A review of current issues and RoadMap(s) towards certification of UAM automated / autonomous operations

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Autonomous UAM: a new System of Systems

→ UAM certification means:

Focus of this presentation

- E-VTOL vehicle certification
  - General design safety requirements: EASA SC-VTOL-01 (02/07/2019; autonomy not addressed)
  - Autonomous systems certification: EASA AI-RoadMap v1.0 (Feb 2020), EASA CS-UAS (2024; CU, C2Link) , EASA CS-VTOL (AI included), others non-EASA…
- Vertiports certification
  - EASA Prototype Design Specifications for Vertiports (24/03/2022)
- Automated UTM / U-space service providers certification
  - EASA U-space/UTM Regulatory Package (EU Reg. 2021/664, 2021/665, 2021/666; applicability early 2023)
- VTOL operator certification (New Air Operations regulations)
  - EASA NPA 2022-06 (30/06/2022) – '*Enabling innovative air mobility with manned VTOL-capable aircraft*'; EU publication in 2025 (includes unmanned air taxis).

General considerations on AI stakes and issues (from press review)

- Developments in computer vision, voice recognition, artificial intelligence and automation will make feasible the next generation of highly-automated and autonomous aircraft that can taxi, take-off, and land without human assistance.

- They are many issues. One example is the fact that AI algorithms — usually trained through machine learning on massive data sets expected to be similar to the environments they will encounter — may struggle with tasks rudimentary to humans (as, when resetting a password, identifying blurry letters in a CAPTCHA challenge employed to distinguish between human and computer users).

- The performance of machine learning-driven autonomous sytems is largely a factor of the quality of the data they are trained on and of the extent of the system training in responding to particular situations.

CAPTCHA: Completely Automated Public Turing Test to tell Computers and Humans Apart

General considerations on AI stakes and issues (from press review) (continued)

- Main stake wil be the certification of autonomous airborne systems, and particularly those non-deterministic (infinite number of pathways to produce the desired output).

- Challenge is the ability to make safety-enhanced updates to advanced aviation software in a timely and cost-effective way: this is critical to the safe rollout of autonomous UAM.

- Pathway to get autonomous or highly automated systems is certainly via high reliability & fail-functional architectures.

EASA AI RoadMap: a stepped approach

as they could mean different things for different actors. However, pushing this concept to an ex
to the aviation domain, we could come up with a classification of AI/ML applications in three leve
the degree of oversight of a human on the machine:

Figure 3. Possible classification of AI/ML applications

Level 1 AI/ML : assistance to human	Level 2 AI/ML : human/machine collaboration	Level 3 AI/ML : more autonomous machine
• Level 1A – Routine assistance • Level 1B – Reinforced assistance	• Level 2A – Human performs a function / Machine monitors • Level 2B – Machine performs a function / Human monitors	• Machine performs functions with no human intervention in operations. Human is in the loop at design and oversight time

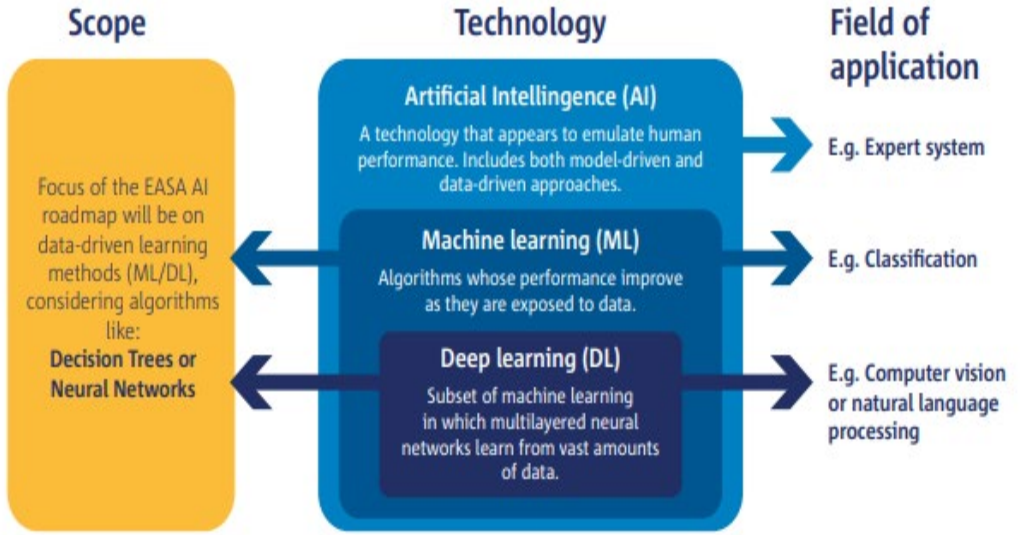

Figure 7: AI taxonomy in the EASA AI Roadmap

EASA view (*) : Issues raised by AI (AI Trustworthiness analysis)

- Traditional development assurance frameworks are not adapted to machine learning
- Difficulties in keeping a comprehensive description of the intended function
- Lack of predictability and explainability of the ML application behaviour
- Lack of guarantee of robustness and of no ‘unintended function’
- Lack of standardised methods for evaluation of the operational performance of the ML/DL applications
- Issue of bias and variance in ML applications
- Complexity of architectures and algorithms
- Adaptive learning processes

(*) EASA AI RoadMap

The EASA AI Trustworthiness concept (*)

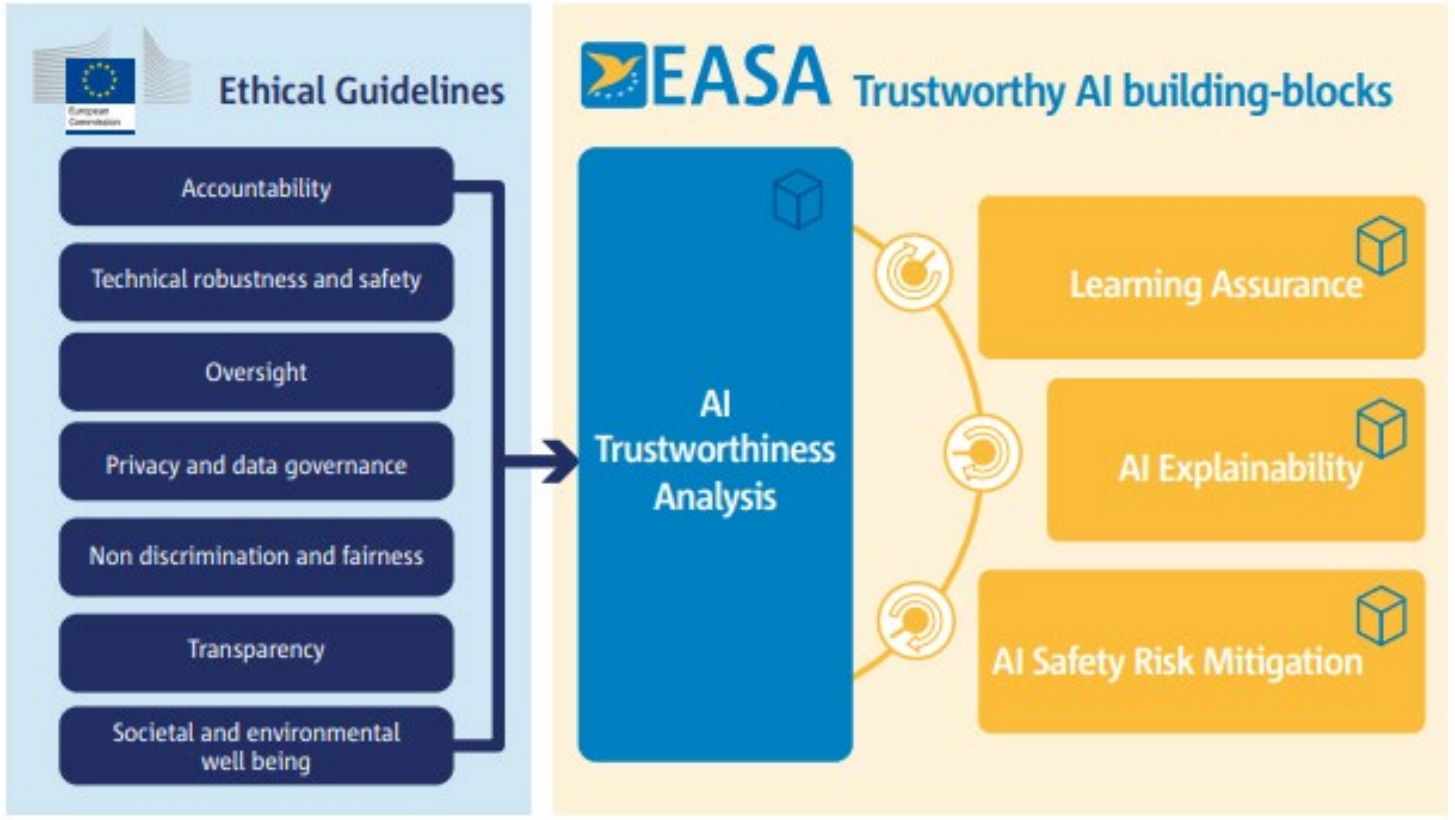

Figure 8: EASA AI trustworthiness building blocks

(*) EASA AI RoadMap

EASA AI Trustworthiness (*): Learning Assurance

The following issues have to be addressed:

- System development assurance
- Data assurance process (end-to-end; data quality)
- Training/verification data sets selection and validation (completeness, correctness, bias mitigation, …)
- Learning model selection and tuning
- Learning model evaluation
- Verification aspects (novel methods, …)
- Mixability aspects (with other components using classical development assurance, with other systems, with human operators)
- Adaptivity aspects (to more complex issues appearing when learning in operations)
- Changes to learning models
- Accident/incident investigation

(*) EASA AI RoadMap

EASA AI Trustworthiness (*): Learning Assurance W-shaped process

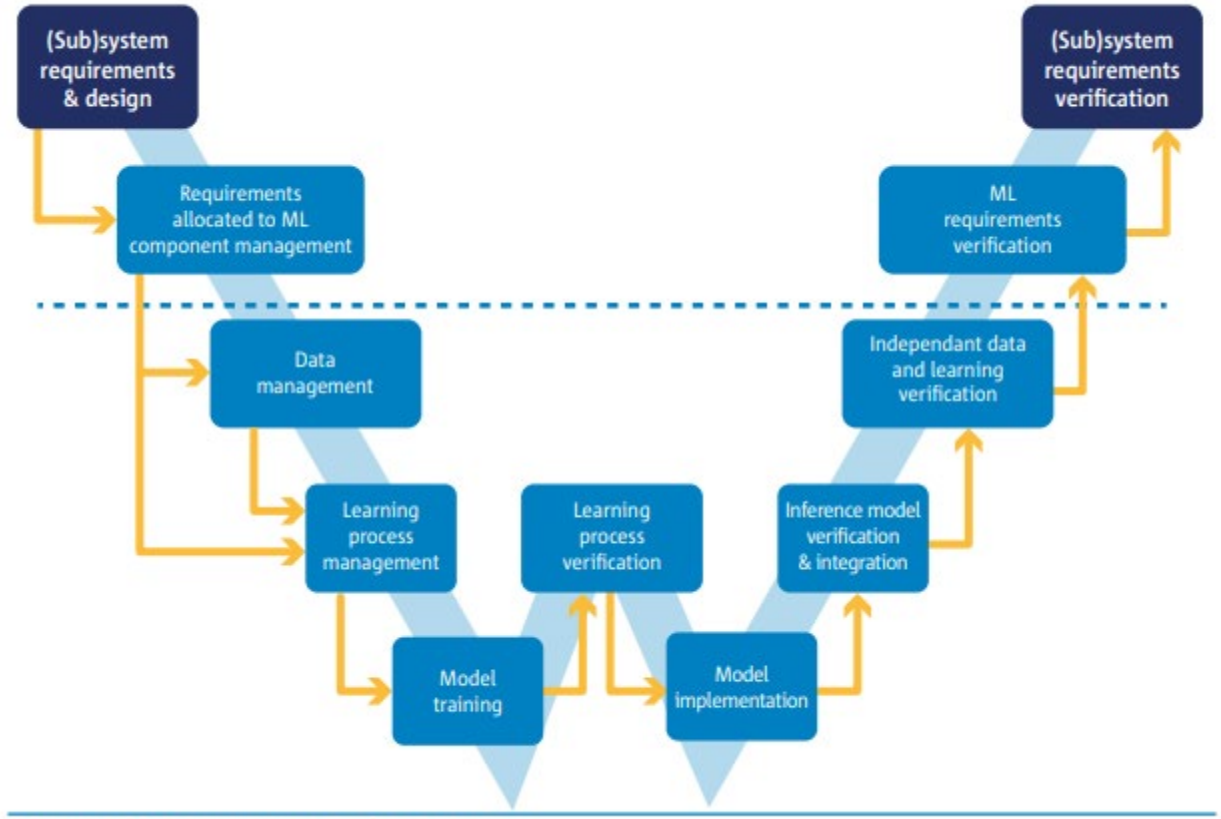

Figure 9: EASA learning assurance W-shaped process

(*) EASA AI RoadMap

EASA AI Trustworthiness (*): Explanability of AI

- A human-centric concept: aim is to provide human understandable explanation on how an AI application is coming to its results and outputs.
- One example is a CNN that would classify pictures between wolves and dogs
- What would explainability mean when using AI/ML techniques other than computer vision in particular when it comes down to decision-making processes?
- Several Research initiatives have started, in particular: DEEL (Dependable Explainable Learning) project, DARPA (US Government Defence Advanced Research Projects Agency) Explainable AI programme.

(*) EASA AI RoadMap

EASA AI Trustworthiness: AI Safety Risk Mitigation

- This could be achieved by several means, among others:
  - keeping a human in command (HIC) or in the loop (HITL);
  - monitoring of the output of the AI/ML and passivation of the AI/ML application with recovery through a traditional backup system (e.g. safety net);
  - encapsulation of ML with rule-based approaches (e.g. hybrid AI);
  - monitoring of AI through an independent AI agent; and
  - in a wider horizon by considering the notion of ‘licensing’ to an AI

(*) EASA AI RoadMap

EASA AI RoadMap Deliverables

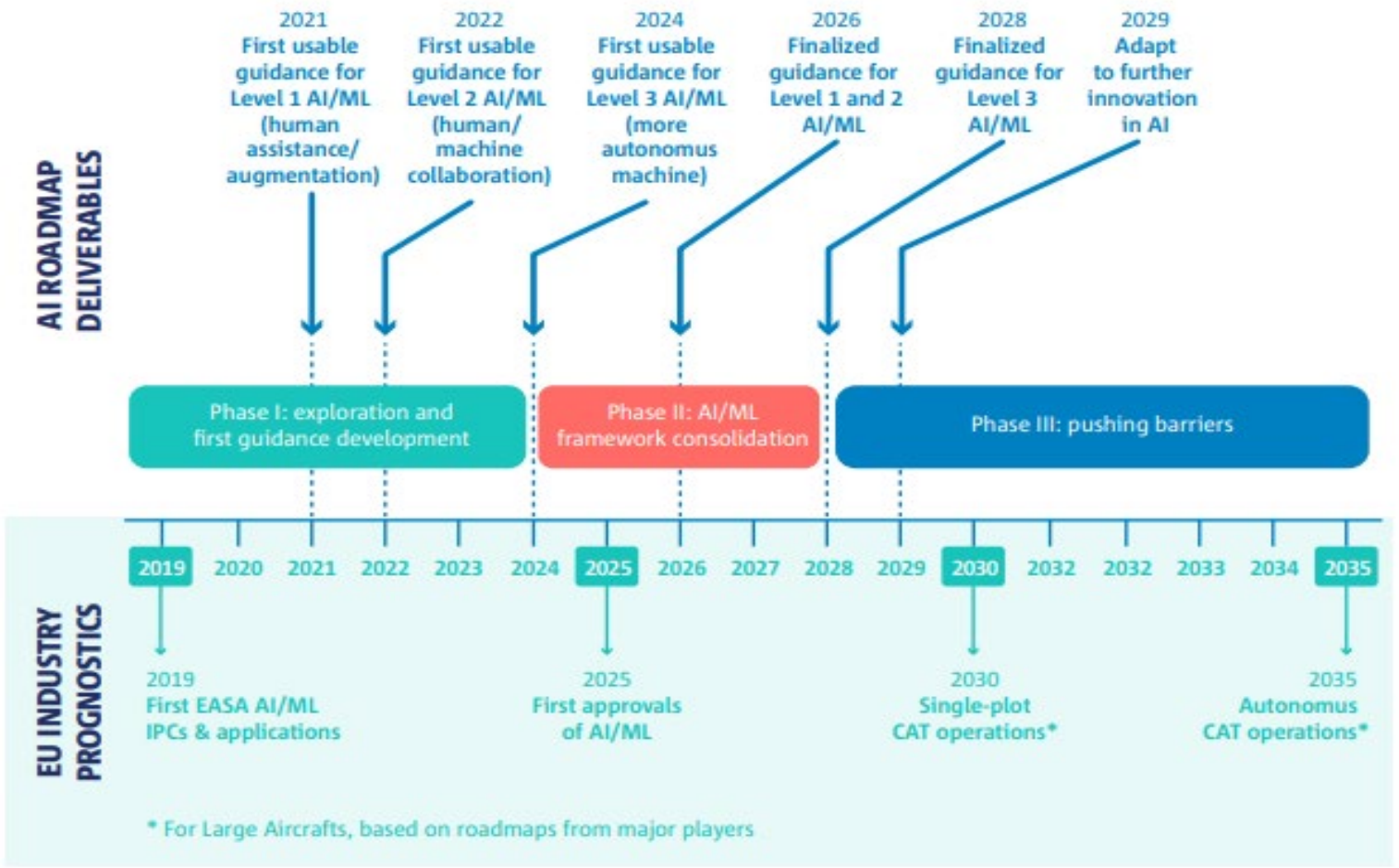

Figure 10: AI Roadmap phased approach

AI detailed certification requirements (Means of Compliance)

Will be defined based on:

- EASA Research Task RES.0037 ‘Machine Learning’ (Final Report: 2023-Q2):
  - The research results will be a set of methods and tools with which EASA shall be enabled to streamline certification and approval processes by identifying concrete means of compliance with the learning assurance objectives of EASA guidance for machine learning applications (level 1, 2 and 3 as defined in the EASA AI Roadmap), with a specific focus on Level 1B and Level 2. The achieved medium-term effect shall be to alleviate some remaining limitations on the acceptance of machine learning applications in safety-critical applications

- EASA Cooperation Projects with Industry (IPC=Innovation Partnership Contract, TAC=Technical Advice Contract)

CONCLUSION

- Certification of UAM autonomous operations means, inter alia, the certification of autonomous airborne systems using AI/ML (including non-deterministic systems).
- Many challenges are associated: comprehensiveness of the scenarii, quality of the data, complexity of architectures and algorithms, lack of standardized methods for evaluation, setting adapted certification design requirements, …
- EASA has started rulemaking and already issued in 2019 the first design rules for vehicle certification (SC-VTOL; AI not addressed). Eventually CS-VTOL, in the late 2020s, should specify the main design requirements for AI.
- In parallel Research (e.g. EASA RES.0037; Final Report 2023-Q2) together with EASA cooperation with Industry on specific Projects (e.g. Innovation Partnership Contracts, Technical Advice Contract) will be the basis of the determination of the concrete means of compliance with the AI Learning Assurance objectives.
- First approvals of eVTOLs with AI/ML applications using critical functions should be possible around 2030; according to Part 21, certification bases will include latest published design specifications (CSs) together with any Special Conditions tailored to each Project.

References

- EASA SV-VTOL issue 1 (02/07/2019)
- EASA Artificial Intelligence RoadMap (Feb 2020 – Version 1.0)
- EASA EPAS 2022-2026 (European plan for Aviation Safety)
- ´MOVING FROM AUTOMATION TO AUTONOMY IN AVIATION
  Oct 16, 2020 by Erin I. Riviera
- ´CERTIFICATION CHALLENGES FOR AUTONOMOUS AIRCRAFT SYSTEMS'
  Nov 4, 2020 by Erin I. Riviera

Glossary

- AI: Artificial Intelligence
- ANN: Artificial Neural Network
- CNN: Convolutional Neural Network
- CU: Command Unit
- DL: Deep Learning
- EPAS: European Plan for Aviation Safety (EASA)
- E-VTOL: electric Vertical Take-Off and Landing (Aircraft)
- ML: Machine Learning
- NPA: Notification of Proposed Amendment (EASA)
- SC-VTOL: Special Condition for VTOL aircraft
- UAM: Urban Air Mobility
- UTM: UAS Traffic Management

END