course but also on the type and weight of aircraft, the dimension of the runway considered and the altitude of the airport.
- Overall, aircrafts that seen most impacted by limitations seem to be heavier ones. But it is important to view impact on an aircraft linked to a specific runway in specific atmospheric conditions. A medium-haul aircraft might have degraded performance at high temperatures but if it is operating on a long runway dimensioned for larger aircrafts, the impact might not be very important.
- It is important to differentiate cases where the margin for degraded performance is high or not. The length of many runways is such that they still permit take-offs under considerably degraded performance.
- It is important to note even though no restriction must be imposed, the TOD “safety margin” (i.e. the remaining distance to the end of the runway when the aircraft reaches a height of 35 ft according to TOD computation) is reduced with degraded performance...
- Most of the studies reviewed focus on large commercial airplanes, mostly A320 and B737 which are medium-haul aircrafts, the main reason for this choice was to make the study’s scope as wide as possible so choosing aircrafts that are largely used around the world, in many airports under a large range of atmospheric conditions. It seems however that the sensitivity of performance to temperature gets higher with heavier TOW so the impact on the largest airplane models needs to be studied.
- In most of the studies cited, most airports are located in North America and Asia. Other continents are not well covered.

5.3.4 Dust, dust storms and sand storms

For details on the origin of atmospheric dust, dust storms and sandstorms, the safety risks caused by dust and sand for aviation and a preliminary review of scientific publications regarding future trends, refer to the appendix.

5.3.4.1 Origin and safety effects of dust and sand

Atmospheric dust and sand are caused by a combination of natural and human factors, including wind erosion of dry soils, desertification, land use and climate variability. The cycles of atmospheric dust and sand involve the movement of particles through various processes such as emission, transport, deposition, and re-suspension. Sand particles are larger than dust particles, are not transported far from the source and fall out of the air faster whilst dust particles are smaller in size and therefore can be transported at high altitudes and over very long distances, even crossing oceans.

Dust and sand in the atmosphere can damage aircraft engines, sensors and windshields, lead to failure of communication and navigation equipment on the ground and of meteorological observations equipment, and cause serious health problems among airport and ground handling staff. Dust and sand can also significantly reduce visibility, making VFR operations impossible.

Especially severe or repeated dust storms or sandstorms have adverse safety effects. Such episodes may lead to simultaneous closure of several airports and large numbers of flight cancellations and/or diversions in the regions where they occur.
Besides dust storms and sandstorms, prolonged exposure to higher background concentration of dust may also have adverse long-term effects on airworthiness, serviceability of ground equipment and the health of ground staff. This is more specifically an issue for operations taking place in the Global Dust Belt that spans over parts of North Africa, the Middle East, South Asia and the Southwest part of USA. Higher concentration of dust in the upper troposphere also exist in the so-called Upper Troposphere Dust Belt.

5.3.4.2 Results of research on trends

This preliminary review of research publications found that the safety risk associated to dust and sand-related hazards is increasing due to climate change in many areas of the Global Dust Belt. However, although climate models and projections provide insights into potential changes that could affect dust storms, it’s important to note that these projections come with uncertainties, and regional variations on the uncertainties exist.
As the mean air surface temperatures continue to rise, many regions in the world are experiencing more frequent and intense droughts, making the soil more susceptible to wind erosion and so providing extended source areas for atmospheric dust and sand. In addition, climate projections suggest that under all Representative Concentration Pathway (RCP)[9] of the IPCC, the surface soil moisture will further decrease in all regions, except for central Africa, central Asia and Alaska. This global decrease of the surface soil moisture is projected to be more significant under the RCP scenarios with higher radiative forcing, and to be more pronounced in winter and summer seasons. This is expected to result in increasing the average concentration of atmospheric dust.
In addition, several publications indicate that climate change is likely to increase the frequency and intensity of dust storms in the Global Dust Belt, where they are already common.
It seems that the future trends for dust storms in Europe and the Artic circle have not yet been explicitly researched. However, research work indicates that the conditions for uplift of dust in the Sahara Desert will be more frequently met. In addition, poleward atmospheric flow patterns favourable for the transportation of dust from North Africa to Europe are expected to become more frequent. The enhanced conditions for dust uplift combined with more frequent conditions for dust transport from the Sahara could result in increasing exposure of Europe to atmospheric dust in the future.

5.3.5 Airborne Icing

From a meteorological perspective, initial icing research focused on icing caused by small water droplets up to 40 µm in diameter. Regulations were then introduced in the 1990s, which describes meteorological conditions with potential for in-flight icing with water droplet diameter up to approximately 2 mm, referred to as supercooled large droplet (SLD) icing. Eventually, as far as the ice

[9] Representative Concentration Pathways (RCPs) are greenhouse gas concentration trajectories until the end of the 21st century that were adopted by the IPCC and are commonly used for modelling future climate trends.

crystal icing is concerned, knowledge of the underlying physics is currently limited. The following preliminary review has focused on water droplet icing (small water droplets and SLD icing). Ice crystals have been disregarded. Please refer to the appendix for more details.

The analysis of past trends of airborne icing is crucial to accurately predict the future trends and to possibly understand the impact of climate change on this physical phenomenon. Past trends of in-flight icing conditions have been assessed over the entire globe and throughout all seasons through CIP/CIP-sonde (Current Icing Product) method and SIGMA (Meteo France's System of Icing Geographic Identification in Meteorology for Aviation) algorithm. The CIP-sonde method uses a version of CIP that was tailored to determine the potential for icing and SLD using coincident observations from balloon-borne soundings and surface stations. The second method, SIGMA, is an algorithm to assess the potential presence of icing from global-scale model reanalyses of temperature (T) and relative humidity (RH).

In general, in past trends of in-flight icing, the low-to-moderate icing risks in the Northern Hemisphere tend to be most frequent in a zonal band poleward of about 40°N latitude, with broad extensions to lower latitudes at different longitudes. These geographical areas of icing risks stretching to southern regions are more significant in January, when the polar jet stream is strong and there is a sharper boundary between polar and mid-latitude air masses, then weaken slightly in April and finally become almost non-existent in July, when the regions with higher risk of icing tend to be confined to the Arctic. As the Arctic quickly cools in the fall, these meridional extensions are reestablished by October. In the tropics, a high-altitude weak icing belt is generally found within 20° of the equator and moves across latitudes throughout the year. In the Southern Hemisphere, icing risks is wide spread longitudinally and most common between 50° and 70°–80°S of latitude, with the southern limit along the coast of Antarctica. Elevated icing frequencies are semipermanent, but maximized in July, the peak of winter there.

Analyses of past trends over about 40 years (1979-2020) of airborne icing show that the frequencies of icing risks at the same altitude decrease when moving from weak to severe risk. Results reveal the seasonality of the airborne icing phenomenon, being the highest frequencies of icing risks at lower altitudes in winter season and at higher altitudes in summer season.

To better understand the impact of climate change on airborne icing, research studies have been carried out to compare the past trends with the future trends of seasonal frequencies of icing risk. Past trends have been based on ERA5 reanalysis data over the time period 1979-2014, whereas future trends have been based on the CNRM-CM6-1 climate model considering Global Warming Level equal to +4°C (SSP 585). For different altitudes the frequency of weak icing risk increases from past to future trends, being more significant at higher than lower altitudes. Even though the weak risk of in-flight icing cannot be considered as weather hazard, its increase of frequency from past to future trends appears still relevant and requires further analyses. The hazard magnitude shall be investigated more deeply as currently publicly available research results do not cover the entire spectrum from weak to severe icing risks. This holds true both for past and future trends of airborne icing. Therefore, nothing can be inferred on the evolution of intensity and duration of airborne icing as weather hazard. As far as the geographical coverage is concerned, global coverage seems not to be met yet for future trends of airborne icing, both in terms of longitudes and latitudes.

Uncertainties mainly relate to:

- models and algorithms to predict icing conditions. Models/algorithms, like CIP/CIP-sonde method and SIGMA algorithm, do have uncertainties that affect their accuracy and that depend on the implemented approach and methodology. In particular:
    - the CIP method has been developed as a multiple data source, hybrid approach to the diagnosis of icing. It combines satellite, radar, surface, and lightning observations with numerical model output and PIREPs to create an hourly, 3D diagnosis of icing and SLD. CIP-sonde similarly examines the vertical structure of the atmosphere using coincident
    - observations from soundings and surface stations. Based on this information, each profile is described by one of several icing scenarios (e.g., classical freezing rain). Within each scenario, fuzzy logic membership functions are applied to the data and then the potential for icing (small water droplets icing and SLD icing) is determined at each level.
    - The SIGMA algorithm requires only grids of T and RH, which can be derived from reanalyses data of the atmosphere, created using observations from soundings, surface stations, and satellites (among others). The operational version of SIGMA combines model forecasts of temperature, T, relative humidity, RH, and vertical velocity with real-time observations of cloud and precipitation characteristics from satellite and radar.
- The climate models used to analyse future trends of in-flight icing. Current research works are assessing the accuracy and performance of climate models in predicting icing conditions compared to ERA5 reanalysis data.
- Future emissions of greenhouse gases depend on socioeconomic and political factors.

Limitations of current investigations are listed hereafter:

- Generally, the techniques/models/algorithms, like SIGMA and CIP-sonde, do not take deep convection into account. This is done because aircraft specifically avoid flight into thunderstorms because of the many hazards they present, such as hail and lightning. Thus, their inclusion would extend the areas of potential exposure to in-flight icing. This choice is likely to result in underestimating actual icing frequencies in areas prone to thunderstorms, especially at relatively high altitudes.
- Current models/algorithms do not include the impact of aerosols on ice formation but research activities reveal that there is a relationship between aerosols and super-cooled water droplets. It seems that super-cooled water form more when there are less aerosols but this requires further investigations.
- Analyses of future trends of airborne icing should extend to higher altitudes that correspond to the typical cruise altitudes of large aeroplanes and include ice crystal icing, which are rarely considered in present investigations.
- Analyses of future trends of airborne icing should cover the entire globe at all latitudes.

5.4 Recommendations

Several recommendations are identified for the climate-related trends considered by the Task Force. For a more detailed analysis of these recommendations, please refer to the appendix.

5.4.1 Severe Convective Storms and Hail

For hail, to the best of our knowledge, studies on hail aloft (HALO) do not exist although they would be very interesting for aviation. Most studies focus on surface hail (because this is interesting both for agriculture and property on the ground), while the major impact on aircraft happens during flight. Hail that may appear on flight level may have melted until it reaches the ground. Thus, based on surface-hail studies, both the frequency of hail encounters and the characteristics of hail aloft (e.g., hailstone size, water content per cubic meter) could be underestimated. John T. Allen specifically highlighted the need for EASA to take action if they would like researchers to specifically study trends regarding HALO. Pieter Groenemeijer emphasized that microwave observation data from satellites could give more information on altitudes for HALO.

Hence, if EASA considers a better understanding of HALO trends—at altitudes relevant for aviation—to be important, we recommend that EASA investigates how to get research teams to work on this specific topic.

Moreover, to close the spatial gaps in future studies, proxies for world regions other than Europe and North America need to be studied. Finally, reducing any of the uncertainties could lead to improved projections.

One of the major problems for convective storms (smaller temporal and spatial scale than current climate models) can be either overcome by a new generation of climate models, or, by—according to interviewed experts—dynamical downscaling. The study of research using this technique (part of which should be published soon) might give more insight. Victor Gensini highlighted that global climate models are unable to simulate perils impacting humans, while dynamical downscaling is able to do so. Moreover, Francesco Battaglioli and Pieter Groenemejier estimated that dynamical downscaling could help to project which type of storm (i.e., isolated storms, long lines of storms, with high tops) will occur—which could be very interesting for aviation. Hence, if EASA considers these points of interest, we recommend that EASA investigates how to get research teams to work on this specific topic. Most studies using dynamical downscaling are performed in and for North America. Hence, if EASA is interested in studies using dynamical downscaling for Europe, we recommend to communicate this to the scientific community and all relevant research programs (such that researchers can obtain funding for the computationally expensive studies).

Both for convective storms in general and for hail specifically, the number of future-trend studies for the middle of the 21st century is limited. The main reason is that statistically significant results can be easier to obtain for the end of the century. However, the economic lifecycles of large aeroplanes (about 30 years) and of infrastructure and ground systems that support large aeroplanes operations make results for the middle of the 21st century more relevant for decisions by EASA and aviation stakeholders than results for the end of the century.

Hence, if EASA considers that an assessment of future trends for the middle of the 21st century is needed by aviation stakeholders, we recommend that EASA communicates this to the scientific community and to all relevant research programs.

5.4.2 Clear Air Turbulence

As far as CAT is concerned, the results of several research team agree on historical trends of increasing MOG CAT frequency over East Asia, Northern Pacific and Northern Atlantic. They also agree that overall, the frequency of MOG CAT will continue to increase, but specific disagreement remains on the most affected regions and on the magnitude of the changes. Uncertainties and limitations in present analyses prevent from reaching accurate predictions in the long-term trends.
Hence, we recommend to further investigate the individual turbulence diagnostic indices and CAT intensity level, and to explore the use of weighted average of set of diagnostics, which may need to be calibrated for the specific conditions of different geographical area. In addition to diagnostics, different forcing scenarios, other than the RCP8.5, should be considered and results should be compared. Moreover, while it seems that climate models play a less significant role regarding the uncertainty in CAT than diagnostic indices, using the new generation of CMIP6 models could bring more accurate results. Eventually, we recommend to extend the range of altitudes under consideration below 10000 m and above 12000 m.

5.4.3 Rising Air Temperatures and Effects on Take-Off Performance

- In light of the cited studies, there is a need for focusing case studies on other parts of the world than North America and East Asia. It would be beneficial to the European aviation sector to get focused studies on European region as well as oversea territories of EU member states, especially those already located in warmer climates, or on islands where it might be difficult to extend the runway: French Caribbean, French Guyana, Reunion Island, Madeira, Canaries Islands, etc. Some of these airports are essential to bring commodities to those who live on such territories.
- As shown in the review, assessing impact with a performance model allows more flexibility in the choice of input parameters and sensitivity analysis. For methodologies using an aircraft performance model, it is possible to easily consider different kinds of technologies (provided you find the data needed) and therefore quantify the sensitivity of each to high temperatures. More than assessing the impact rising temperatures due to climate change have on current aircrafts, it could inform the conception of future aircrafts more resilient in a context of adaptation to climate change. It is important to study the sensitivity of aircraft and propulsion technologies to high temperatures as such conditions will become inevitably more frequent.
- The use of performance models of aircrafts in academic research studies is faced with one challenge: access to data for validation of performance models. These models are based on many assumptions and simplifications of mechanical equations and their results need to be confronted with real performance data in order to be validated. Unfortunately, performance data are sensitive and difficult to obtain from either manufacturers or operators.

- When analysing the impact of future temperatures, a high time resolution might allow to quantify more into detail the daily impact on operations. The exceeding of a temperature threshold for take-off performance might not have the same impact on the daily organisation of operations if the threshold is only exceeded for a short or long time slot.
- Quantifying the effect of surface winds together with temperature would be interesting on a safety level for crosswinds and on a performance level for headwinds.
- On a safety level, attention needs to be given to the reduction in safety margins that can be caused by extreme temperatures. In particular, when adding other factors for insufficient take-off performance, like a too low pitch angle or an error in the estimation of take-off weight (TOW). For example, the sensitivity of the take-off performance to a range of TOW error should be quantified under different temperature conditions.

5.4.4 Dust, dust storms and sand storms

According to this preliminary review of research publications, the studies on historical trends of background dust concentration levels and on historical trends of dust and sandstorms seem to be rather seldom, limited to some geographical regions and to only give general trends. It would be beneficial to establish a complete and more detailed picture of these historical trends, especially for the European region and the surrounding regions (Northern Atlantic, North Africa, Middle East).
It seems that research on future trends could further investigate the effects of long-term changes to the general atmospheric circulation caused by climate change on the transportation of dust. Research on future trends could also investigate possible changes to the characteristics of the Global Dust Belt and of the Upper Troposphere Dust Belt, and the possible consequences of such changes in terms of dust storms and sandstorms, and of background dust concentration levels.
This preliminary review has not looked into the use of climate models in the research works on future dust and sand trends. This aspect would deserve further investigation.
Finally, works on future dust and sand trends should include projections for the middle of the 21st century, as this time horizon is probably more relevant for decisions by EASA and aviation stakeholders than results for the end of the century.

5.4.5 Airborne Icing

For airborne icing, to the best of our knowledge, the analysis of future trends of icing risks, considering the impact of climate change, is still limited from different perspectives: the hazard magnitude and frequency, the geographical coverage, the range of altitudes and the potential sources of in-flight icing. The magnitude of airborne icing in future trends shall be investigated more deeply as currently publicly available research results do not cover the entire spectrum from weak to severe icing risks. This holds true both for past and future trends of airborne icing. Therefore, nothing can be inferred on the evolution of intensity and duration of airborne icing as weather hazard due to climate change. Future trends of airborne icing shall also cover the entire globe at all latitudes and longitudes and analyses shall extend to higher altitudes that correspond to the typical cruise altitudes of large airplanes and include ice crystal icing, which are rarely considered in present investigations. Eventually, as current models and algorithms to predict icing risks do not include the impact of aerosols on ice formation, we recommend to consider this effect as research activities reveal that there is a relationship between aerosols and super-cooled water droplets.

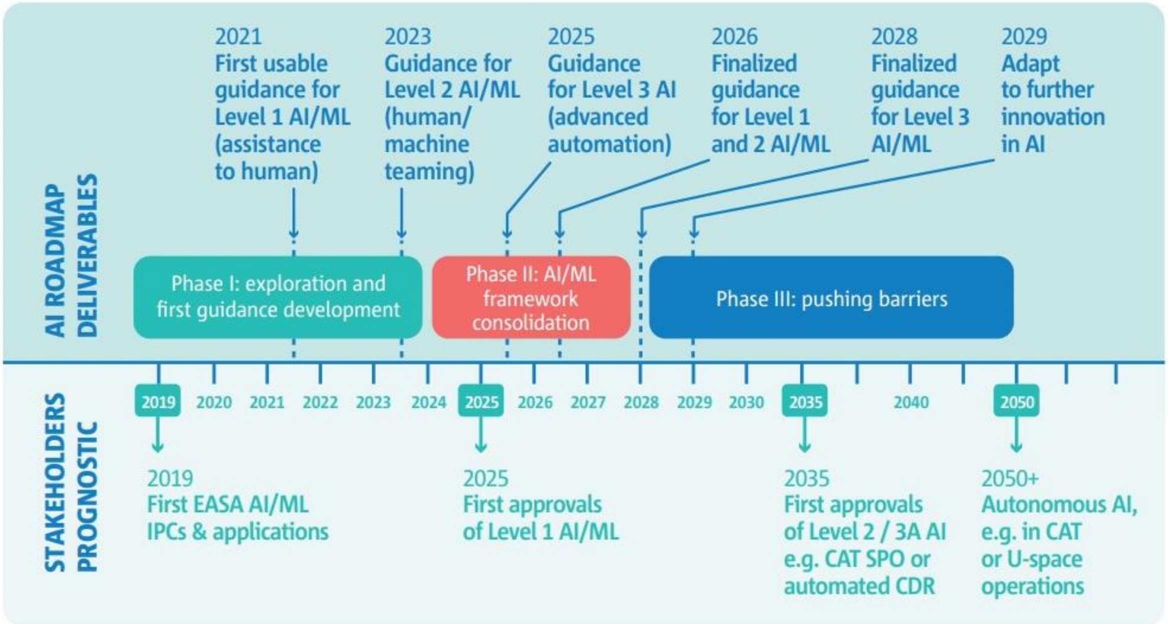
6 Report of Task Force #3: Artificial Intelligence

6.1 Introduction and Scope

The EASA's Scientific Committee provides advice on scientific issues that may influence the future development of the EASA expertise in scientific and technical domains linked to research, innovation, and disruptive technologies. In this respect, Artificial Intelligence (AI) was proposed by EASA as one of the most pressing topics to investigate jointly in the frame of a dedicated **'EASA SciComm AI task force'**.

The use of Artificial Intelligence technology in safety related or critical applications has been rapidly accelerated in the past five years, mainly due to the emergence of deep learning techniques which offer more performant and efficient solutions, in particular in the domain of computer vision and natural language processing, that open possible applications in safety related domains of aviation.

In May 2023, the Agency has published the **EASA AI Roadmap v2.0** to organize its action plan to prepare the necessary 'AI trustworthiness' guidance and anticipate necessary regulation updates to accompany this innovation wave. EASA has developed a further set of guidance as part of the 'exploration and first guidance development' phase of the EASA AI Roadmap.

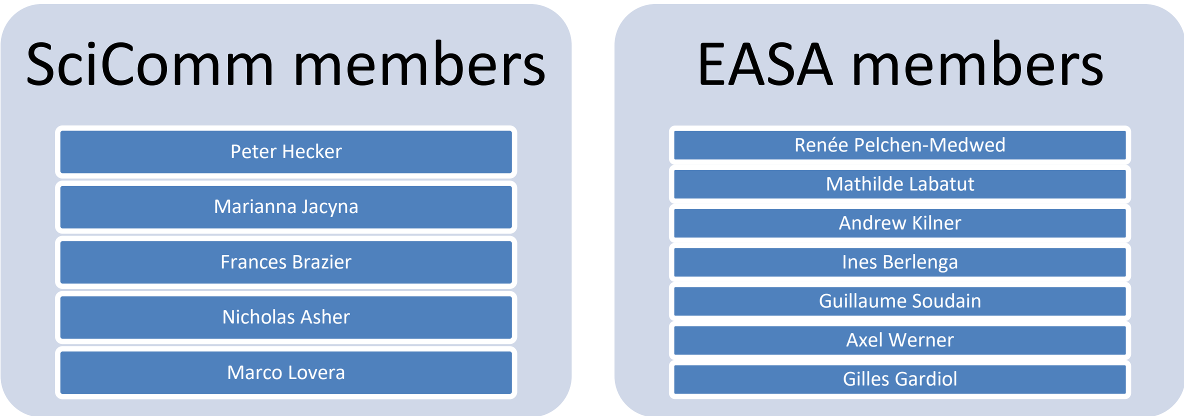


In support of the EASA AI Roadmap implementation effort, the Scientific Committee AI Task Force agreed in 2023 to launch three parallel work streams, on the basis of the published **Concept Paper 'First usable guidance for Level 1&2 machine learning applications' Proposed Issue 02** from February 2023 (building on the two work packages #1 and #2 from the 2022 AI Task Force activity):

- **Work package 3** - The novel **ethics-based assessment** builds on the ethical guidelines and checklist (ALTAI) from the High-level Group on AI of the European Commission (2018), as well as on the draft EU AI Act regulation (from April 2021). The guidance development has brought several important topics to attention, and with the support of the AI Task Force, EASA prepared a survey on ethics-based matters to determine where to put the emphasis and which boundaries to consider for the ethics-based assessment guidance.
- **Work package 4** - EASA has in 2023 entered in the finalisation of the **Level 2 AI guidance dedicated to Human-AI teaming (HAT)**. Beyond the already developed concepts of ‘learning assurance’ and ‘AI explainability’, Level 2 AI applications require to augment the AI trustworthiness framework with additional human factors guidance. The AI Task force supported the validation of changes to the proposed human factors objectives and the development of supporting ‘anticipated means of compliance’.
- **Work package 5** - The Level 2 AI guidance consolidation is the current priority. However, knowing that a number of use cases in **advanced automation AI (Level 3 AI)** are already in preparation, in particular related to drones, innovative air mobility or U-space operations, it is essential for EASA to start anticipating the main driving principles for this future development towards the deployment of more advanced automation powered by AI. What best forum than the Scientific Committee AI Task Force to pave this way.

6.2 Work Plan and Methodology

Before entering into the work plan and methodology, let’s first highlight the AI Task Force team composition:



The work of the EASA Scientific Committee AI Task Force has been organized through the following work plan for the 2023 activity:

→ **Work Package 3: Ethics based assessment (target beginning Q4/2023)**
  → Review of guidance principles for outstanding social/societal ALTAI items (e.g. management of unfair bias, risk of deskilling of humans, end-users monitoring…).
  → Support the development of ethical AI survey for aviation professionals.

- → **Work Package 4: Testing of the Human-AI teaming guidance (target beginning Q4/2023)**
  - → Validate the refinement of the 'Human Factors for AI' objectives based on public consultation and Scientific Committee Task Force feedback.

- → **Work Package 5: Anticipation of design principles for Level 3 AI (target beginning Q4/2023)**
  - → Review definitions and concepts from EASA AI Roadmap 2.0 on advanced automation and autonomy (Level 3 AI).
  - → Perform a state-of-the-art review on technology for advanced automation and autonomy in aviation and in other domains (automotive, railway, medical…).

Following the kick-off meeting for the AI Task Force on the 22nd March 2023, the activity of has been conducted through 5 virtual plenary meetings of 2 hours and 13 workshops of 1 to 3 hours.

In addition, a debrief from the activity of the AI Task Force has been presented at the general EASA Scientific Committee meeting on 20th September 2023.

6.3 Key Findings in 2023

Work Package 3: Ethics based assessment survey

This main activity for this work-package aimed at preparing the first phase of the EASA survey on 'Ethics of AI for aviation'. This initiative is designed to involve two distinct audiences. The first part, scheduled for end of 2023, is aimed at aviation professionals, while the second part, scheduled for 2024, is aimed at the general public.

Overall, the objective of this survey is to communicate on the EASA AI Roadmap and its associated 'AI Trustworthiness' framework, as well as to gather diverse perspectives on AI in aviation through a scenario-based survey. This comprehensive approach is intended to facilitate the creation of ethics-based guidance in the EASA AI Concept Paper (EASA, 2023) in line with guidelines from the European Commission High-Level Group on AI.

To ensure a robust survey framework, valuable input has been gathered from key contributors, including DLR (German Aerospace Centre), the Scientific Committee, the EASA AI Programme team and the EASA Network of Experts.

The survey includes nine use cases, each with 5-7 questions, covering critical ethical objectives such as reliability assessment, privacy of personal data, avoiding unfair bias, improving skills for the AI team, and de-skilling. In addition, practical considerations for regulating the field are explored, with a dedicated scientific section in the second part of the survey.

The survey, was officially distributed on the 15th December to EASA stakeholders, including the MAB and SAB, and published simultaneously on LinkedIn. The deadline for responding to the survey is the 15th January 2024. This strategic timetable will enable comprehensive information to be obtained from aviation professionals and the general public.

The results of this first survey will contribute to the identification of clear boundaries for the ethics-based assessment and guidance in the next version of EASA's AI Concept Paper (EASA, 2023), to be published in the first quarter of 2024. They will also be the basis for the development of phase 2 of the survey to gather the views of the general public in 2024.

Work Package 4: Testing of the Human-AI teaming guidance

The aim of this activity was originally to test and validate the Human – AI teaming guidance on the basis of the virtual use case "Proxima" that was developed as part of the AI task force activity in 2022. As the objectives of the HF for AI chapter in the concept paper are based on Proxima, the activity was re-scoped to address:

1) **Review and, where needed, update to the HF objectives, considering clustering, merging, splitting, and adding objectives.**
   The criteria for the review were whether the objectives were clear and understandable and whether they were positioned correctly in the document referring to the appropriate chapter.
2) **Identify the objectives needing additional Means of Compliance (MOC) and drafting of these MOCs.**
   The criteria for drafting the MOCs were directly linked to whether further details were needed so that the objectives are considered to be clear and understandable. Moreover, the drafting of MOCs facilitated the possibility to include examples.

This activity concerned the entire 'Human Factors for AI' chapter with a focus on 'Human-AI teaming', 'modality of interaction and style of interface', and partially on 'error management'.

The modality of interaction and style of interface includes considerations on:

- → design criteria for communication to address spoken natural language as well as spoken procedural language;
- → design criteria for gesture non-verbal language;
- → design criteria for management of multi-modal interaction.

Error management refers to the contribution of AI-based systems to a new typology of human errors and how AI-based systems will affect the methods of error management.

Results of objective review: the activity resulted in two newly added objectives: one in the chapter 'design criteria for communication to address spoken natural language' and one in the chapter 'design criteria for communication to address spoken procedural language' respectively.

One objective (HF-26) related to "design related errors made by the human-AI teaming" in the 'error management' chapter was deleted, and merged with the more generic objective HF-25 related to the minimisation of the likelihood of "design related human errors" in a generic manner.

Results of the MOC review: throughout the entire HF for AI chapter thirteen new MOCs were drafted by the agency with the help and review of the Scientific Committee AI Task Force team.

The review and with that the activity of WP4 resulted however not only in the drafting of MOCs but also in the definition of **new concepts such as 'situational representation' and 'relevant and alternative solutions'**:

- → Situation awareness is a well-known definition in aviation formulated by M. Endsley (1988) as "the **perception** of elements in the environment within a volume of time and space, **comprehension** of their meaning, and the **projection** of their status in the near future ". This concept however referred so far only to humans. With the existence of AI-based systems and their development over different AI levels the need for a similar concept for the AI based system became necessary. The Scientific Committee together with EASA developed the term 'situational representation' with the following draft definition: "**Collection** of the environment and system state as well as of the state of the human end user, **processing** of this information, with the aim to enable **extrapolation** a target status in the near future from this information."
- → Concept of relevant and alternative solutions: during the workshops it was discussed that it is not possible to define an optimal solution or to determine when a solution is optimal, therefore the term "optimal and suboptimal" was replaced with more "relevant and alternative solutions".
- → Other discussions and clarifications occurred around specific concepts like "poor decision making", "misunderstanding and misinterpretation".

Work Package 5: Anticipation of design principles for Level 3 AI (advanced automation)

The first activity performed under this work package was the **review of the existing definitions of automation, advanced automation and autonomy from the EASA AI Roadmap v2.0**. The consideration that automation and autonomy are distinct topics has been validated by the Scientific Committee. Automation is referring to the use of systems without human intervention, whereas autonomy is a characteristic of an advanced automated system.

> **Autonomy** — Characteristic of a system that is capable of modifying its intended domain of use or goal without external intervention, control or oversight[10].
>
> **Advanced automation** — The use of a system that, under specified conditions, functions without human intervention[11].

An important discussion has been raised around the notion of **machine-machine interaction**, which will have a very important weight when developing guidance for systems above Level 3B in the future Issue 03 of the EASA AI Concept Paper.

The second and major activity concerned the **state-of-the-art review on advanced automation and autonomy in the various domains of aviation (UAS, ATM, military) and other domains (automotive, railway, medical and space)**. This review aimed at supporting the preparation of a set of recommendation for anticipating the future Level 3 AI (advanced automation) guidance. The scope of the review focused on 'advanced automation' (levels 3A/3B AI) and anticipated autonomous AI (potential Level 3C). It excluded more traditional automation (e.g. autopilots). The selected research papers did not need to focus necessarily on AI-driven applications: the review also considered papers, e.g. in the UAS domain, to support the identification of design principles for advanced automation even without the use of AI (e.g. automatic subways), which are considered relevant to the guidance anticipation effort. A template has been used for each domain and the full reviews are provided in appendices to this report.

The main conclusions of the state-of-the-art review are:

→ Machine learning and deep learning are identified as essential for the development of advanced automated or autonomous systems in all of the reviewed domains;

→ Experiences from certain domains such as railway can only be transferred to a limited extent to aviation, considering the difference in complexity of the environment, despite similarities in the levels of autonomy;

→ In the ATM domain advanced automation and autonomy are a relevant topic since decades as they are key drivers in advancing safety and performance in control and management of air traffic. Accordingly, a large number of publications is available, of which the majority however does not build on a coherent and commonly agreed terminology in the context of automation, autonomy, and AI. Most related publications address new approaches of conventional automation as well as the application of AI in the ATM context. The latter aspect is mainly discussed in the context of UTM, personal mobility and drones. Still, the framework of 'Levels of Automation' is seen as a standard and guidance is provided through a taxonomy, which is laid down e.g. in the summary report „Automation in Air Traffic Management: Long-term vision and initial research roadmap" published by the SESAR JU. Within this document reference is provided to the EASA Artificial Intelligence Roadmap 2.0 allowing a mapping between the two schemes, which is considered very helpful in establishing a common ground.

→ In the UAS and innovative air mobility domains, research in the field of "autonomous UAV" is increasing rapidly, with a prevalence of the "navigation", "planning" and "vision" categories, as well as "decision-making" and "multi-agent";

→ In most of the domains under study, the term "autonomy" is used in lieu and place of "automation" or "advanced automation", although the classification schemes for the so-called level of autonomy generally refer to "levels of automation". One paradox is that in domains such as UAS and innovative air mobility, the level of automation rarely supports real "full automation/autonomy", as human intervention is mentioned in most the corresponding definitions.

Note: a number of definitions provide imprecise (e.g. in the ATM Master Plan 2020 between Level 3 (conditional automation, where automation can initiate actions for some tasks and Level 4 (high automation, where automation can initiate actions for most tasks) or non-generally applicable (domain specific) boundaries between levels (e.g. in the automotive domain between Level 1 (assistance, automating either lateral or longitudinal motion control) and level 2 (partial automation, automating both lateral and longitudinal motion control)).

- → The classification scheme proposed in the EASA AI Concept Paper Proposed Issue 02 has the merit to provide clear boundaries and to offer a traceability to any of the other domain domains automation schemes (see table below).
- → It is recommended to consider the notion of mission complexity and environment complexity from the NIST ALFUS study as a basis for a further refinement of the EASA AI Level 3B.
- → The notion of team work is rather absent from the respective domains’ automation schemes, and the link to Human-AI collaboration at Level 2B needs to be reinforced within the aviation sub-domains.
- → Finally, the Scientific Committee agrees with the anticipation that the AI Safety Risk Mitigation building block need to be extended to manage the risks inherent to the lack of human end-user in operations at Level 3B or higher. This should encompass the notion of risk management by the systems, with capabilities to manage uncertainty and operational complexity (mission, environment).

The following table provides a summary of the corresponding automation levels between domains, including a mapping of the EASA AI trustworthiness guidance that is anticipated to be applicable:

UAS/UAM (JARUS AutoMethod 1.0)	ATM/ANS (Master Plan 2020)	Medical ()	Railway GoA (IEC 62290-1)	Automotive (SAE J3016)	Level of AI (EASA AI Roadmap and Concept Paper)	Applicable EASA Concept Paper Guidance			
						ET	AIA	HF	SRM
Level 1 – Assisted operations	Level 0 - Low automation / task execution support	Level 1 - Data presentation	GoA1 – Manual?	Level 0 – no driving automation	Level 1A - Human augmentation				
-	Level 1 - Decision support	Level 2 - Clinical decision support	-	-	Level 1B - Human cognitive assistance				
Level 2/3: Task reduction / supervised automation	Level 2/3 – Conditional automation	-	GoA2 – Semi-automatic (STO)	Level 1/2 – Assistance / Partial automation	Level 2A - Human-AI cooperation				
-	-	-	-	-	**Level 2B - Human-AI collaboration**				
Level 4: Manage by Exception	Level 4 – High automation (most tasks)	Level 3 – Conditional automation	GoA3 – Driverless (DTO)	Level 3 - Conditional automation	Level 3A – Supervised advanced automation				
Level 5: Full automation	Level 5 – Full automation	Level 4/5 – High/full automation	GoA4 – Unattented (UTO)	Level 4 – High automation	Level 3B – Non-supervised advanced automation for non-complex operations				Extended AI SRM
					Level 3C – Non-supervised advanced automation for complex operations				
-	-	-	-	Level 5 – Full automation	Level 3D – Autonomous AI				

ET = Ethics-based assessment objectives
AIA = AI assurance objectives
HF = Human Factors objectives
SRM = AI safety risk mitigation
GoA = Grades of automation (railway domain)

6.4 Conclusions for the AI Task Force activity in 2023

The AI Task Force activity in 2023 has been instrumental for the EASA AI Programme, enabling the preparation of the first AI Ethics Survey for aviation, refining the set of Human Factors objectives for Human-AI teaming, and anticipating a first set of principles for the development of Level 3 AI guidance (advanced automation).

6.5 Recommendations for future work within the AI Task Force

The AI Task Force team recommends to extend the activity of the AI Task Force in 2024 to address the next upcoming priorities of the EASA AI Programme:

- → **Work Package 6: Ethics based assessment**
  - → Support to general public survey
  - → Support to update of guidance on ethics-based assessment in view of EASA Concept paper Proposed Issue 03

- → **Work Package 7: Testing of the Human-AI teaming guidance**
  - → Testing Level 2 AI Human Factors guidance with the identified use case
  - → Further develop teaming concepts for Level 3A
  - → Support to final guidance development for the 'HF for AI' building block

- → **Work Package 8: Anticipation of design principles for Level 3 AI applications**
  - → Support development of design principles (Level 3 AI)
  - → Selection of use cases for Levels 3B to 3D AI.

7 Conclusions

The EASA Scientific Committee has continued its operation in the year 2023 and has successfully closed its second full annual cycle of activities.

On the organisational level the SciComm has further refined its internal process for organizing its workflow. This process has proven its suitability also over the second year as it has ensured an efficient operation and delivering maximum support to EASA. Along the turn over to the third year of operation the tree Task Forces have been continued and their work programme has been updated according to the needs of EASA and the recommendations provided by the Committee in 2023. They continued delivering important results, which have been summarized in this report. All three Task Forces delivered output relevant for short term considerations (to be taken up immediately enabling "quick wins") as well as for long term considerations supporting the strategic level.

The **PhD Task Force has** identified additional long-term options for connecting the European academic body to EASA enabling a win-win-situation for both entities. On the **longer term** an additional exchange with aviation related Doctoral Networks funded under the Marie Skłodowska-Curie Action scheme should be approached and interfaces identified. In addition, the EASA PhD Conference has proven to enable a long-term stability of relations between academia and EASA; which should be further exploited. This should be accompanied by a more formalized and institutionalized Academic Network linked to EASA.

On **short term**, the first edition of the "EASA PhD Conference" has been held successfully and excellent PhD students were presented with an award, recognising the quality and pertinence of their work. A bilateral engagement with EASA experts has been carried out allowing EASA to gain insights on certain aspects of new technologies and new challenges, while students got an opportunity to get feedback on the operational application of their research work.

According to the research works reviewed by the **Task Force on impact of climate change**, there are consistent indications that climate change is increasing the frequency of severe thunderstorms, hail and lightning strikes in Europe, North America and other world regions. The reviewed research works also consistently find historical increase of the probability of encountering severe clear air turbulence over East Asia, the Northern Pacific and Northern Atlantic, but they don't fully agree on which region will be most impacted in the future. According to the analysed research works, rising air surface temperatures result in more frequent days where the take-off performance of large aeroplanes is significantly decreased. This affects airports in Europe, North America and Asia, and this trend is predicted to continue and even accelerate after the mid-century. Research works also indicate that the risk of dust storms is likely to increase in the regions already affected by such events, and that Europe may become more and more frequently exposed to the dust coming from North Africa. Only preliminary results on airborne icing trends of one research team could be found and reviewed. In all these works, there remain numerous uncertainties and knowledge gaps, and this report contains several recommendations to help progress knowledge on each of the investigated weather hazard trends.

The **Task Force on Artificial Intelligence** allowed **on the short term** to prepare and launch the **survey 'Ethics for AI in Aviation'**. This survey will fuel the next steps of guidance development and a dedicated work stream for the AI Task Force activity in 2024. It also enabled the consolidation of the concepts from the **Human-AI teaming** guidance laid down in the Proposed Issue 02 of the EASA Concept Paper on Artificial Intelligence from February 2023, in view of the publication of final Issue 02 early 2024.

On the **longer term** the anticipation work on the design principles for advanced automation (Level 3 AI) paved the way for a finer grain classification of 'non-supervised advanced automation' operations, based on the complexity of the operations and on their real autonomy. The notion of autonomy is confirmed to be a characteristic, triggered at the very end of the advanced automation scale, for systems capable of setting their own intended domain of use or goal without external oversight. Moreover, a mapping to other domains automation schemes confirmed the genericity of the EASA AI Levels classification scheme and highlighted the lack of consideration on Level 2B and on real autonomy in most of the other domains, opening future perspectives of wok for the AI Task Force in 2024. Overall, this work will inspire the future development of EASA guidance for Level 3 AI in the upcoming Issue 03 of the EASA AI Concept Paper.

8 References

(2021). *Terms of reference for EASA.2019.CEI.14.EC010: Scientific Committee.*