AER 1216H - Fundamentals of UAS

Project Presentation

Group 10

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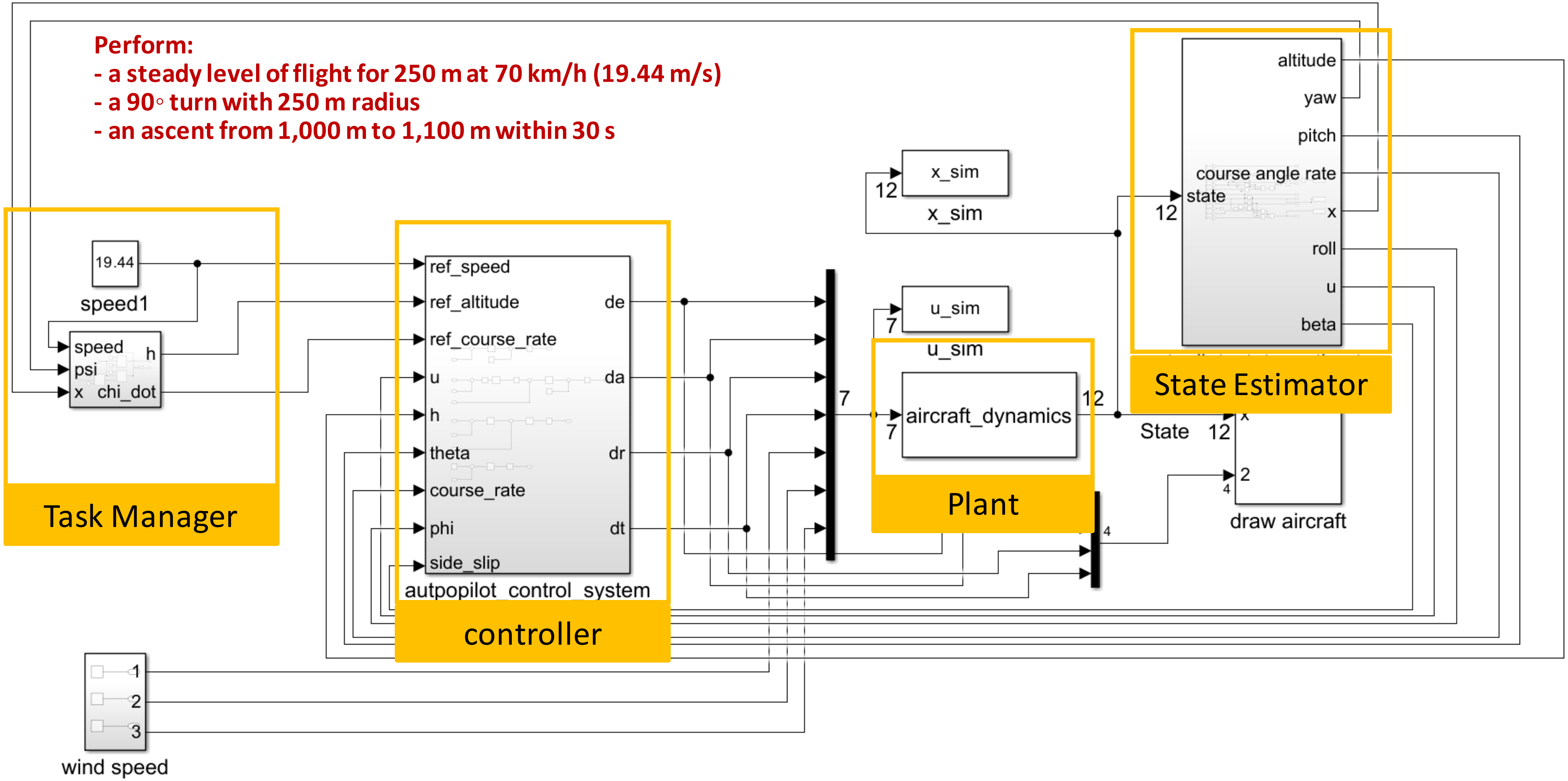
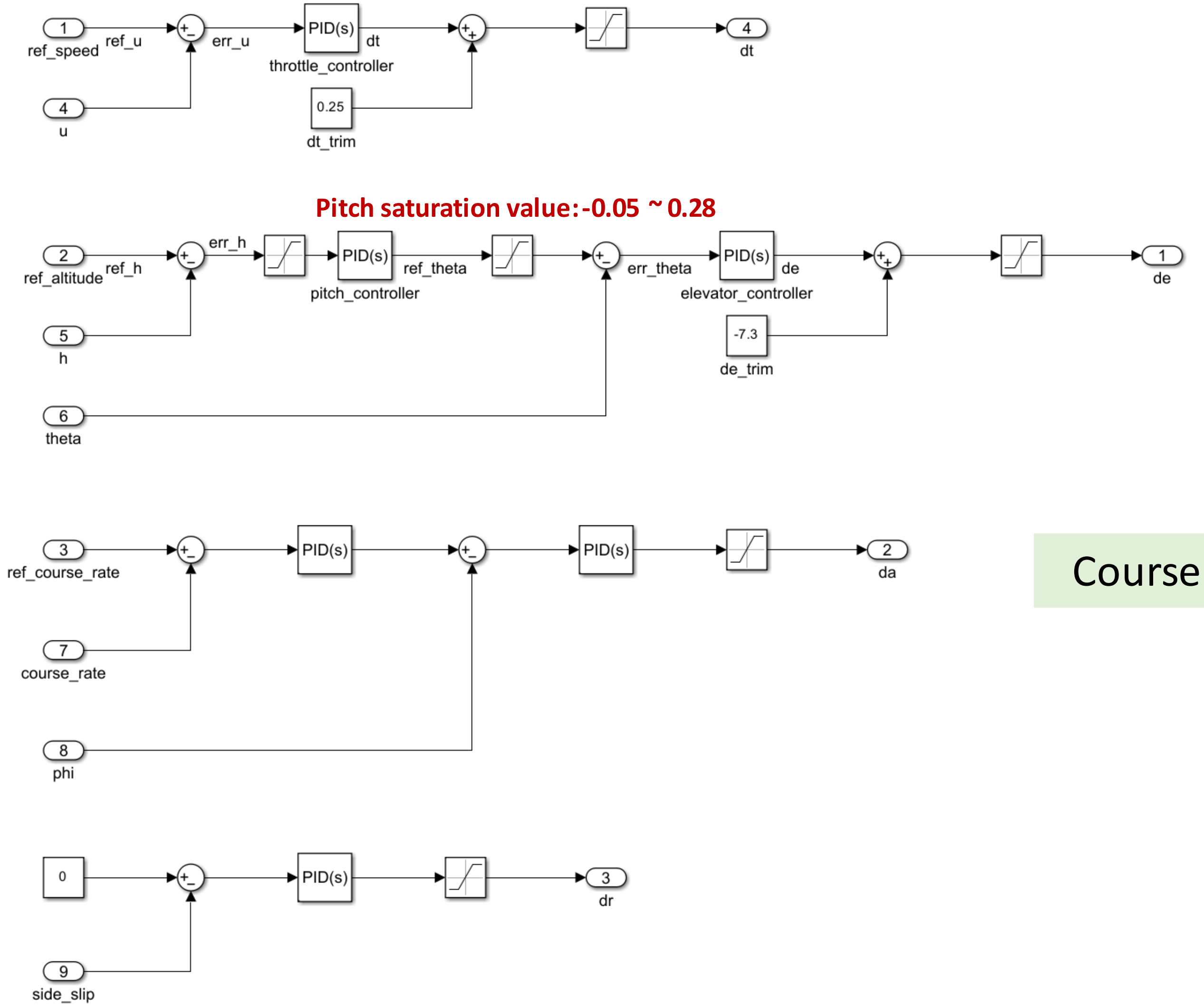
Fixed-Wing UAS Development – Full System

Perform:
- a steady level of flight for 250 m at 70 km/h (19.44 m/s)
- a 90◦ turn with 250 m radius
- an ascent from 1,000 m to 1,100 m within 30 s



Fixed-Wing UAS Development – Controller



Speed → Thrust

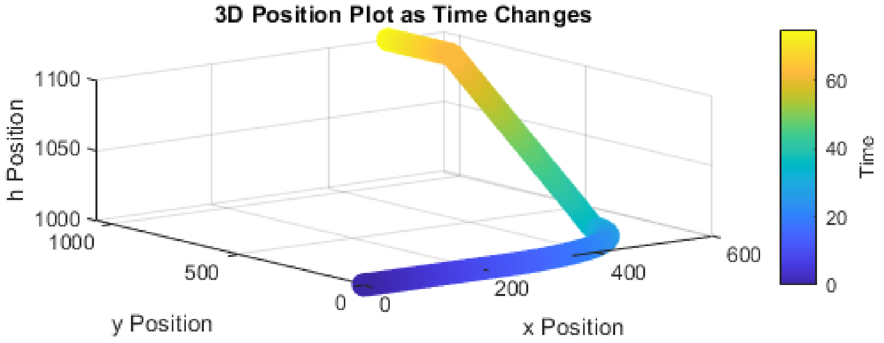
Altitude → Pitch → Elevator

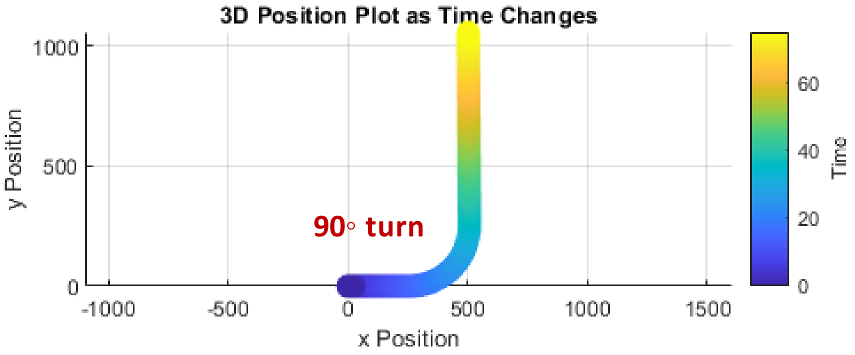
Course angle rate → Roll → Aileron

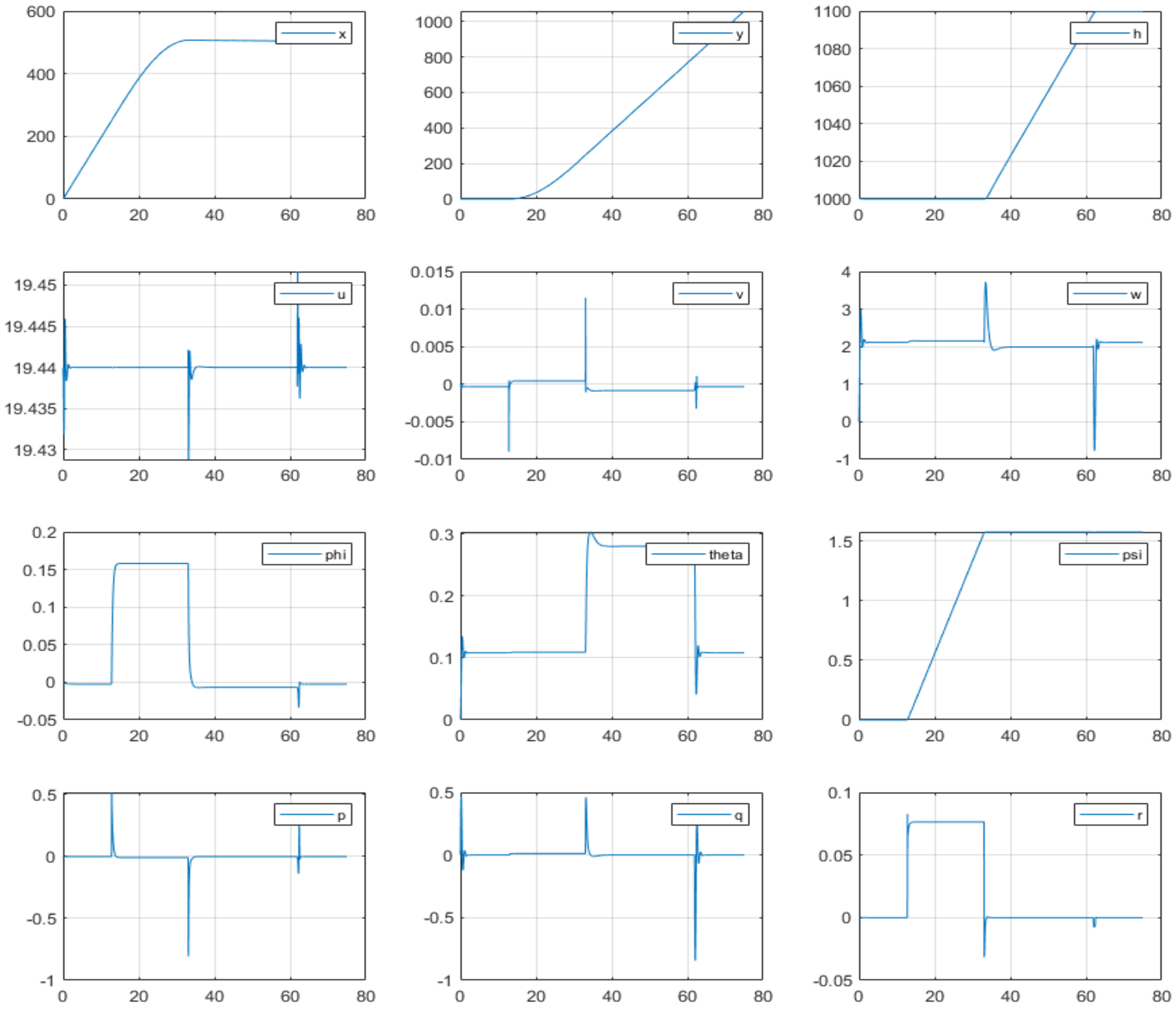
Sideslip angle → Rudder

Fixed-Wing UAS Development – Results

- Resulted an ascent from 1,000m to 1,100m within 29s – windless condition

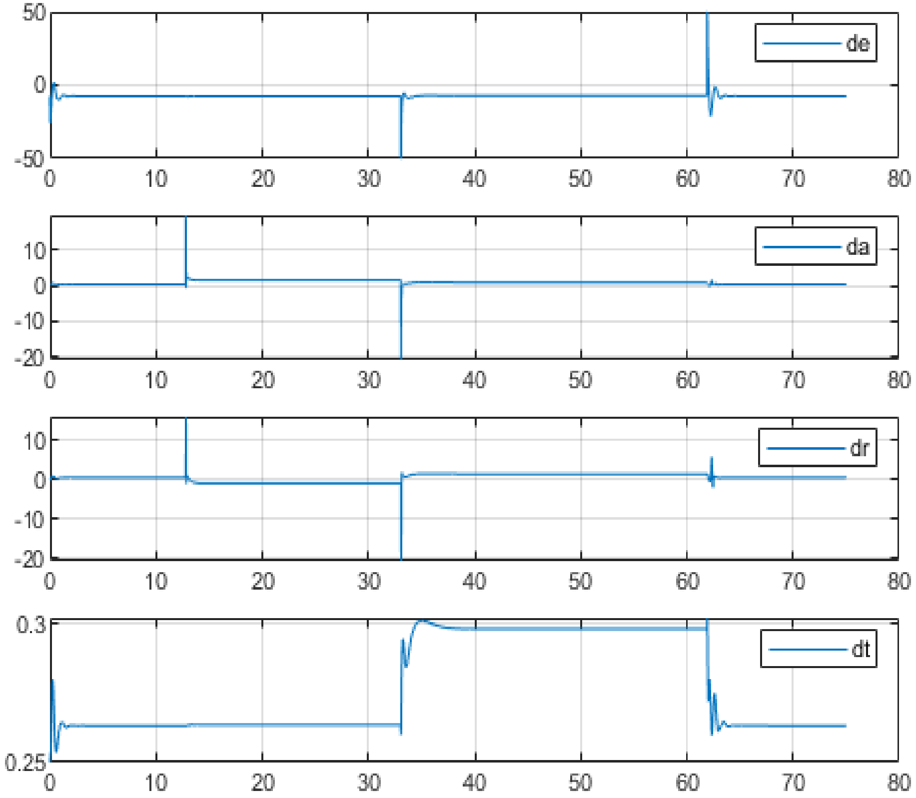




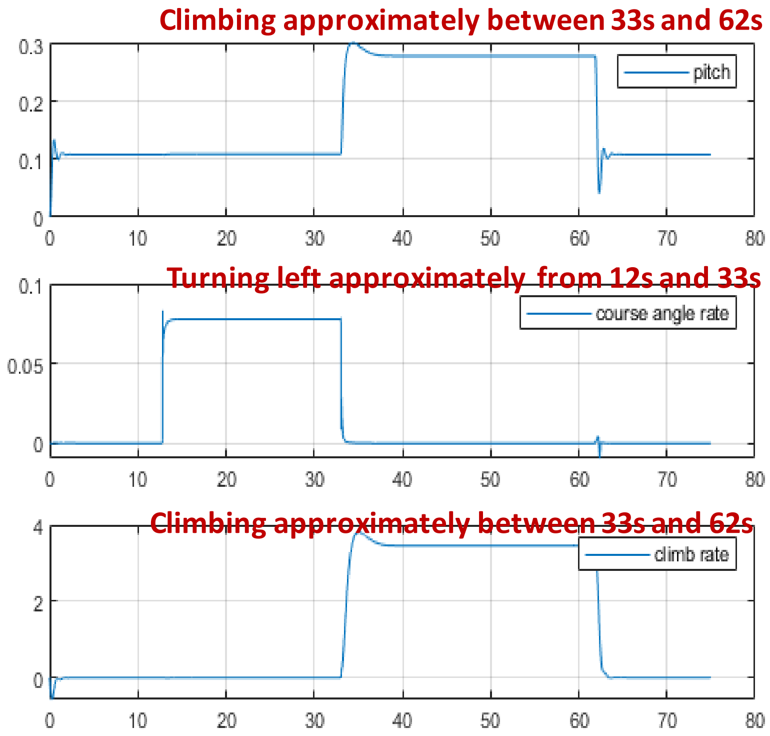


Fixed-Wing UAS Development – Results

- Showing the relationship of elevator, aileron, rudder, and normalized thrust based on the aircraft movement.



- de: elevator
  - Around 33s, the aircraft starts to climb.
  - Around 62s, the aircraft starts to lower to level.
- da: aileron
  - Around 12s, the aircraft adjusts to right.
  - Around 33s, the aircraft makes left turn.
- dr: rudder
  - Around 12s, the aircraft adjusts to right.
  - Around 33s, the aircraft makes left turn.
- dt: normalized thrust
  - Around 33s, the aircraft thrusts to climb.
  - Around 62s, the aircraft adjusts the thrust to level.

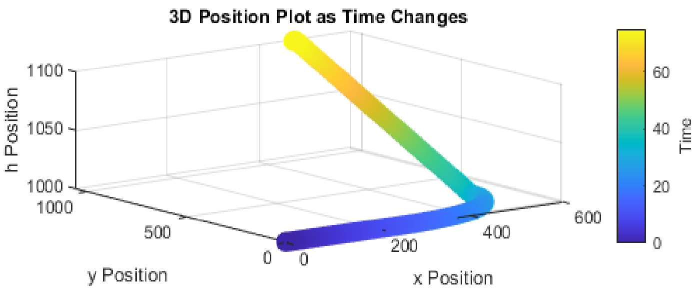


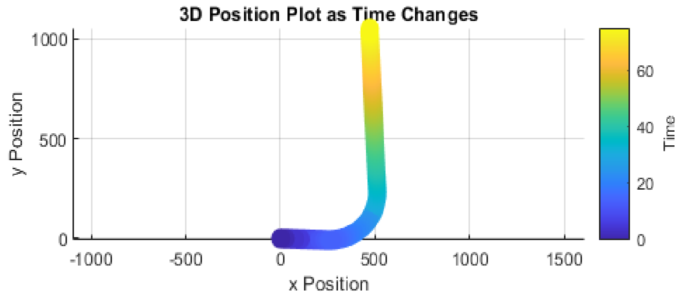
Fixed-Wing UAS Development – Results

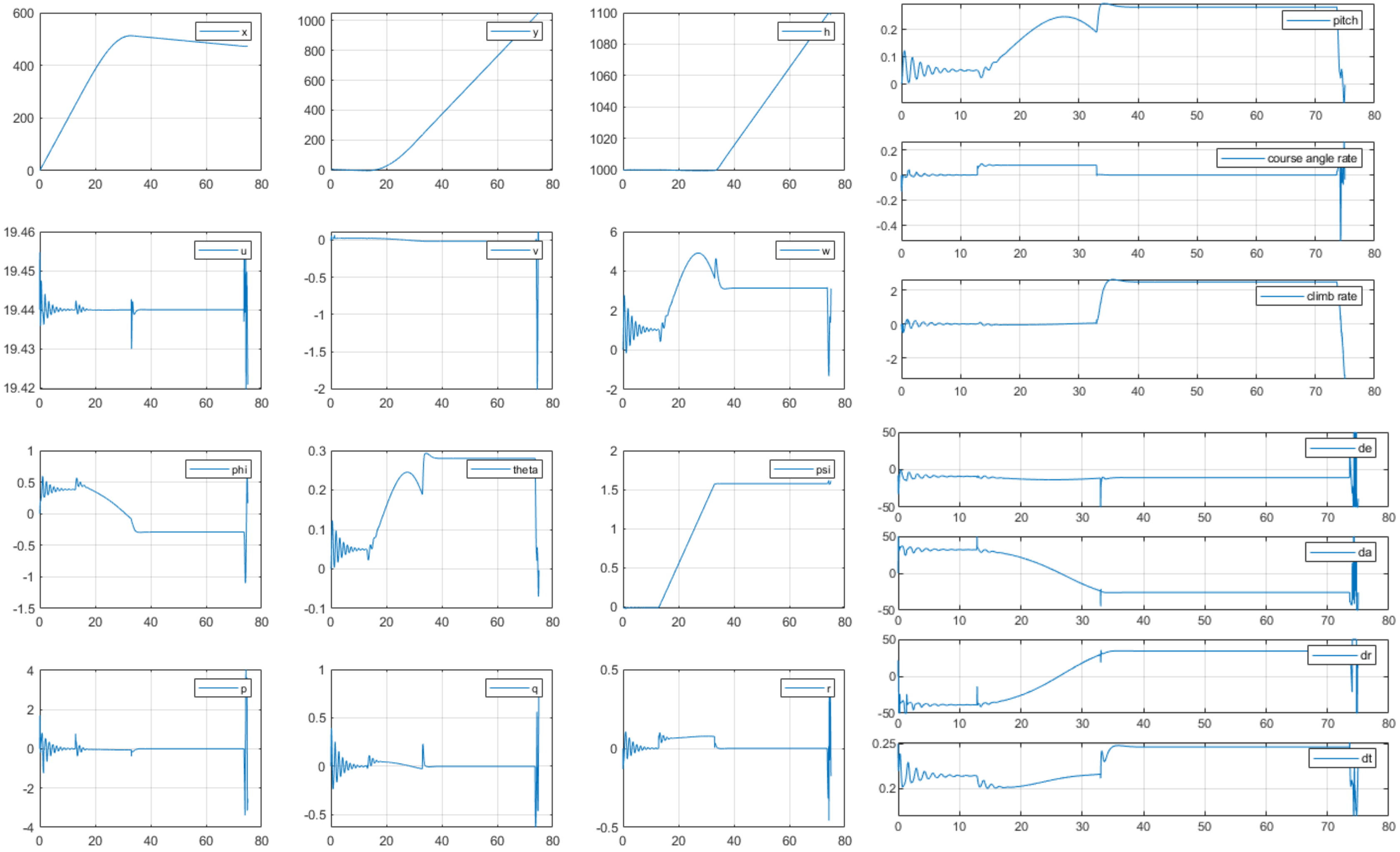
- Wind effect

Wind Direction	Speed (m/s)
u	2.80
v	4.10

The recommended maximum wind speed for safe operation in our design is considered to be 4.96 m/s (9.64 knot).







Fixed-Wing UAS Development – Range & Endurance

$$dt = \frac{1}{c_p}\frac{\eta}{P}dW$$

$$E = \frac{\eta}{c_p}\sqrt{2\rho S}\frac{(C_L)^{3/2}}{C_D}\left(\frac{1}{\sqrt{W_1}} - \frac{1}{\sqrt{W_0}}\right) = 55\ hr$$

$$R = \int_{W_0}^{W_1} V\,dt = \int_{W_0}^{W_1} \frac{\eta}{SPC}\frac{V}{P}dW = \int_{W_0}^{W_1} \frac{\eta}{SPC}\frac{1}{T}dW$$

$$R = \frac{\eta}{c_p}\frac{C_L}{C_D}\ln\left(\frac{W_0}{W_1}\right) = 3048\ \mathrm{km}$$

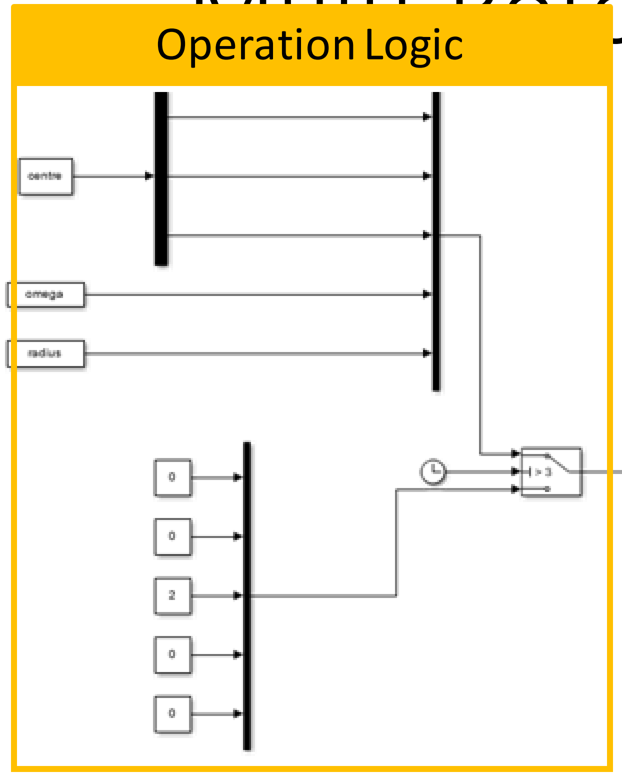
Fixed-Wing UAS Simulation vs Expectation

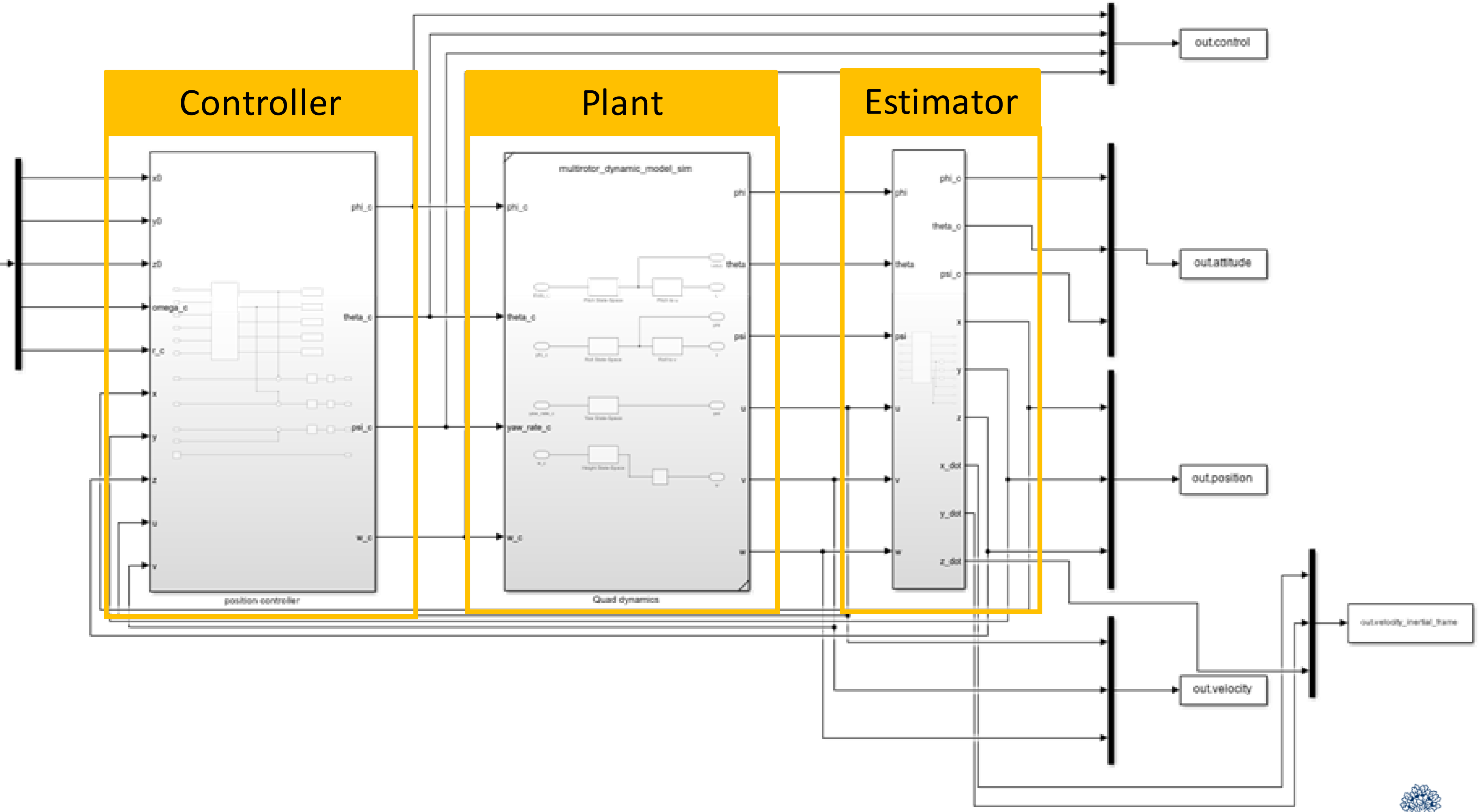
- Discrepancy in angle of attack likely due to nonzero elevator in maintaining pitch.
  - Elevator used in simulation for pitch, hard to capture in theoretical model

	Angle of Attack	**Yaw Rate**	**Climb Rate**
Calculation	0.08 rad	0.077 rad/s	3.94 m/s
Simulation	0.11 rad	0.08 rad/s	3.43 m/s

For requested operation at no wind condition.

Multi-Rotor UAS Development – Full System

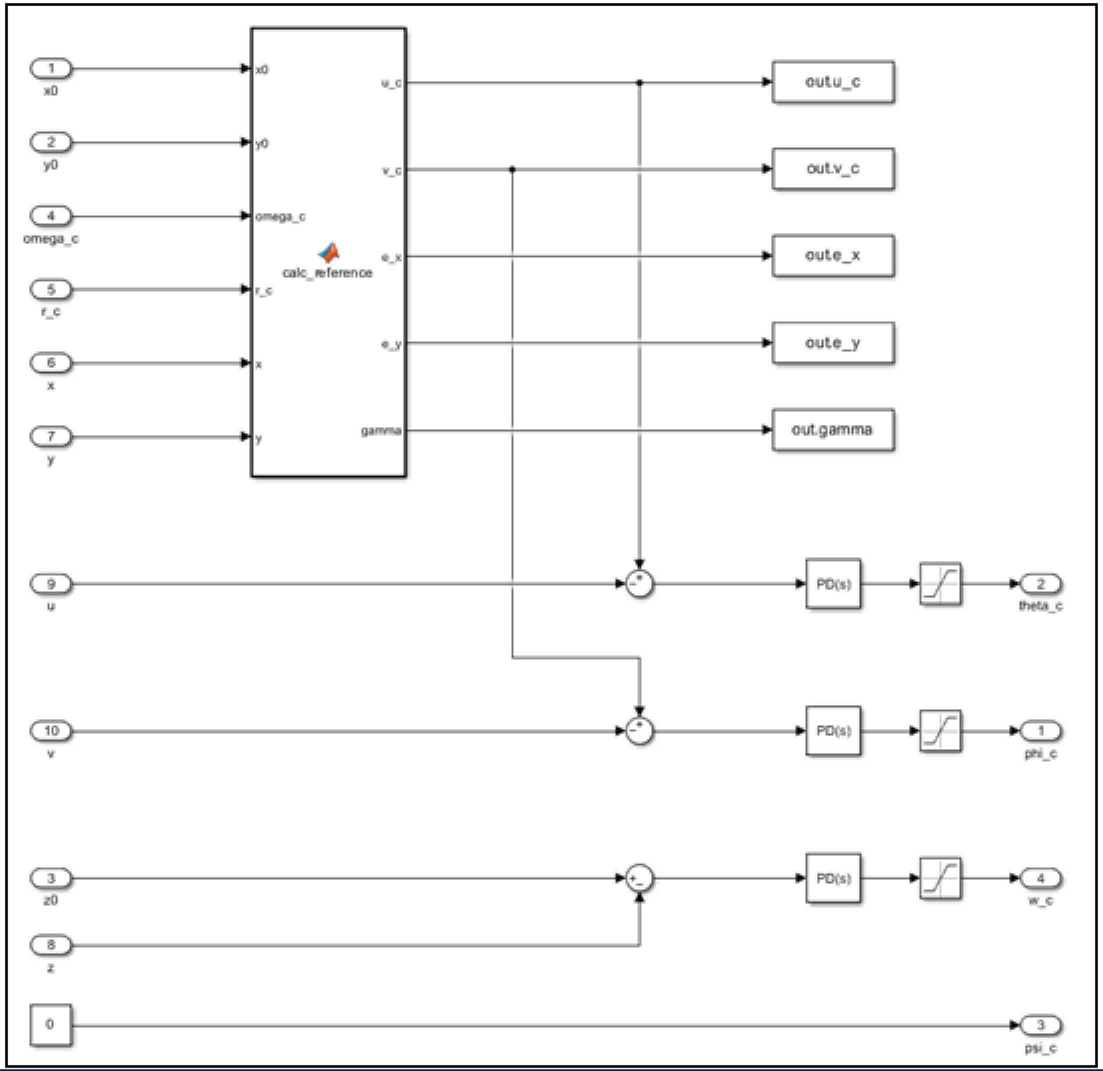


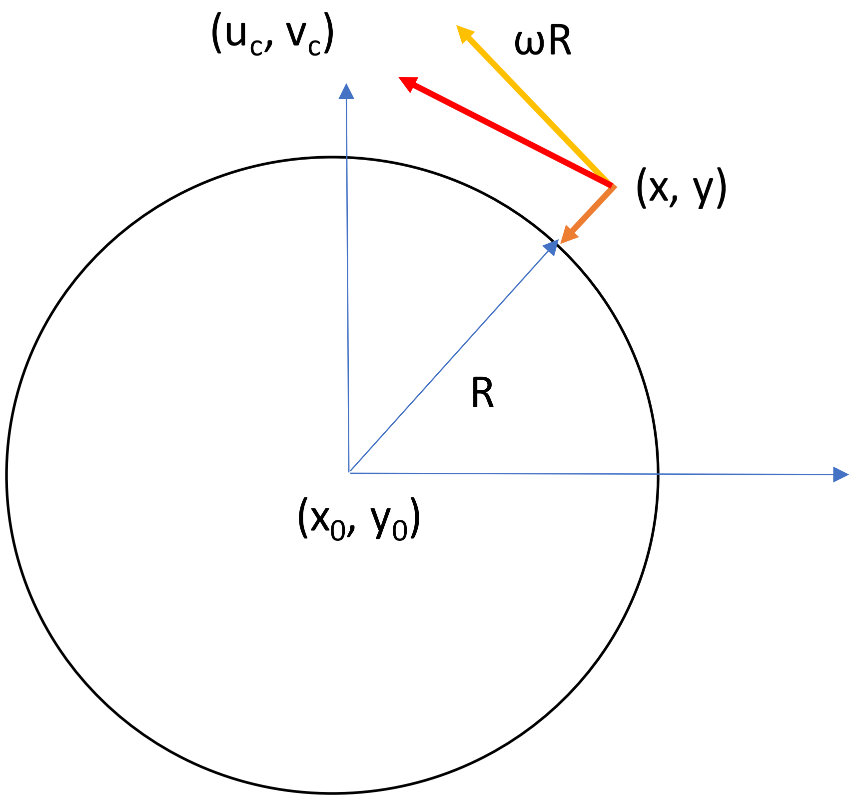


Perform take-off and hover at
2 m then horizontal circle orbiting at 1 m/s.

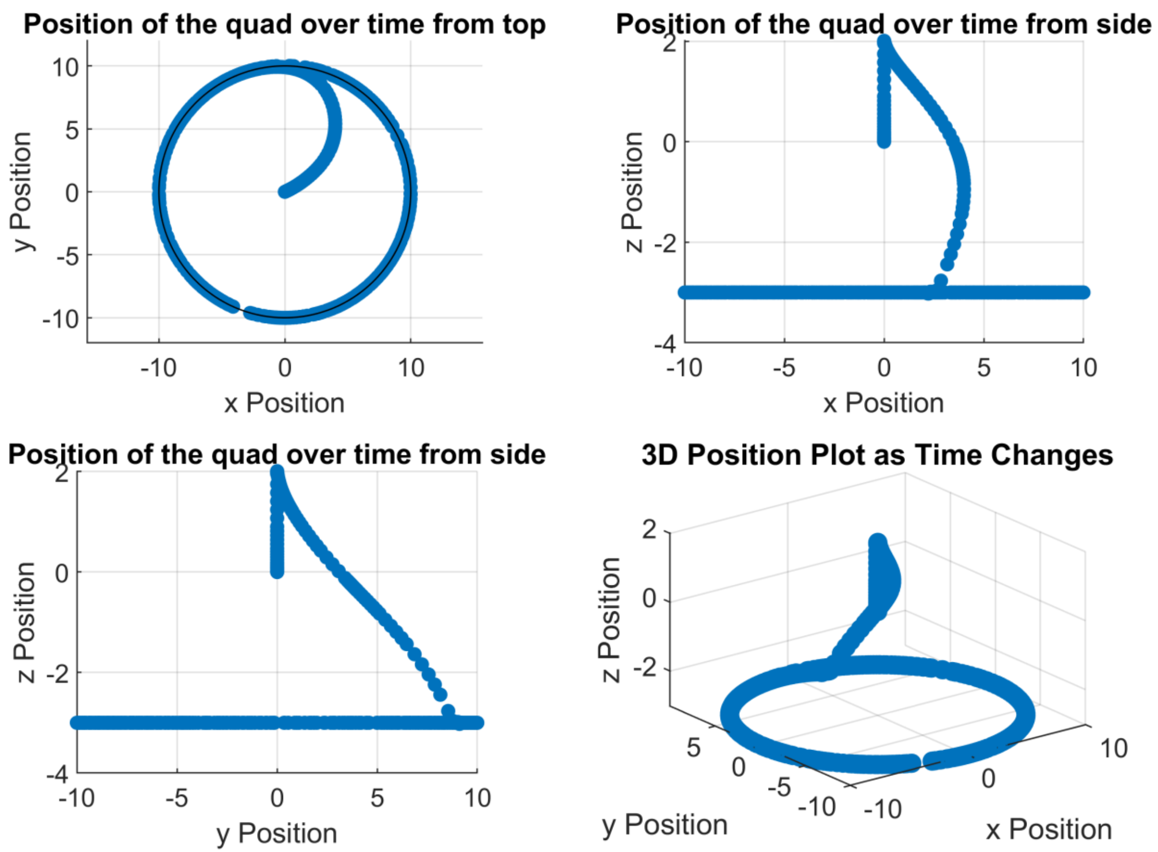
Multi-Rotor UAS Development – Control System

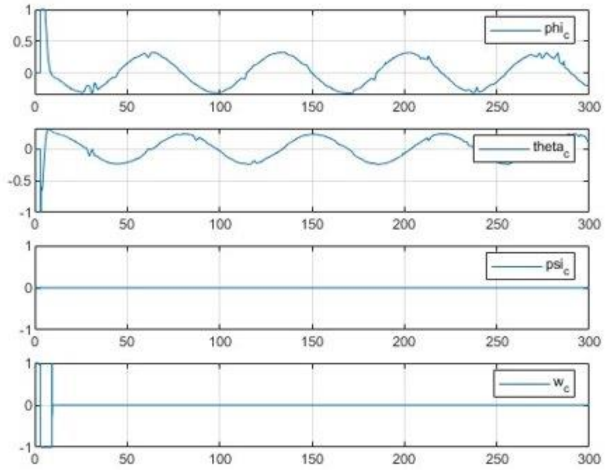
Position Controller

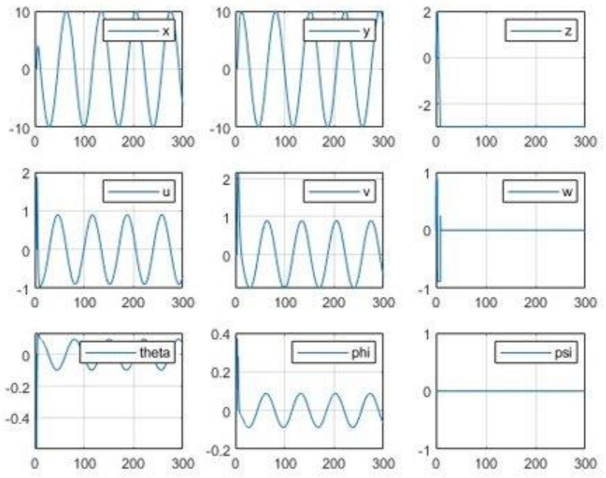




Multi-Rotor UAS Development – Results

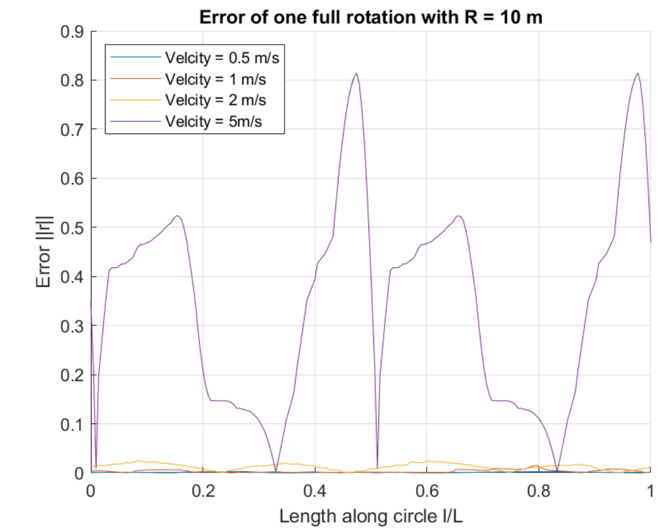


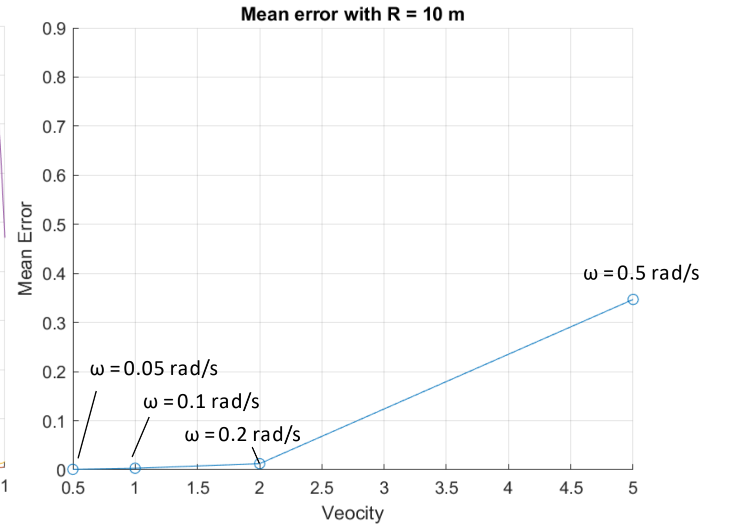


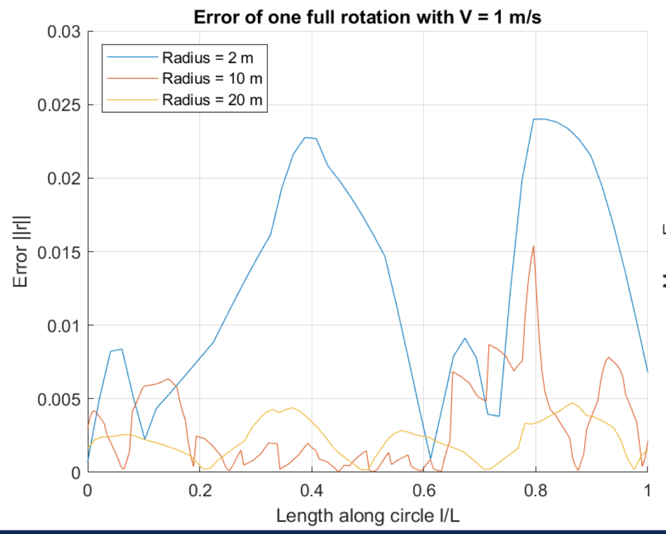


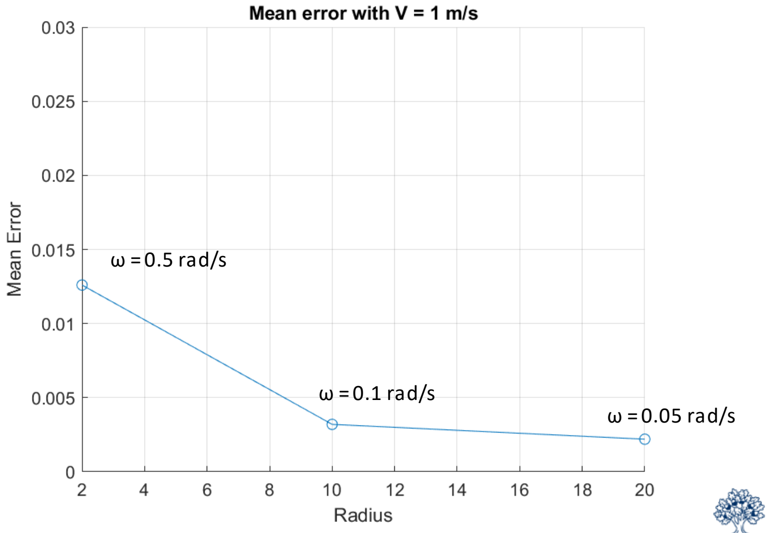
Multi-Rotor UAS Development – Results

- Increasing the velocity leads to increased error
- Increasing diameter reduces error
- Not directly a function of rotation speed







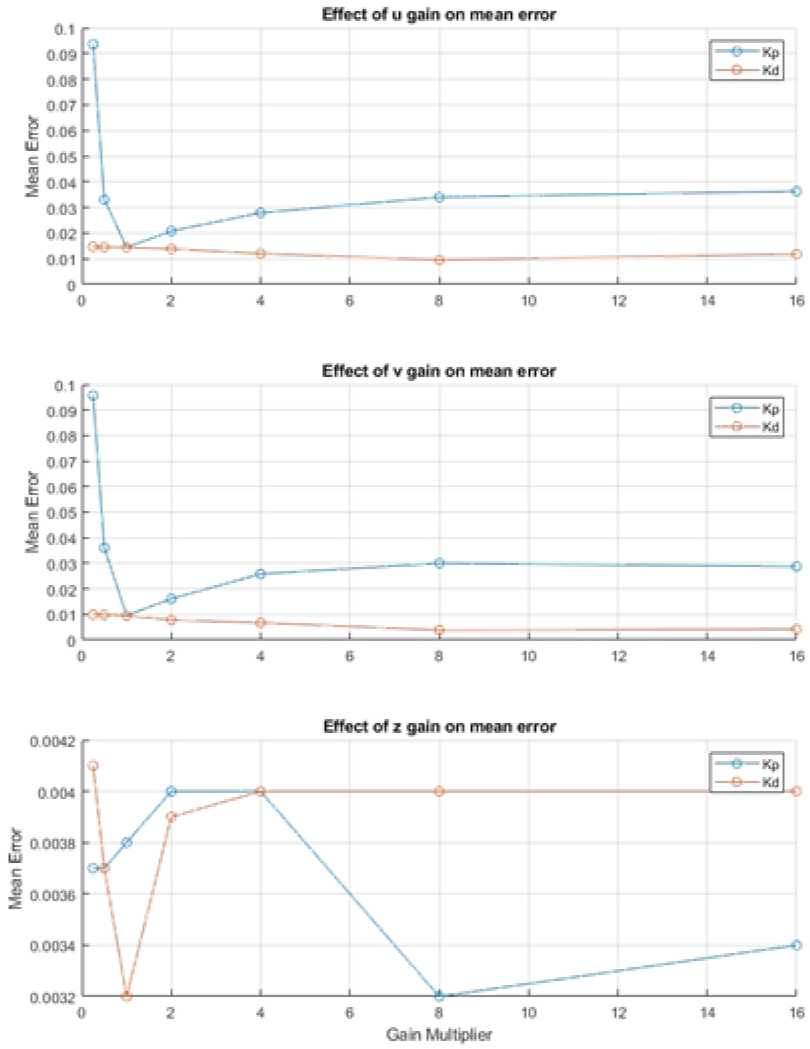


Multi-Rotor UAS Development – Results

- Began with gains from a stable model and multiplied them by factor of 2

- The gain for the x and y axis acts similarly

- K_p from z-gain acts similar to K_d from other two
    - All proportional to velocity

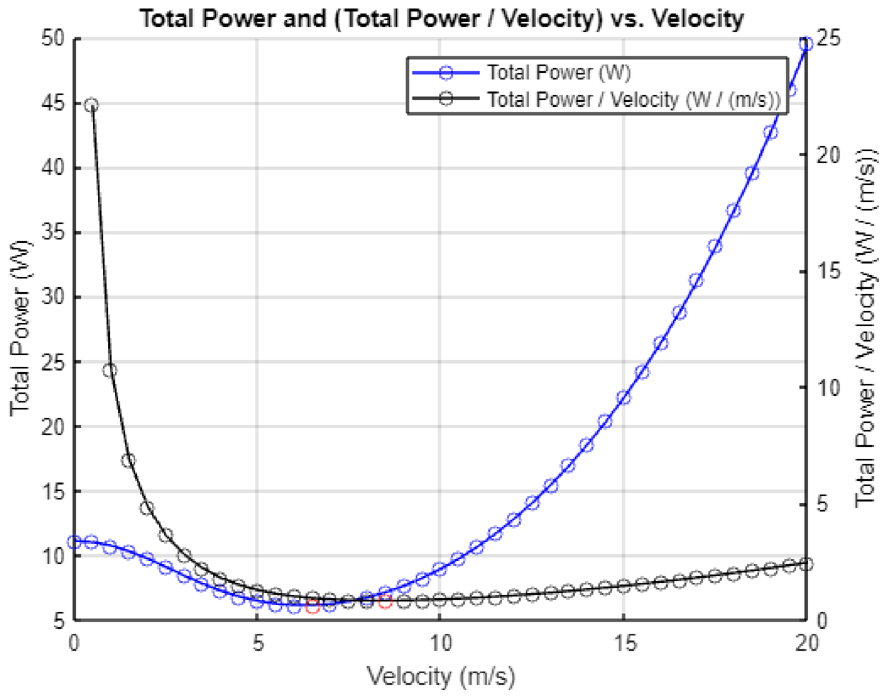


Multi-Rotor UAS Development – Range & Endurance

- The estimated maximum range is calculated to be **40 km** at **8.5 m/s**.

- The estimated maximum endurance is calculated to be **91 mins** at **6.5 m/s**.

- Forward flight momentum theory and 0^{th} order battery model were used with a velocity range of 0~20 m/s also having 70% efficient of motor and 80% efficient of ESC.



$$R = \frac{E_b \eta_m \eta_e}{(P_{tot})_{min}/v}$$

$$E = \frac{E_b \eta_m \eta_e}{(P_{tot})_{min}}$$

Conclusions / Lessons Learned

- Saturation can help with system with both large error and small error.
- Accuracy vs stability: for positional error, integral term can make system unstable when error is large.
- For the same operation, choosing controller input matters a lot (tracking position vs tracking velocity).

Thank you

Questions?