# Reliability Analysis & Risk Assessment

**Sharif University of Technology**
Department of Aeronautics and Astronautics

Course Project
B.Sc.

2025-1
Due: NA

## Probabilistic Safety Assessment of Aircraft Crew Oxygen Systems

**The Engineering Imperative**

As future aerospace engineers, you will be responsible for signing off on systems where failure can result in the loss of human life. A notable example of such a failure is the 2005 crash of Helios Airways Flight 522, which was caused by a misunderstanding of cabin pressure warnings that originated in the design of the oxygen system. Your task is to conduct a probabilistic safety assessment (PSA) of a crew oxygen system similar to that of a Boeing 737. This exercise is not just academic, as it requires the development of analytical rigor mandated by FAA Part 25.1309. This regulation states that catastrophic events must be "extremely improbable," occurring less than once in every $10^{-9}$ flight hours. In performing these calculations, we are not only working with numbers, but also building the ethical foundation for certifying life-critical systems. Any single oversight could have far-reaching consequences, contributing to decades of aviation disasters. This analysis will determine whether the system meets the required standard and propose cost-effective improvements to ensure the safety of the system.

**Project Roadmap**

1. **System Modeling & Reliability Prediction**
   Construct a reliability block diagram (RBD) mapping the oxygen supply chain: chemical generators → distribution lines → pressure sensors → mask deployment. Using FAA ASRS incident data and OREDA failure rates, assign probability distributions (Exponential for valves, Weibull for generators). Calculate system reliability over 50,000 flight hours (typical aircraft life). *Critical question: Does your baseline design meet FAA's "extremely improbable" threshold?*

2. **Failure Criticality & Scenario Modeling**
   Perform FMECA on five critical components (e.g., generator thermic core, pressure sensor). Apply MIL-STD-882 severity classifications and compute Risk Priority Numbers (RPN). Then, build a fault tree for the top event: "Insufficient oxygen delivery during decompression." Identify minimal cut sets and quantify failure probability using your RBD parameters. Validate with a 10,000-trial Monte Carlo simulation. *Critical reflection: Are your assumed failure rates defensible given real-world incidents like Alaska Airlines Flight 261?*

3. **Risk Mitigation & Decision Analysis**
   Propose two design upgrades (e.g., redundant sensors, accelerated inspection intervals). Estimate each solution's cost (installation, maintenance) and risk reduction (ΔRPN). Construct a decision tree evaluating utility using the function $U = (\text{Risk Reduction} \times 10^6) / (\text{Cost} + \$50K)$. Justify your recommendation through sensitivity analysis on cost parameters. *Critical challenge: Would your solution prevent a Helios-like cascade?*

4. Extension (Optional):
   Apply FORM to a limit state (e.g., $g(x) = \text{Required } O_2 \text{ Flow} - \text{Actual Flow}$) with 1 variable (e.g., sensor drift).

**Deliverables**

- Technical report (15 pages max) structured as an FAA advisory circular + oral presentation of your work:
  - ► System reliability assessment with uncertainty bounds
  - ► FMECA tables with justification of severity/detection scores
  - ► Fault tree quantification with MCS dominance analysis
  - ► Cost-benefit decision matrix with sensitivity discussion
- Simulation scripts with commented code

## General Notes

Projects that address open science practices will also be awarded **bonus marks up to 20%**. Open science refers to practices that promote openness, integrity, and reproducibility in research. This includes but is not limited to submissions via GitHub links to your publicly available repository. Please note that sharing research publicly should be done responsibly, ensuring that any sensitive data is appropriately anonymized or removed.

Remember, due dates are our guiding stars, missing them causes problems. All submissions shall be in digital format, **AVOID HARDCOPIES, PLEASE**. Keep your reports concise. Julia programming language and English submissions get an extra 10% bonus, by the way. Enjoy!