ME 410 – Week 6
Christopher Luey

(a) Text Description

Milestone 1 – Yaw P Control *(Completed Week 5)*
Disabled pitch and roll. Mapped left joystick to desired yaw rate; applied proportional control (Yaw_gain = 2, Yaw_amplitude = 50).
Logs confirmed alignment between commanded and measured yaw rates.

Milestone 2 – Attitude PID for Ground-Effect Hover

Total Tuning Time: 25 h (5 sessions), ~500 flights.

Thrust Stabilization
Thrust held at PWM = 1450 with magnitude of 200 to get off ground and reduce ground affect (~0.5 m hover in ground effect) to isolate attitude control.

Pitch Angle Debugging
Initial pitch estimates were inaccurate (±5°). Diagnosed and resolved incorrect `atan2()` axis mapping — IMU X and Y accel inputs were swapped.
After correction, pitch error dropped to ±0.5°, enabling clean loop behavior. Graphs were produced and verified by Professor Rubenstein in order to validate sensor data.

Tuning Protocol

- **D-Gain Sweep:** Start at D=0.00, increase by 0.5 to oscillation ($D_0 \approx 0.70$). Binary search → D* = 3.5 (Pitch and Roll).
- **P-Gain Sweep:** Fix D*, increase P by 0.5 until oscillation ($P_0 \approx 13.5$); binary search → P* = 5 (Pitch and Roll).
- **D Rollback:** Step down in 0.02 increments until oscillations cease → D = 3.43 (Pitch), D = 3.24 (Roll).
- **P-Gain Fine-Tune:** Increment P by 0.05 until drone responsive → P = 5.2 (Pitch), P = 4.85 (Roll).
- **Yaw Tuning:** Increment Yaw Gain until spinning ceases → Y_gain = 0.8

Roll Tuning Notes
Roll loop exhibited more sensitivity than pitch — higher oscillation frequency and greater response to

overdamping.

Required finer derivative tuning and lower P-gain to suppress instability.

Combined-Axis Validation
10 s hover with both loops active: no cross-axis oscillation; logs showed <0.05 m attitude‑equivalent drift.

Final PID Gains

- **Pitch:** P = 5.2, D = 3.43
- **Roll:** P = 4.85, D = 3.24

Milestone 3 – Free Ground-Effect Flight
Status: Deadline Extended

(b) Task Assessment

Successes

- Fixed IMU axis bug—enabled precise pitch estimation.
- Minimal yaw drift without I-control.
- Achieved stable hover with both pitch and roll loops active (PD controller).

Challenges

- *Pitch Estimate Bug:* Incorrect IMU axis mapping in `atan2()` fixed on Day 2 firmware patch.
- *Ground Effect:* Nonlinear thrust behavior <0.3 m—resolved by holding PWM ≥1450 and magnitude = 200.
- *Roll Tuning:* Required more careful damping to avoid overshoot and instability.
- *Yaw Drift:* Required slight P-gain increase to fully eliminate residual rate.
- *Inconsistent Behavior:* Drone would behave completely differently even with exact same tuning parameters based on initial conditions, solving PD gains for robustness was a challenge
- *Center of Mass:* Position of battery and wires affected performance significantly. Tape required to position battery precisely.

- *Battery Charge:* Battery charge affects efficiency of motors affecting tuning process — another variable we had to juggle.

Planned Improvements

- Dedicated session for Milestone 3 free-hover flight.
- Incorporating integral gain for flight to reduce drift

(c) Team Member Effort

Both members were tuning together.

- **Jason (50%)**
  Performed ~25 hours of PD tuning
- **Christopher (50%)**
  Performed ~25 hours of PD tuning