Comparison of Open-Source CFD Software for Aerodynamic Analysis of Mini-UAV

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- Free Software
- Mini-UAVs
- Aerodynamic Analysis

- The **aerodynamic analysis** often plays a **major role** in the **early stage of a design phase**.
  - **Major** changes **during** conceptual phase
  - **Minor** changes **after** conceptual phase
- Incorrect analysis => loss of money
- Suitable aerodynamic behavior is necessary.
- Two options:
  - Wind tunnel test
  - **CFD analysis**

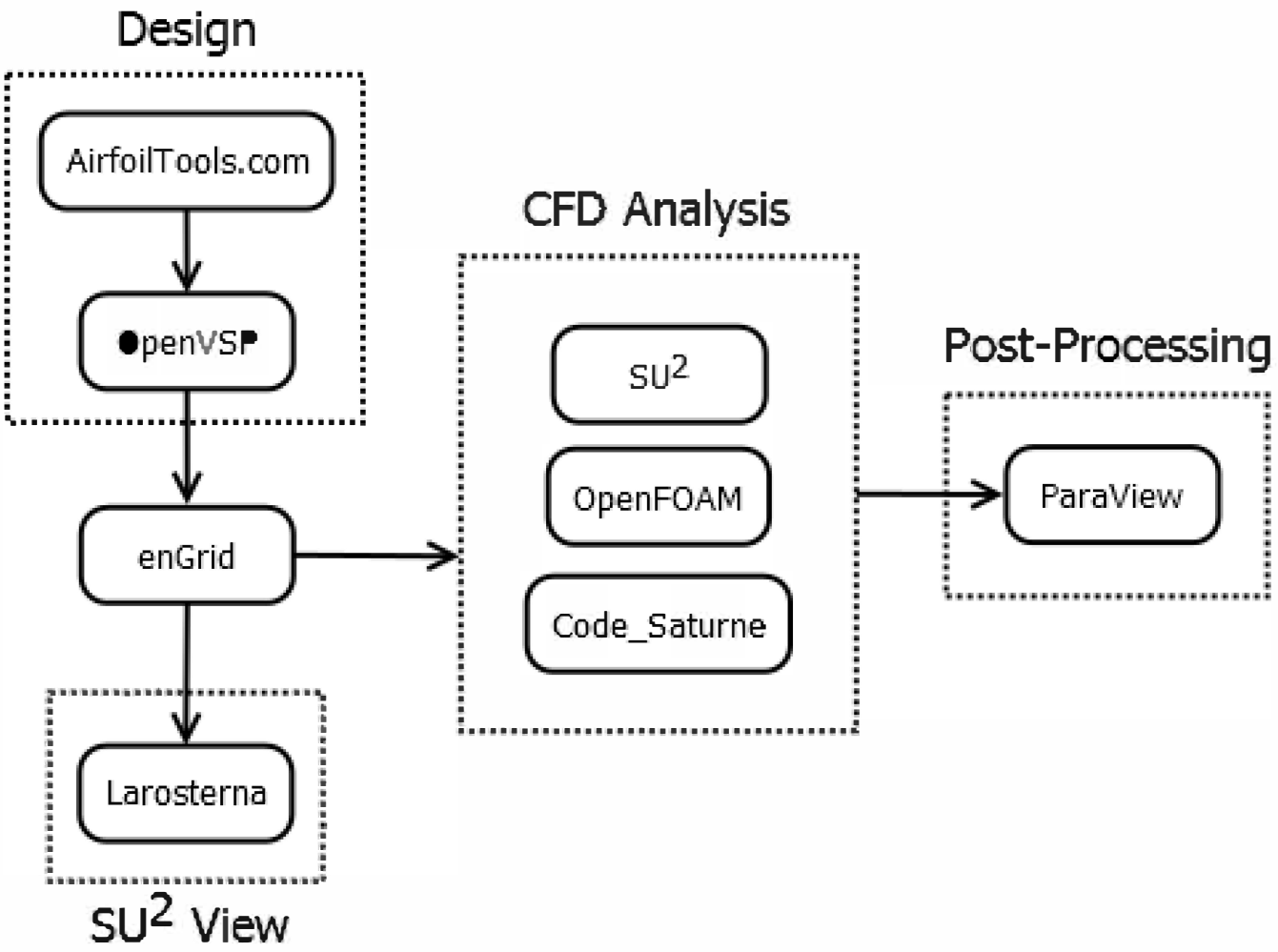

Figure 1. Free Software Connections

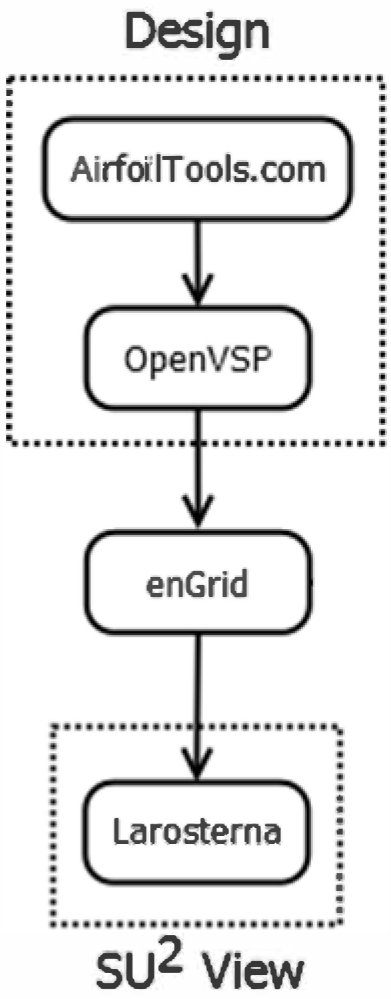

Figure 2. Design & Mesh

- **OpenVSP** is a parametric and easy-to-use aircraft geometry application.
- **AirfoilTools** generates the Selig and Lednicer airfoil DAT files.
- **enGrid** is an open-source mesh generation application.
- **Larosterna** is a design tool with an option to import a SU^2 mesh file.

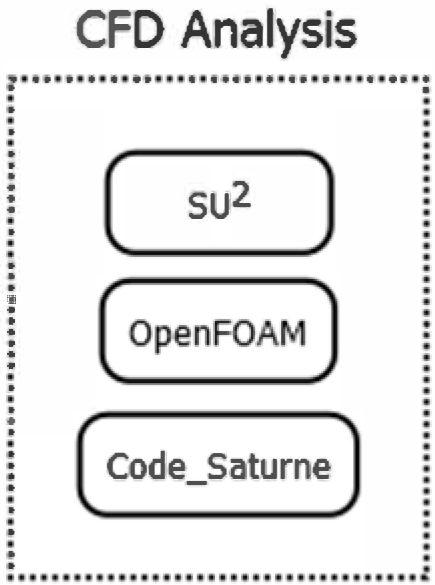

Figure 3. CFD Software

- The Stanford University Unstructured **(SU²)** suite solves complex, multi-physics analysis and optimization tasks using arbitrary unstructured meshes.

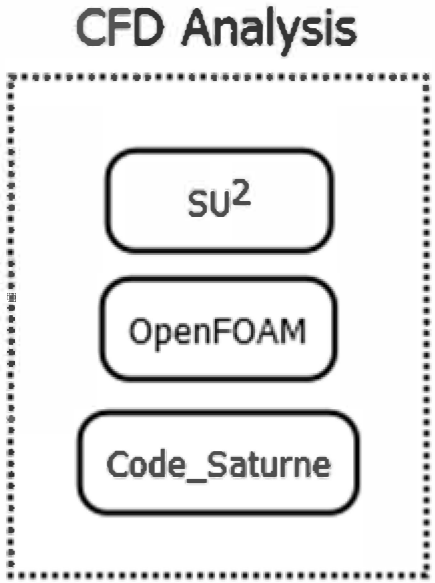

Figure 3. CFD Software

- The Open Field Operation and Manipulation (**OpenFOAM**) CFD Toolbox includes:
  - over 80 solver applications
  - over 170 utility applications for pre- and post-processing tasks

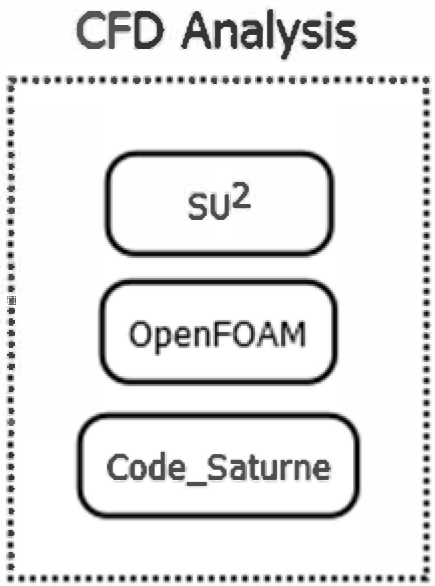

Figure 3. CFD Software

- **Code_Saturne** is based on a Finite Volume Method which accepts 3D meshes built with
  - any type of cell (tetrahedral, hexahedral, prismatic, pyramidal, and polyhedral)
  - any type of grid structure (unstructured, block structured, hybrid)

- Common parameters of mini-UAVs:
  - Wingspan < 6 m
  - Weight < 25 kg
  - Low speeds (between 20 and 120 km/h)
  - Low altitudes (from 3 to 1000 m)
- Primary Requirements:
  - Long **flight duration**
  - All-weather capabilities
  - Success in missions

Figure 4. SAGITTA UCAV Concept [1]

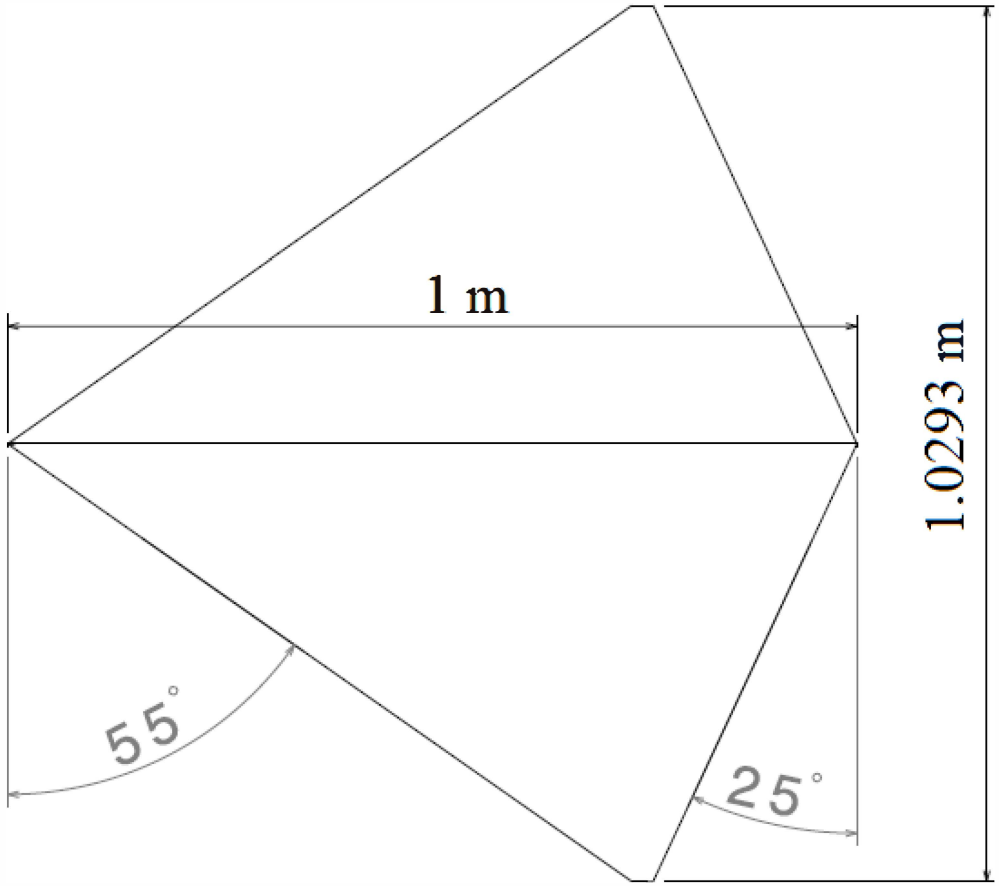

Figure 5. Wing Planform of SAGITTA Demonstrator [2]

- Symmetrical airfoil - NACA64A012

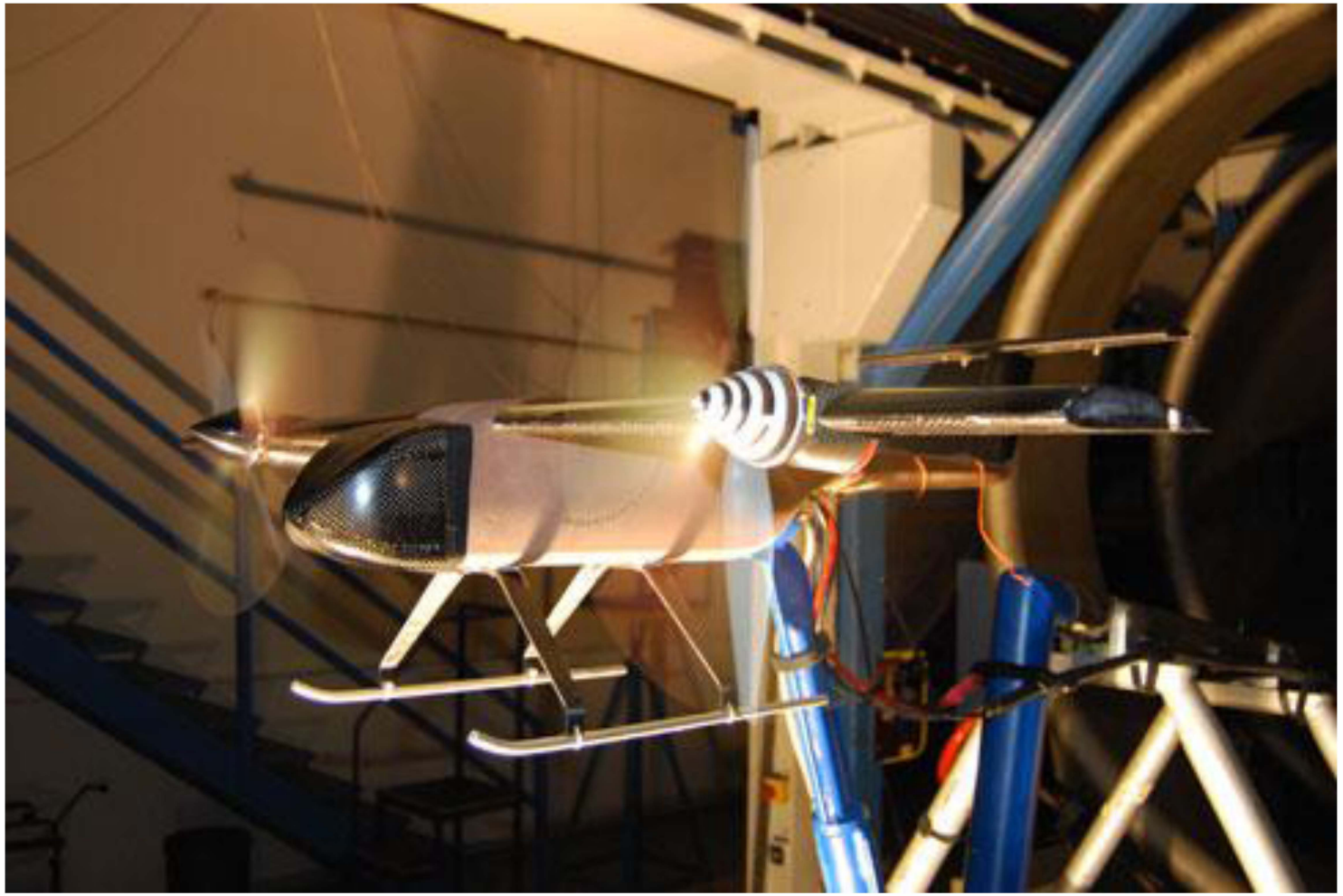

Figure 6. Wind Tunnel Model of AVIGLE UAV [3]

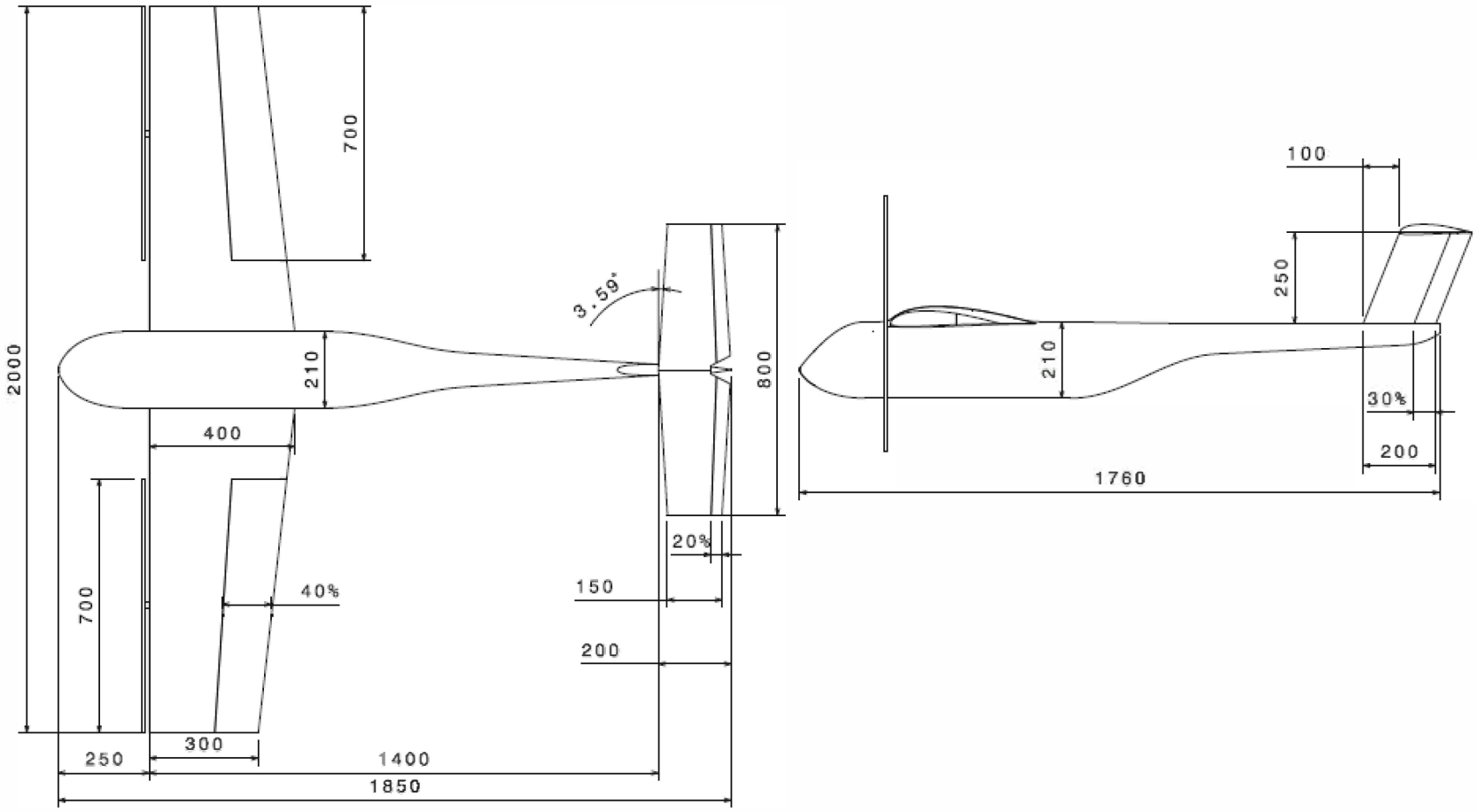

Figure 7. Geometry of AVIGLE UAV [3]

- 2 mini-UAVs analyzed in 3 CFD applications
  - SU^2
    - ROE (Roe's Approximate Riemann Solver)
    - JST (Jameson-Schmidt-Turkel)
  - OpenFOAM
  - Code_Saturne
- Results
  - SAGITTA **with** Boundary Layer
  - AVIGLE **without** Boundary Layer (enGrid crashed)
  - *SAGITTA **without** Boundary Layer (for comparison)*

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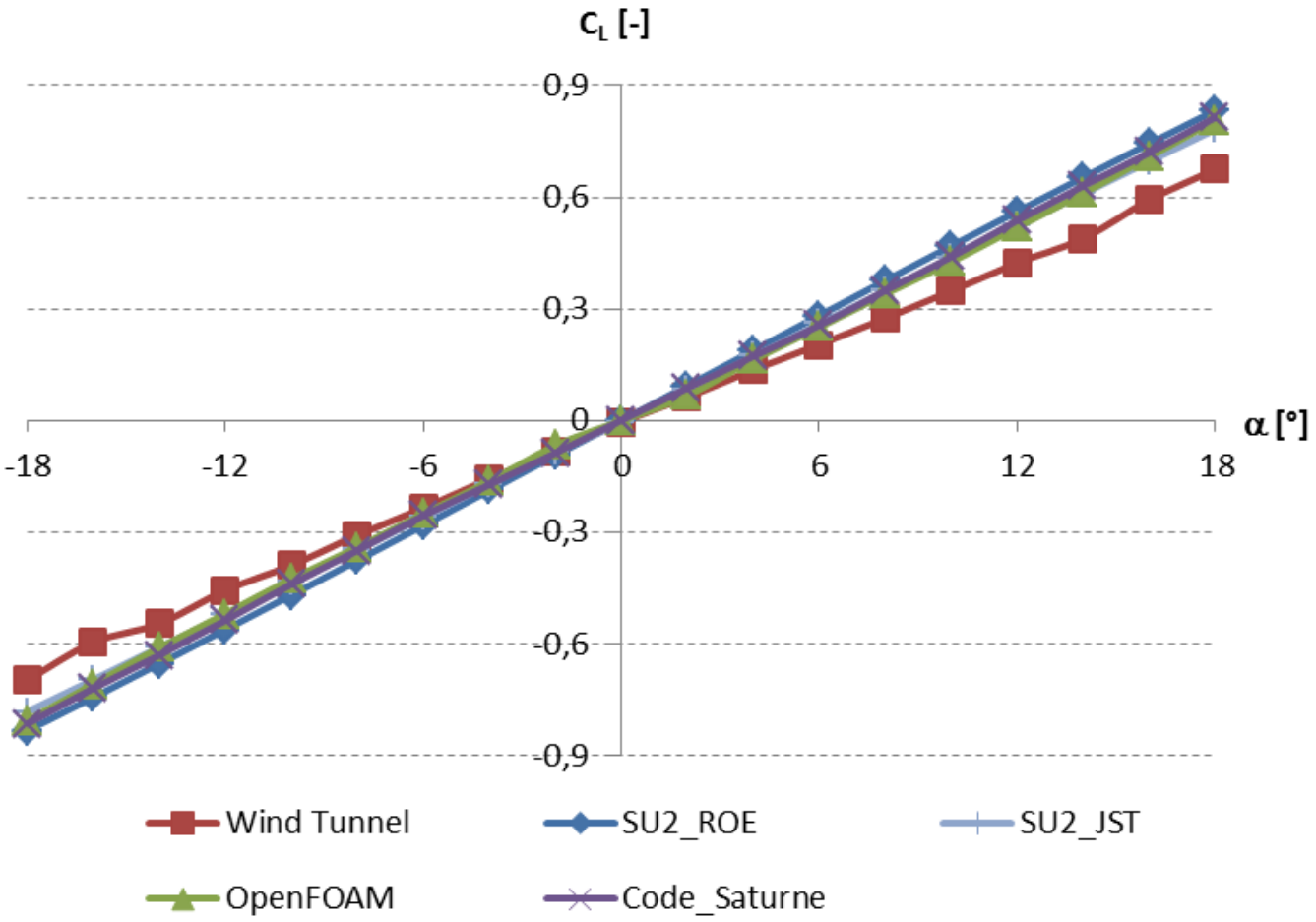

Figure 8. SAGITTA Demonstrator - C_L vs. α

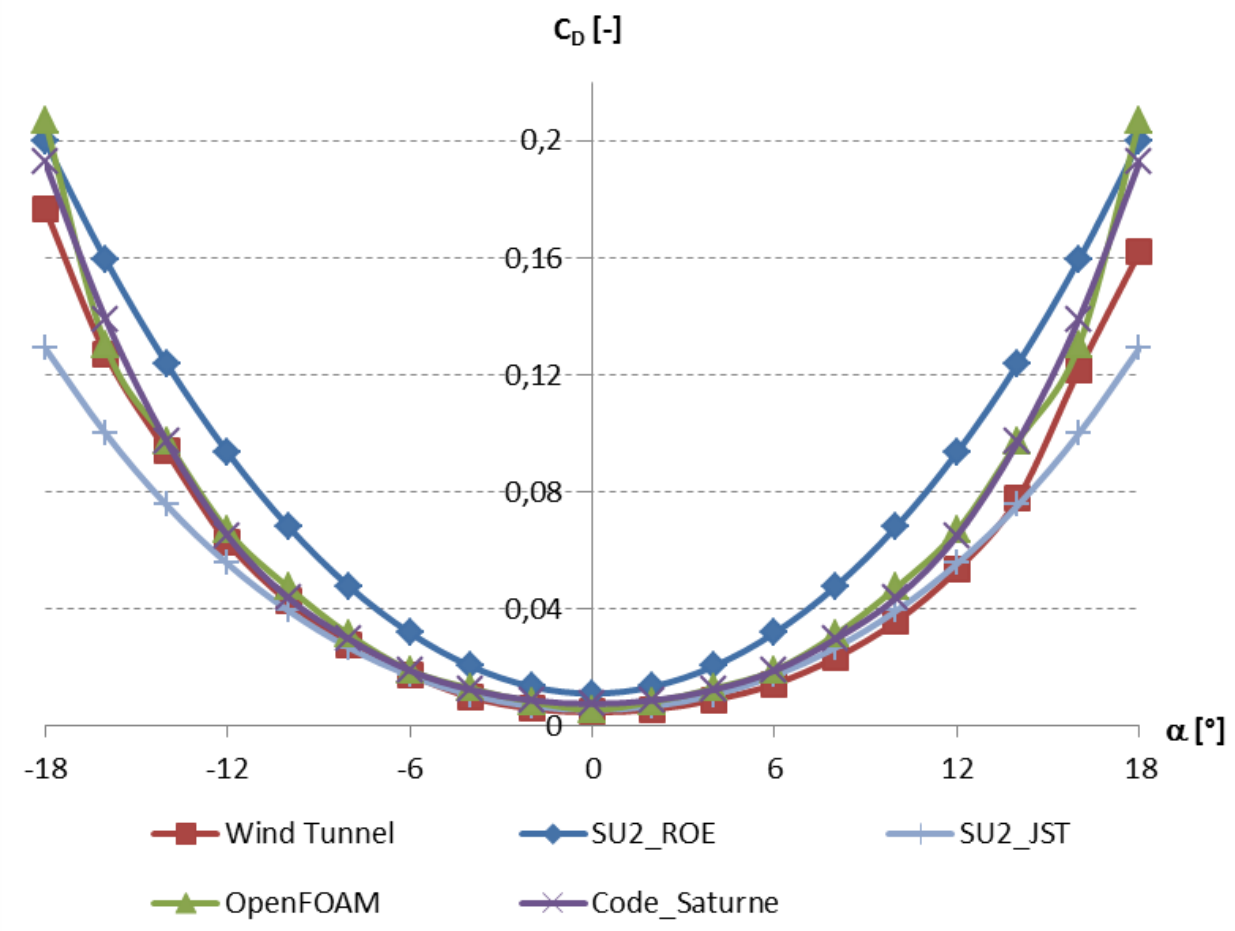

Figure 9. SAGITTA Demonstrator - C_D vs. α

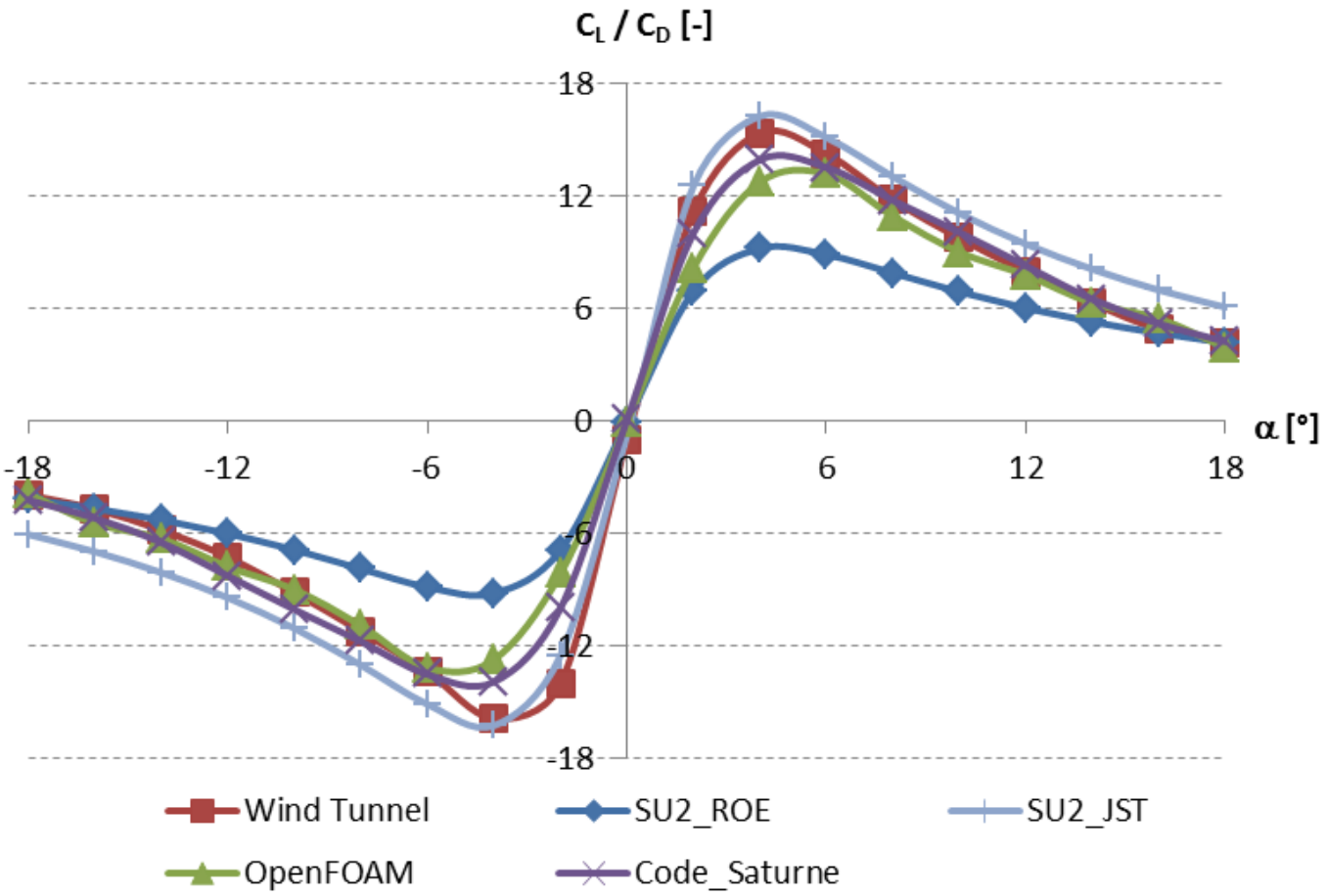

Figure 10. SAGITTA Demonstrator - C_L/C_D vs. α

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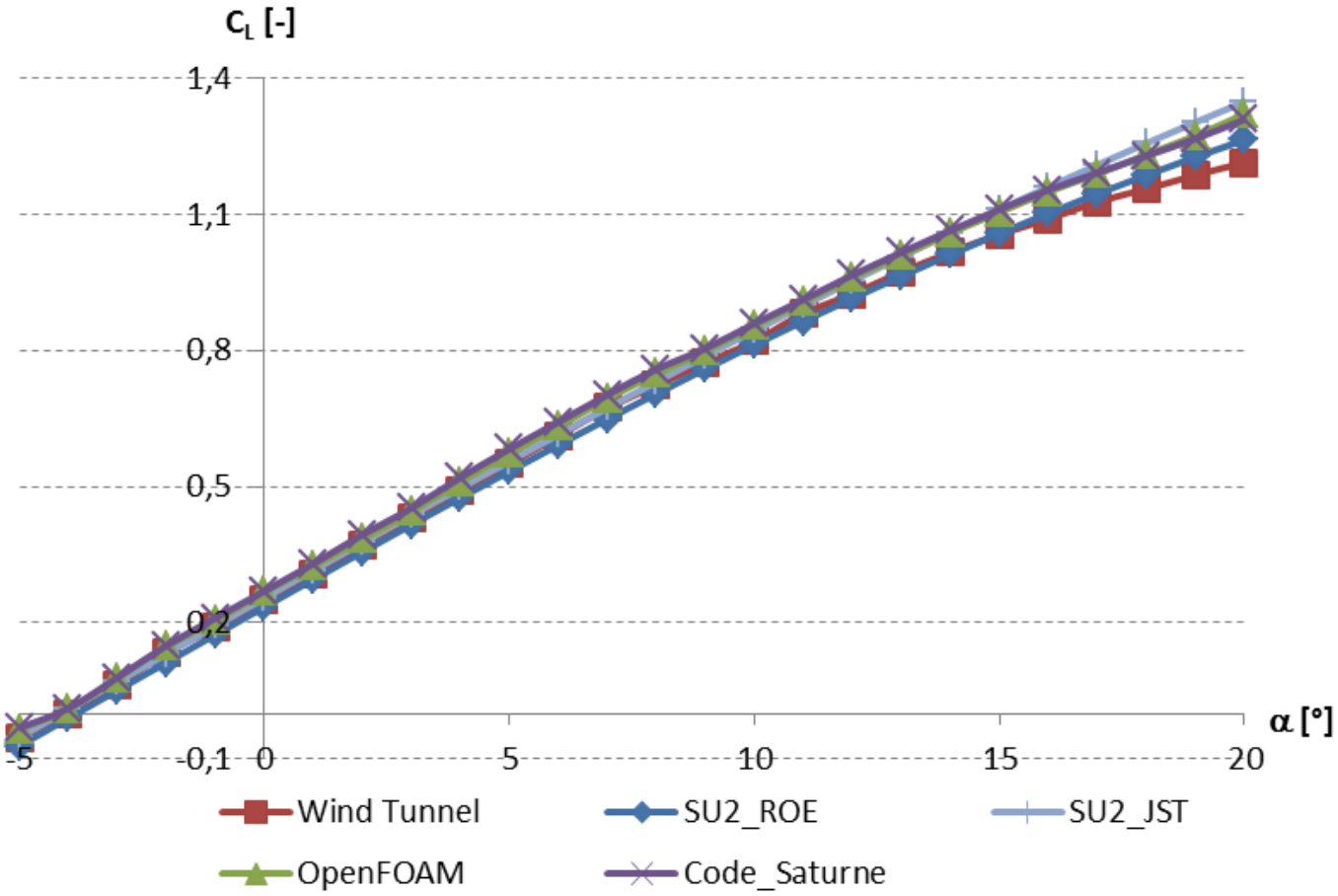

Figure 11. AVIGLE Tiltwing UAV - C_L vs. α

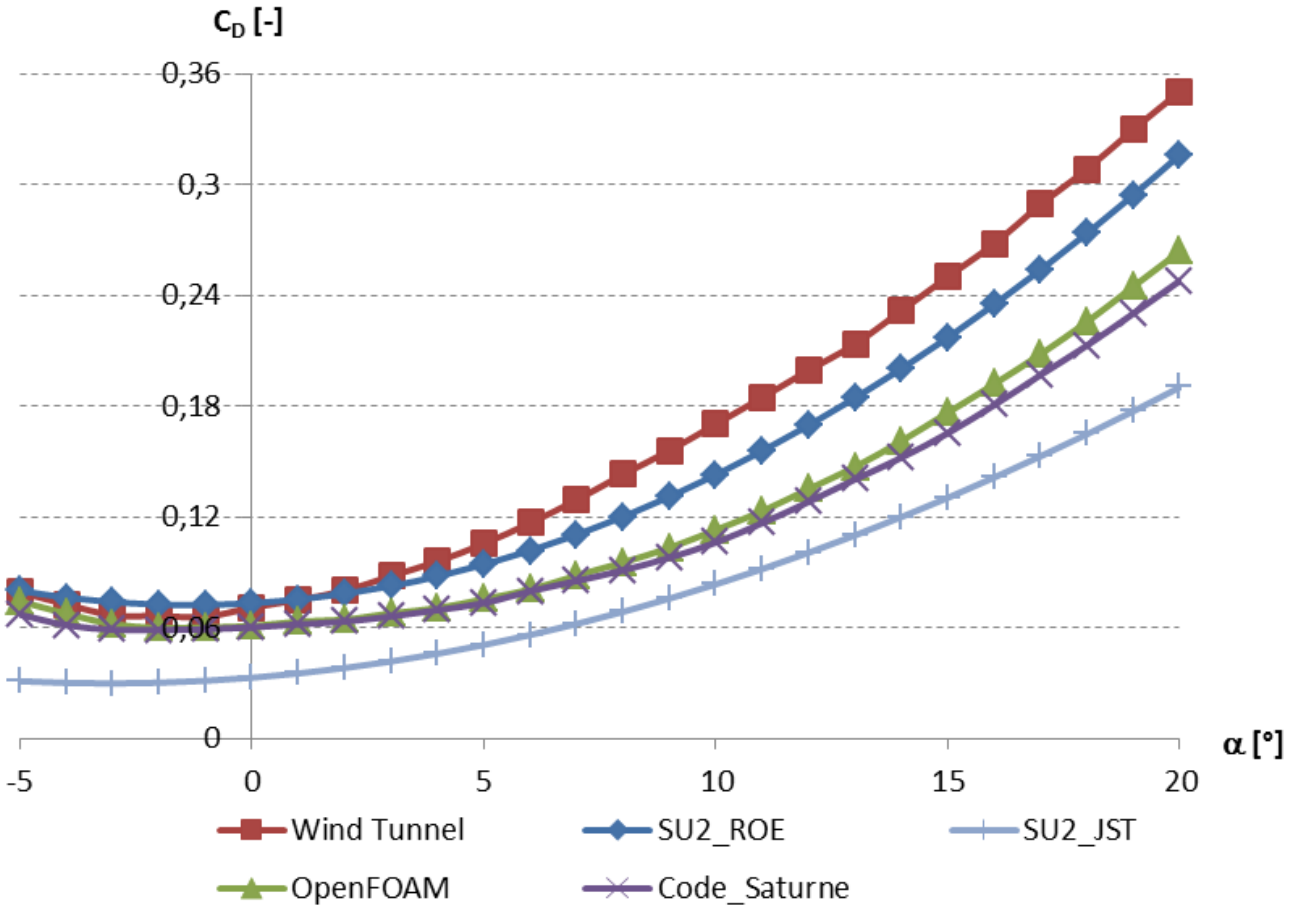

Figure 12. AVIGLE Tiltwing UAV - C_D vs. α

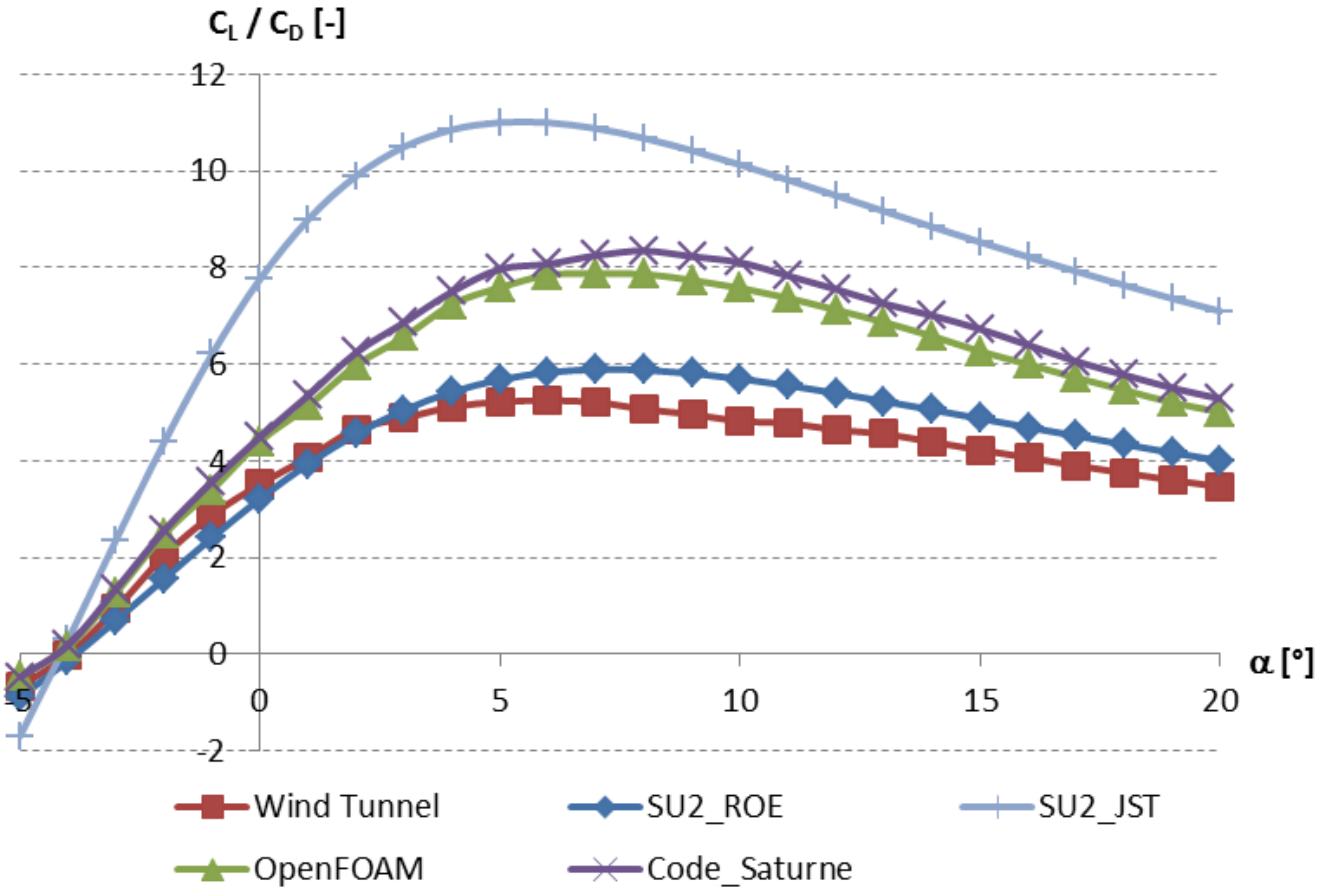

Figure 13. AVIGLE Tiltwing UAV - C_L/C_D vs. α

SAGITTA with and without Boundary Layer – Lift

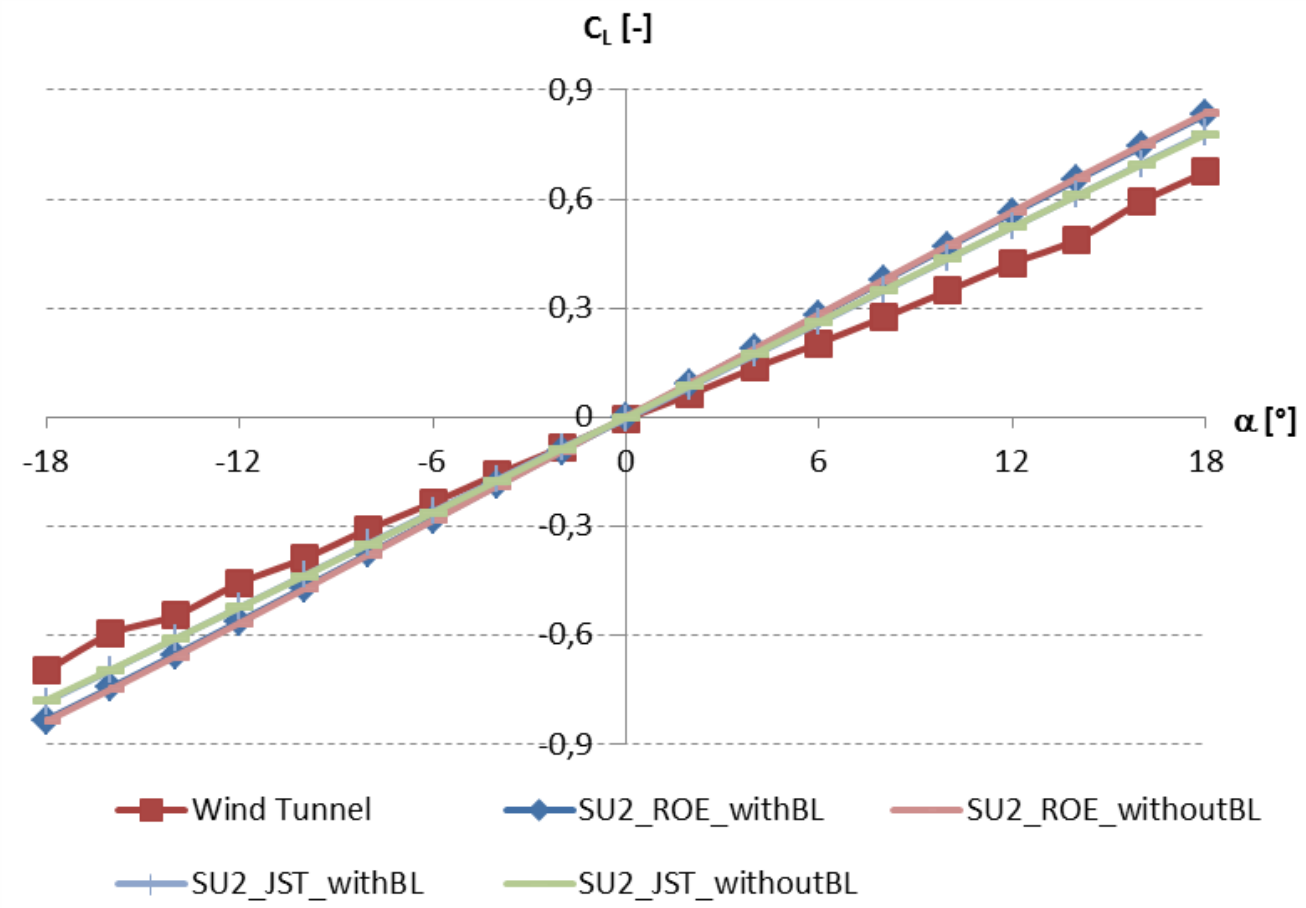

Figure 14. SAGITTA Demonstrator with and without Boundary Layer - C_L vs. α

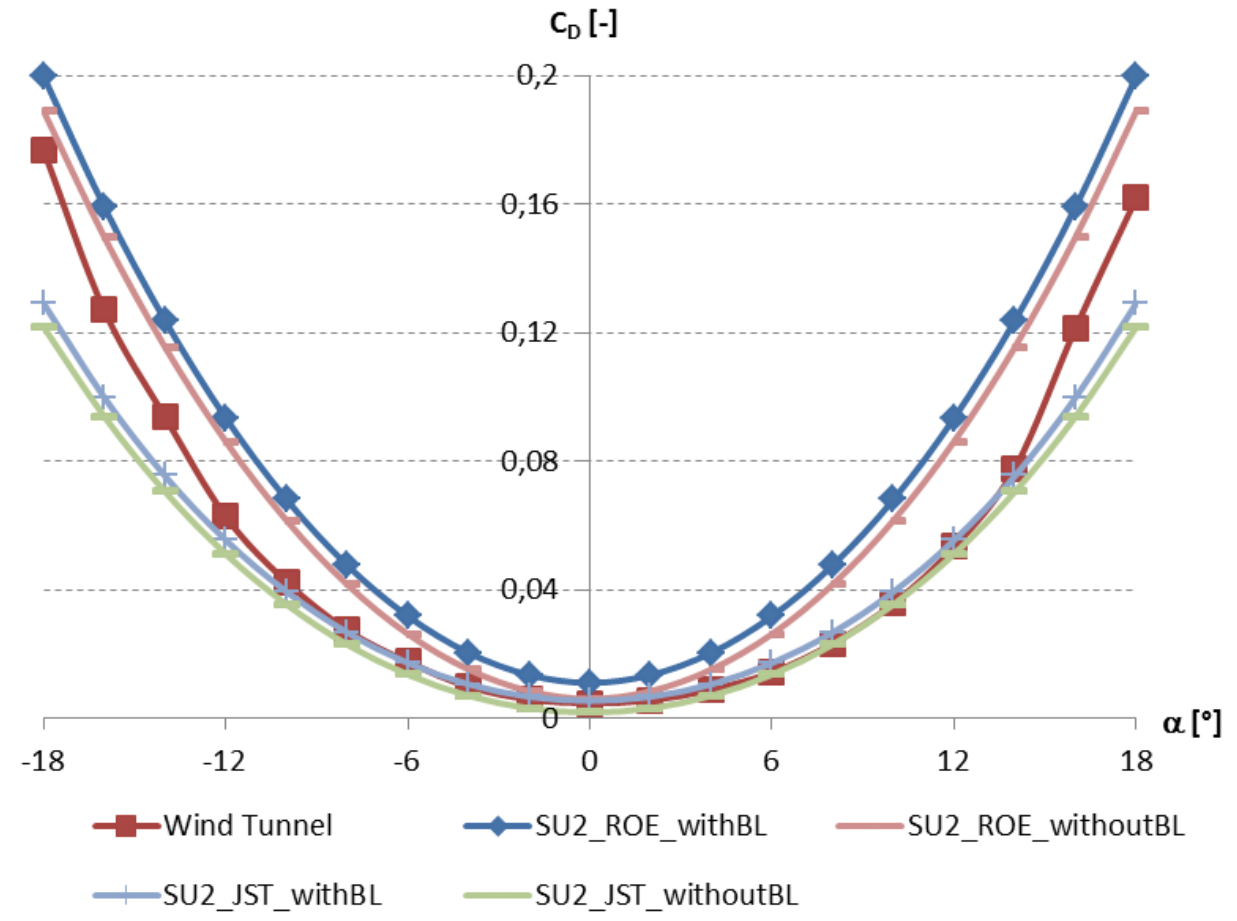

Figure 15. SAGITTA Demonstrator with and without Boundary Layer - C_D vs. α

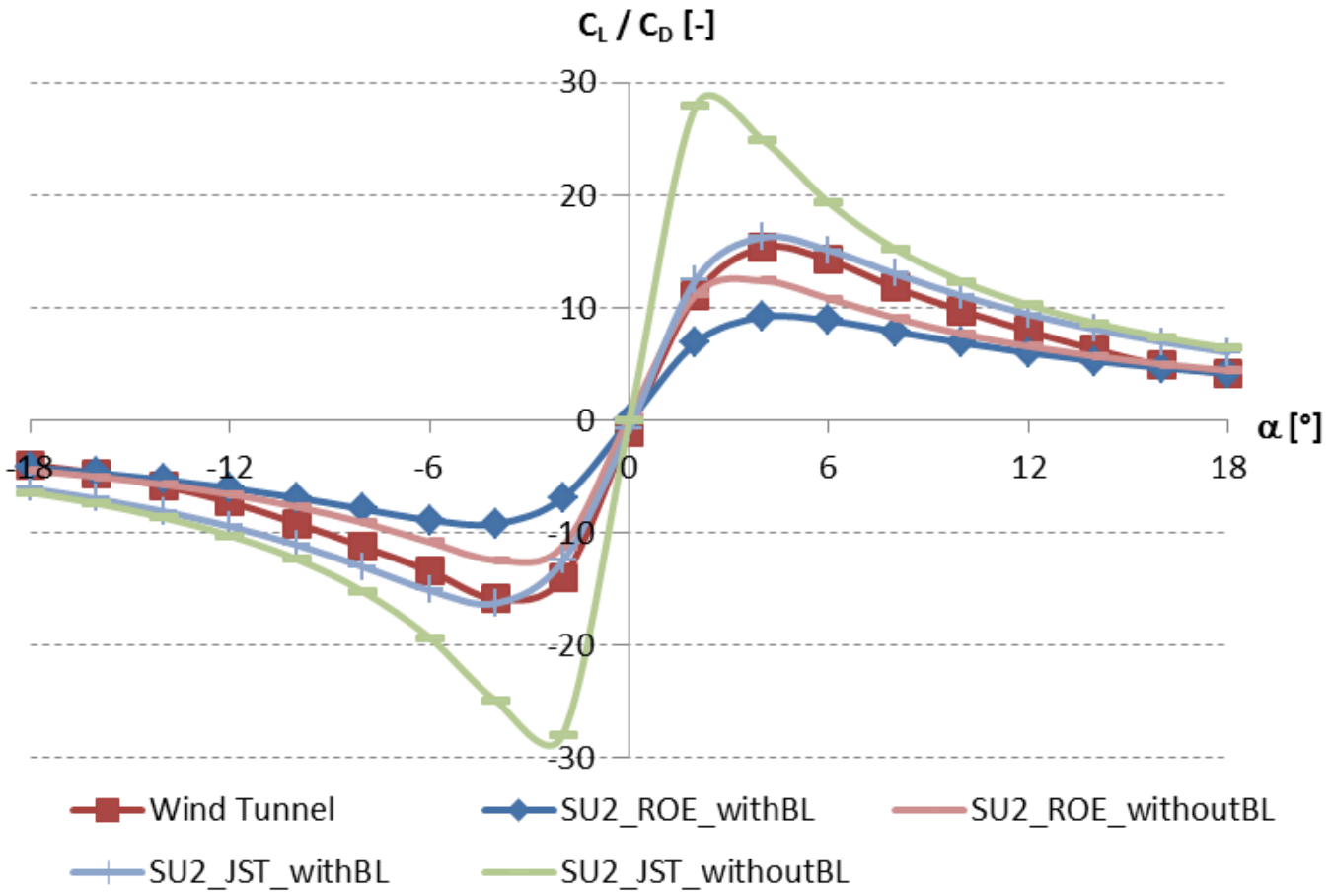

Figure 16. SAGITTA Demonstrator with and without Boundary Layer - C_L/C_D vs. α

- CFD results depend on:
  - Software/Developers
  - Mesh quality of UAV model
  - Modeler
- Wind-tunnel results depend on:
  - Wind tunnel
  - Measuring instruments
  - Manufacturing quality of UAV model
  - Human factor

- Open-source CFD software with an appropriate setting and mesh may accurately compute lift and drag coefficients.
- Time vs. Money & Repeatability
- Similar results from OpenFOAM and Code_Saturne
- SU^2
  - JST – symmetrical UAVs (or wings) with higher Reynolds number ($1.7e^6$)
  - ROE – asymmetrical UAVs with lower Reynolds number ($2.82e^5$)

- Free software
- 2 mini-UAVs analyzed in 3 CFD applications
  - SU^2
    - ROE (Roe's Approximate Riemann Solver)
    - JST (Jameson-Schmidt-Turkel)
  - OpenFOAM
  - Code_Saturne
- Results
  - SAGITTA with and without Boundary Layer
  - AVIGLE without Boundary Layer

- 3D-printed models -> wind-tunnel tests
- Printed model ≈ computer model
- => more precise and objective CFD evaluation
- Results
  - PyFR
  - HiFiLES

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Thank you for your attention

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Do you have any question?

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