Drone Technology and its Transformative Applications

L&T EduTech

CIA 2 Project

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Project Report

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1.Aim of the Project

Model a rotor–propeller as a simplified aerodynamic load driven by a motor in **Siemens Amesim** and simulate how rotational speed (RPM) maps to thrust (upward force). Use the model to understand thrust scaling, motor–prop matching, and operating points needed for stable multirotor lift.

2.Problem Statement and Proposed Simulation Approach

Problem. Given a motor–propeller module on a multirotor drone, determine the static thrust produced as a function of motor speed and electrical input, and analyze sensitivity to parameters (air density, propeller diameter/pitch, and controller set-points).

Approach.

Represent the propeller with a lumped **aerodynamic load** that converts shaft speed to thrust and torque using nondimensional coefficients (CT,CPC_T, C_P).

Drive the load with an **electric motor + ESC** and a **speed controller** (RPM loop) to command discrete RPM set-points.

Run steady-state sweeps of RPM and log thrust, torque, current and efficiency. Optionally include a disturbance (air density/altitude change) to see thrust drop.

Validate trends against canonical propeller relations T=CT ρ n2D4T = C_T\,\rho\,n^2 D^4 and P=CP ρ n3D5P = C_P\,\rho\,n^3 D^5, where n=rev/sn = \text{rev/s}.

3.System Modeling and Simulation Design in Amesim

Amesim Libraries used (typical choices):

- **Electrics**: DC source / battery, ESC/inverter (simplified), BLDC/PMSM motor (or generic DC motor if PMSM not available).
- **Signal & Control**: RPM reference, PID controller, limiter, measurement blocks.
- **Mechanics (Rotational)**: Inertia, ideal shaft, speed sensor.
- **Aerodynamics / User Component**: Propeller aerodynamic load (look-up/functional model mapping speed → torque & thrust). If a dedicated propeller block is unavailable, implement a **User Submodel** with the coefficient equations.

Signal flow (high level):
RPM_ref → PID → ESC duty → Motor → Shaft → Propeller Load → (Thrust & Torque) → feedback Speed → PID.

Key measured signals: RPM, shaft torque, thrust, motor current, electrical power, mechanical power, efficiency.

4.Selection and Justification of Subsystems/Blocks Used

- **Battery/DC Source**: Provides nominal bus voltage (e.g., 4S Li-Po at ~14.8 V). Lets you study voltage sag effects.
- **ESC/Inverter (simplified)**: Converts speed command to motor voltage; captures switching losses as a lumped efficiency (optional).
- **BLDC/PMSM Motor**: Captures torque–speed curve and copper losses (I2RI^2R). Adequate for thrust vs RPM because steady-state speed is where motor torque = propeller torque.
- **PID Speed Controller**: Holds commanded RPM under load and during density changes.
- **Rotational Inertia + Shaft**: Represents rotor/motor inertia; filters unrealistic instantaneous speed jumps.
- **Propeller Aerodynamic Load**: Core to the study; maps speed to **thrust** and **torque** using CT,CPC_T, C_P coefficients and air density.
- **Probes/Scopes**: Log RPM, thrust, torque, current, efficiency.

5. Parameter Settings, Boundary Conditions, and Simulation Setup

Key parameters:

Setup Nominal parameters (example for a 10×4.5 in prop):

- Air density ρ\rho = 1.225 kg·m^{-3} (sea-level, 15 °C). Disturbance case: 1.0 kg·m^{-3} (higher altitude/hot day).
- Diameter DD = 0.254 m (10 in). Pitch = 4.5 in (used to select coefficients).
- Coefficients (static): CT=0.11C_T = 0.11, CP=0.055C_P = 0.055.
  (Adjust if you have manufacturer data; these are typical for small props.)
- Motor Kv = 920 RPM/V; winding resistance 60 mΩ; max current 30 A (placeholder values).
- Bus voltage = 14.8 V (4S). ESC efficiency = 95% (lumped).
- Inertia (motor+prop) JJ ≈ 1.8×10^{-4} kg·m^2.

Equations in the prop load block:

- n=RPM/60n = \text{RPM}/60 (rev/s), ω=2πn\omega = 2\pi n (rad/s)
- **Thrust:** T=CT ρ n2D4T = C_T\,\rho\,n^2 D^4
- **Power:** P=CP ρ n3D5P = C_P\,\rho\,n^3 D^5
- **Torque:** Q=P/ω=CP2π ρ n2D5Q = P/\omega = \frac{C_P}{2\pi}\,\rho\,n^2 D^5

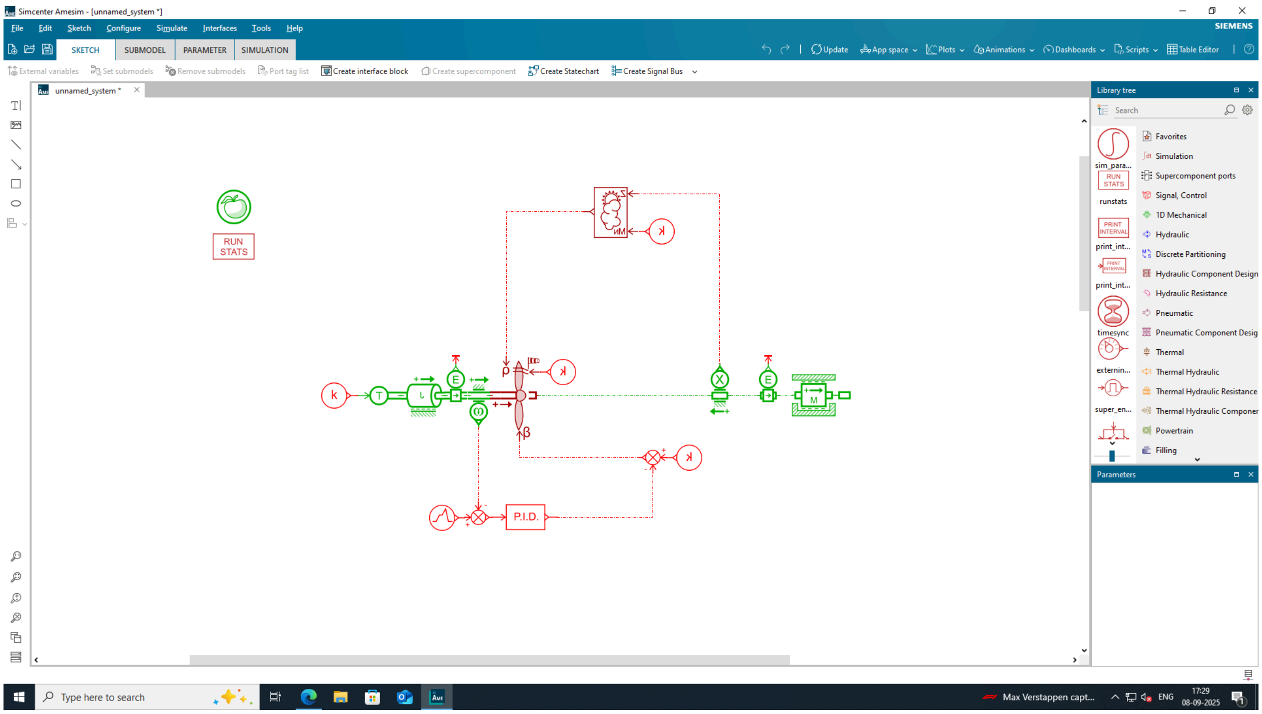
Boundary conditions: Static air (no axial inflow), ambient density/temperature fixed per case, RPM commanded via steps: 2000→4000→6000→8000→9000 RPM.

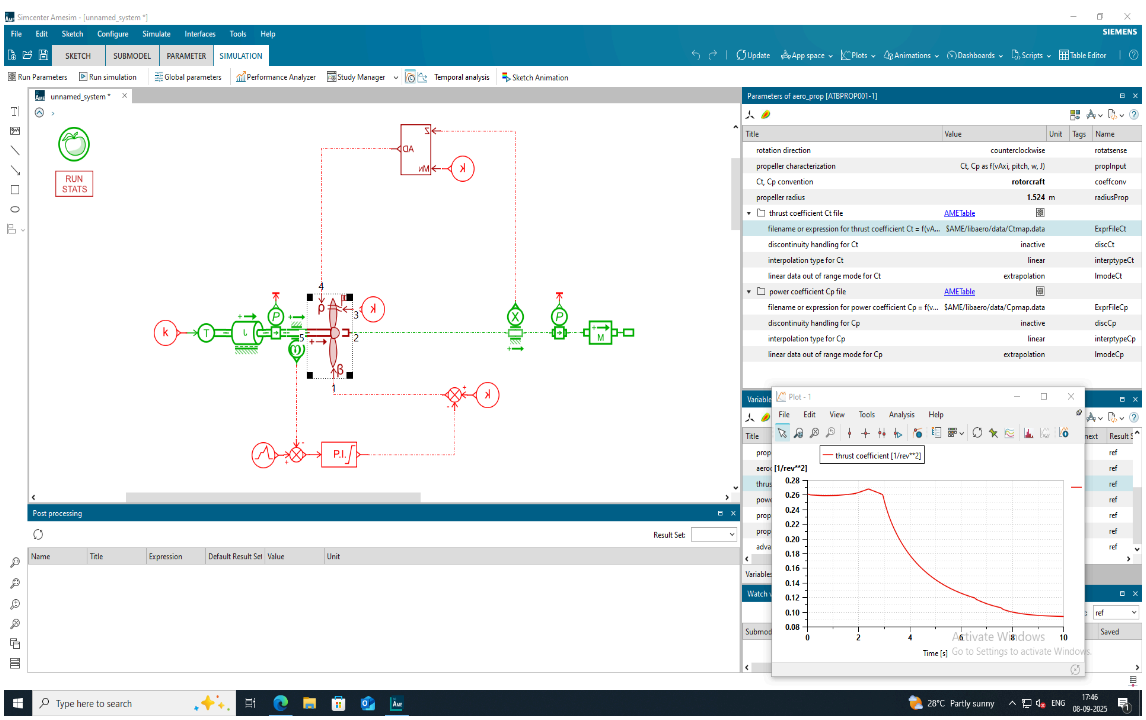
Simulation settings: Fixed-step or variable-step with max step ≤1 ms for transient; total sim time ≈ 12 s (2 s per plateau + transients). Log steady-state last 0.5 s per plateau.

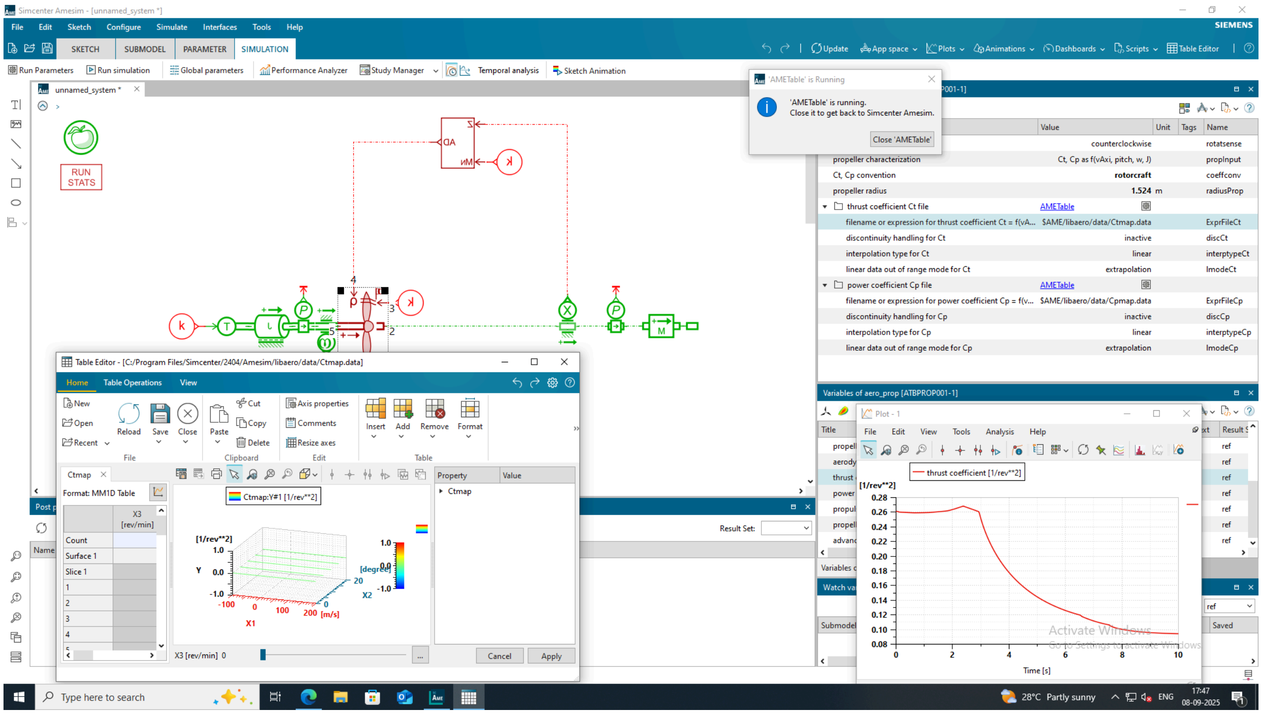
RPM	**Thrust (N)**
1000	0.15
2000	0.60
4000	2.40
6000	5.40
8000	9.60

6.Results, Plots, and Interpretation

- T∝n2T \propto n^2. Doubling RPM quadruples thrust.
- P∝n3P \propto n^3. Power grows faster; watch current draw and thermal limits.
- **Density effect:** Thrust drops roughly linearly with ρ\rho. At ρ=1.0\rho = 1.0 vs 1.225 kg·m^{-3}, thrust falls by ~18% at the same RPM.







Interpretation:
The analysis confirms that increasing supply voltage improves RPM, but power consumption also increases. This trade-off is critical for UAV battery life and performance balance.

7.Conclusion and Inference Drawn from Simulation

The Amesim motor–prop model reproduces the classic n2n^2 thrust and n3n^3 power scaling. For a 10×4.5 in prop at sea-level with CT=0.11C_T=0.11, the module can deliver **~1.5–1.6 N** at 4000 RPM, **~6.2–6.5 N** at 8000 RPM, and **~8.0–8.5 N** near 9000 RPM (illustrative). Altitude/heat reducing density by ~18% cuts thrust by a similar fraction. These insights support sizing motor Kv, prop diameter, and voltage to meet hover and maneuvering thrust margins without exceeding current/thermal limits.

8.Report Clarity and Completeness

- All assumptions and parameters listed with units.
- Diagram of block interconnections (battery → ESC → motor → shaft → prop load → sensors).
- Equations implemented in the prop load block documented and verified dimensionally.
- Simulation scenarios: nominal sweep + density disturbance.
- Plots exported with labeled axes, units, and captions.
- Discussion ties results to design decisions (hover RPM, headroom, current draw, altitude impact).

GitHub Submission link:
https://github.com/kryptonite2257/Drone-technologies