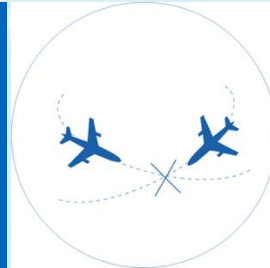




**CTU**

**CZECH TECHNICAL  
UNIVERSITY  
IN PRAGUE**

Faculty of Transportation Sciences  
Department of Air Transport



Aviation Safety and Security  
Research Group

# AI AND ITS LIMITATIONS WITH AVIATION SAFETY DATA

---

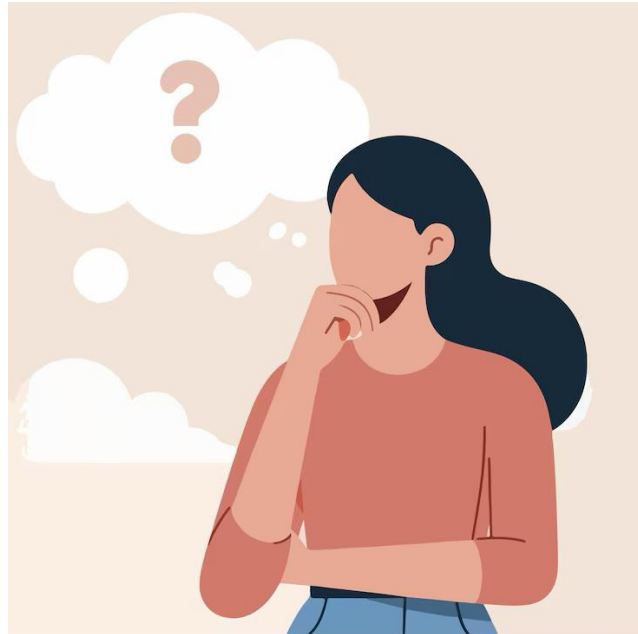
13.05.2025

# ARTIFICIAL INTELLIGENCE

AI will change the world.

Does AI have any limitations?

AI can do anything.



Can I use AI for anything?

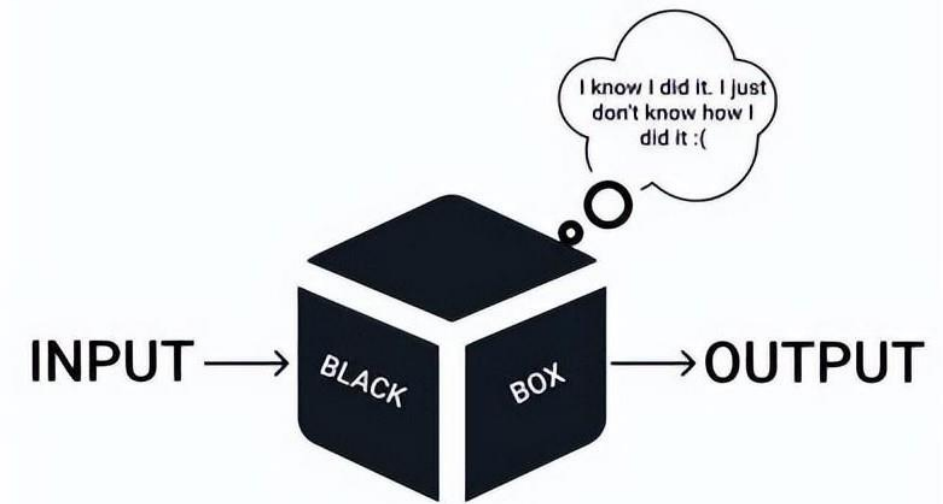
AI is the best at solving problems.

Is it true or not?

# WHY AI HAS LIMITATIONS WITH AVIATION SAFETY DATA?

## 1. Lack of Transparency ("Black Box" Problem)

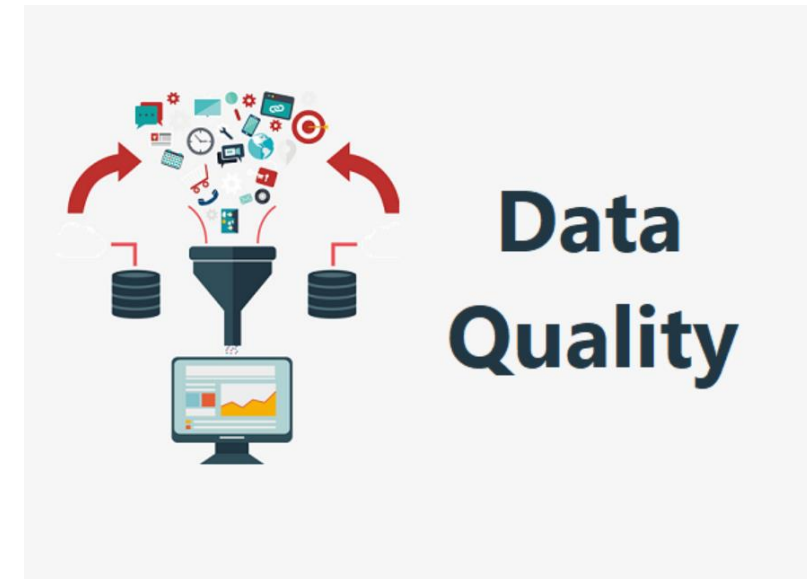
- Most AI models (especially machine learning and deep learning) cannot easily explain why they make a certain prediction or decision.
- In aviation safety, we must **trace causality and have arguments** for audits, regulations, and investigations — **"we think" is not enough.**



# WHY AI HAS LIMITATIONS WITH AVIATION SAFETY DATA?

## 2. Data Quality and Sparsity

- Aviation safety data is often **sparse, noisy, and irregular**.
- e.g., rare incidents, different reporting standards
  
- AI needs **large amounts of clean, uniform data** to be accurate. If trained incorrectly, **AI can miss rare but critical safety signals**.



# WHY AI HAS LIMITATIONS WITH AVIATION SAFETY DATA?

## 3. Bias and Generalization Problems

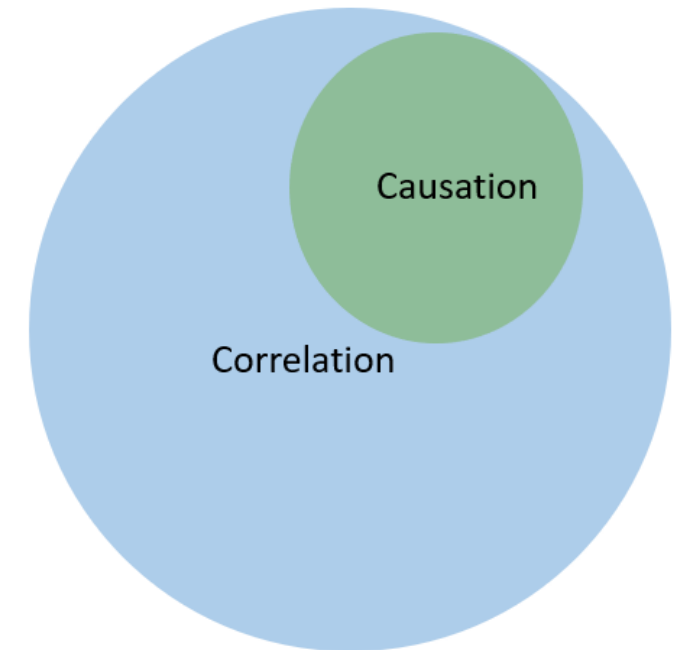
- AI models can **over-fit** to patterns from the past and **fail to generalize** to new, unseen hazards.
- In safety-critical environments like **aviation**, the inability to predict hazards leading to a rare but catastrophic event is **unacceptable**.



# WHY AI HAS LIMITATIONS WITH AVIATION SAFETY DATA?

## 4. Lack of Causal Understanding

- Traditional AI models find **correlations**, but correlations do not imply causality.
- **Aviation safety** demands understanding **causal chains** — what triggered what — not just pattern matching.



# WHY AI HAS LIMITATIONS WITH AVIATION SAFETY DATA?

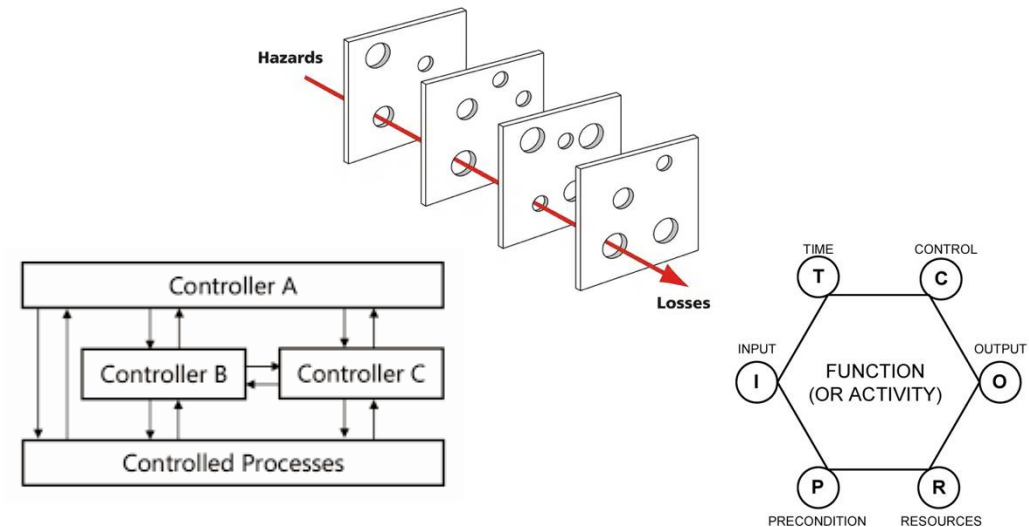
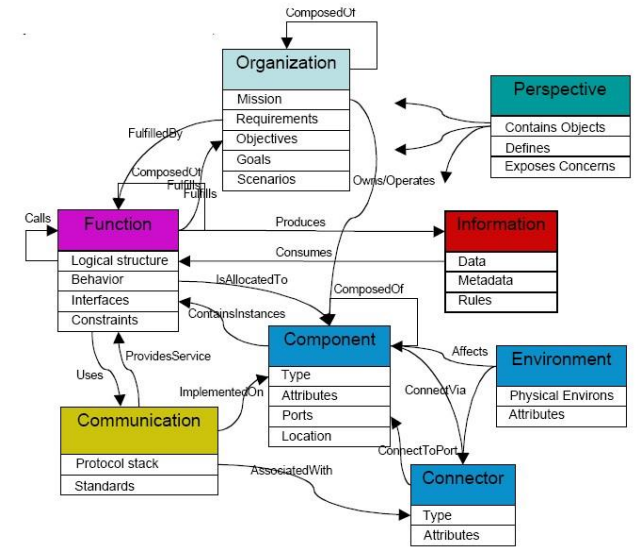
## 5. Regulatory and Certification Challenges

- Authorities like FAA, EASA, ICAO demand **explainable, verifiable systems**.
- Black-box AI is **very difficult** (sometimes impossible) to **certify** under existing aviation safety regulations.



# WHAT ARE THE ALTERNATIVES?

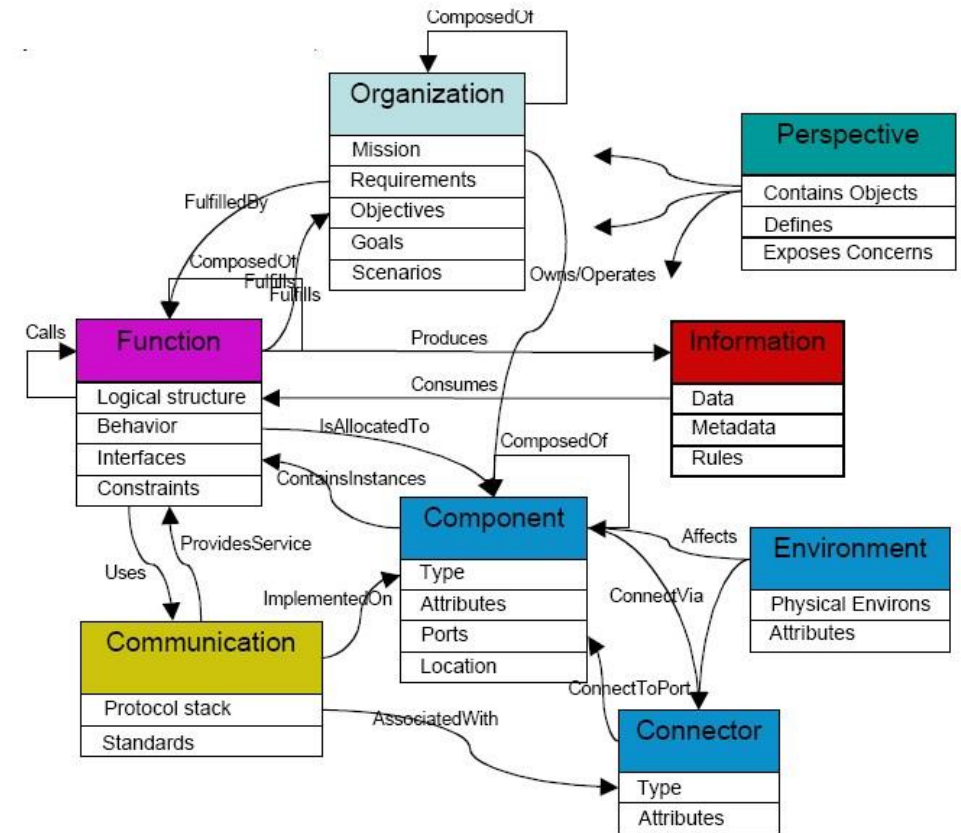
- It is possible to use a combination of:
  - "explainable AI" (XAI) => ontologies,
  - verified safety causality models.
  
- **Goal:** Ability of systems to provide clear and understandable explanations for their actions and decisions.



# WHY ONTOLOGY-BASED SYSTEMS ARE BETTER FOR AVIATION SAFETY DATA

## 1. Structured, Human-Understandable Knowledge

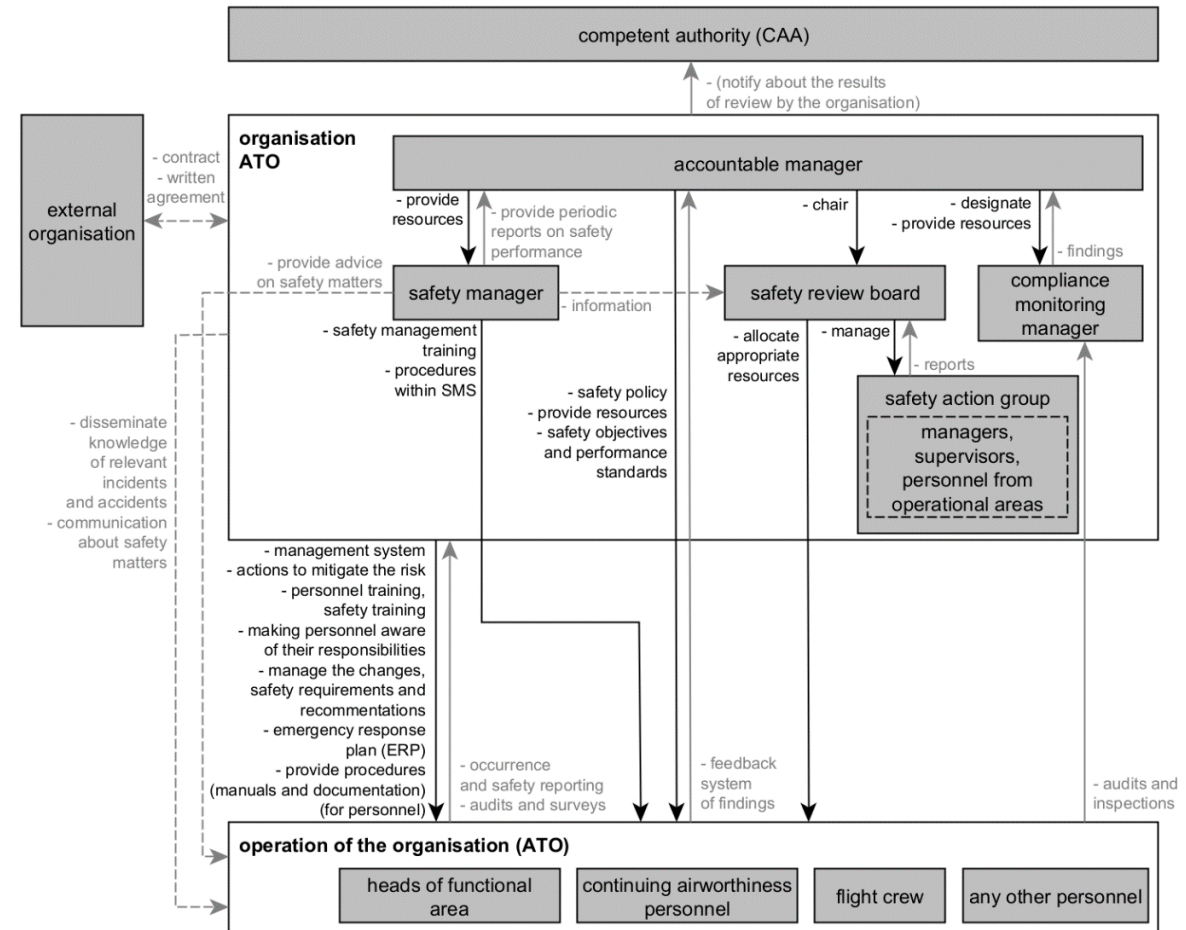
- Ontologies explicitly **model concepts** (like "flight phase," "weather condition," "mechanical failure") and **relationships** between entities (e.g., "engine fire can cause emergency descent").
- Inspectors, engineers, and regulators **can easily review and verify the structure.**



# WHY ONTOLOGY-BASED SYSTEMS ARE BETTER FOR AVIATION SAFETY DATA

## 2. Support for Causal Reasoning

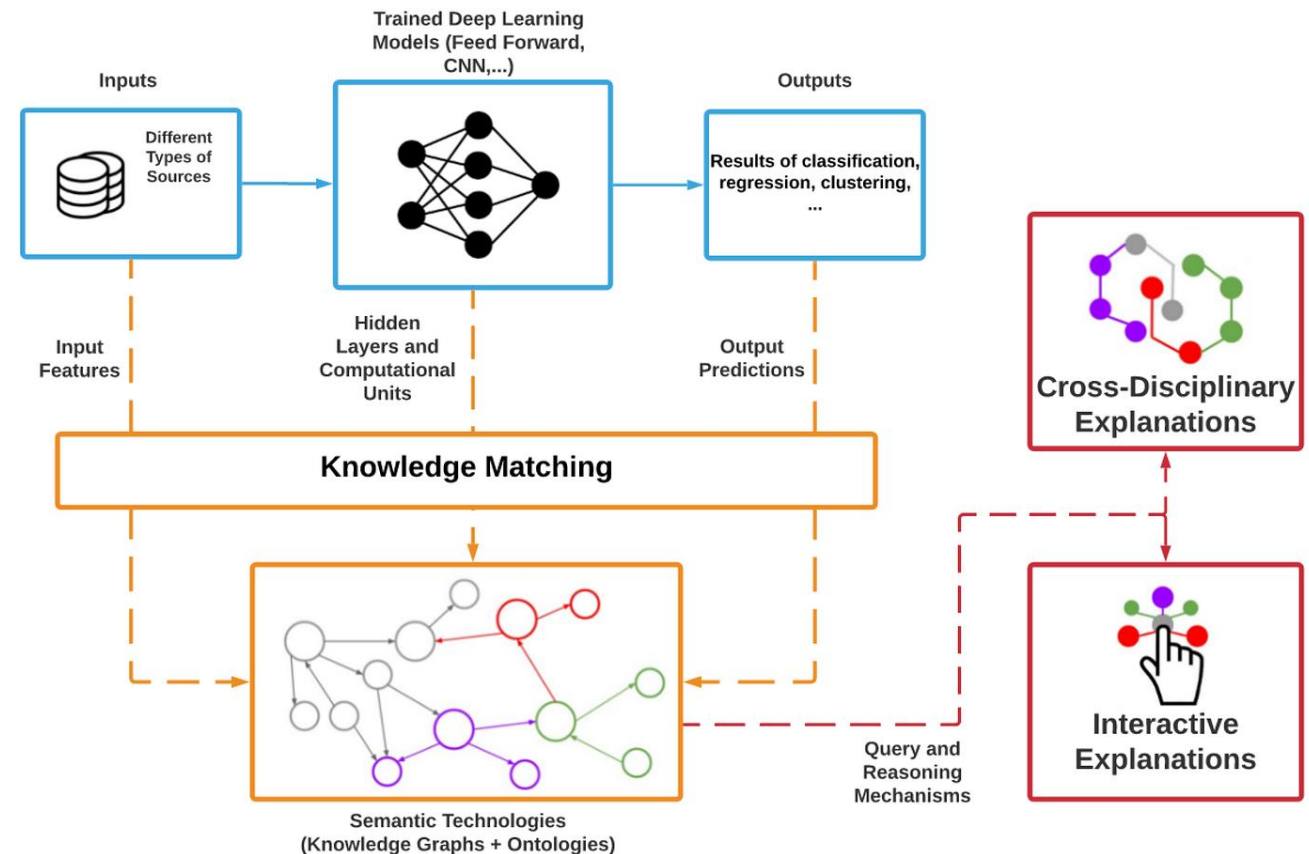
- Ontologies can integrate with causal models.
- We use **STAMP** (System-Theoretic Accident Model and Processes). STAMP models the safety control structure (SCS) and uses it for causal analysis.
- This supports **systemic accident analysis**, beyond the current failure-based analyses.



# WHY ONTOLOGY-BASED SYSTEMS ARE BETTER FOR AVIATION SAFETY DATA

## 3. Explainability and Traceability

- Every conclusion drawn from an ontology is **explainable step-by-step** ("because A is linked to B under condition C").
- This fits well with incident/accident investigations or safety audits etc.



# WHY ONTOLOGY-BASED SYSTEMS ARE BETTER FOR AVIATION SAFETY DATA

## 4. Flexibility and Reusability

- **You can expand ontologies** as new hazards or technologies appear.
- e.g., new aircraft types, new automation features
- Ontologies are modular and **can be updated without retraining a model.**



# WHY ONTOLOGY-BASED SYSTEMS ARE BETTER FOR AVIATION SAFETY DATA

## 5. Regulatory Compliance

- Ontology-based systems fit into aviation regulators' expectations: logic-driven, rule-based, documented.



# SUMMARIZING INFORMATION ABOUT AI

...in the context of aviation safety data

- AI – we've known it for quite a long time, but now we have powerful computers.
- Inefficient – you have to teach it using clean and accurate data.
- Black box – we just hope it learns what we wanted.
- "Big data" approach based on stochastics.



# COMPARISON

<b>AI in Aviation Safety</b>	<b>Ontology-based Systems</b>
Black-box, hard to explain	Transparent, explainable logic
Needs large, clean data	Works with expert knowledge
Finds correlations, not causes	Models causal relationships
Hard to certify for safety	Easier to verify and certify
Poor with rare events	Good with expert-driven modeling



**METHODOLOGY**

for improving analysis and management of risk  
with the utilization of conceptual modeling

Research project TA CR Zéta No. TJ01000377

Department of Air Transport  
Faculty of Transportation  
Sciences  
CTU in Prague

Department of Cybernetics  
Faculty of Electrical  
Engineering  
CTU in Prague

Prague Airport, Ltd.

Czech Airlines  
Technics, Ltd.

Handková Lenka, Ing.  
Lališ Andrej Ing., Ph.D.  
Stojč Slobodan Ing., Ph.D.

Ahmad Jana, Ing.  
Kostov Bogdan, Ing.

Kalková Markéta, Ing.

Szenkeresztiová  
Katarína, Ing.


**T A  
Č R**

Technology  
Agency  
of the Czech Republic

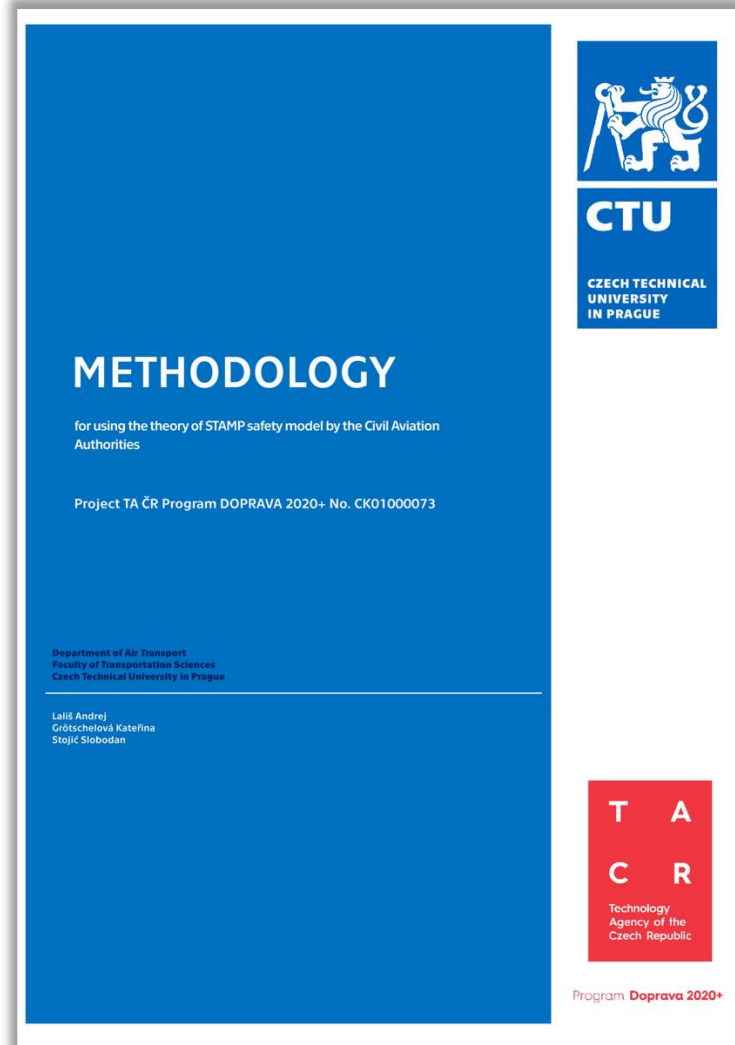
Program **Zéta**



**CTU**  
CZECH TECHNICAL  
UNIVERSITY  
IN PRAGUE

- [http://uldbeta.fd.cvut.cz/stazeni/vedecke\\_vystupy/Methodika\\_1\\_EN.pdf](http://uldbeta.fd.cvut.cz/stazeni/vedecke_vystupy/Methodika_1_EN.pdf)



**METHODOLOGY**

for using the theory of STAMP safety model by the Civil Aviation  
Authorities

Project TA CR Program DOPRAVA 2020+ No. CK01000073


Department of Air Transport  
Faculty of Transportation Sciences  
Czech Technical University in Prague

Lališ Andrej  
Grötschelová Kateřina  
Stojč Slobodan

**T A  
Č R**

Technology  
Agency of the  
Czech Republic

Program **Doprava 2020+**



**CTU**  
CZECH TECHNICAL  
UNIVERSITY  
IN PRAGUE

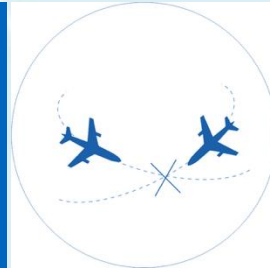
- [https://uld.fd.cvut.cz/wp-content/uploads/2024/04/Methodika\\_073\\_EN-1.pdf](https://uld.fd.cvut.cz/wp-content/uploads/2024/04/Methodika_073_EN-1.pdf)



**CTU**

**CZECH TECHNICAL  
UNIVERSITY  
IN PRAGUE**

Faculty of Transportation Sciences  
Department of Air Transport



**Aviation Safety and Security  
Research Group**

# THANK YOU FOR YOUR ATTENTION

---

**13.05.2025**

**Kateřina GRÖTSCHELOVÁ**

**[grotskat@fd.cvut.cz](mailto:grotskat@fd.cvut.cz)**