TEAM 031

Smart Active Winglet

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Background

Winglets reduce drag and save fuel, but traditional designs are fixed and cannot adapt to changing airflow. Adaptive winglets can improve efficiency, yet current systems rely on expensive actuators and complex controllers.
Our project offers a low-cost, sensor-driven adaptive winglet using TinyML and embedded control to optimize performance in real time.

Problem Statement

A fixed winglet cannot maintain optimal aerodynamic efficiency across all airspeeds. We need a compact, lightweight, real-time adaptive mechanism that senses airflow, predicts the optimal cant angle, and actuates the winglet with high precision.

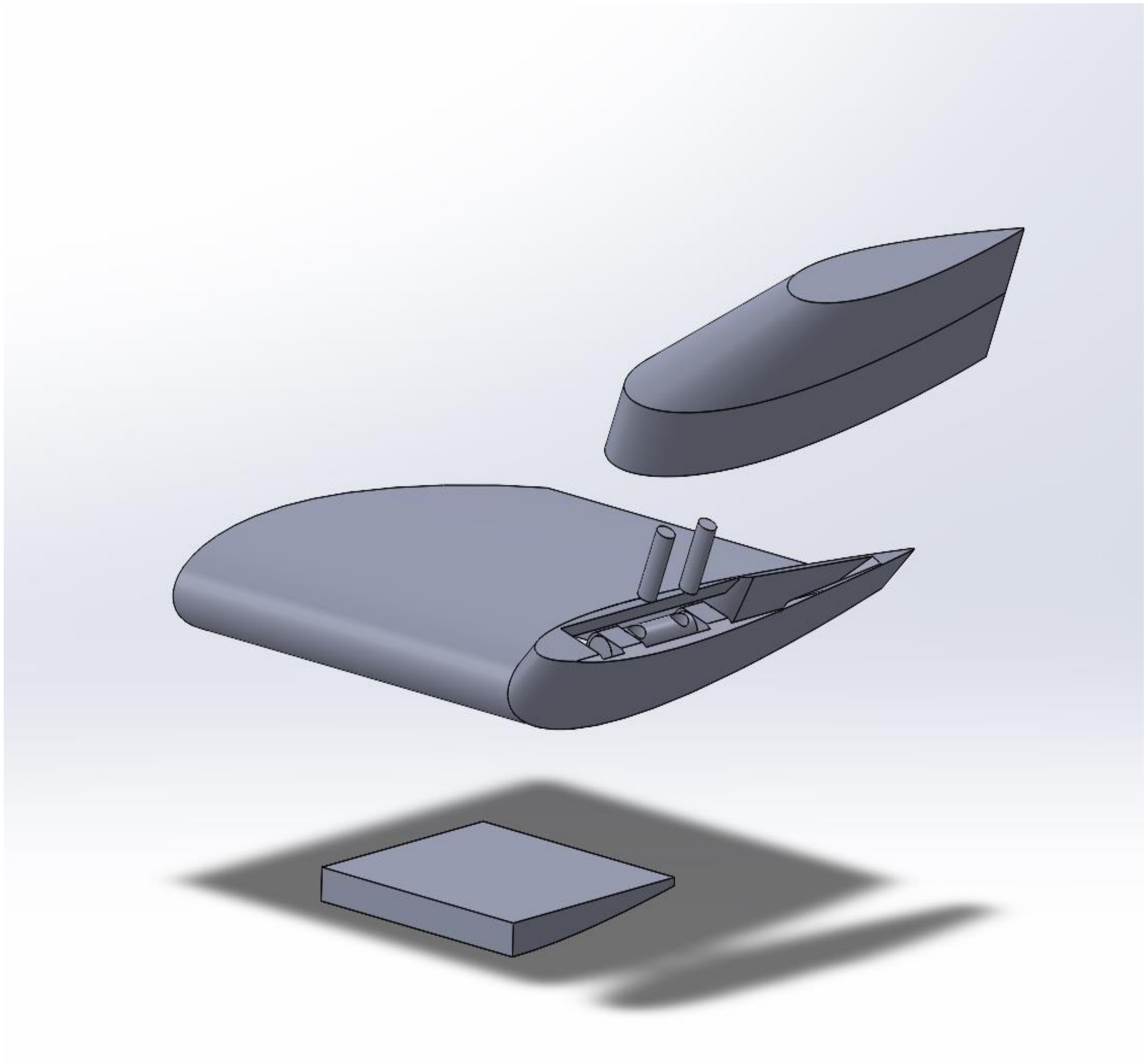
Our goal:

Reduce drag and improve aerodynamic efficiency by automatically adjusting winglet cant angle based on airspeed.

Prototype

-15 Degrees

+15 Degrees



Constraints

- Cant angle must stay within ±15°
- Validate aerodynamic performance at 20–50 m/s.
- Microcontroller power must stay below 500 mW
- Actuator must provide at least 1.5 kg·cm torque
- Total winglet system weight must be under 500 g.

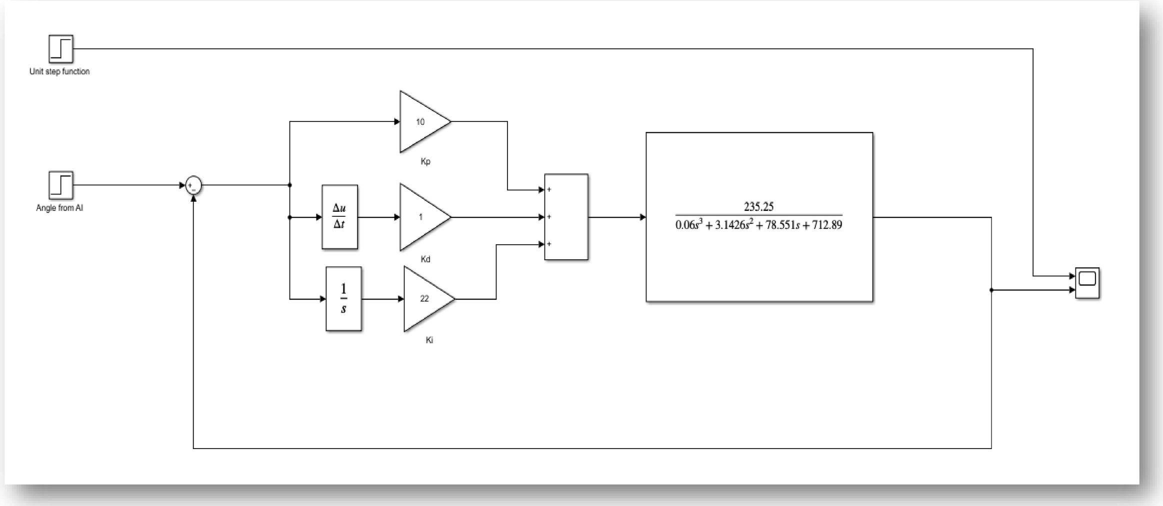
Specifications

- Flight-state prediction accuracy ≥ 90%
- Total system power ≤ 3 W (sensors + controller + servo)
- Drag reduction during cruise ≥ 2%
- The winglet shall have dimensions of ≤60 × 20 × 10 cm
- The AI model shall have a maximum size of ≤ 50 KB

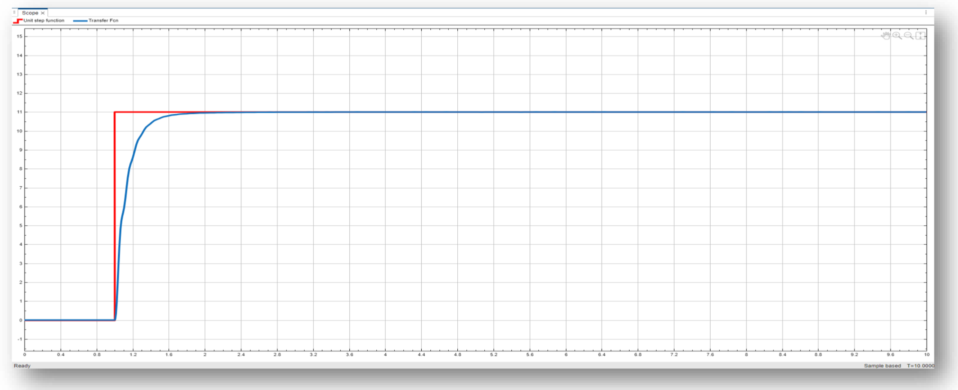
Conclusion

The smart winglet reliably adjusted its angle in real time, improving aerodynamic performance using TinyML.

Testing & Validations



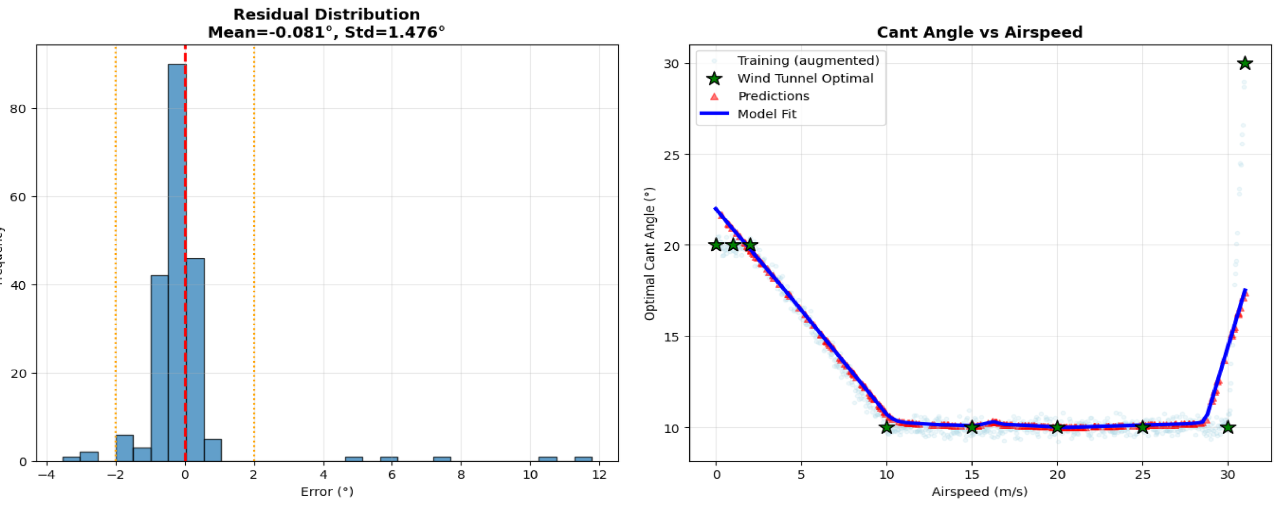
PID feedback loop in MATLAB/Simulink



PID Performance:
Kp = 10,Kd = 1, Ki = 22

$$H(s) = \frac{235.25}{0.06s^3 + 3.1467s^2 + 78.551s + 712.89}$$

Transfer Function for PID Control



Dynamic Pressure Equation

$$q = \frac{1}{2}\rho V^2$$