Progress review

Effect of structural/material ecodesign levers on wing design

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Context & Motivation

- Interest in **Composite materials** in aeronautical sector.
- **A320**: **10%** of A/C weight due to composite materials.
- **A350** : **53 %** of A/C weight is due to composite materials.

Interest in reducing the weight of mid range aircafts

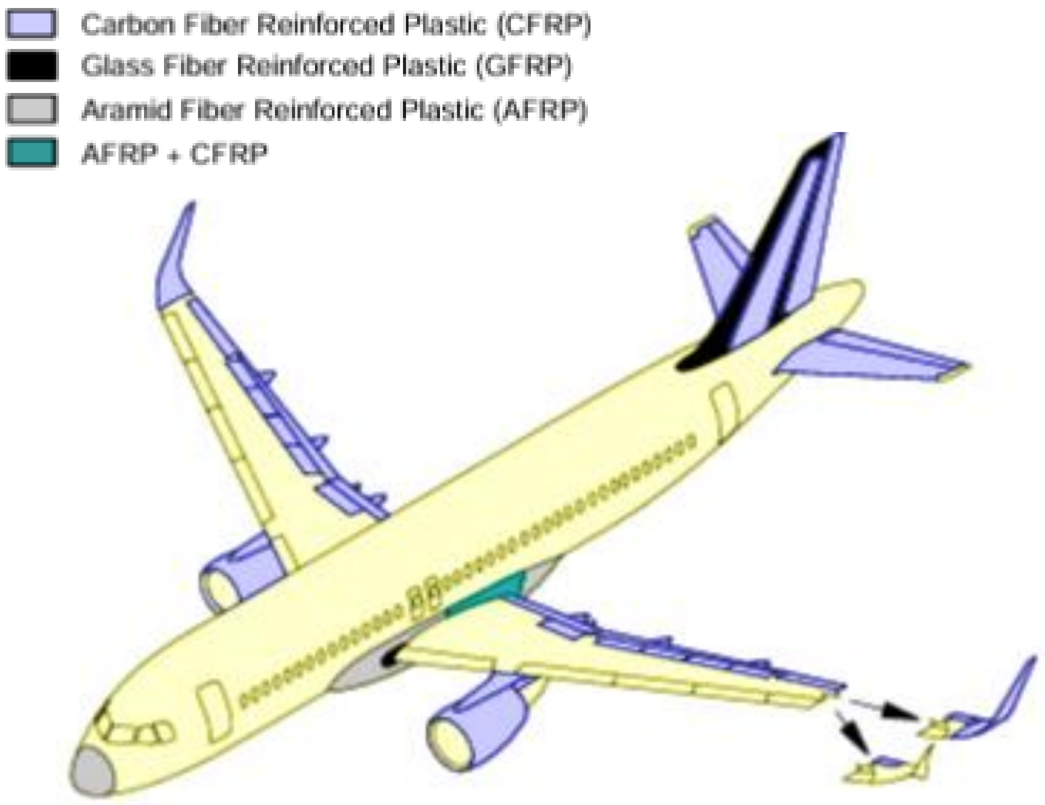

Figure 1: Structural parts made out of composite materials in A320

Source: A320 technical data sheet (https://www.airbus.com)

Research Questions & Objectives

1. How can aircraft wing design be optimized to reduce **structural weight** and **CO_2 emissions** across the aircraft's life cycle?

2. What is the impact of **ultralight structural materials** on aircraft performance and environmental footprint?

Source: https://caneurope.org/europe-is-staying-the-course/

- Main goals:
  - Aero-structural analysis of various materials.
  - **Multi-objective optimization** (fuel burn, weight, emissions, manufacturing environmental footprint)

3.1 Materials

CARBON FIBERS
Recyclability limitations of thermosets

?

NATURAL FIBERS
Lower stiffness that degrades flutter performance

Other solutions:
- Hybrid composites: Combining bio-fibers and recycled carbon fibers. [2]
- Ultra-Light Carbon-Based Composites validated via FEA [3]

Material	*E* *GPa*	*G* *GPa*	*σ_y* *MPa*	*ρ* *kg/m^3*
PLA+3%NCF/Ramie	8.7	5.5	124	1357
PLA+3%NCF/CF	40	27	540	1573
Phenolic Res./CF	42	27	543	1586
EpoxyRes./CF (Ref1)	75	47	550	1576
Al 6061 T6 (Ref2)	69	26	276	2700

Figure 2: Ramie-fiber and carbon fiber composites input parameters and data for conventional CFRP and aluminum. [1]

Thermosets (e.g Epoxy/CFRP) used in wings and fuelage are hard to recycle but still excell in mechanical properties

Sources: [1] Kling, U., et al. Future aircraft wing structures using renewable materials. Deutsche Gesellschaft für Luft-und Raumfahrt-Lilienthal-Oberth eV, 2015.
[2] J. Bachmann et al., “Outlook on ecologically improved composites for aviation interior and secondary structures,” 2018.
[3] N. Fantuzzi et al., “Mechanical analysis of a carbon fibre composite woven composite laminate for ultra-light applications in aeronautics,”

3.2 MDO

Structures & Aerodynamics

Environmental factors: CO_2, buy to fly ratio, energy.

Gradient based (OpenAerostruct), VAE, Gradient free

Variational Autoenconders (VAE)

- Cross-sectional area continiuously varies while material properties are discrete.
- Need of VAE to convert discrete data into a continuous differentiable space.

Variational Autoenconders (VAE)

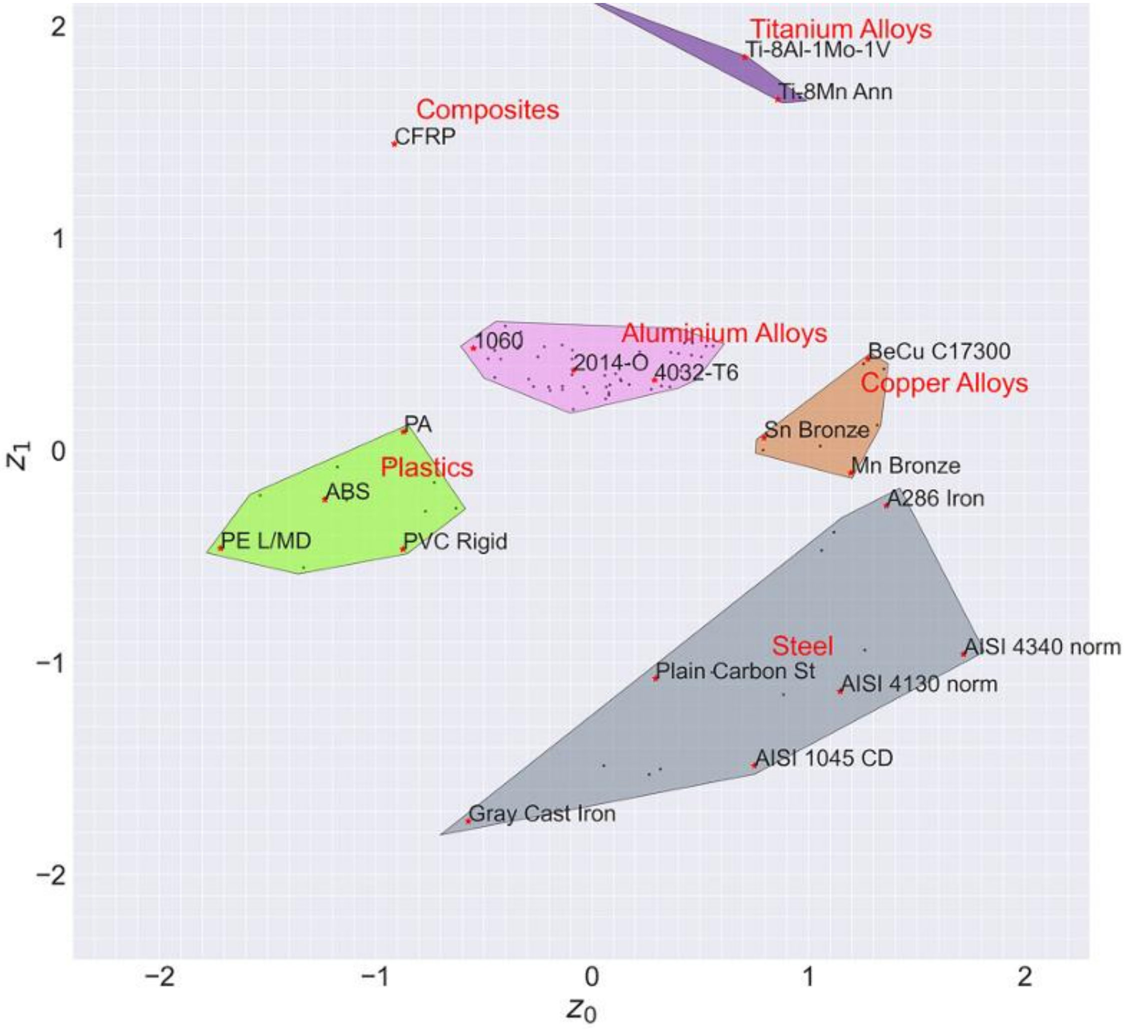

Figure 3: Material representation in a two-dimensional latent space [4]

Source: [4] L. Y. Llorente, J. Morlier, S. Sridhara, and K. Suresh, “A hybrid machine learningand evolutionary approach to material selection and design optimization for eco-friendly structures”

Methodology

- Use of **OpenAeroStruct** (OAS) for aero-structural optimization.

- Reference aircraft: **A320-200 / A321-200**. **CeRAS** model wing :
  - Baseline: Aluminum 7075.
  - Comparison: CFRP, Titanium, Steel.

- **Goal**: Minimize fuel burn, estimate wingbox mass.

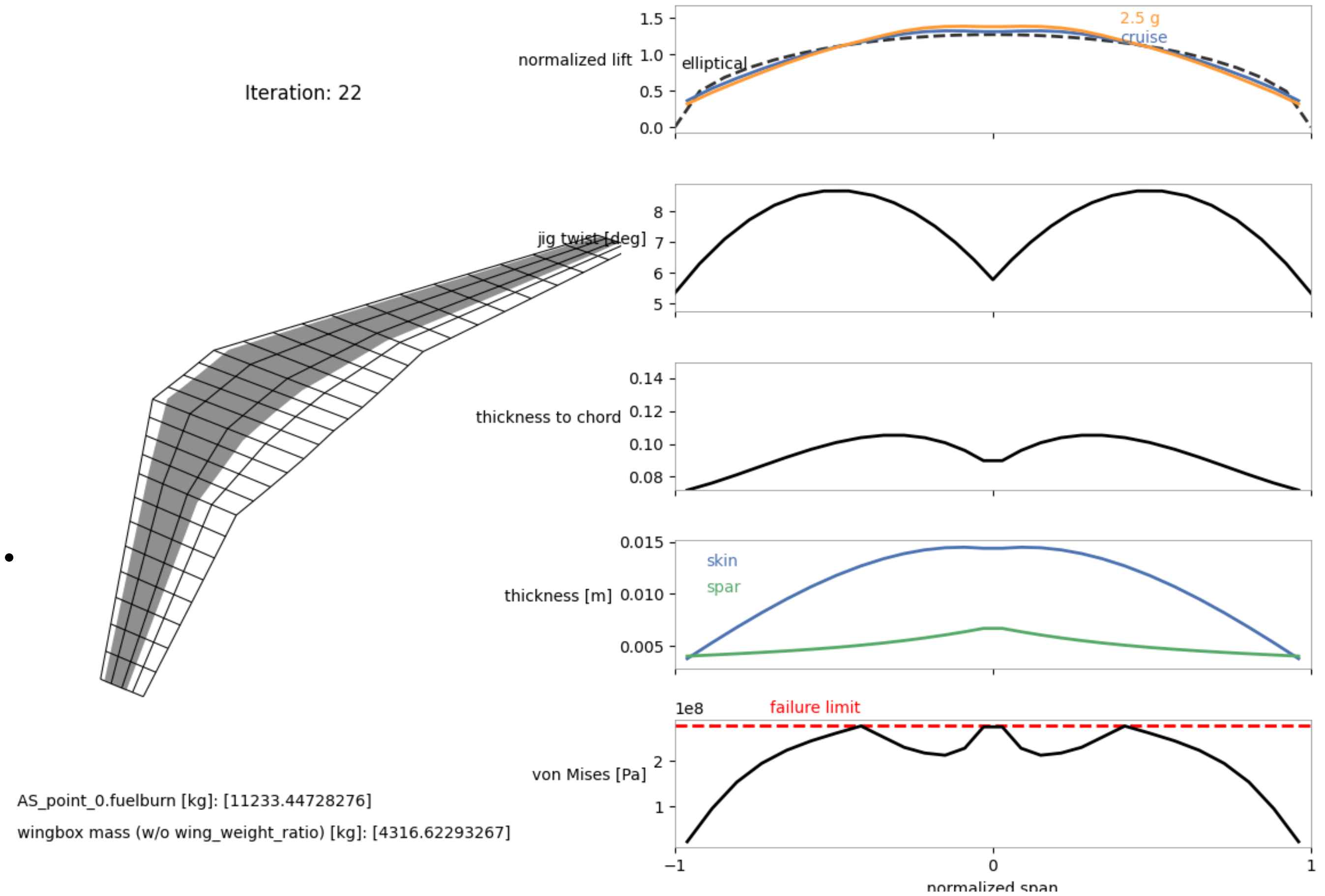

Figure 4: Example of OpenAerostruct optimization of A320 aluminum wingbox.

First Results

- Results based on structural material trade studies for the **Airbus A320 wingbox**.

- Comparison of **wingbox mass** and corresponding **fuel burn** for four materials:
    - Al 7075, CFRP, Ti, Steel.

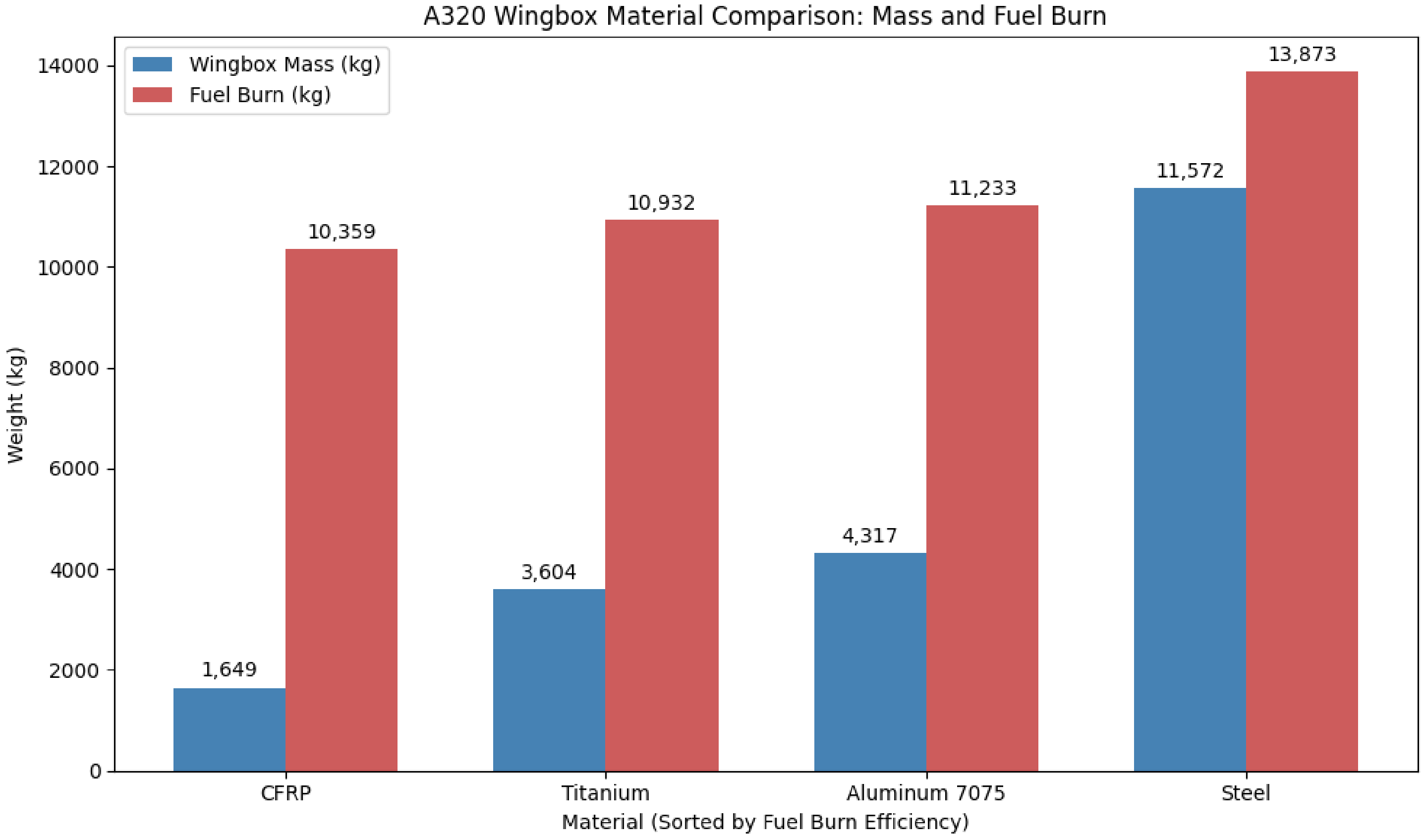

Figure 5: Comparison of Wingbox Mass and Fuel Burn Across Materials

Work Plan

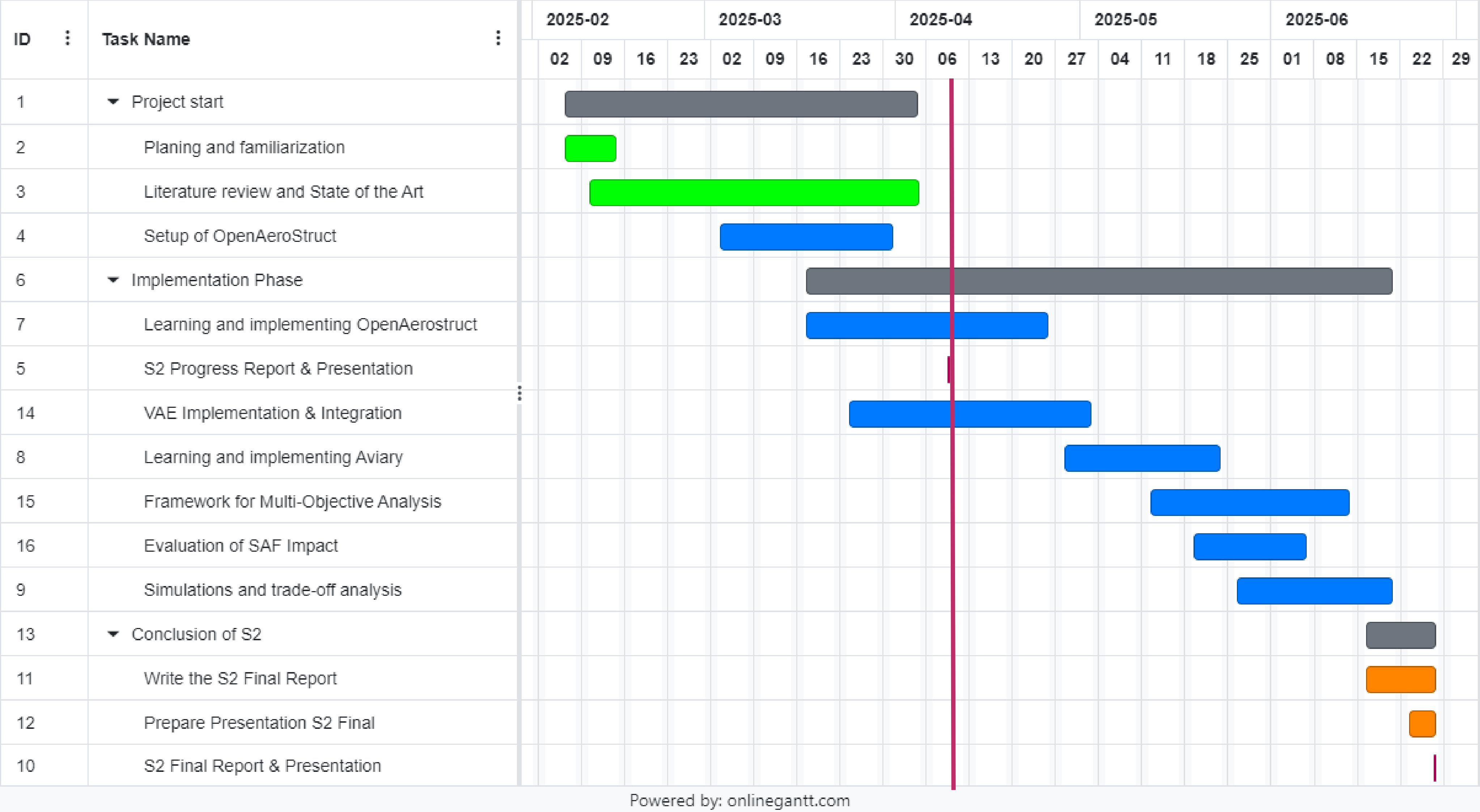

Figure 6: Work Plan as a Gantt Diagram

Thank you for your attention!

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