

# Taking the Simulation Onboard:

Power-in-the-loop Simulation of HIL Multi-Rod in UAVs

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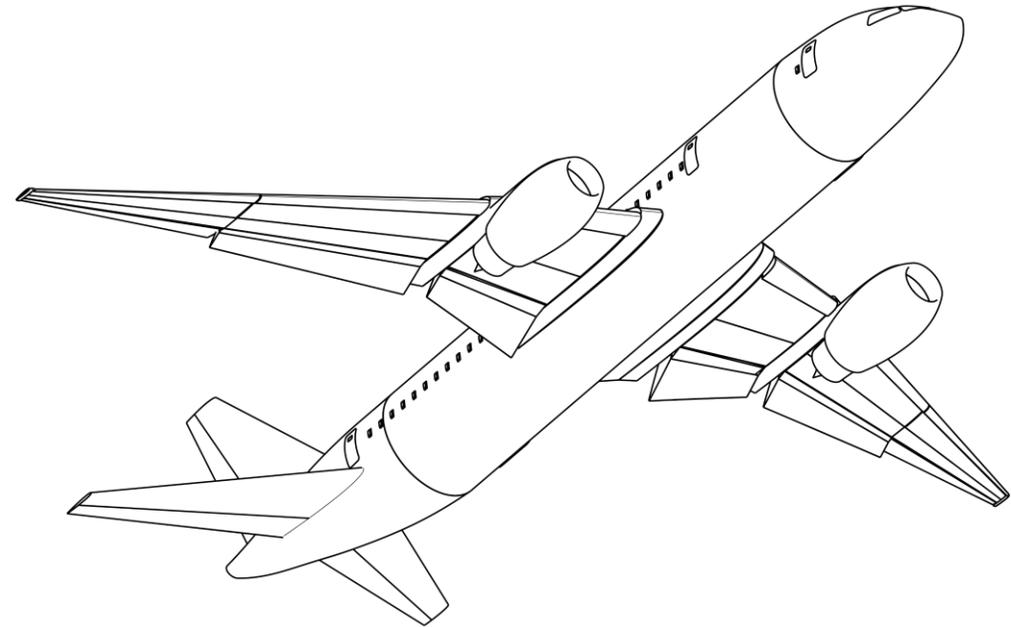
# Context – Aircraft Actuators

Most common:

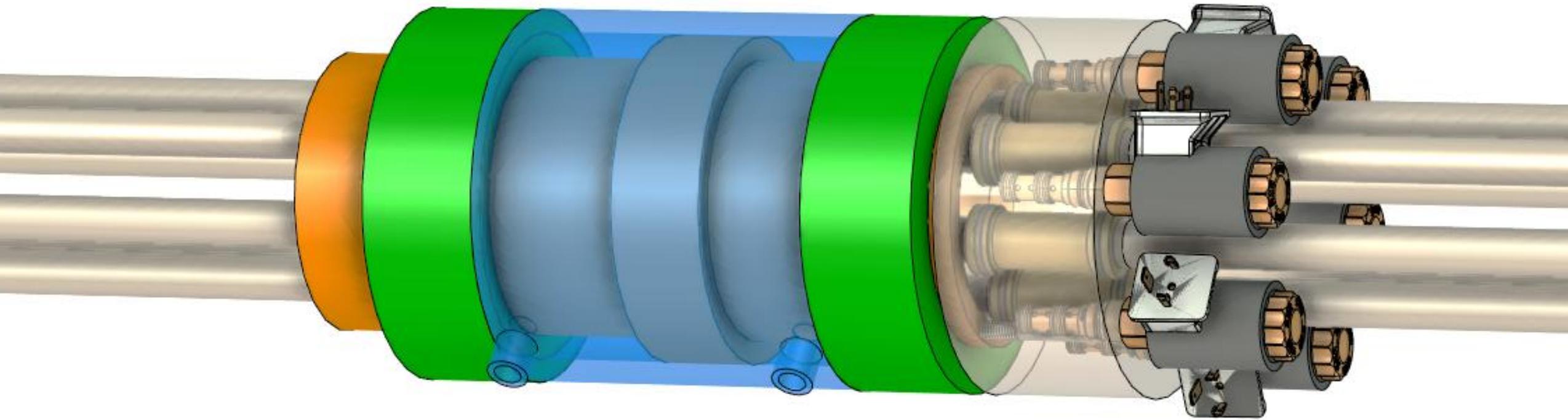
Electro-Hydraulic Servo Actuator



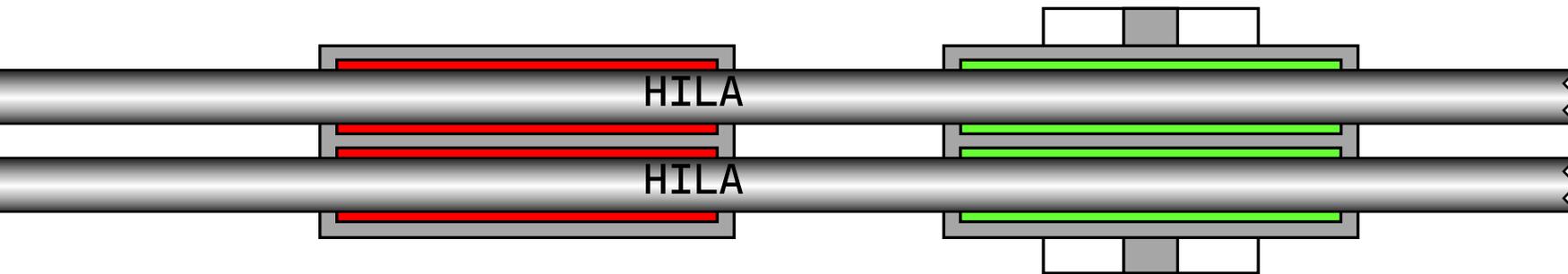
- Cylinder length equals stroke length
- One rod (output) per actuator



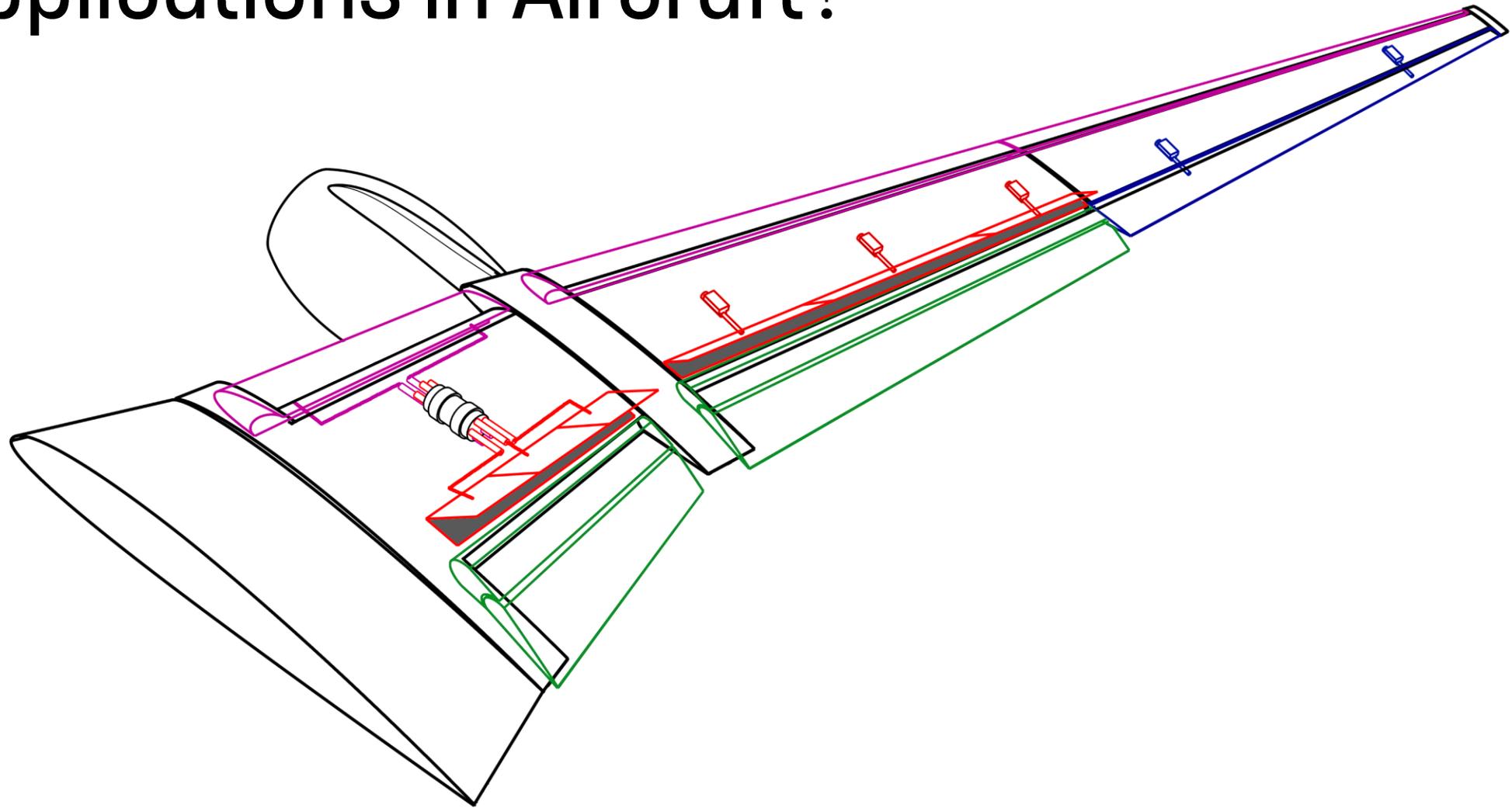
# Hydraulic Infinite Linear Actuator Multi-Rod HILA (MR)



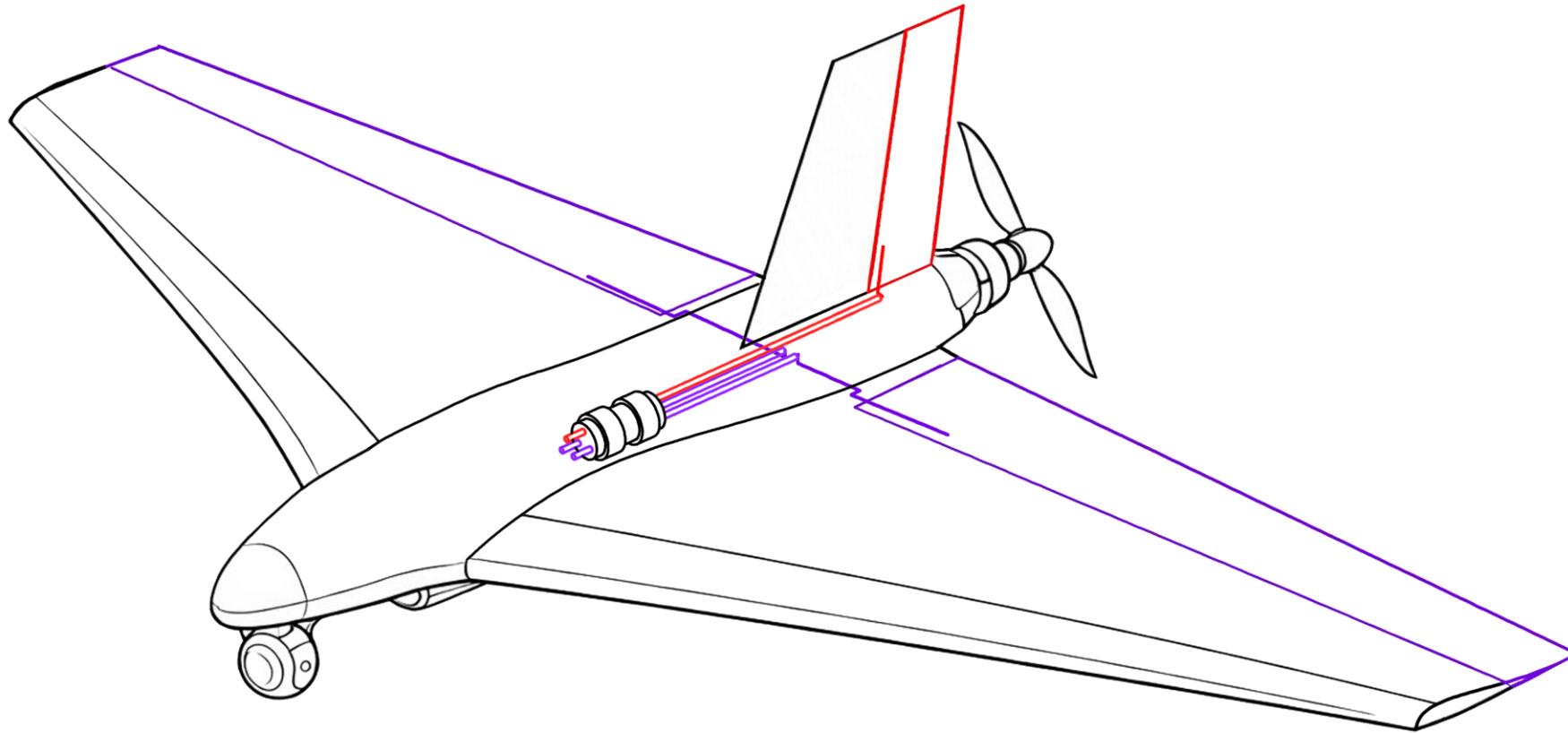
# HILA MR Single-servo



# Applications in Aircraft?

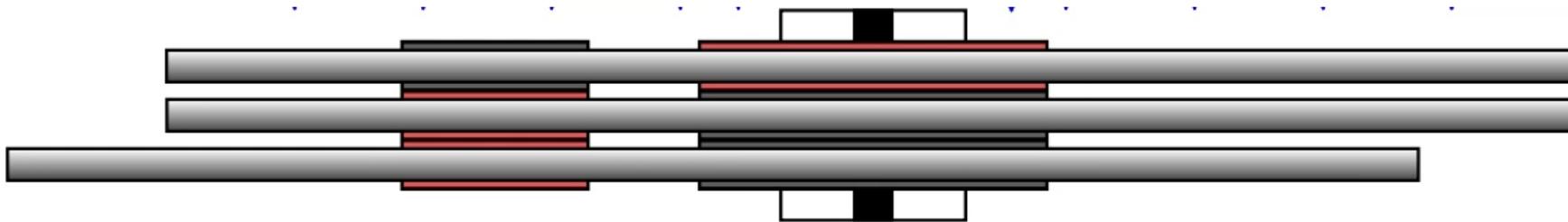
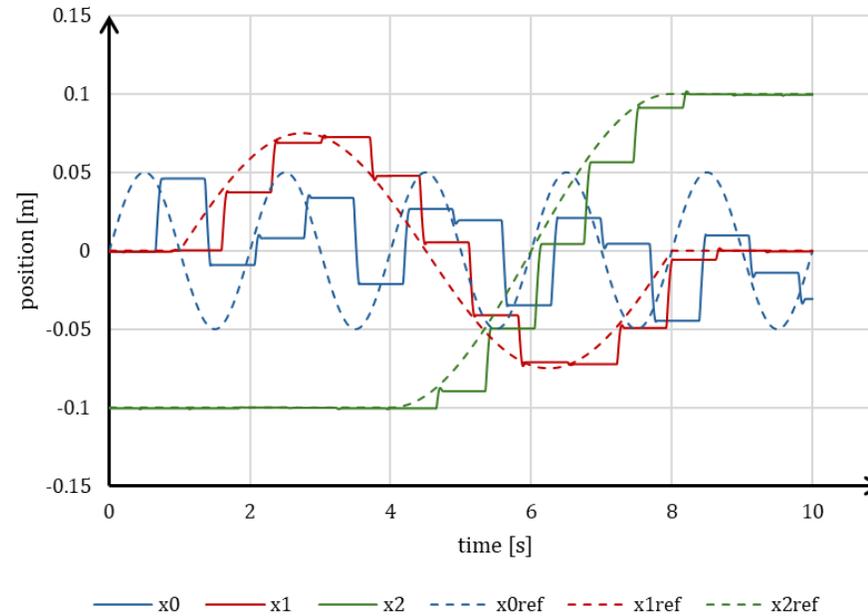


# Applications in Aircraft?



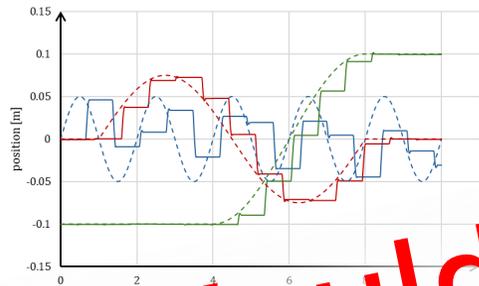
# Control scheduling algorithms

Example: Time-Division Multiplexing Algorithm

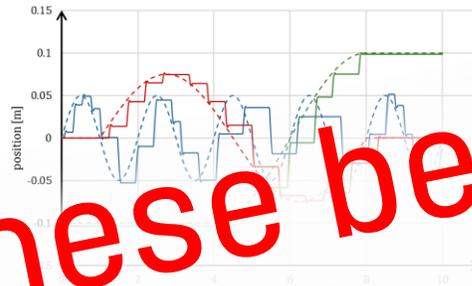


# Control scheduling algorithms

Time-Division Multiplexing



Round Robin



Early Return Round Robin

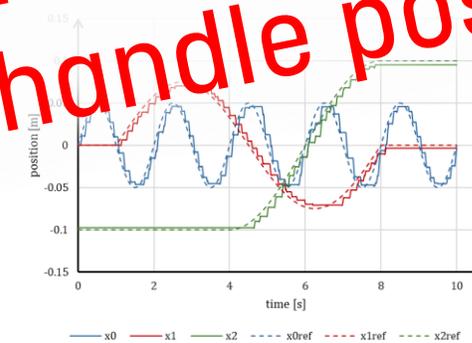


Would these be flyable?  
Which one is "best"?  
How do we handle possible failures?

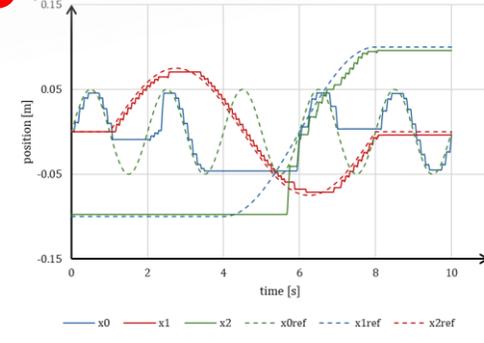
Greedy Round Robin



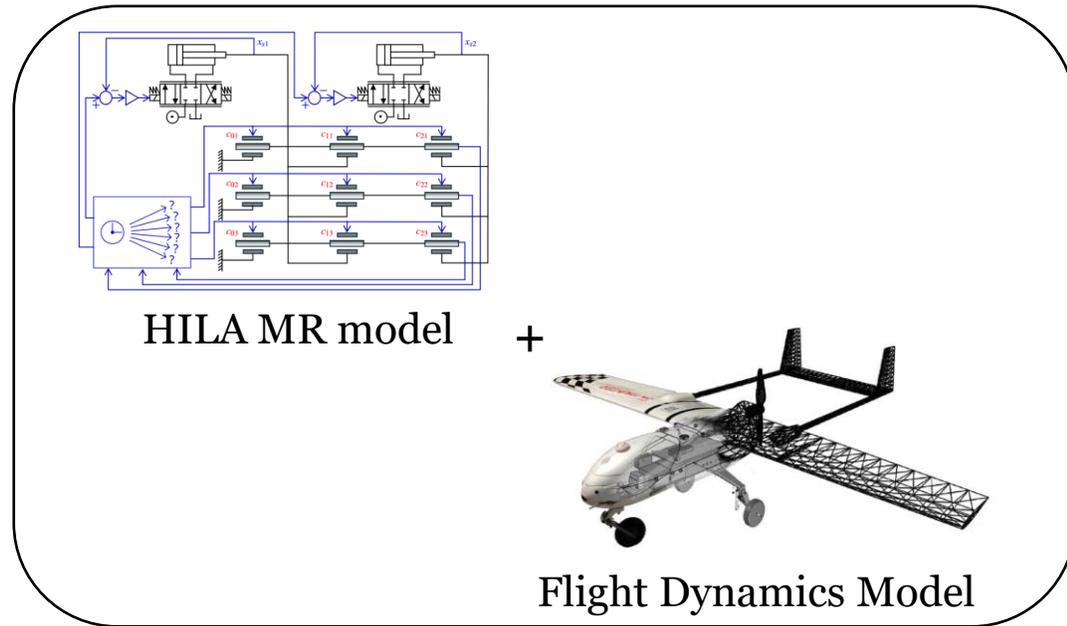
Asynchronous Multi-Grid



Rate Prioritization



# Multiple paths to an answer...

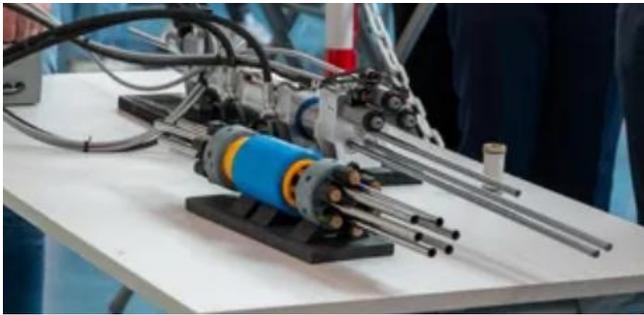


Modelling and Simulation



Subscale Flight Testing

# Subscale Flight Testing



HILA MR<sup>[1]</sup>

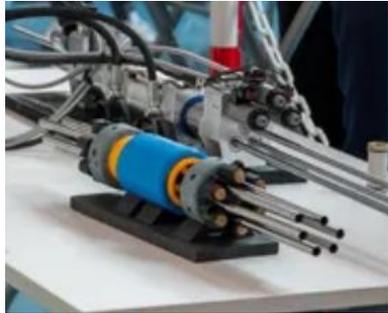
≈ 20...30 kg system weight



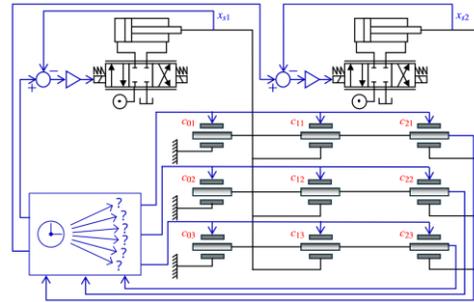
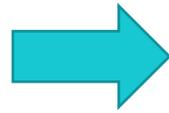
Subscale UAV<sup>[2]</sup>

≈ 4 kg system weight

# Subscale Flight Testing



HILA MR

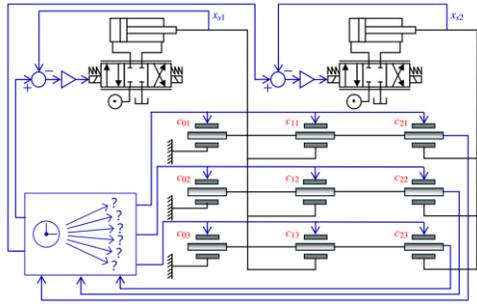


HILA MR model

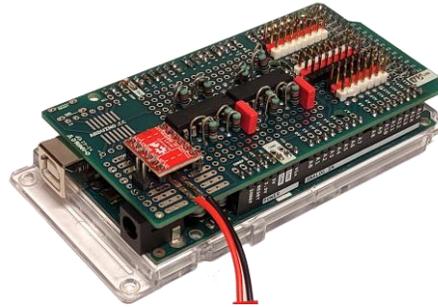
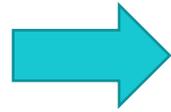


Subscale UAV

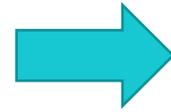
# “Real-Time” Actuator Simulator (RTAS)



HILA MR model

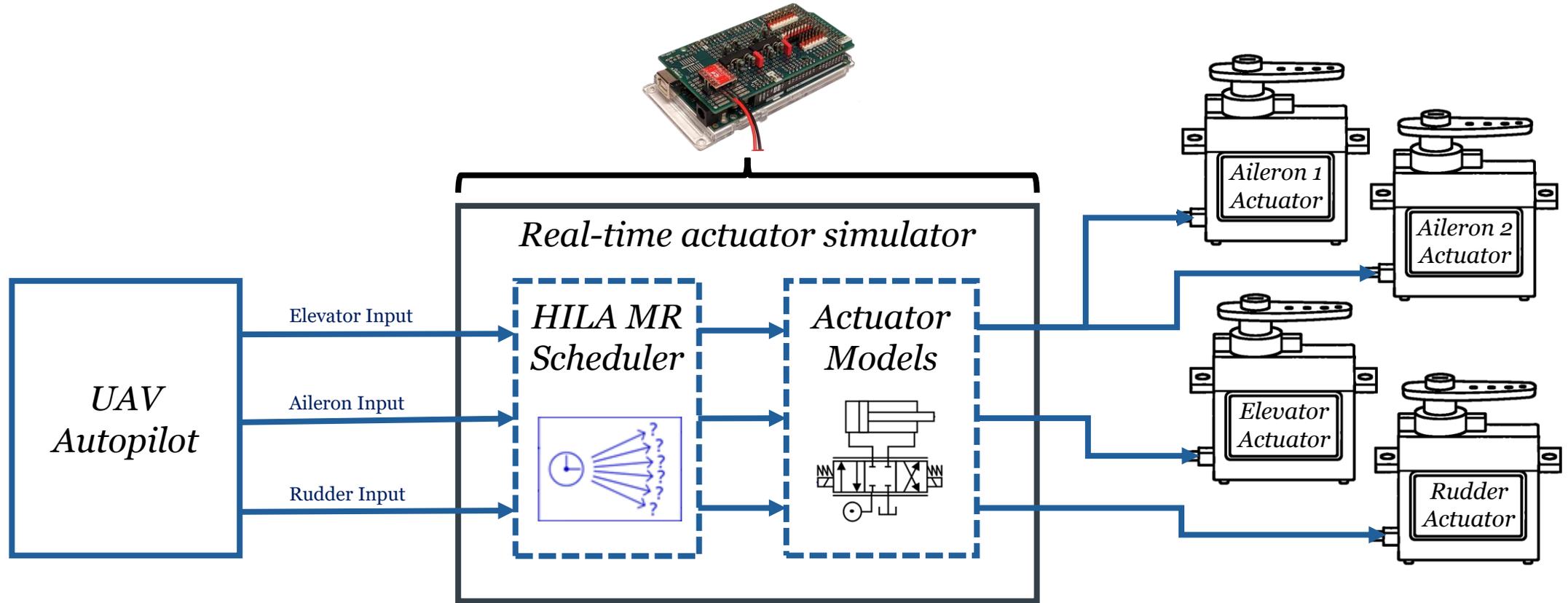


RTAS

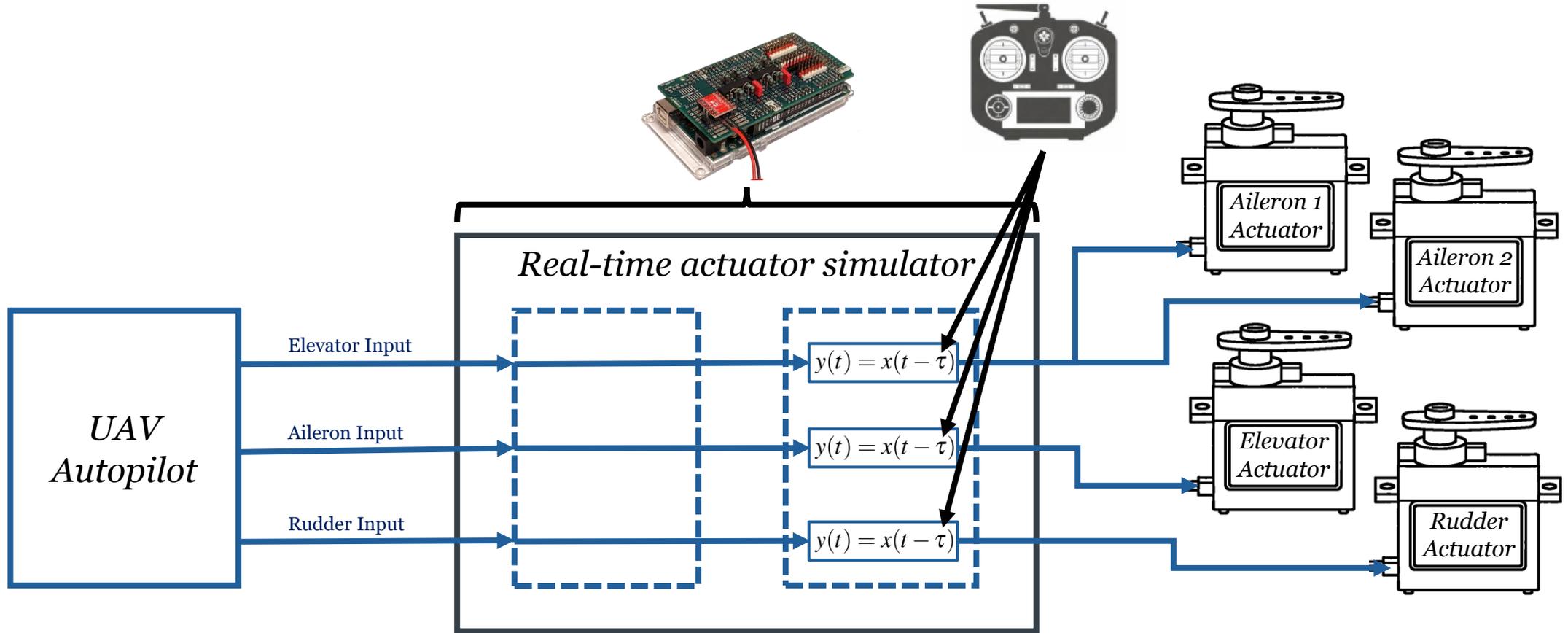


Subscale UAV

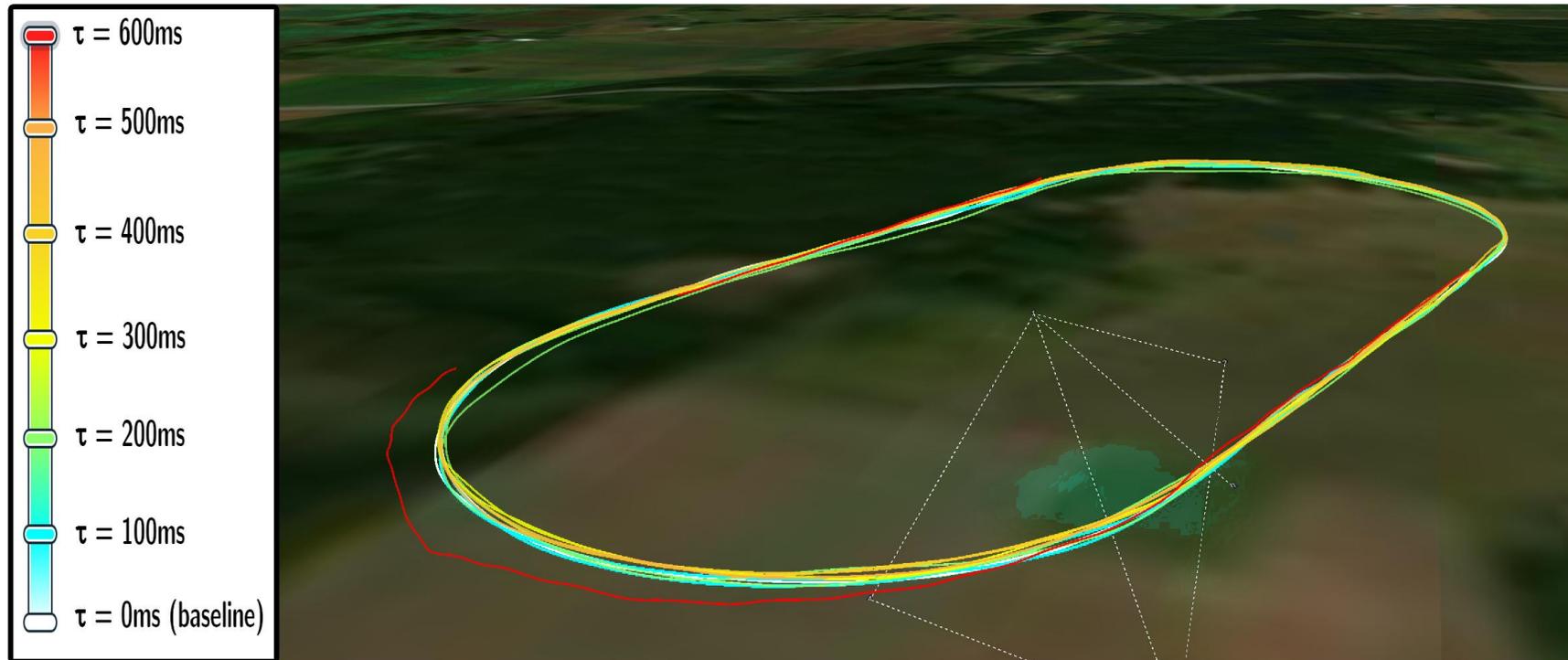
# "Real-Time" Actuator Simulator (RTAS)



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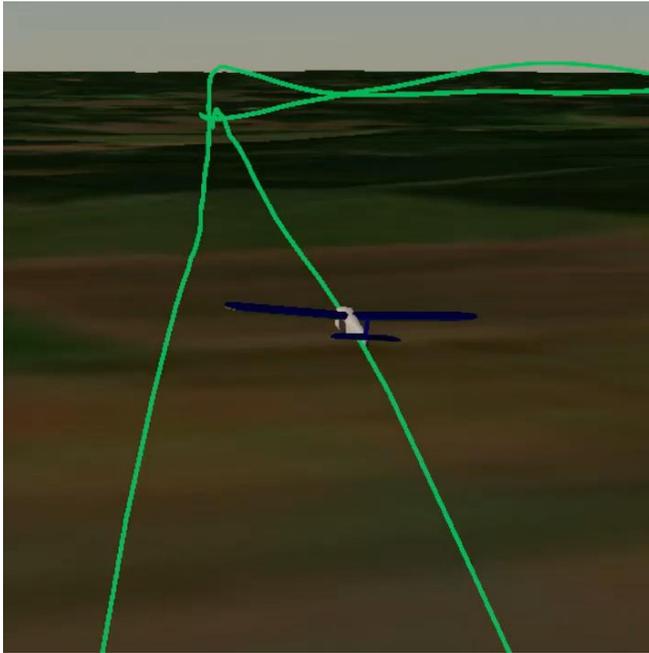


# Results

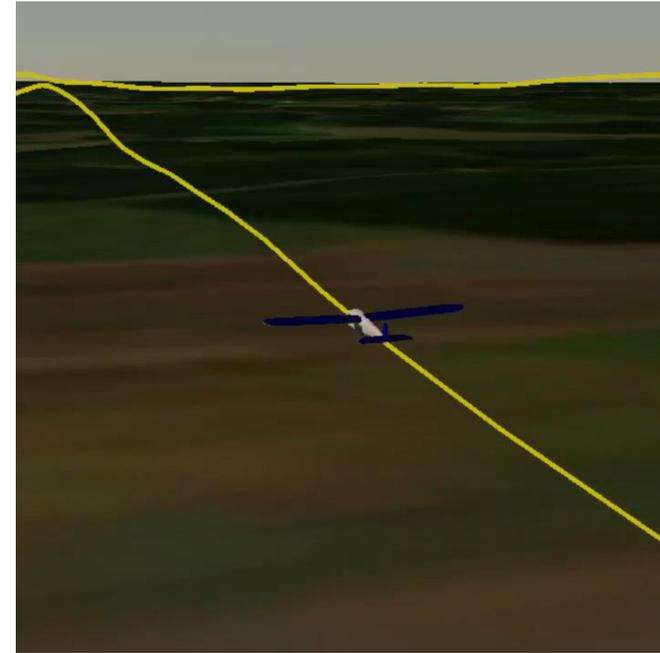


Reconstructed trajectories of the UAV based on log data from real flights with varying time delays added to control system

# Results



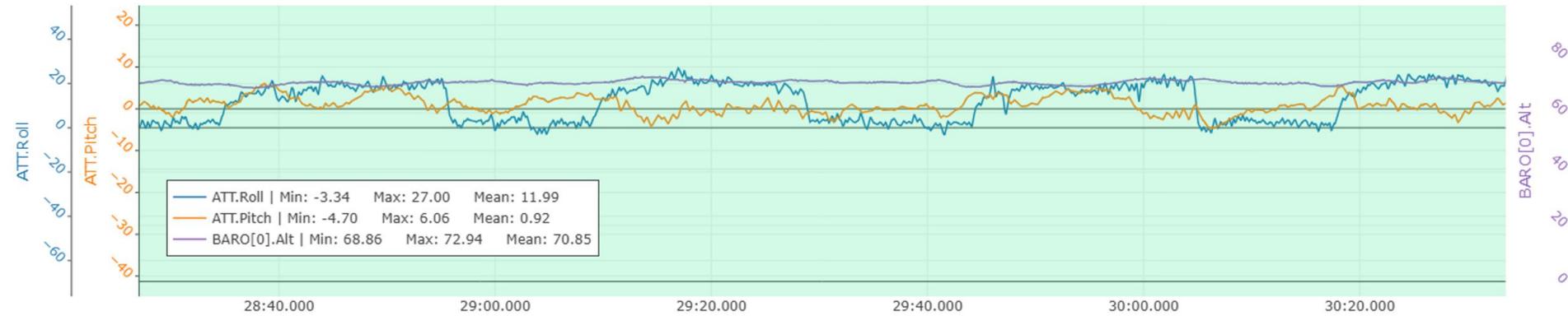
Actuator delay = 100ms



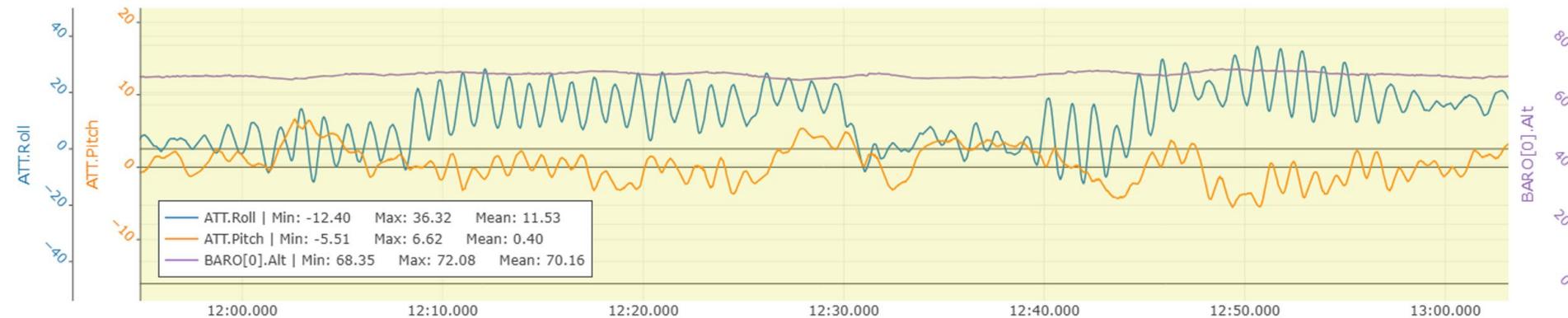
Actuator delay = 500ms

Reconstructed trajectories of the UAV based on log data from real flights

# Results



Actuator delay = 100ms



Actuator delay = 500ms

# Conclusions

- “Power in the loop simulation” or “software stubs” in real systems allow us to study the effects of novel actuators without the cost and risk of installing them in real aircraft
- RTAS bridges the gap between pure simulations and full implementation

# Future Work

- Test scheduling algorithms using RTAS and evaluate performance
- Install a HILA MR prototype on a large UAV



F720, a 7.2m wingspan UAV

[1] Fotograf: Teiksmå Buseva, <https://liu.se/nyhet/ny-typ-av-roderstalldon-tanker-som-en-dator>

[2] Fotograf: Stefan Riethausen

# Thank you!

Questions?

