

eVTOL Aircraft and Automation

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eVTOL Evaluation Challenges

- Diversity in proposed aircraft and control concepts
- Operations in low speed and hover may be restricted for some candidate eVTOL aircraft due to lack of cyclic and/or collective control
- Powered Lift (e.g., winged eVTOL) have additional control challenges in transition
- Automation is proposed to help with these challenges
 - Industry concepts proposing Indirect Flight Controls (IFCS)
- Existing Means of Compliance inadequate for IFCS and increasing automated functions
 - IFCS airplanes have only been certified under Special Conditions
- How do we evaluate whether proposed concepts of operations are compatible with eVTOL aircraft and automation?





NASA Model and Simulation Development

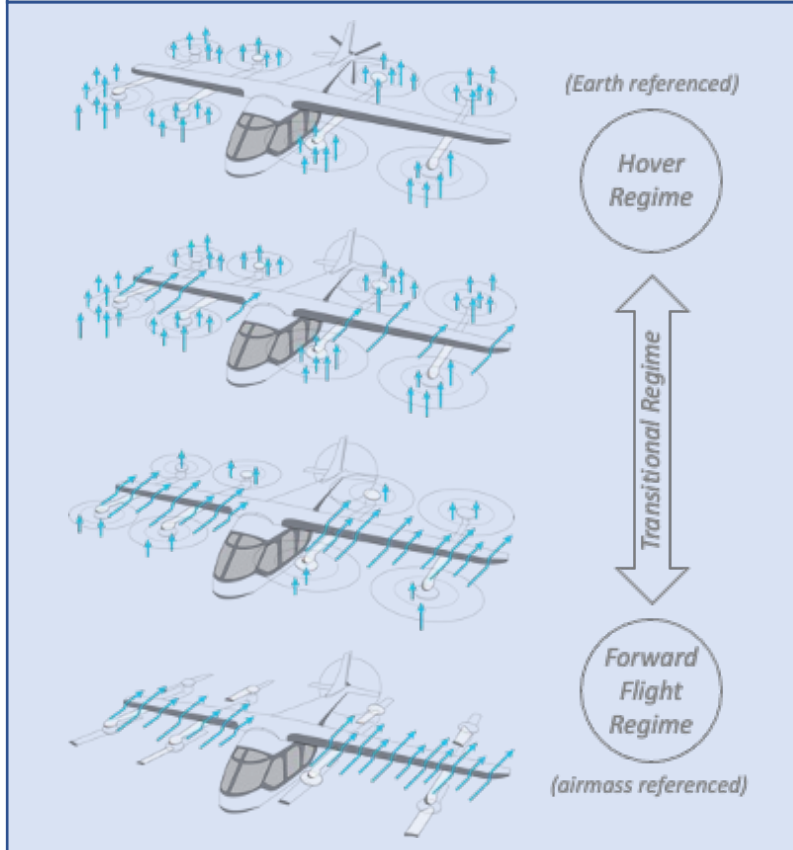
Vehicle Models

- RVLТ design concepts with stability/control analysis¹



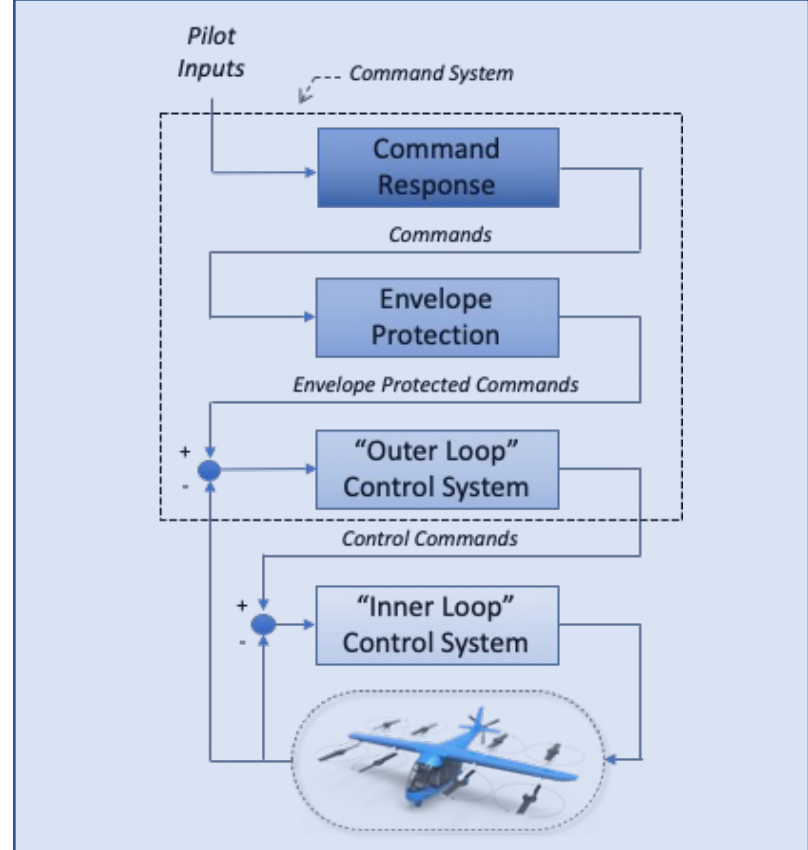
Vehicle Transitions

- Lift and control mode transitions (e.g., winged eVTOL taxonomy)



Command Concepts

- Enabling operations with command response types²



1) Silva, C., Johnson, W., Antcliff, K., and Patterson, M., “VTOL Urban Air Mobility Concept Vehicles for Technology Development”, AIAA 2018-3847, June 2018.

2) Kaneshige, J., Lombaerts, T., Shish, K., Feary, M., “Command and Control Concepts for a Lift Plus Cruise Electric Vertical Takeoff and Landing Vehicle”, AIAA 2023-3910, June 2023.

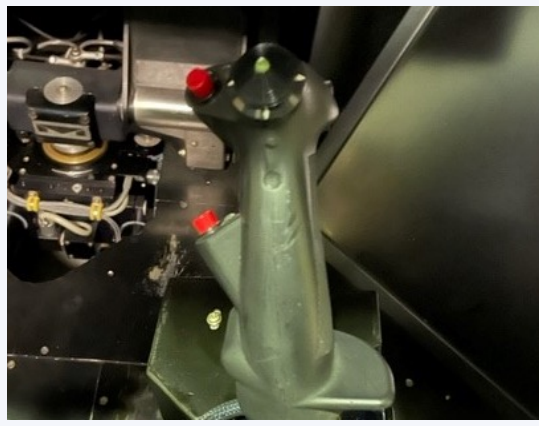


Inceptors, Controls and Displays

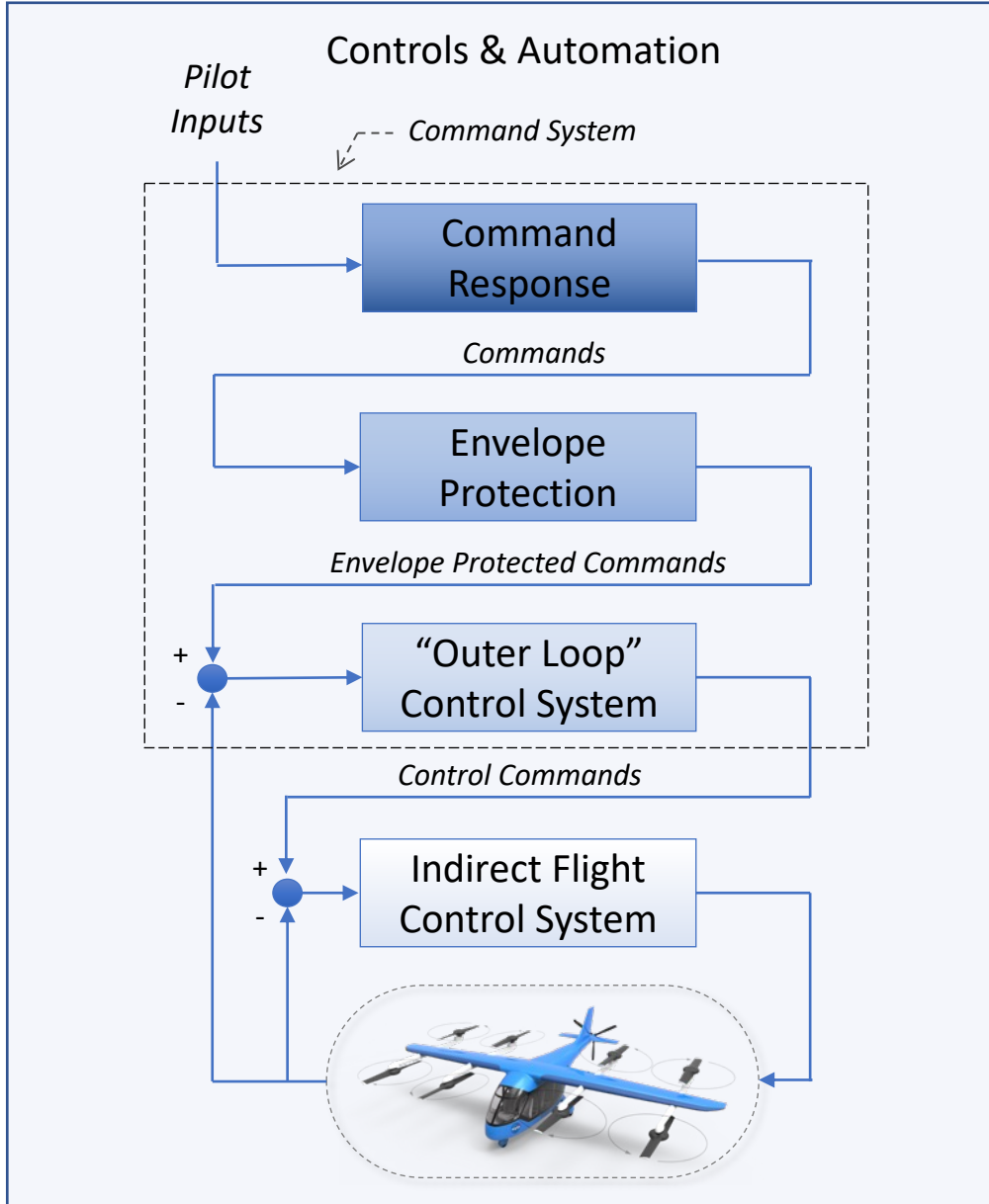
Dual Inceptors



Left Stick with Hover Engage/Disengage Buttons



Right Stick with Automation Command Concept Selector Buttons



Enhanced/Synthetic Vision Displays



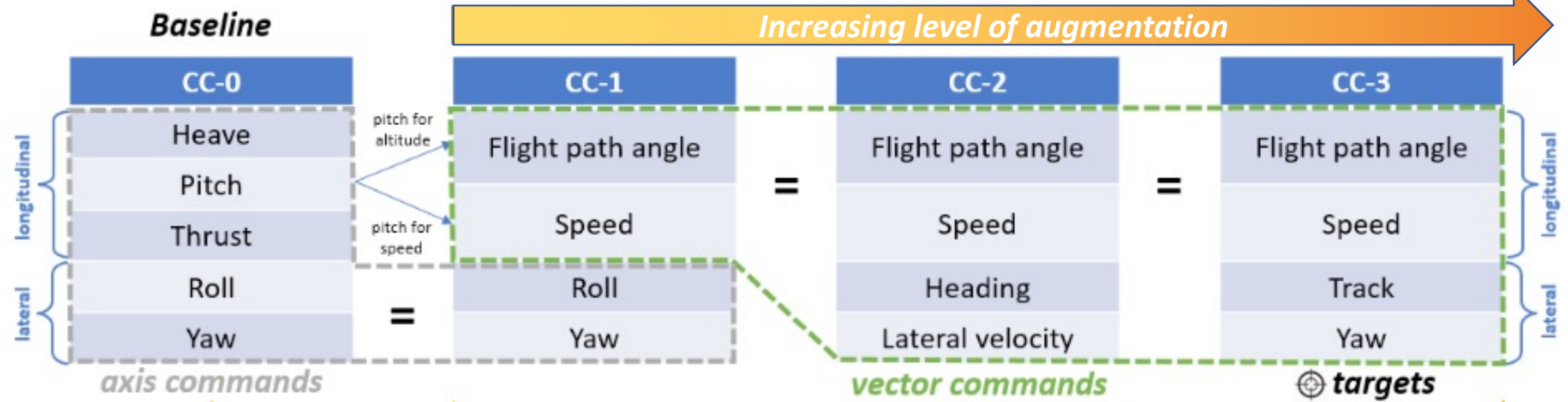
MAP with Hover Prediction



PFD with Commanded Velocity Vector

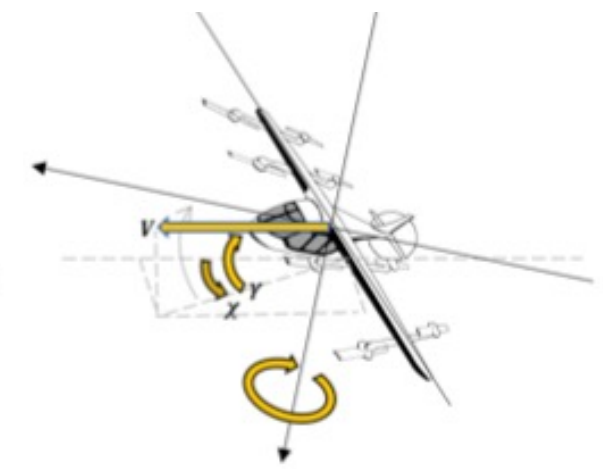
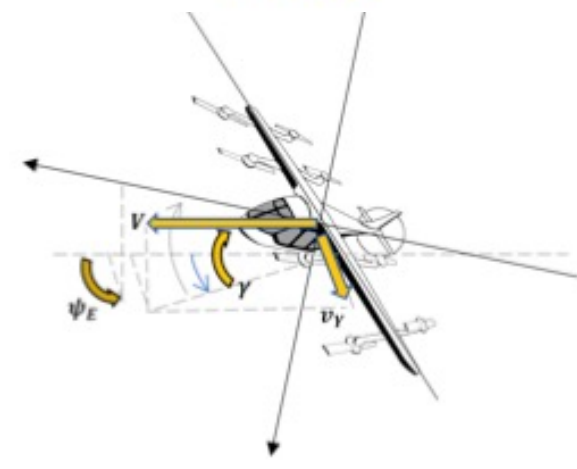
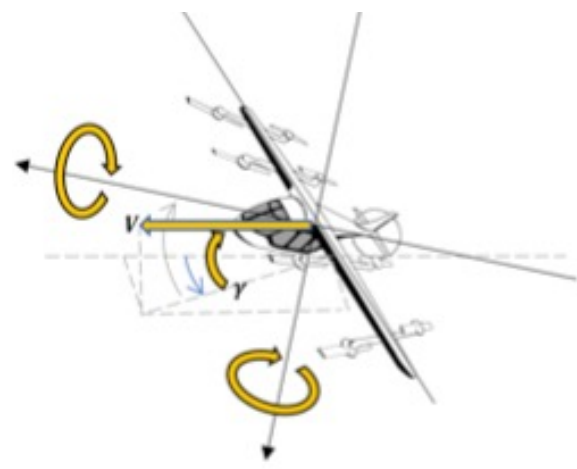
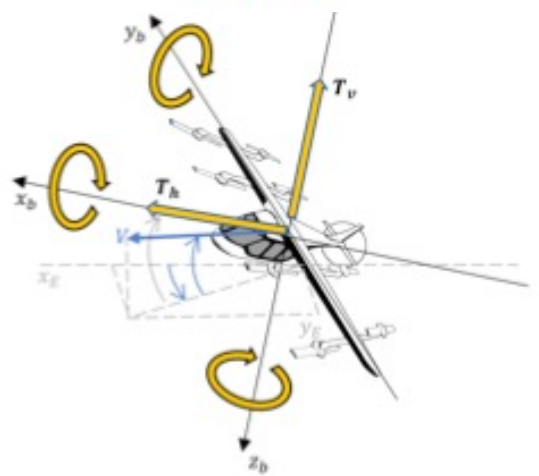


Command Concepts



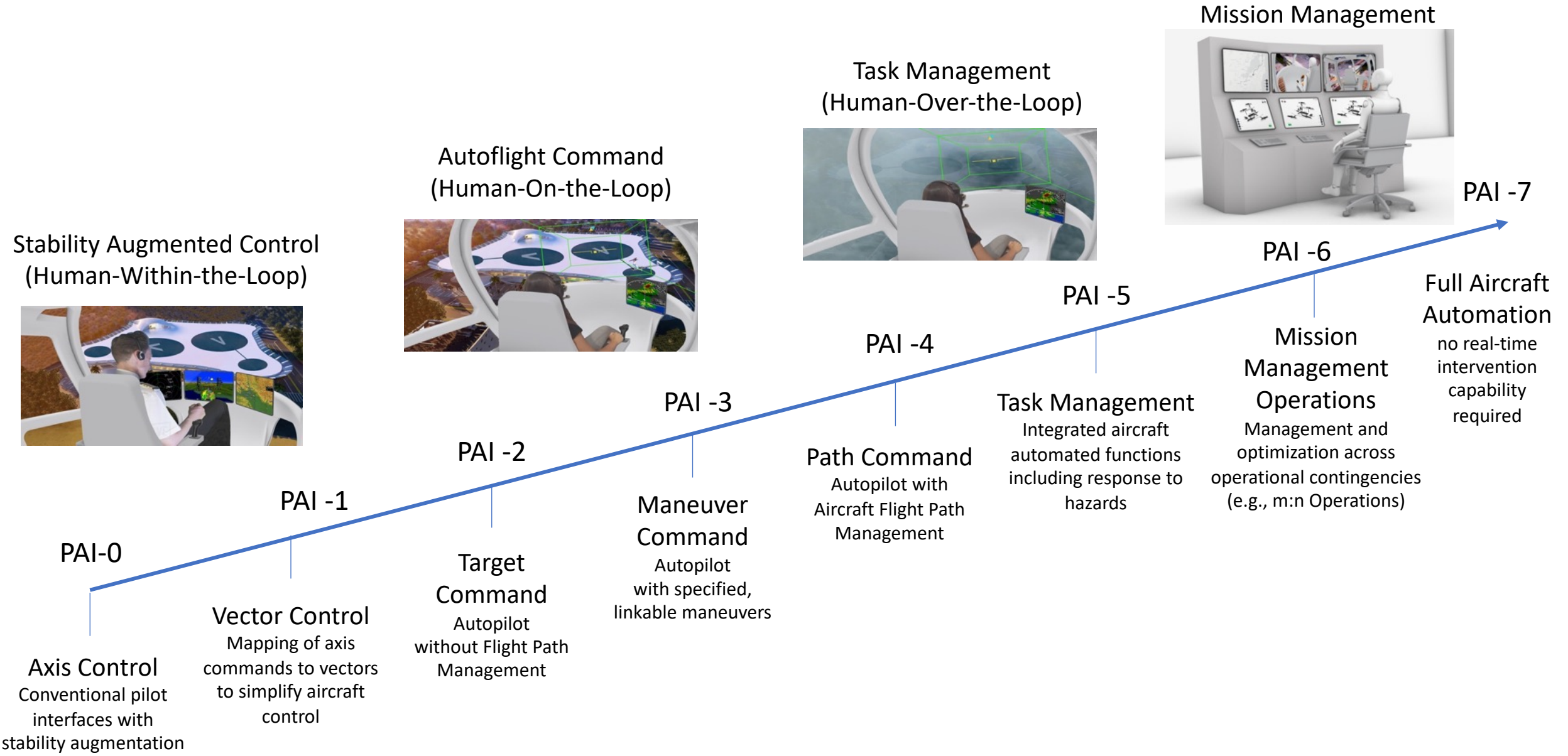
5 axes (Independent heave/thrust axes only applies for LPC)

4 axes (Extra DoF used to trim AoA/pitch for LPC)

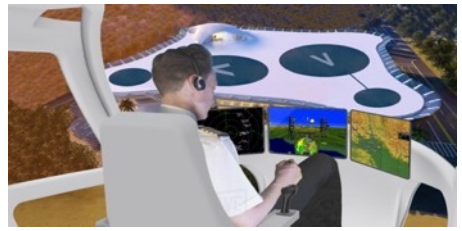




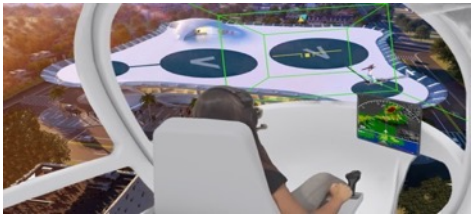
Pilot Automation Interaction (PAI) Framework



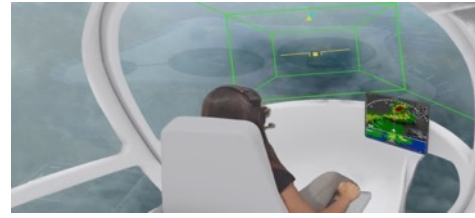
Stability Augmented Control (Human-Within-the-Loop)



Autoflight Command (Human-On-the-Loop)



Task Management (Human-Over-the-Loop)



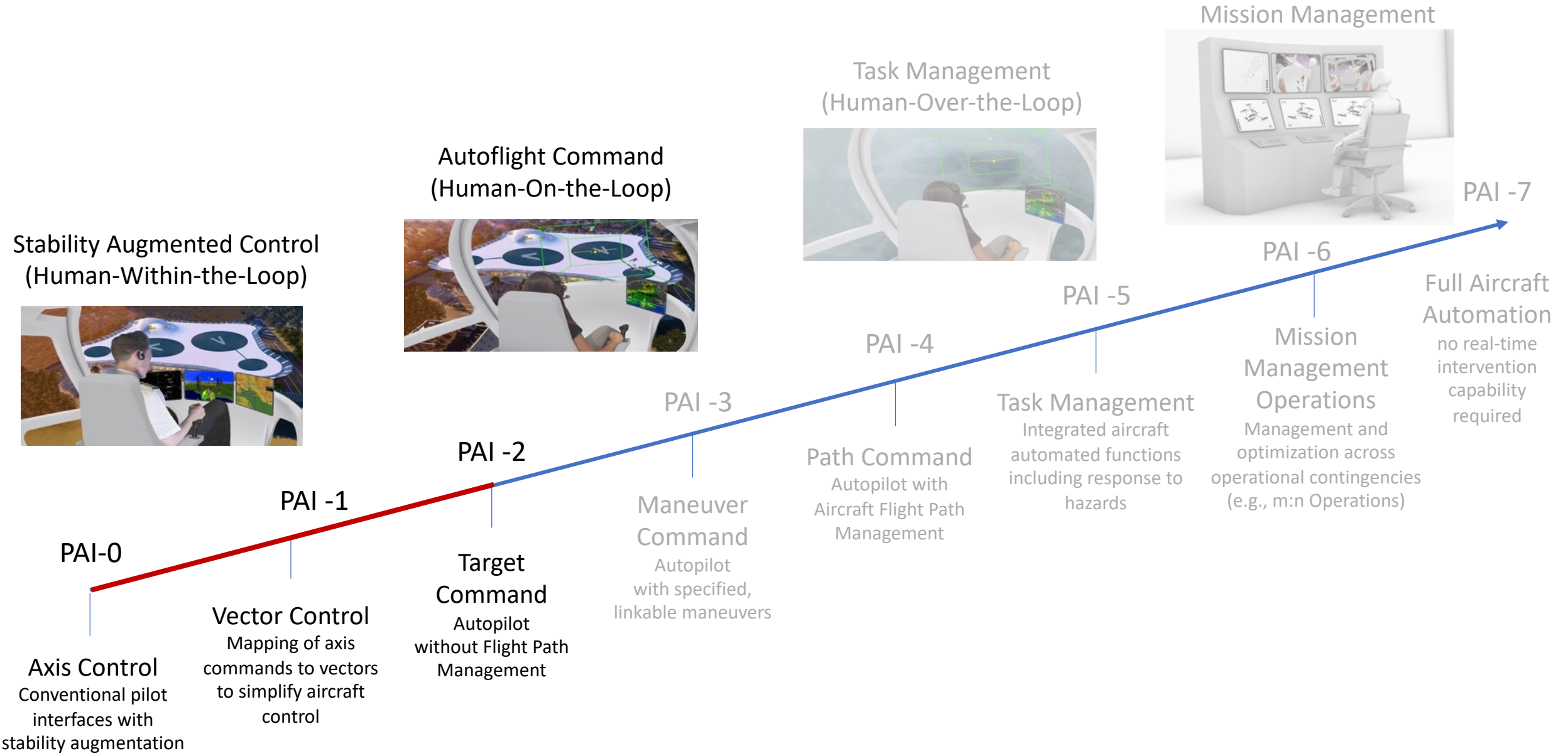
Mission Management



PAI -7



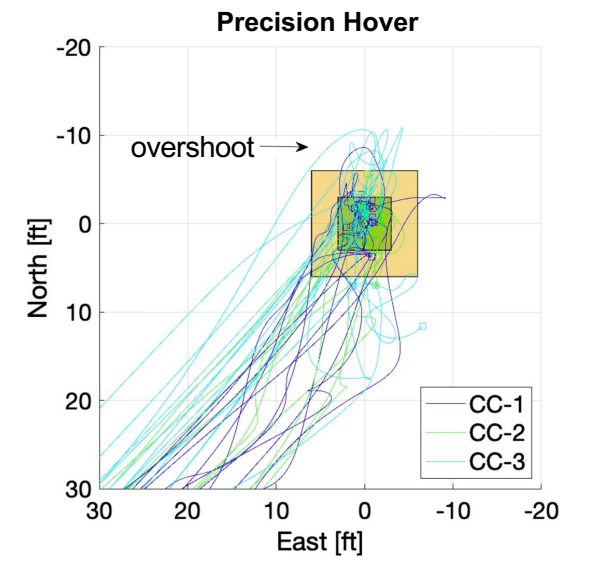
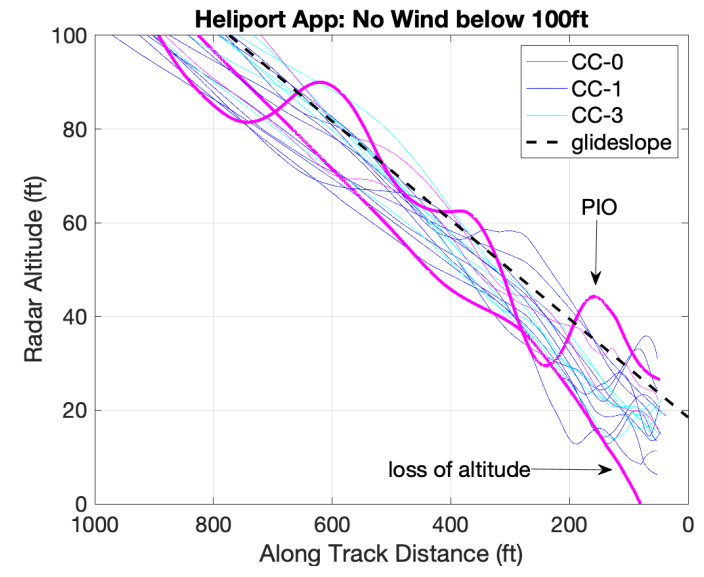
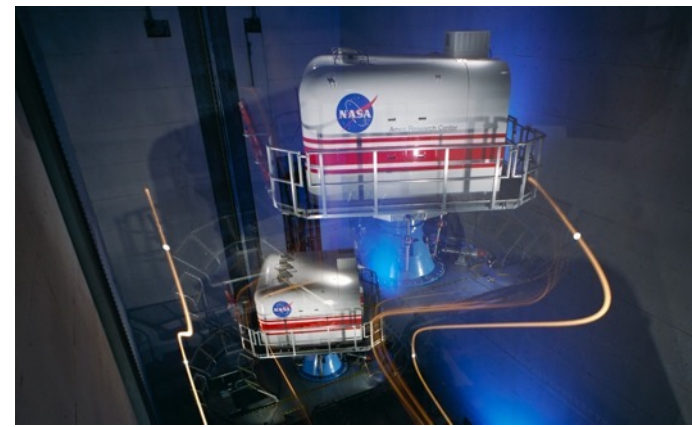
Pilot Automation Interaction (PAI) Framework





Automation Enabled Pilot Studies

- Objective: Evaluate challenges associated with information and automation requirements for expected Urban Air Mobility (UAM) operations using representative powered lift aircraft
- Developed 11 candidate maneuvers
- Evaluated through series of three VMS experiments
- Findings provided lessons on automation design and supported means of compliance evaluation



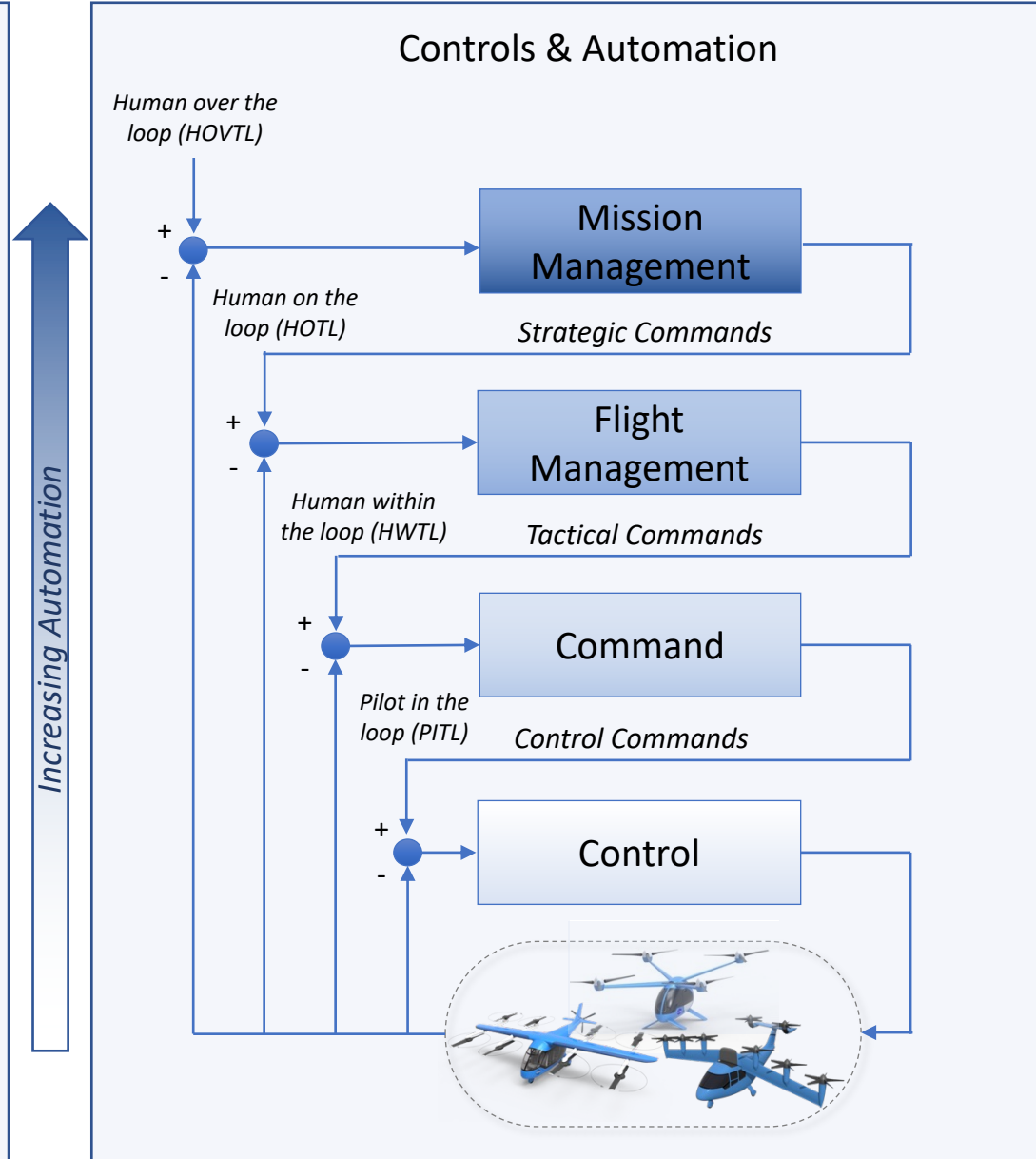


Future Interfaces, Automation, Information

Mission Management Interfaces

Flight Management and Autopilot Interfaces

Hands On Throttle And Stick (HOTAS) Inceptors



Increasing Automation

Increasing Automation

System Health Displays

NAV/MAP Display

Primary Flight Display (PFD)

Questions?