EASA
European Union Aviation Safety Agency

EASA SCIENTIFIC COMMITTEE

Annual Report 2022

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Disclaimer

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1 Executive Summary

EASA has established a Scientific Committee with the objective to provide advice to its 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. Eleven internationally recognized experts have been selected as committee members for their expertise, being mostly of academic nature, with direct access to universities, Academia and PhD networks.

The Scientific Committee took up its activities in 2022. It has developed working arrangements in close exchange with EASA in order to provide its support via efficient and lean processes following an annual working cycle. For the first cycle 2022 three relevant thematic areas have been selected and dedicated Task Forces have been initiated for each of them. They address

- 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 have delivered results relevant for short term actions as well as for long term strategic considerations.

For connecting the Scientific Community with EASA, promising long term schemes have been identified for establishing strong networks between relevant stakeholders. On short term, a new conference scheme "EASA PhD Conference" has been established for initiating exchange and awareness. The first conference is scheduled for March 2023 and a significant interest from the stakeholders has been recognized.

In the field of climate change the Task Force members reviewed the state-of-the-art knowledge on severe thunderstorms, hail and clear air turbulence. They identified gaps in data, modelling and forecasting capabilities. Recommendations regarding short term research needs have been developed. In addition, longer term research streams were identified generating relevant knowledge and supporting EASA and aviation stakeholders in their strategic decisions.

The Task Force on artificial intelligence has provided advice on design principles for Level 2 AI applications targeting Human-AI teaming (HAT). The existing 'Operational Explainability' guidance has been analysed leading to an update of the according EASA Concept Paper. In addition, the selection of a dimensioning use case of Level 2 AI application has been initiated. Furthermore, design principles targeting human-AI interaction with a focus on language recognition as well as roles in human/machine teaming/collaboration have been elaborated, again feeding into the respective EASA Concept Paper.

In light of the upcoming second activity cycle, recommendations regarding the way forward on the current topics have been elaborated by the committee. Relevant new potential thematic areas have been identified like e.g. Space ATM.

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 first operational year 2022. It describes the background and motivation of setting up the committee, the selection of members and the starting up of the committee including the definition of its internal procedures and working arrangements. In addition, the content related activities are covered, which have been focused in the first year on the following three relevant organisational and scientific topics:

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 at different time scales. At short term time scale "quick wins" will be presented providing the option of immediate consideration and implementation in order to leverage existing opportunities. On a longer time scale results 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 herewith 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.

Finally, the report is intended to be the first in a series of annual reports recording the activities undertaken by the Scientific Committee member. 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 Organisation 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 following chairman and members for the Committee for a duration of three years in their personal capacity:

Prof. Dr. Peter Hecker, Chairman	Vice President TU Braunschweig
Dr. Nicholas Asher	Director of the Artificial and natural Intelligence Toulouse Institutes
Prof. Hester Bijl	Rector Magnificus and Member of Executive Board at Leiden University
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. Vincent- Henri Peuch	Director the Copernicus Atmosphere Monitoring Service
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	Associate Professor of Aerospace Systems at Politecnico di Torino and Post-Graduate master programs with ISAE-Supaero and Leicester University
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

3.3 Organisation and Formation of Task Forces

As an initial step the SciComm has 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 helps ensuring an efficient operation and delivering maximum support to EASA. At the same time it allows for flexibility regarding the evolution of priorities and topics while recognizing the available resources of the committee.

Defining Priorities and Topics

The Scientific Committee has agreed to organize the workflow along consultation periods of one year. At the beginning of each period an initial overview of relevant areas, needs and priorities is developed through a preparatory dialogue between EASA representatives and the SciComm chairperson. The dialogue builds upon an initial but not exclusive set of areas including technical, operational, societal, legal, economic and environmental challenges as defined by EASA. During this phase the potential matching of the member's areas of expertise against the topics is already considered.

This preparatory exchange is followed by a SciComm meeting during which relevant areas are proposed and presented by EASA and discussed with the SciComm members. SciComm members may provide additional proposals based on their expertise. A reasonable number of areas (2-4 per period) is selected via a collaborative process according to the priorities of EASA and the expertise of the SciComm members.

For the first working period 2022 three relevant topics have been identified:

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

Setting up and running Task Forces

In order to contribute to the topics in an efficient manner one Task Force per topic has been initiated and SciComm members have been assigned to the Task Forces. An assignment list is provided in table 2.

As a general principle SciComm members are assigned to the TFs according to their expertise and interest. SciComm members can be members of several TFs as long as workforce and resources allow. In addition, the number of members per TF is kept reasonably low in order to allow for efficient work and lean communication. Each TF has identified a chair person and for each TF an EASA representative is nominated as point of contact. A clear mission statement has been defined per area.

	Taskforce #1 PhD Scheme Development	**Taskforce #2 Impact of climate change**	**Taskforce #3 Artificial Intelligence**
EASA PoC	Emmanuel Isambert	Guillaume Aigoin Filippos Tymvios	Guillaume Soudain
Prof. Dr. Peter Hecker	X		

Dr. Nicholas Asher			X
Prof. Hester Bijl	X		
Prof. Frances Brazier			X
Prof. Marianna Jacyna	X		
Prof. Martin Kaltschmitt	X		
Dr. Vincent- Henri Peuch		X	
Dr. Christiane Schmidt		X	
Prof. Nicole Viola		X	
Prof. Marco Lovera			X
Dr. Torben Hovald			

Table 2: Composition of Task Forces

Concept of operating Task Forces

The Task Forces elaborate and provide the requested advice to EASA. For this purpose, the TFs agree on schedule, workshare, mode of operation and tasks. They organize their activities typically via email exchanges, collaborative online working spaces and virtual meetings. They stay in contact with their EASA PoC, who may provide relevant material and involve additional EASA members as required. The TFs report briefly the progress during the SciComm meetings over the consultation period. This may allow a general awareness across the whole SciComm and ensures a regular update and involvement of all SciComm members.

At the end of a consultation period the Task Forces summarize their activities and provide input to annual report, which is requested according to the SciComm's Terms of Reference. In general, the reporting is 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

Significant research on aerospace technologies, systems and processes is undertaken by universities as well as research and technology organizations. New fundamental knowledge is continuously being developed and more matured knowledge is translated into applications via applied research. Research is addressing the air vehicle itself as well as its operation in the overall air transport system. The sustainability of air transport as well as the role of air transport in future societies are more and more gaining importance.

Typically, this research carried out by doctoral students feeds via joint research programmes with industrial stakeholders into the development cycle of future products like e.g., aircraft. Taking up new streams of research at an early stage will allow accompanying the technology development from an early stage and preparing for its later deployment. On the other hand, researchers need to receive feedback from the operational and regulatory domain as early as possible in order to choose development paths which are compatible with later operational requirements. Therefore, linking academia and EASA closer together may provide benefits for both stakeholders enabling a win-win-situation: Academia can focus their research towards relevant and deployable solutions, while EASA will gain insight in upcoming developments at a very early stage. Interaction at such early stages will be beneficial for both entities.

In order to connect academia with EASA a Task Force of the SciComm was implemented investigating options and solutions. Potential solution like networks, associations, PhD funding schemes and other means of communication and dissemination were to be investigated.

4.2 Work Plan and Methodology

At the first meeting of the SciComm on 10 March 2022 the PhD Task Force discussed the scope and boundaries of its work and agreed on a workplan. The work plan covered the following steps:

- Identifying the relevant stakeholders related to the Task Forces mission,
- defining the expectations and impacts for the EASA PhD scheme,
- finding best practices of other known schemes EU institutions and Joint Undertakings, including the administrative constraints they may generate,
- setting up a survey of existing similar networks and interest groups,
- investigating the procurement options and limitations to connect students with EASA,
- identifying existing funding sources,
- developing a step-wise PhD scheme to involve relevant universities,
- possibly organising a PhD event to promote the scheme, once in place, which could take place to assist in launching it.
- Having found the Workshop/Conference event being the most successful way to initiate a contact to academia and to promote networking, the TF then decided to focus on the preparation of the event.

The Task Force implemented the work plan sequentially as indicated. The work was organized via a series of Task Force meetings with off-line preparatory work performed by the Task Force members. During the offline-phases the members provided input based on their long-lasting experience in similar activities. Finally, recommendations for following up the activities of the first year were provided.

4.3 Key Findings in 2022

The following main outcomes were achieved:

A short term and a longer-term strategy for connecting academia with EASA has been developed:

- At **short** term a partnership between universities (specifically targeting the PhD students) and EASA shall be developed with a supporting role of EASA. The objective is to provide transparency and understanding on topics and solutions of interest having an impact on the aviation system.
- The intent is also to share with students the 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. At the same time EASA experts will be acquainted with new know-how, methodologies e.g., for product design or testing. Through informal networking actions, EASA will be able to identify the potential areas of interest and get the status of academic research activities.
- For selected partnership with PhDs and academia, EASA experts may contribute as mentors (depending on their availability) and support visits of students to EASA teams.
- At **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 can be considered.

The short-term strategy shall be implemented through **networking actions,** which should be based on 'light' arrangements as far as possible avoiding complex legal structures. The Task Force discussed such means and identified a joint EASA / university workshop as a promising way forwarded. It was agreed to organise a **Conference in March 2023 to promote the PhD scheme and support the networking**, involving a **call of abstracts** from PhD students whose PhD work related to a specific list of topics. The Task Force focussed their activities on the preparation of such an event.

In preparing the event, several working papers were drafted, notably:

- '**Background, intent and concept**' paper:
  - The event is to be a new instrument of EASA to enlarge the aviation innovation ecosystem. It targets supporting the readiness of aviation standards for disruptive technologies through facilitating the development of technological excellence networks. Connecting researchers at European Universities with experts of the European Union Aviation Safety Agency will build the foundation of advancing and disseminating knowledge in new and emerging fields relevant for aviation.
  - The event would be organized as annual event providing a platform for scientific exchange on topics of common interest for the scientific community, society, and EASA. Every edition will

provide a focus on up to three scientific or application-oriented domains. These specific topics will range from classical aeronautical domains up to new and emerging domains from other scientific disciplines relevant for aviation at large.
  - The event is based on an open call inviting contributions from doctoral research focusing on thematic areas. Keynotes and presentations from stakeholders and EASA experts will set the scene and provide the foundation for the scientific presentations. A networking event will provide opportunities to get in contact with researchers and partners in the respective scientific domain.
- '**Conference**' paper:
  - The conference paper describes the structure of the event and the related processes including the launch call of abstracts, the development of an agenda incl. social event, templates for the call for abstract applicants, and the way to approach interested parties.
  - The conference scheme foresees a two-day conference with networking drink end of day 1. The agenda will allow for presentation slots per topic, a parallel session will be held for the AI topics.
- '**Call for abstracts**' paper
  - The Call for Abstracts is to be published on the EASA website and promoted via the social media. It includes
    - Selection criteria (e.g., limited to candidates studying at an EU university or other entity)
    - A 'submission form' for the call to be published on the EASA website.
    - A scoring grid to be applied for the abstract evaluation
  - A workflow and timeline according Figure 1 were agreed.

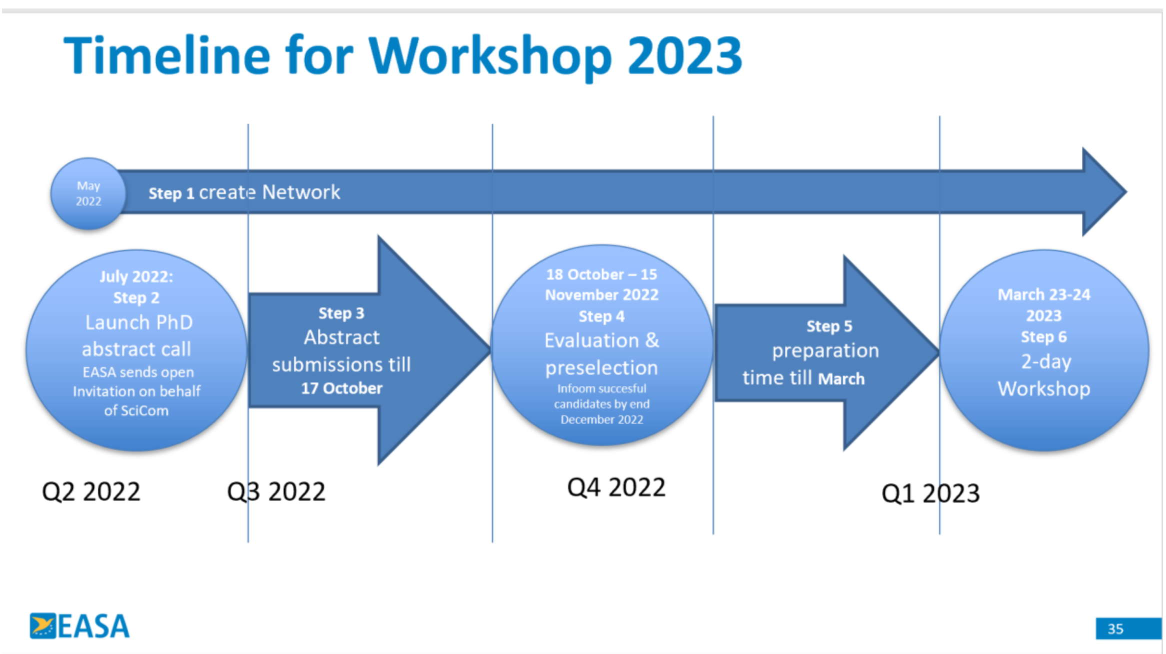


Figure 1: Workflow of organizing the EASA PhD conference

At each plenary meeting the TF asked for guidance to the concept, approach, papers and publications and received much valuable input.

Workflow of the preparation for the Conference

Step 1 is fulfilled in parallel to the remaining steps

Step 2 &3: the call was launched on 11 July and by 17 October, addressing the four following topics:

1. **Artificial intelligence** (AI) in aviation:
   - Development of applications integrated into civil aviation products along EASA AI roadmap, incl. validation and verification solutions
2. Impact of **climate change** and extreme weather phenomena on the air transport system:
   - Methodologies and tools for assessing the impact of changes to weather phenomena on civil air transport system components and operations
3. **Environmental sustainability** (emissions, noise, air quality, another nuisance...):
   - Methodologies and tools to assess the impact of aviation products and operations and the proposed mitigations
4. New approaches and methods for **safety risk management**:
   - New methods, tools to support safety analysis, risk identification and management

In response 43 eligible abstracts were submitted.

Step 4: The evaluation of abstracts was conducted by members of the SciComm, who split up the abstracts according to the topics and competencies therein. Furthermore, EASA experts in the domains were asked to also evaluate the abstracts which matched their competences.

The evaluation resulted in 20 abstracts being accepted. Consequently 20 students will be presenting their topics at the Conference with the following split over the topics:

1. **Artificial intelligence**: nine abstracts will be presented at the conference (as AI topic received the most submissions it was strongly recommended by the Task Force to provide more time for presentations)
2. **Climate Change**: three submitted abstracts will be presented
3. **Environmental sustainability**: four abstracts will be presented
4. **Safety risk management**: four abstracts will be presented

Step 5: The successful students have been informed and invited to the conference, and a certain amount of reserve list abstracts have been identified in case the 'winners' cannot attend.

The remaining students are invited as participants for the conference. A poster session is being considered to ensure the possibility to engage with other participants and EASA experts.

4.4 Recommendations

The work carried out by the Task Force has resulted in a short term and a long-term strategy. The short-term strategy has been implemented and a first cycle of an EASA PhD conference has been initiated.

On short term it is recommended to follow up and conclude the first conference cycle. Once the conference has be held it is recommended to

- Carry out an evaluation of the conference among different stakeholder groups (PhD students, tutors, participant from industry, EASA),
- Collect feedback from EASA and SciComm members on further developing and refining the related processes.
- Publish the presentations and provide an inventory of related material to interested parties (at least the registered participants),
- Analyse the outreach and identify entities not yet reached.
- Re-visit the communication options related to the conference (developing it as a brand, increasing visibility, using it for marketing and communication purposes, etc.)
- Consider continuing the conference on an annual / biennial schedule, and
- Initiate the next cycle.

For those PhD students who have been selected as candidates for a closer interaction with EASA a standardized support scheme should be developed. Objective, means and schedule of interaction should be defined and “code-of-conduct” could be developed in order to achieve an appropriate level of quality control.

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

Climate change affects trends related to hazardous weather phenomena (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. Hence, EASA expressed an interest to obtain an overview of the current state of knowledge and research on trends related to these weather phenomena, including the (spatial, temporal, seasonal, magnitudal) accuracy of the projections. The initial focus is on commercial aviation with large aircraft. For future trends, the interest is on the projected changes associated with different emission scenarios from the IPCC. The typical economical lifecycle of large aircraft puts the major focus on changes until the middle of the century.

EASA expressed an interest in these potential hazards and safety risks:

- Severe turbulence (within cloud and in clear air) during climb, cruise and descent
- Hail during the flight
- Lightning strike during the flight
- Low-level windshear during approach, take-off or initial climb
- Contaminated or flooded runway 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

The Task Force was formed in the SC meeting on March 3, 2022. It consists of three scientific members (Vincent-Henri Peuch, Christiane Schmidt, and Nicole Viola) and two EASA members (Guillaume Aigoin and Filippos Tymvios).

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, and wildfire. In addition, severe airborne icing during flight and temperature raise were also preliminary analysed.

The scientific members reviewed the state-of-the-art knowledge (review of ca. 50 scientific papers) of the chosen hazards and deepened open issues with international experts in the fields, namely 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 modeling and Global change (GLOBC) Team at CERFACS and PhD Students of the GLOBC Team at CERFACS) for clear air turbulence. Specific virtual meetings were scheduled with these international experts to further discuss their latest findings.

All members of the Task Force, i.e., the three scientific members and the two 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 2022

5.3.1 Severe Convective Storms and Hail

For details of the development of convective weather and associated phenomena, definitions, observations, proxies[1] for projections, projections, as well as knowledge gaps and uncertainties, we refer to Appendix **Error! Reference source not found.**. Most projections are based on proxies.

Hail.

- Any observational data for hail is sparse.
- For ***Europe***, past trends on hail show little agreement.
- For ***Europe*** a **slight increase of the frequency of environments that are favorable for hail** (with low significance and some contradictions, e.g., the UK) **is projected**—even for the middle of the century.
- 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 favoring 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 results for the **middle of the century are limited**.
- For ***Oceania***, the only past trends exist for Sydney, with a negative trend for sever hail
- For ***Oceania***, even projections are scarce, but the existing studies agree in trends: **an increase in frequency, severity, and favorable 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:

[1] 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.

- 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) data are 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 invariability.
- Proxy-based studies have a low resolution, 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.
- For ***Europe***, an **increase in frequency of favorable environments for severe thunderstorms and the number of days with such environmental conditions is projected**—with varying magnitude. However, for **southwestern and southeastern Europe, 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**.
- For ***North America*****,** an **increase in frequency of favorable 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**—with largest increases for **regions close to the Gulf of Mexico and the Atlantic**.
- 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 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:

- Projecting when a convective storm initiates is still very imprecise.
- No good proxies are known for regions not in the USA or in Europe.
- 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.
- Existing climate models and severe convective storms have different scales; hence, many severe storms cannot be detected by the current generation of climate models.
- When projections are made for severe convective storms, different phenomena (wind, hail, tornadoes) are aggregated; however, these are not favored by the same environmental conditions, and considering them as a unified set of hazards is problematic.
- Environments that are favorable 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 favorable for severe convective storms—this does not mean that a severe convective storm actually forms.
- Many phenomena have large interannual variability and discriminating between climate change and natural variability is problematic.

For a detailed description of the reasons and consequences of the knowledge gaps and uncertainties, 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 Appendix **Error! Reference source not found.** 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 kilometers down to centimeters. 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.

Annual-Mean Percentage Changes in the Amount of CAT From Pre-Industrial Times (picontrol) to the Period 2050–2080 (RCP8.5)

Strength	North Atlantic		North America		North Pacific		Europe	
Category	200 hPa	250 hPa	200 hPa	250 hPa	200 hPa	250 hPa	200 hPa	250 hPa
Light	+75.4	+47.3	+110.1	+71.0	+120.7	+82.0	+90.5	+59.9
Light-to-moderate	+124.1	+80.7	+113.6	+57.5	+106.6	+53.8	+130.7	+75.8
Moderate	+143.3	+74.4	+100.3	+50.2	+90.2	+41.6	+126.8	+60.8
Moderate-to-severe	+148.9	+71.0	+94.3	+47.0	+73.1	+35.3	+142.1	+66.1
Severe	+181.4	+88.0	+112.7	+58.9	+91.6	+40.1	+160.7	+90.6

Strength	South America		Africa		Asia		Australia	
Category	200 hPa	250 hPa	200 hPa	250 hPa	200 hPa	250 hPa	200 hPa	250 hPa
Light	+18.3	+13.4	+24.2	+18.9	+102.5	+65.1	+18.0	+9.5
Light-to-moderate	+27.1	+18.0	+27.9	+23.3	+92.4	+48.7	+23.1	+12.9
Moderate	+34.3	+22.8	+34.3	+26.0	+78.1	+48.7	+29.6	+19.1
Moderate-to-severe	+43.3	+23.8	+36.6	+26.9	+59.2	+47.9	+36.9	+24.8
Severe	+62.0	+31.6	+51.1	+40.2	+64.1	+55.4	+52.5	+35.4

Note. The changes are calculated for five turbulence strength categories, at two pressure altitudes, and within eight geographic regions. The changes are averaged over 20 CAT diagnostics. The geographic regions are: North Atlantic (50–75°N, 10–60°W), North America (25–75°N, 63–123°W), North Pacific (50–75°N, 145°E–123°W), Europe (35–75°N, 10°W–30°E), South America (55°S–10°N, 35–80°W), Africa (35°S–35°N, 15°W–50°E), Asia (10–75°N, 45–140°E), and Australia (12–46°S, 113–177°E).

Figure 2: Annual Mean Percentage Changes in the Amount of CAT

Current results 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 (12000 m) over North America** (+112.7%), **the North Pacific** (+91.6%), **and Europe** (+160.7%). 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., Europe). For each strength category and geographic region, **the percentage change is larger at 200 hPa (12000 m) than 250 hPa (10000 m)**. **The percentage changes generally display relatively little seasonality**.

Uncertainties mainly relate to:

- **diagnostics**. Diagnostics indices do not have all the same skills. The skill of a diagnostic is higher if there is higher agreement with observation data or reanalysis data. Weighted average of diagnostics that have better skills can reduce uncertainties as weighted average of diagnostics allows to make more skillful diagnostics count more.
- **Future radiative forcing scenarios**. The emissions of future radiative forcing scenarios depend on socioeconomic and political factors. These estimations are of course affected by uncertainties.
- **Climate models**. Climate models, which have coarser resolutions than numerical weather prediction models that are used to forecast clear-air turbulence operationally, are sources of uncertainties for different reasons. The jet streams in the upper troposphere and lower stratosphere in different climate models may respond for instance differently to a given radiative forcing anomaly dependent of the parameterization scheme selected in the models.

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 10000-12000 m of altitude, have been investigated so far. 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 10000-12000 m 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.

5.4 Recommendations

Several recommendations are identified for the climate-related trends considered by the Task Force.

As far as CAT is concerned, uncertainties and limitations in present analyses prevent from reaching accurate predictions in the long-term trends.

Hence, we recommend to further investigate the topic to increase accuracy of results by improving the diagnostic indices themselves and by using weighted average of set of diagnostics. In addition to diagnostics, different forcing scenarios, other than the RCP8.5, should be considered and results should be compared. Moreover, the uncertainty in CAT should be quantified by using more climate models, such as the next generation of CMIP6 models that will have substantially higher spatial resolutions. Eventually, we recommend to extend the range of altitudes under consideration below 10000 m and above 12000 m.

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 still 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.

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 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—overlaying the low-resolution global climate models with high-resolution simulations (with resolution comparable to what is used in operative weather forecasts) for areas of interest for convective storms. The study of research using this technique (part of which should be published soon) might give more insight.

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 lifecycle of large aircraft (about 30 years) makes 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.

For a more detailed analysis of these recommendations, please refer to the appendix.

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 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 known a rapid acceleration 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 February 2020, the Agency has published the **EASA AI Roadmap v1.0** to organize its action plan to prepare the necessary 'Ai trustworthiness' guidance and anticipate necessary regulations updates to accompany this innovation wave. EASA is currently developing a first set of guidance as part of the first phase 'exploration and first guidance development' of the EASA AI Roadmap effort.

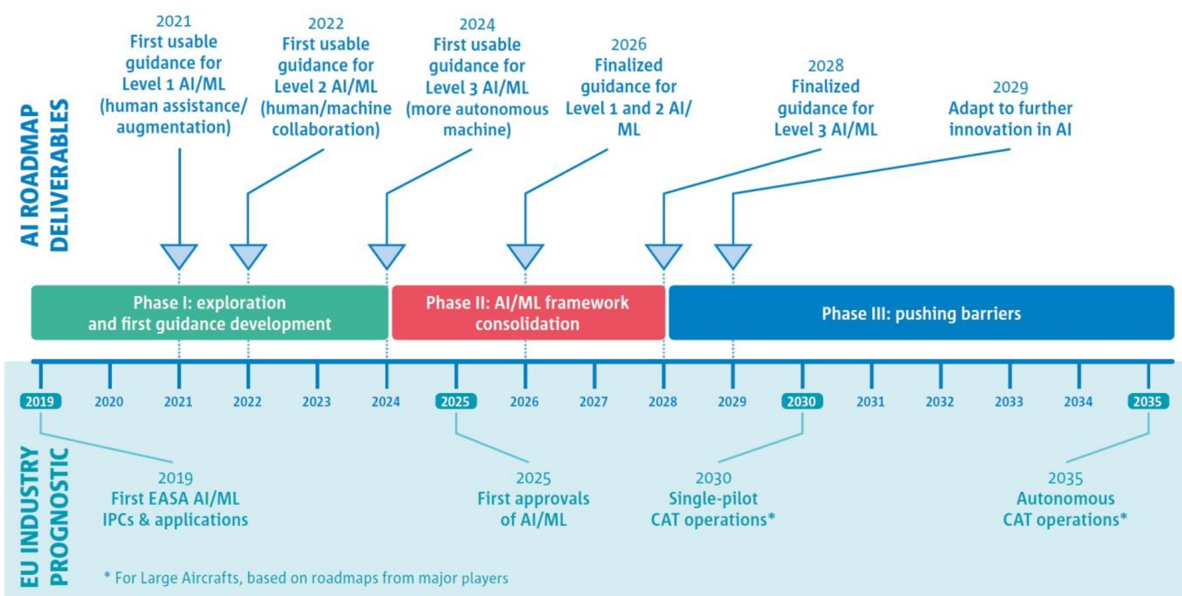


Figure 3: EASA AI Roadmap

On the basis of the first published **Concept Paper 'First usable guidance for Level 1 machine learning applications'** from December 2021, EASA has in 2022 entered in the development of the Level 2 AI guidance dedicated to Human-AI teaming (HAT). Beyond the already development concepts of 'learning assurance' and 'AI explainability', Level 2 AI applications require to augment the AI trustworthiness framework with additional human factors guidance.

This is the starting point from the EASA SciComm AI Task Force, whose work focused on the **identification of design principles for Level 2 AI applications**.

6.2 Work Plan and Methodology

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

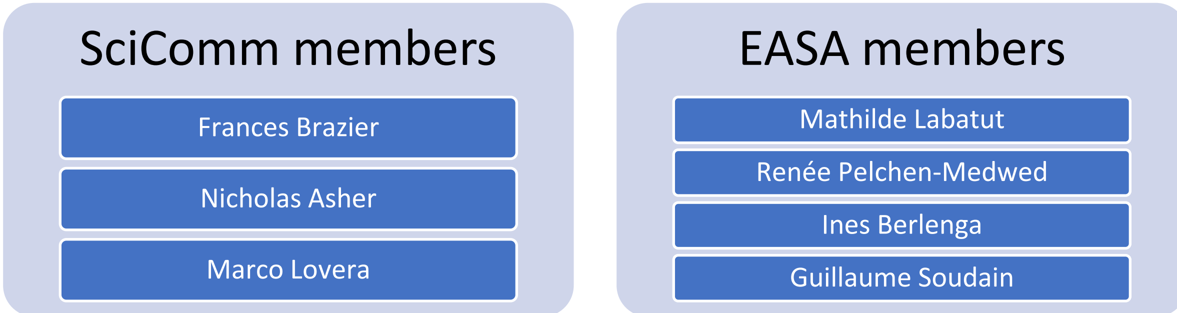


Figure 4: AI Task Force Composition

The work of the EASA SciComm AI Task Force has been organized through the following work plan for the 2022 activity:

- → **Work Package 1: definition of the human-centric approach to increased automation (target end Q2/2022)**
  - → Terminology and definitions
  - → Use case selection and description
- → **Work Package 2: design principles for human machine teaming (end October/2022)**
  - → Design principles for human-AI interaction (focus on language recognition)
  - → Design principles for Roles in human/machine teaming/collaboration
  - → Validation on proposed Level 2 AI HF (17th October 2022 final AI TF session)
- → **Work Package 3: adaptation for the ethics-based framework (2023)**
  - → This work package has been postponed to the future work plan for the activity in 2023, in order to focus on the first priorities in 2022 (WP1/2)

Following the kick-off meeting for the AI Task Force on the 10th March 2022, the activity of has been conducted through 5 virtual workshops meetings of 2 to 3 hours which took place on 5th May 2022, 24th May 2022, 5th July 2022, 31st August 2022 and 17th October 2022.

In addition, a debrief from the activity of the AI Task Force has been presented at the general EASA SciComm meeting on 23rd June 2022.

6.3 Key Findings in 2022

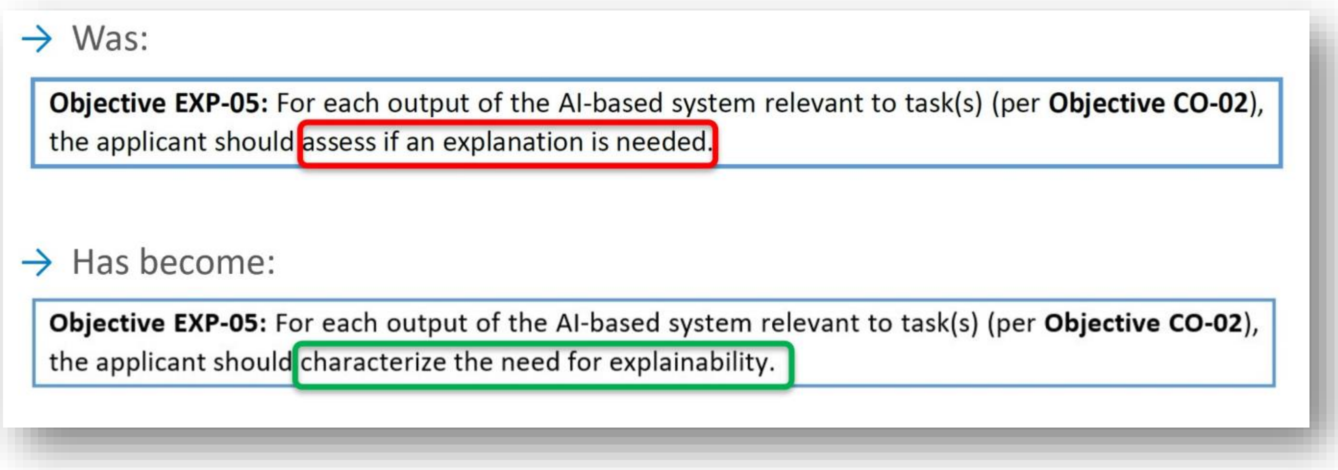
Work Package 1: definition of the human-centric approach to increased automation (target end Q2/2022)

The **first activity** conducted by the team was to review the existing 'Operational Explainability' guidance from the EASA Concept Paper 'First usable guidance for Level 1 machine learning applications' from December 2021, in order to identify the need for discussion and alignment on **terminology and definitions**. Two topics were retained and investigated:

The definition of the Level 2 AI (overseen and overridable automatic decision-making/action implementation) included the monitoring by the human end-user of "every decision and action". This could be an unrealistic requirement, limiting the capability of Level 2 AI-based systems. It was agreed that removing the word "every" helps clarifying the intent.

Note: the definitions have further evolved while EASA developed the Level 2 HF guidance and the notion of "Human-AI Teaming" now encompasses two distinct level 2A (Human-AI cooperation) and 2B (Human-AI collaboration).

- ✓ The objective EXP-05 is the top-level entry objective for the Operational Explainability guidance. It consists in the identification of the necessary explainability, for all outputs of an AI-based system that is relevant to the high-level task(s) performed jointly with a Human end-user. The wording "assess if an explanation is needed" was considered too generic and may be misunderstood as yes/no answer approach. The following figure reflects the detailed change:


→ Was:

Objective EXP-05: For each output of the AI-based system relevant to task(s) (per **Objective CO-02**), the applicant should assess if an explanation is needed.

→ Has become:

Objective EXP-05: For each output of the AI-based system relevant to task(s) (per **Objective CO-02**), the applicant should characterize the need for explainability.

Figure 5: top-level entry objective for the Operational Explainability guidance.

Deliverable for WP1.1: the EASA Concept Paper (for Level 2 AI) has been updated according to the outcome of the AI Task Force discussions.

The **second activity** focused on the **selection of a dimensioning use case of Level 2 AI application**. The current state of technology appears to present certain limitations in meeting the provisions of Level 2 AI. As it is currently difficult to identify a dimensioning use case from industry, a case was devised. Here is a brief outline of the selected use case 'Proxima':

> In Single Pilot Operation aircraft, Proxima and the pilot will share tasks and will have a common set of goals. Through perception and analysis, Proxima will learn from the situations encountered and will be able to continually adapt to the current situation to assist the crew in its decision-making process. Proxima will also have the ability to respond appropriately to displayed information. Proxima will also identify any mismatch between information Proxima has that is relevant to a pilot's decision and the information available to the pilot via displays and other means. It will then respond appropriately.
>
> Proxima can:
>
> ✓ Follow pilot activities and displayed information and adjust its support level in view of those activities and the displayed information
>
> ✓ Assess the mental and physical state of the human pilot through sensors and cameras to some degree
>
> ✓ Detect human pilot workload, incapacitation, and make correlation between the situation and the human pilot states to adapt its level of support.
>
> ✓ Monitor human communications and data link with the ground and aircraft position to ensure appropriate flight path management and intervene where appropriate.

Deliverable for WP1.2: the descriptive document (see Annex Error! Reference source not found.**) has been prepared as an output of the task and will be used by EASA to illustrate Level 2 AI applications in the updated Concept Paper. This use case will be used in further activities to test the Level 2 AI HF guidance and support further activities of the SciComm AI Task Force. It will also provide the opportunity to initiate the discussions on the possibilities of multi-modal interactions which will be continued in 2023.**

Work Package 2: design principles for human machine teaming (for Level 2 AI applications) (target end October 2022)

The heart of the activity of the AI Task Force for this year consisted of iterative discussion and exchange of draft text developing the design principles throughout the various virtual workshops.

The Human factors guidance for Level 2 AI applications, focus of this work package 2, was then developed by the EASA AI team as an extension of the existing Operational Explainability guidance. This led more recently to EASA reorganizing the AI trustworthiness building block called "AI explainability" to expand its scope to cover more widely the notion of "Human factors for AI", encompassing but not limited to Operational Explainability.

The **first activity** opened the opportunity for several sessions of work on the d**esign principles for human-AI interaction, with a focus on language recognition.**

Summary of important feedback exchanged:

- ✓ When discussing natural language dialogue capability for an AI-based system, the SCiComm team insisted on the importance to open the **capacity for the end-user to ask the AI-based system for clarifications in different modalities/languages**. Indeed language is flexible and allows to provide clarification, either through request to access specific data or parameters of the system.
- ✓ One important feedback provided by the SciComm members was on the identification of the capabilities linked to natural language:
    - *Conversational*
    - *Questions/Answers*
    - *Argumentation / Negotiation*
    - *Follow-up questions*
    - *Corrections*
    - *Explanations*
    - *Acknowledgements*

  Time did not allow for the development of detailed principles around these capabilities but the SciComm members can provide additional proposals when performing the pre-review of the EASA Level 2 AI Concept paper.

- ✓ Finally a design principle has been prepared to address the capability to identify and alert for possible misunderstandings, through the capability to confirm a certain interpretation by the human end-user:
    - *The applicant should ensure that the AI-based system spoken natural language capability can confirm a certain interpretation, can alert the user to possible misunderstandings and help clarify and clear up the misunderstanding.*

The **second activity** focused on the development of **Design principles for Roles in human/machine teaming/collaboration**.

Summary of important feedback exchanged:

The most important point of discussion was on the necessity to split the current level 2 AI in two levels 2A and 2B to account for the gap observed between traditional automation performing automatic decision-making and/or automatic action implementation and the potential advanced assistants capability of bi-directional communication which will be necessary if aviation industry wants to meet the challenges of for instance single pilot operations in commercial aviation.

This discussion directly influenced the choice form EASA to the split of Level 2 AI into Level 2A for 'Human-AI cooperation' and level 2B for 'Human-AI collaboration'. The following definitions have been retained to crystallize the difference between the two levels.

The terminology might still evolve however this split is considered by the SciComm AI Task Force team as well adapted to the anticipated progressive challenge of deployment of more and more advanced type of assistance in aviation applications.

Deliverable for both WP2.1 and WP2.2: the EASA Concept Paper (for Level 2 AI) has been updated according to the outcome of the AI Task Force discussions. It will be released by EASA for a pre-consultation (involving the AI Task Force team members) by mid of November 2022 and then for a public consultation end of February 2023.

it is important to mention an **additional activity**: a very interesting presentation from Frédéric Deshais, triggered by an invitation from Nicholas Asher, demonstrated the perspective of using neuro-science to improve the collaboration between human and AI-based systems. This could be a further topic for future activity.

The **last activity** consisted in the validation of the final concepts in the proposed Level 2 AI Human Factors guidance by the SciComm members. This occurred in the last session of the AI Task Force for 2022, on 17th October. All actions were closed in that session and a proposed work-plan for 2023 activity outlined.

This closed the activity of the AI Task Force team for the year 2022.

Many thanks to all AI Task Force team members for their contributions!

6.4 Recommendations

The AI Task Force team recommends to extend the activity of the Task Force in 2023 to address the next upcoming priorities of the EASA AI Programme:

- → **WP3: adaptation for the ethics-based guidance framework (2023)**
  - → Guidance principles for outstanding social/societal ALTAI items (e.g. risk of deskilling of Humans)
  - → Guidance principles for monitoring of end-users (brain activity, emotions, …)
  - → Guidance principles for accountability (legal case)
- → **WP4: testing Level 2 guidance with the Proxima use case (2023)?**
- → **WP5: anticipation of design principles for more autonomous operations (2023)**
  - → State of the art review: is technology ready for autonomy
  - → Selection of use cases for Levels 3A/3B
  - → Monitor what happens on military side regarding autonomy and HMI
  - → Design principles for supervised autonomy and transition to « take over »
  - → Design principles for compensating Human skills (adaptability, coping with uncertainty)

(Optional) WP6: anticipation of design principles for monitoring of end-users (2024)?

7 Conclusions

The EASA Scientific Committee has taken up its activities in the year 2022 and has successfully undertaken one full annual cycle of activities.

On the organisational level the SciComm has developed and implemented an efficient internal process for organizing its workflow, i.e. the structuring, prioritizing and managing of activities along the Terms of Reference. This process has proven its suitability over the first year as it has ensured an efficient operation and delivering maximum support to EASA. Along the turn over to the second year of operation it has demonstrated a high degree of flexibility regarding the evolution of priorities and topics while recognizing the available resources of the committee. The results of the first year have provided good evidence that the established scheme of distributing the activities to dedicated Task Forces according to the thematic priorities and the expertise of the SciComm members is fit for purpose.

Three Task Forces on topics relevant for EASA and its stakeholders have been established. They delivered 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** identified long term options for connecting the European academic body to EASA enabling a win-win-situation for both entities. On the **longer term** a better guidance can be offered to academia by supporting them in identifying relevant research directions and providing input from the operational and regulatory domain at early stages. At the same time EASA may benefit from becoming aware of emerging knowledge in the aviation domain and beyond, which impacting future products, which may require an early awareness.

On **short term** an EASA PhD conference has been setup, which will take place 23 - 24 April 2023. The conference scheme has raised a significant interest in the scientific community already in its first run, as a high number of submissions have been received. An promising programme covering ongoing PhD work at a mature stage on selected topics has been prepared and a significant interest of all relevant stakeholder groups has been recognized. This conference will build the foundation for closer interaction and future networks.

The Task Force on Impact of climate change surveyed past-trend and future-trend studies on convective storms, hail, and clear air turbulence; and highlighted knowledge gaps and uncertainties. On the longer term, the Task Force recommends EASA to investigate how to stimulate research teams to work on trend predictions of weather hazards that include all the altitudes used by commercial aviation; on using greenhouse gases forcing scenarios other than IPCC RCP8.5 for trend predictions of weather hazards; on improving the diagnostic indices for CAT; on future-trend predictions for the middle of the 21st century in addition to the end of the 21st century; and on proxies for hail and convective storms for world regions other than Europe and North America.

On the shorter term, the results obtained by the Task Force in 2022 could be presented to EASA and aviation stakeholders so as to make them aware and to discuss the related recommendations in this report.

The **Task Force on Artificial Intelligence** allowed **on the short term** to consolidate certain concepts from the Operational AI Explainability guidance laid down in the first issue of the EASA Concept Paper on Artificial Intelligence from December 2021. It also enabled a **validation the Human Factors guidance principles for Level 2 AI** developed in the second issue of the EASA AI Concept Paper, to support the emerging '**Human-AI teaming**' paradigm.

On the **longer term** the description of the use case of virtual co-pilot assistant 'Proxima' (see Annex **Error! Reference source not found.**) provides a reference point for the evaluation of the novel Human Factors guidance for Level 2 AI. This activity is foreseen in the work plan of the Scientific Committee AI Task Force for 2023.

8 References

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