

Evaluation of Novel eVTOL Aircraft and Automation Concepts

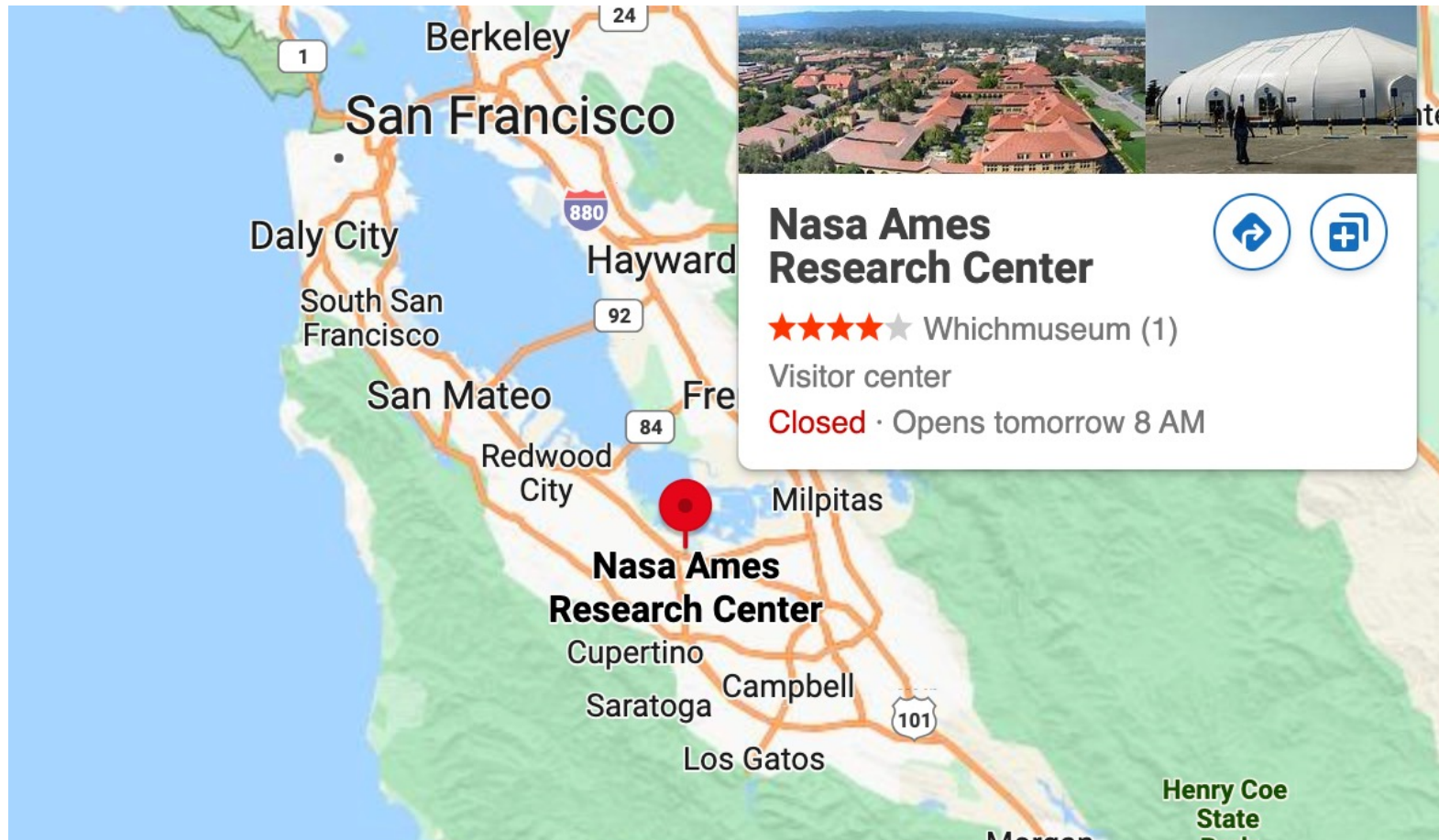
NASA-Ames Research Center



Feary, M., Kaneshige, T., Lombaerts, T., Shish, K. and Haworth, L.
Flight Test Society of
Australia

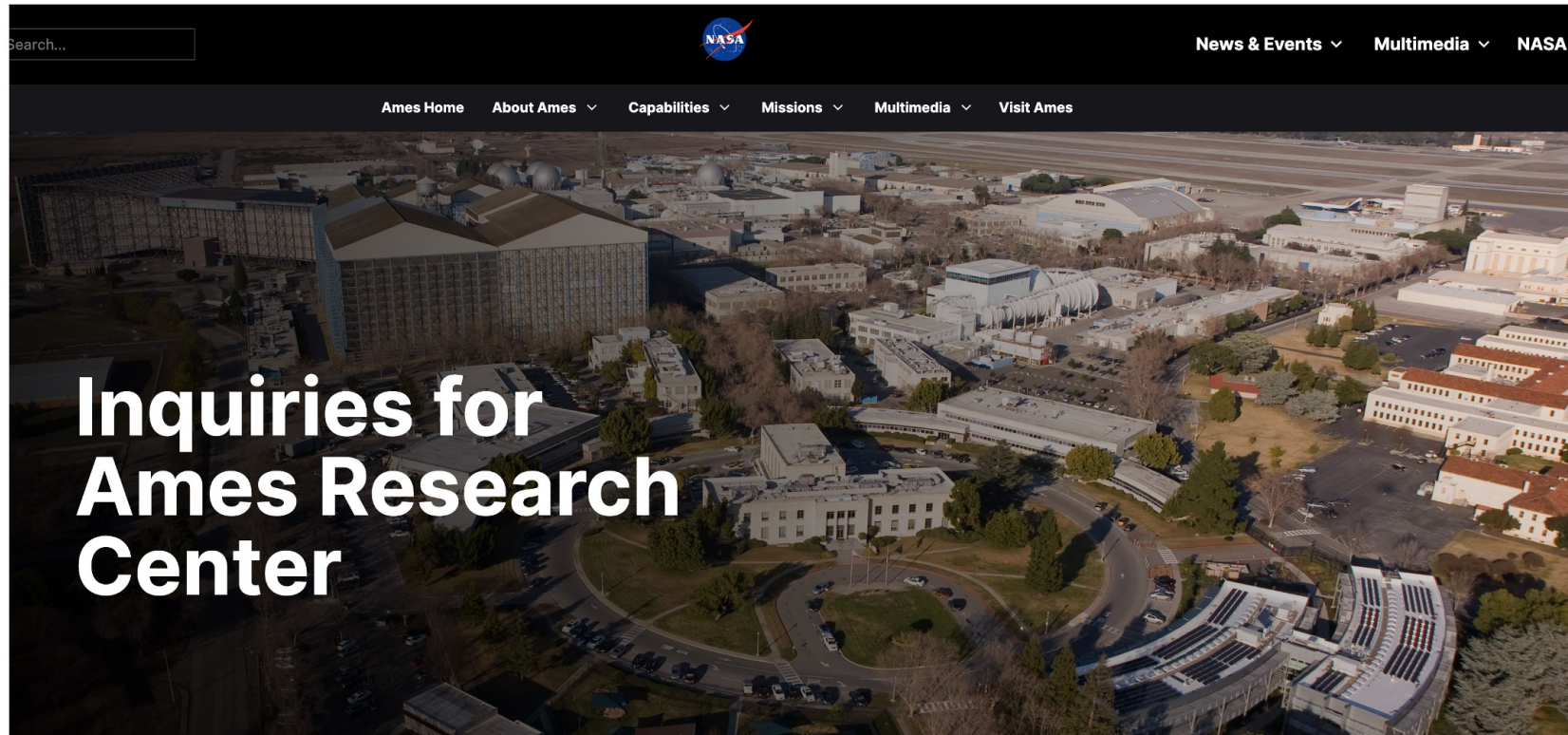
- Where is NASA-Ames Research Center
- Showing off Ames and Facilities
- Early NASA-Ames Vertical Flight and Simulation Research
- Comanche Example and Indirect Flight Control (Research Driver)
- Advanced Air Mobility and Revolutionary Vertical Lift Technology Project
- Aeronautical Design Standard and Mission Task Elements
- AEP-1 Research and Data examples

NASA Ames Research Center Location



[nasa ames research center - Search \(bing.com\)](https://www.bing.com/search?q=nasa+ames+research+center)

NASA Ames



<https://www.nasa.gov/ames/inquiries-for-ames-research-center/>

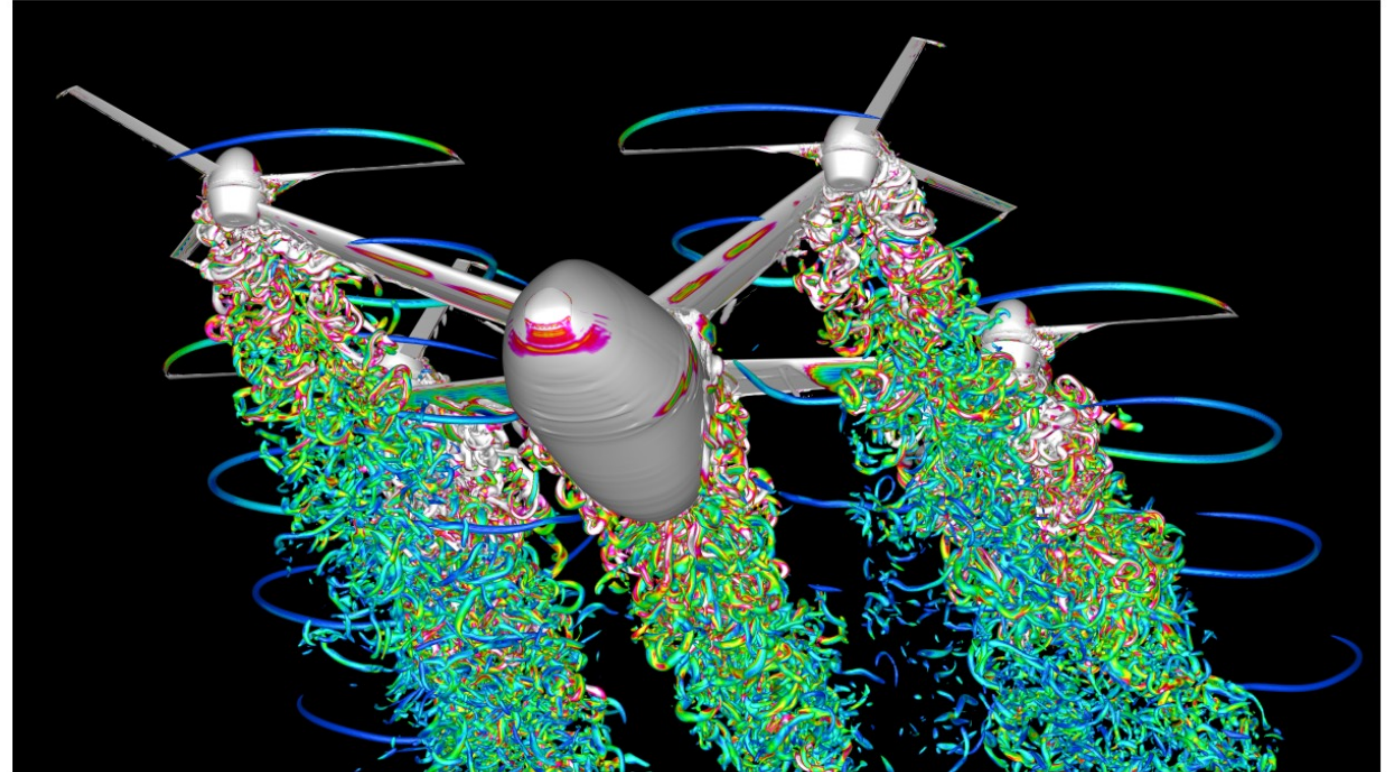
NASA-Ames Research Center



Facilities: NASA-Ames 80 X 120 Wind Tunnel



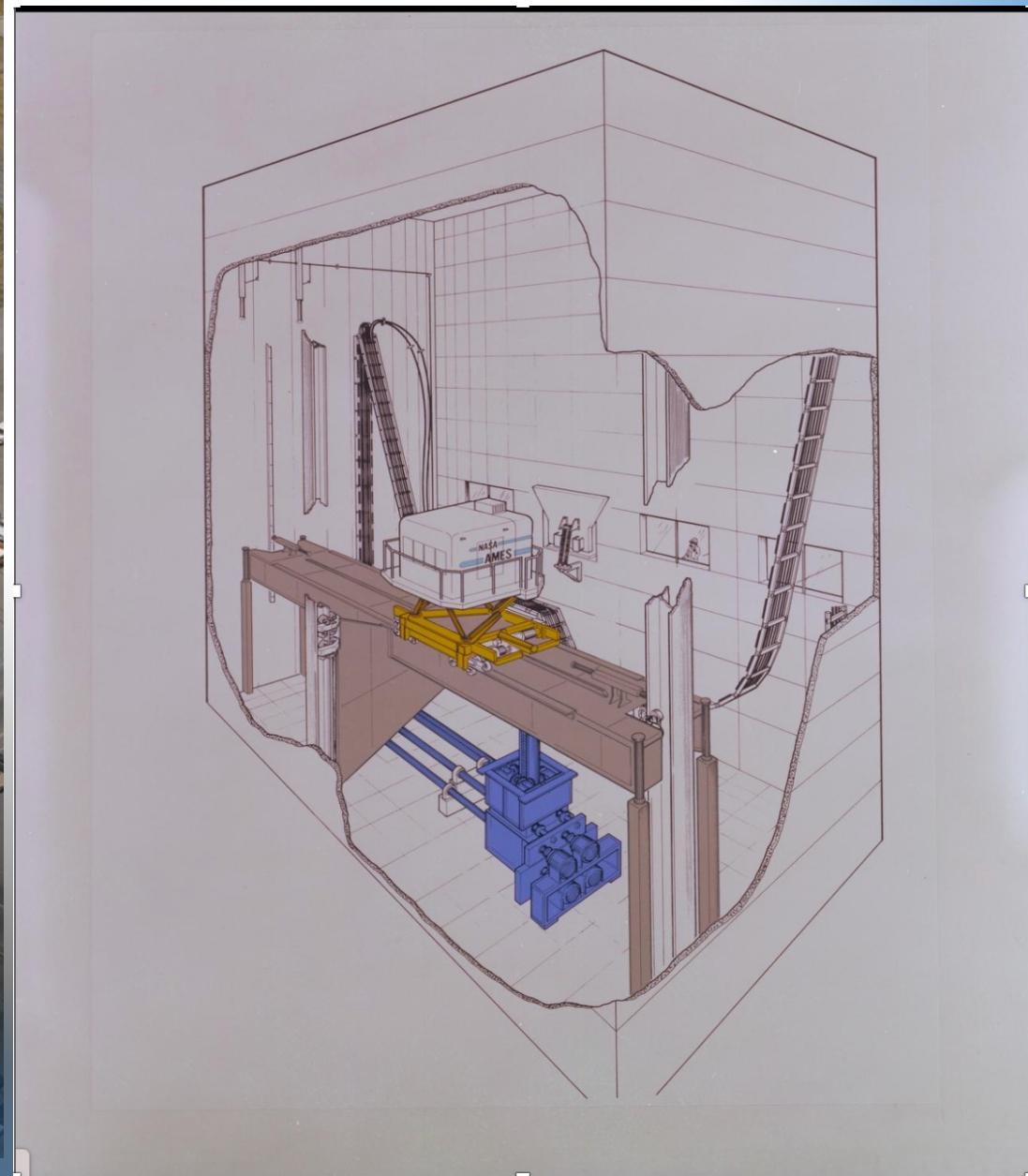
Supercomputing,
Computational
fluid dynamics
Supporting
Advanced Air
Mobility Concepts



Two of Ames' longtime strengths – supercomputing and computational fluid dynamics – come together in this visualization of the flow of NASA's six-passenger quadcopter concept for Advanced Air Mobility.

NASA / Patricia Ventura Diaz

Facilities: Vertical Motion Simulator





Ryan VZ-3RY Vertiplane



Bell X-14B (VTOL experimental aircraft)



Ryan XV-5B ("fan-in-wing")



Harrier AV-8B



NASA-Ames Vertical Flight Research



ASCAL on the flight ramp, NASA A



Flying Laboratory for Integrated
Test & Evaluation (FLITE)



FLITE and RASCAL



CSRDF – appeared on the front
cover of Aviation Week,
November 27, 1989

Comanche surrogate (Sikorsky)



RAH-66 Comanche prototype

- **Advanced Air Mobility**

Airspace is no longer only for large aircraft high above—it is overhead in urban environments and will soon hover just above our doorsteps. This will require even more intense management. As these new forms of flight become more common, including the air taxis and air cargo delivery drones that Advanced Air Mobility envisions, NASA leads the collaborative effort between government, industry, and academic partners to ensure they integrate the airspace safely and efficiently. Software development and simulation facilities at Ames are integral parts of this research.



Research Activities

- Clean and Efficient Propulsion
- Efficient and Quiet Vehicles
- Safety, Comfort and Accessibility
- Modeling/Simulation and Test Capability

Reference: [Revolutionary Vertical Lift Technology Project Overview \(nasa.gov\)](https://www.nasa.gov/research/revolutionary-vertical-lift-technology-project-overview)

eVTOL Operational Dimensions



Aircraft Performance



Pilot Requirements



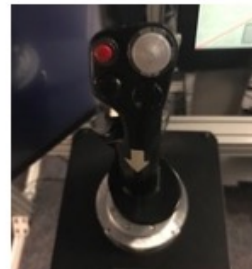
Operations



Automated Systems



Controls



Displays



eVTOL Flight Challenges

- Diversity in Proposed Aircraft
- Powered Lift (e.g., Winged eVTOL) have additional challenges in transition
 - Operations in Low speed and Hover will be restricted for many candidate eVTOL aircraft due to lack cyclic and/or collective control
- Automation proposed to help with these challenges
- All concepts currently proposing Indirect Flight Controls (IFCS)
 - See Kaneshige et. al in MST-03 for development
- Existing Means of Compliance Inadequate for IFCS and increasing automated functions
 - IFCS airplanes have only certified under Special Conditions
- Evaluation methods will need to cross airworthiness and operations
- Need for industry representative VTOL aircraft and automation for developing and as baseline evaluation methods



Beta ALIA-250
(Lift + Cruise)



Joby S4 (Tilt Rotor)



Lilium Jet (Tilt Ducted Electric Fans) [Vectored Thrust]



Archer Maker
(Tilt Rotor Hybrid)



Wisk Cora (Lift + Cruise)

Photos courtesy of Vertical Flight Society, 2023

Quadcopter



- Designed Gross Weight = 6480 lbs
- Payload 1200 lbs (6 passengers)
- 4 collectively controlled rotors

Performance Parameters

- Range = 50 nm
- Best endurance speed = 56 kts
- Best range speed = 98 kts
- Maximum speed = 109 kts

Lift Plus Cruise



- Designed Gross Weight = 6013 lbs
- Payload = 1000 lbs (5 passenger)
- Wingspan = 47.42 ft
- 8 collectively controlled rotors
- 1 pusher propeller
- 2 ailerons, 1 elevator, 1 rudder

Performance Parameters

- Range = 50 nm
- Best endurance speed = 90 kts
- Best range speed = 122 kts
- Maximum speed = 123 kts

Tilt Wing



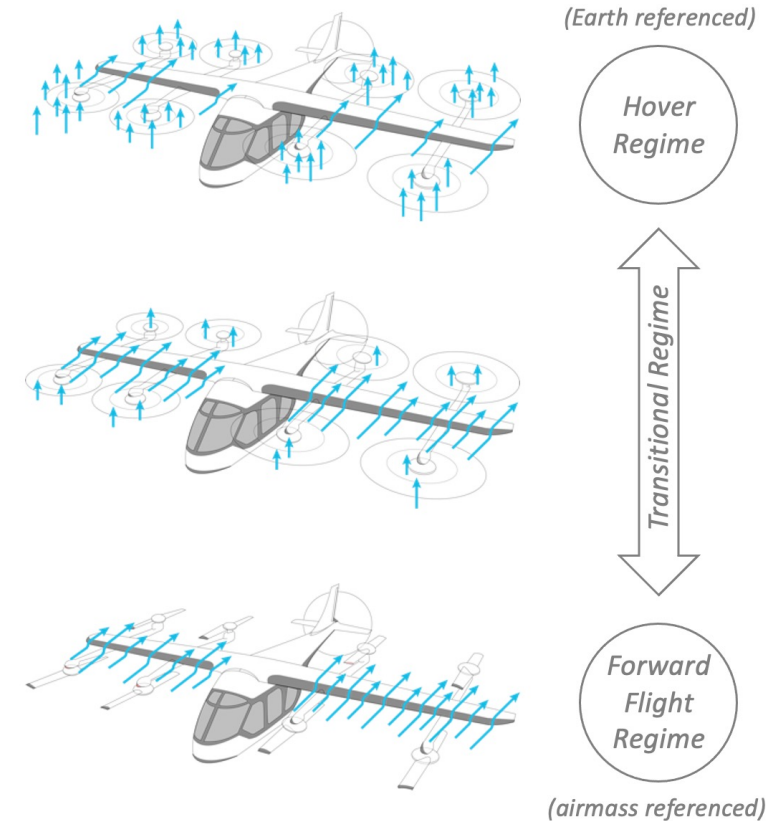
- Designed Gross Weight = 6000 lbs
- Payload = 1200 lbs (6 passenger)
- Wingspan = 44.4 ft
- 8 collectively controlled rotors
- 2 ailerons, 1 elevator, 1 rudder

Performance Parameters

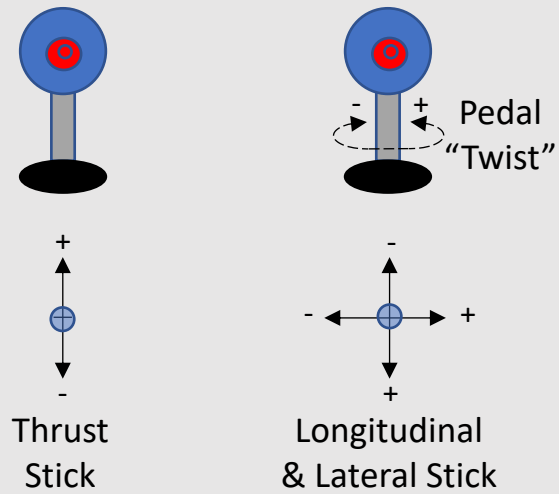
- Range = 75 nm
- Best endurance speed = 102 kts
- Best range speed = 148 kts
- Maximum speed = 194 kts

Winged eVTOL Taxonomy

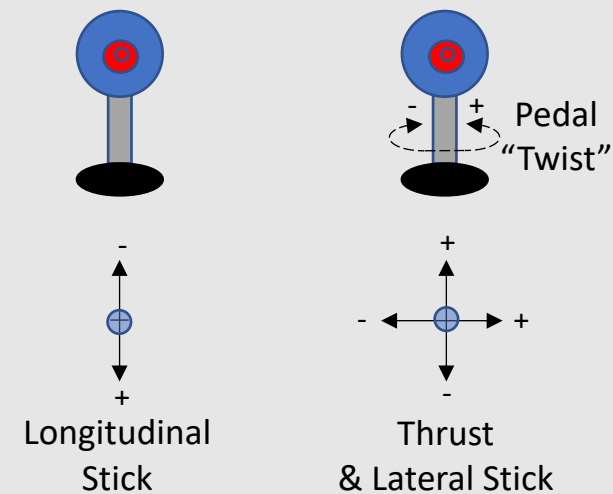
- **Thrust Borne Lift**
 - Rotors provide lift
 - Airframe produces minimal aerodynamic effects
- **Semi-Wing Borne Lift**
 - Airframe provides primary lift
 - Rotors provide some lift (e.g., for AoA protection)
 - Airframe produces moderate aerodynamic effects (i.e., requiring AoA and sideslip considerations)
- **Wing Borne Lift**
 - Airframe provides lift
 - Rotors are stopped or tilted forward



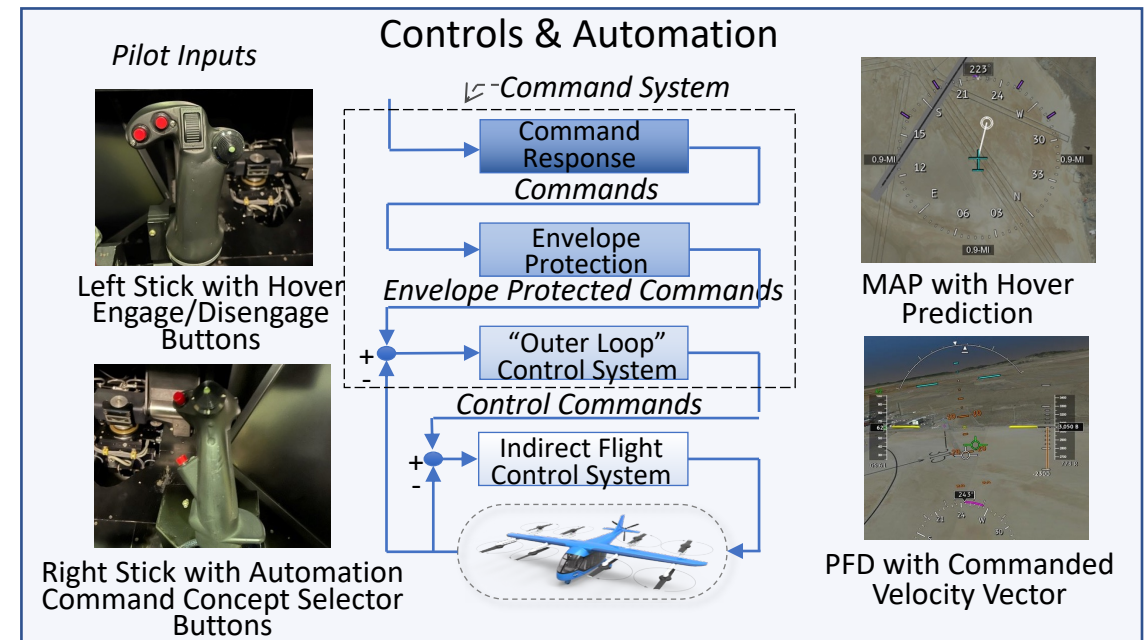
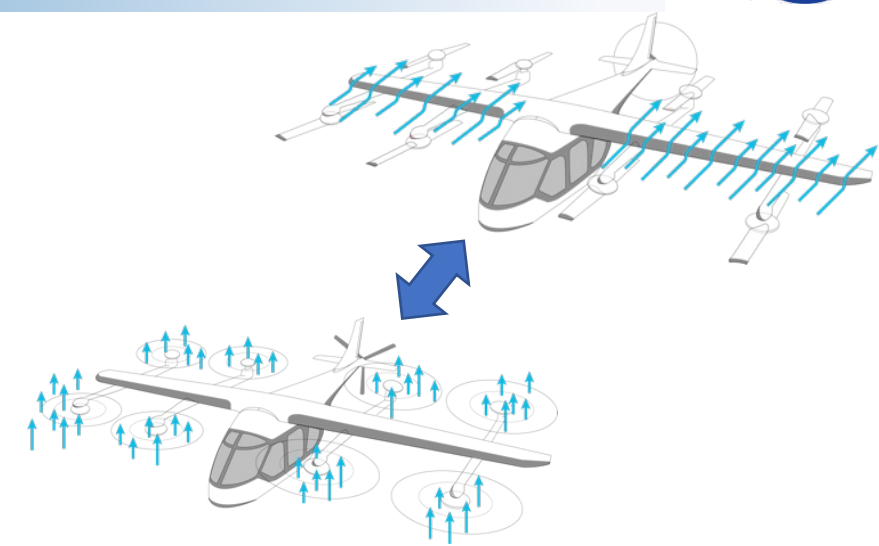
Inceptor Configuration 3
Unified
(IC-3)



Inceptor Configuration 3
Reverse Unified
(IC-3R)



- **Lift – Mode Transitions**
 - Thrust <> Semi-Thrust <> Semi-wing <> Wing Born lift source
- **Reference frames**
 - Earth/Airmass/Body frame
- **Command (CS) and Response Types (RT) and RT combinations**
 - e.g., CS: Rate vs. attitude
 - e.g., RT: Heading and altitude hold
- **Flight Control Modes**
 - Ground, Hover, Velocity
- **Pilot Interfaces beyond IFCS**
 - Information integration and alerting
- **Envelope protection**
 - Behavior at transitions



- Mission Task Elements (MTE) developed by the US Army for evaluating military rotorcraft. MTEs enable evaluation by mission rather than aircraft type or configuration.
- Focus on the defining the Mission/Operational Concept
 - Determine performance criteria
- Criteria do not change for the different vehicle configurations
- Criteria do not change for varying automation capabilities or configuration
 - Scalable from today's operational concept to m:n operations



Precision



Aggressiveness

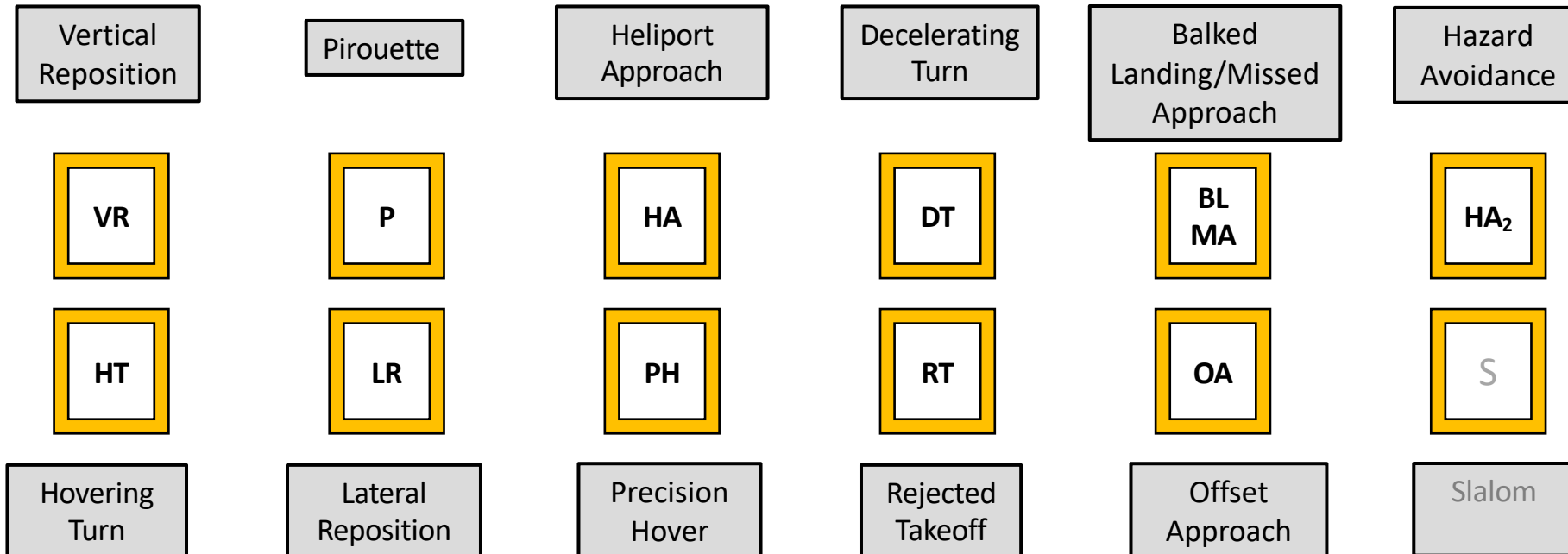
MTE	RE- QUIRED AGILITY	ROTORCRAFT CATEGORY				EXTER- NALLY SLUNG LOAD
		ATTACK	SCOUT	UTILITY	CARGO	
Tasks in GVE						
Hover	L	✓	✓	✓	✓	✓
Landing	L	✓	✓	✓	✓	
Slope Landing	L	✓	✓	✓	✓	
Hovering Turn	M	✓	✓	✓	✓	
Pirouette	M	✓	✓	✓	✓	
Vertical Maneuver	M	✓	✓	✓	✓	✓
Depart/Abort	M			✓	✓	✓
Lateral Reposition	M			✓	✓	✓
Slalom	M	✓	✓	✓	✓	
Vertical Remask	A	✓	✓			
Acceleration and Deceleration	A	✓	✓			
Sidestep	A	✓	✓			
Deceleration to Dash	A	✓	✓	✓		
Transient Turn	A	✓	✓	✓		
Pullup/Pushover	A	✓	✓	✓		
Roll Reversal	A	✓	✓	✓		
Turn to Target	T	✓	✓			
High Yo-Yo	T	✓	✓			
Low Yo-Yo	T	✓	✓			
Tasks in DVE						
Hover	L	✓	✓	✓	✓	✓
Landing	L	✓	✓	✓	✓	
Hovering Turn	L	✓	✓	✓	✓	
Pirouette	L	✓	✓	✓	✓	
Vertical Maneuver	L	✓	✓	✓	✓	✓
Depart/Abort	L			✓	✓	✓
Lateral Reposition	L			✓	✓	✓
Slalom	L	✓	✓	✓		
Acceleration and Deceleration	L	✓	✓			
Sidestep	L	✓	✓			
Tasks in IMC						
Decelerating Approach	L	✓	✓	✓	✓	✓
ILS Approach	L	✓	✓	✓	✓	
Missed Approach	L	✓	✓	✓	✓	
Speed Control	L	✓	✓	✓	✓	

MTE maneuvers, ADS-33E-PRF (1996)

Flight Test Tasks (FTT)



- Catalog of FTM developed for military evaluation of IFCS and advanced automated control as an FAA Means of Compliance.
- Maneuvers and Performance Criteria are based on expected Concept of Operations
 - Do not change for vehicle configuration or automation
- Maneuvers are designed to:
 - Expose deficiencies in aircraft controllability
 - Be agnostic to aircraft and automation configuration (including inceptors)
 - Stress test aircraft and automation configuration in operationally representative maneuvers
- Performance criteria are designed for expected:
 - Environmental conditions



Automation Enabled Pilot Study 1 (AEP-1)

- **Study Requirements:**

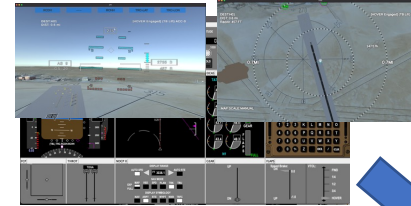
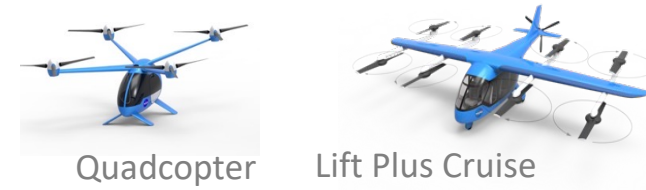
- Simulation environment for AAM operations (Out-The-Window, Inceptors, Cockpit Displays)
- Industry representative VTOL aircraft and aircraft automation configurations

- **Method**

- Remote capability required during the pandemic including new OTW for home testing
- Automation framework to characterize automation configurations
- Fixed-Base simulator for development test and training
- Evaluation in Vertical Motion Simulator (VMS)

- **Data Collection Participants**

- 6 formally trained and experienced test pilots (all had VTOL and powered lift experience)
- 4 from extensive rotary wing background
- 2 from fixed wing background



Desktop Development

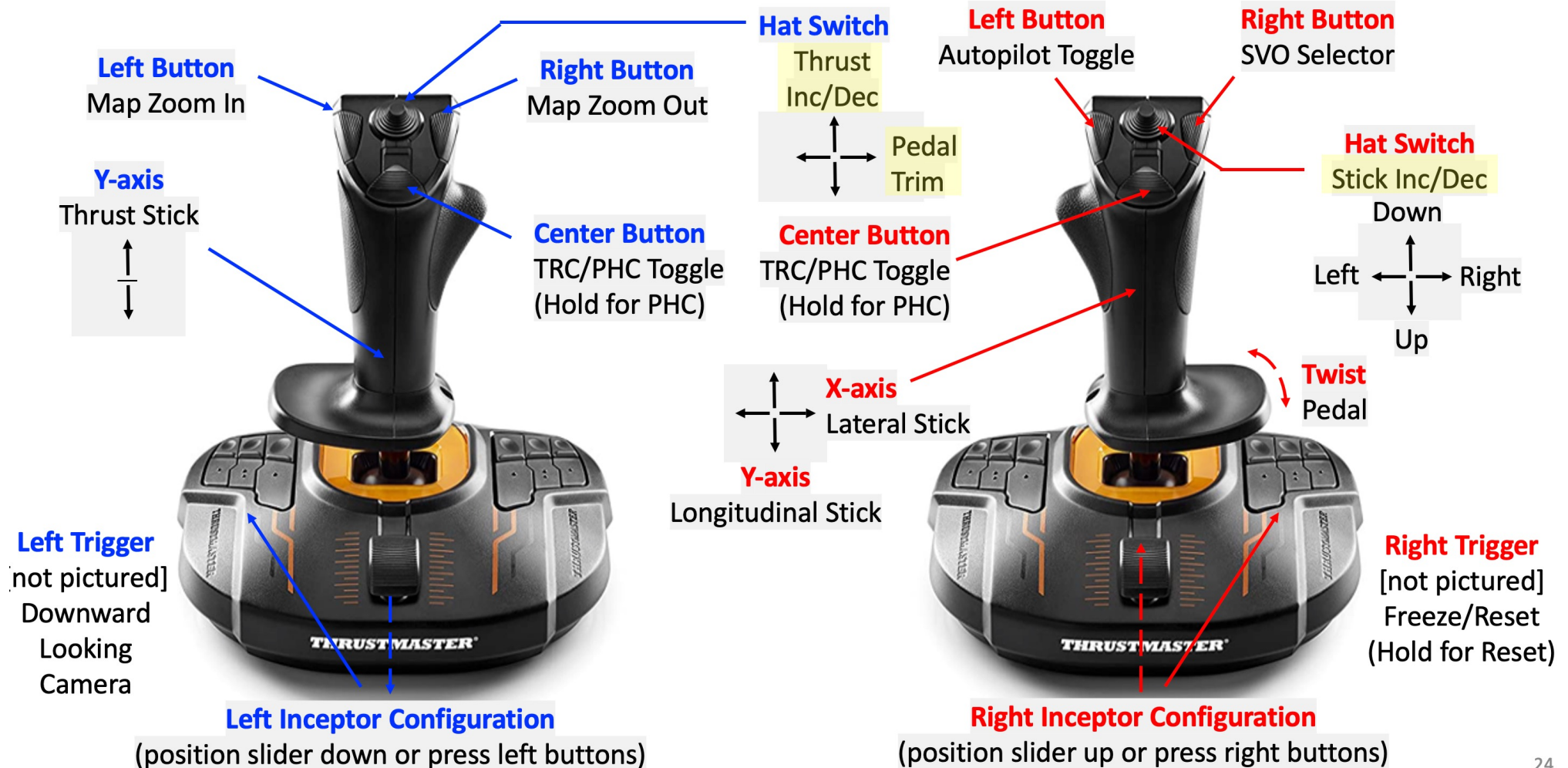


Fixed-Base
Development and Test



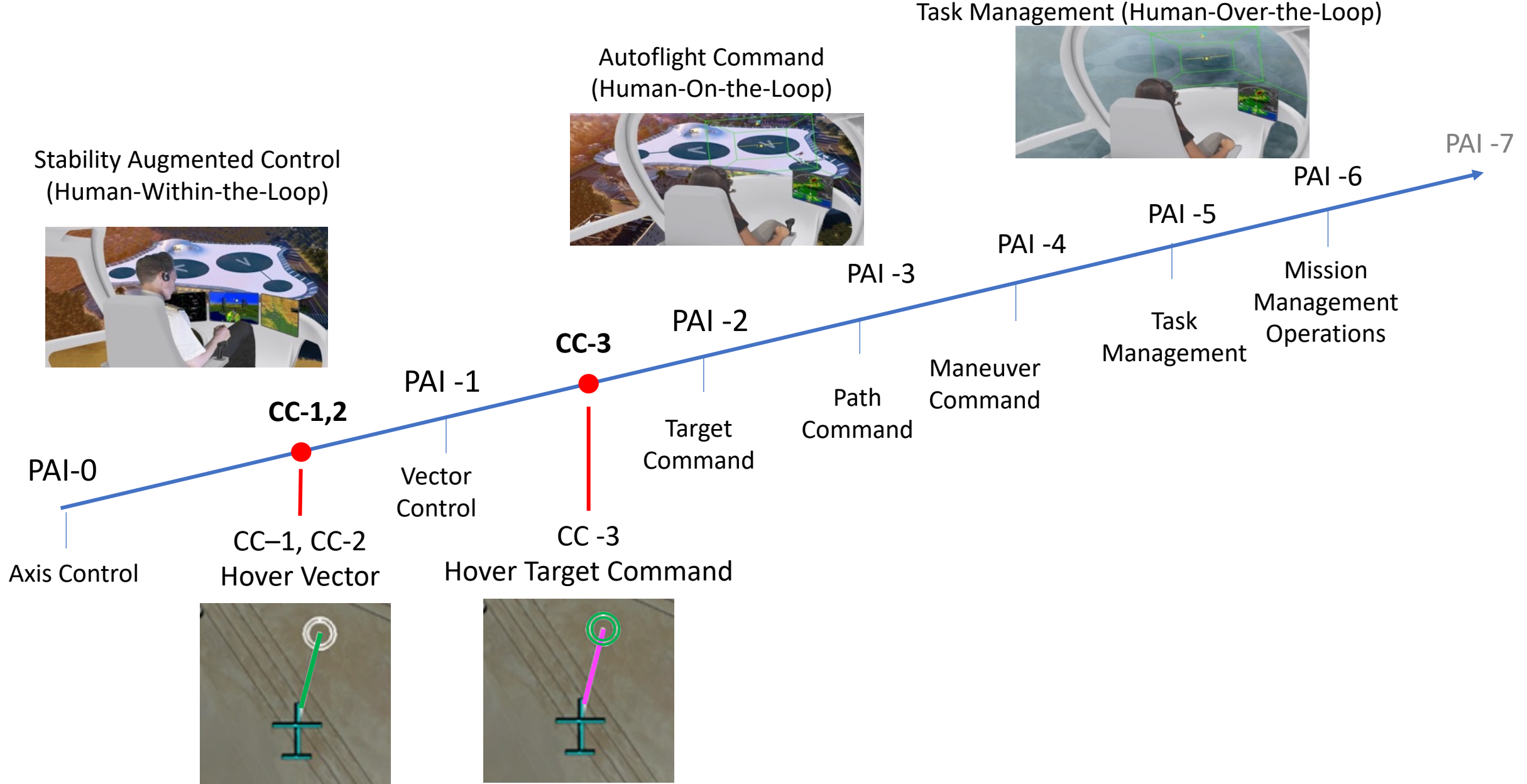
Thrustmaster T16000 Dual Inceptors (Remote Capability)

(Rudder pedals not shown in slide)



Used in conjunction with Mac Computers

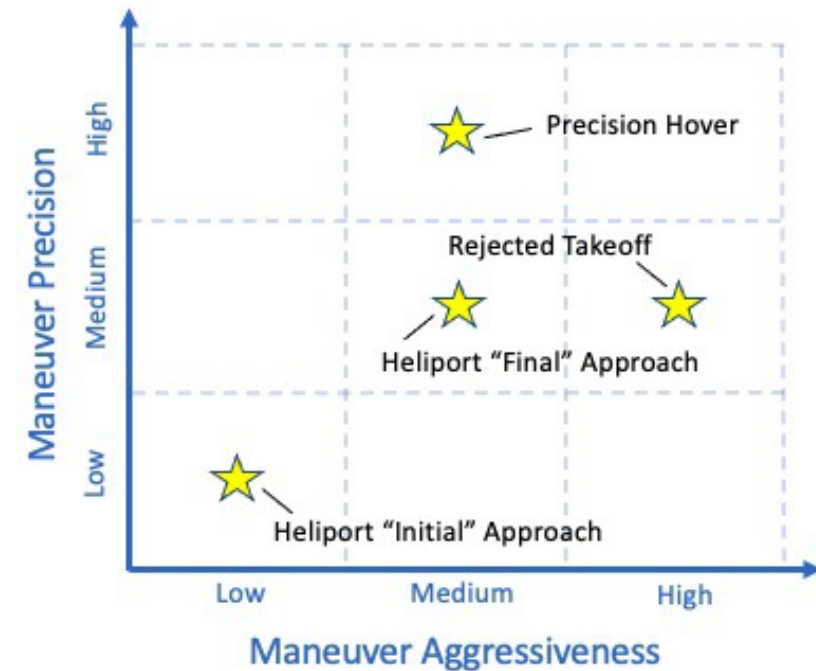
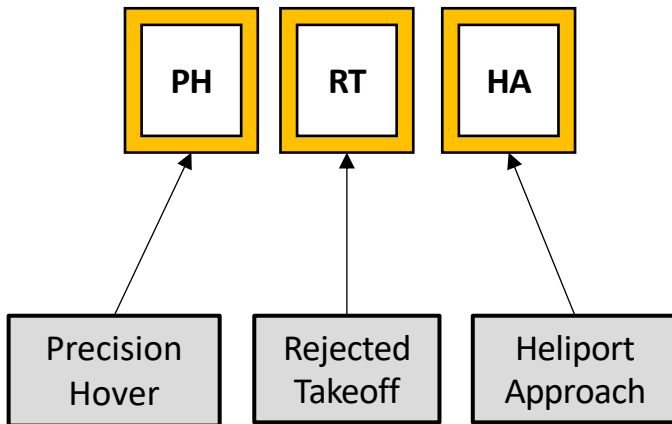
AEP – 1 Investigation Example



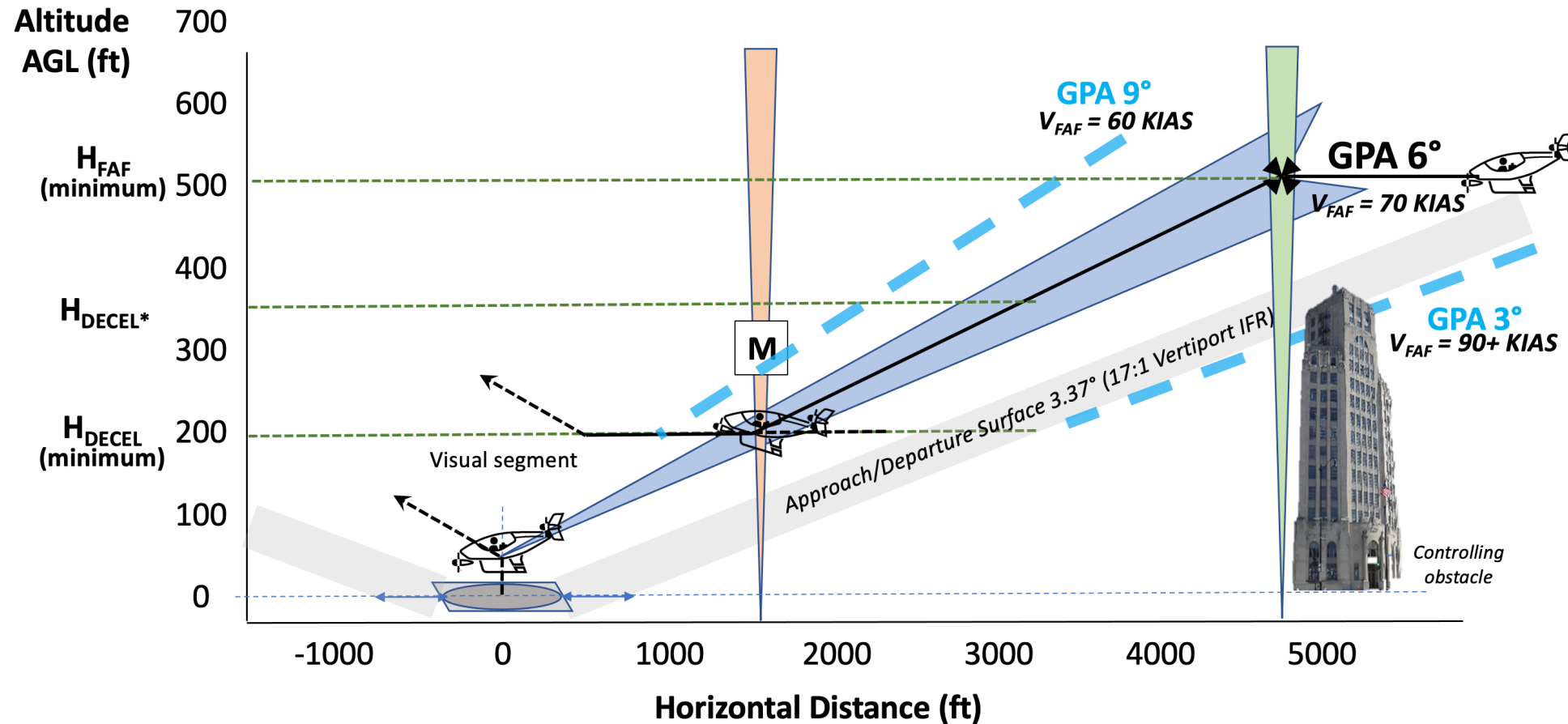
AEP-1 Study Results

Test points

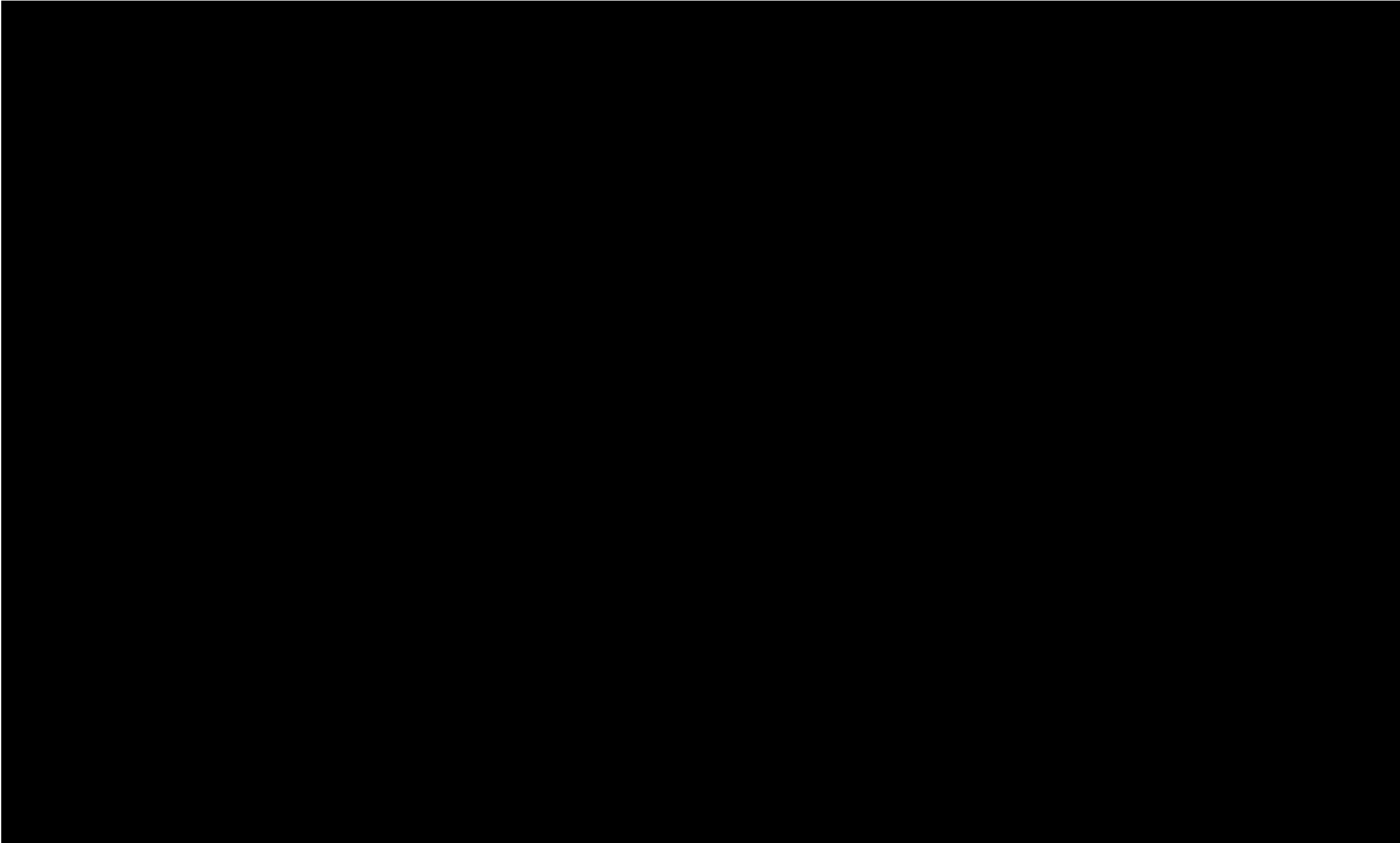
- 102 data points collected
 - 3 industry representative Automation Configurations (Command Concepts -1, -2, -3)
 - 3 Maneuvers (Precision Hover, Rejected Takeoff, Heliport Approach)
 - 2 wind conditions (calm, 17 knot wind)



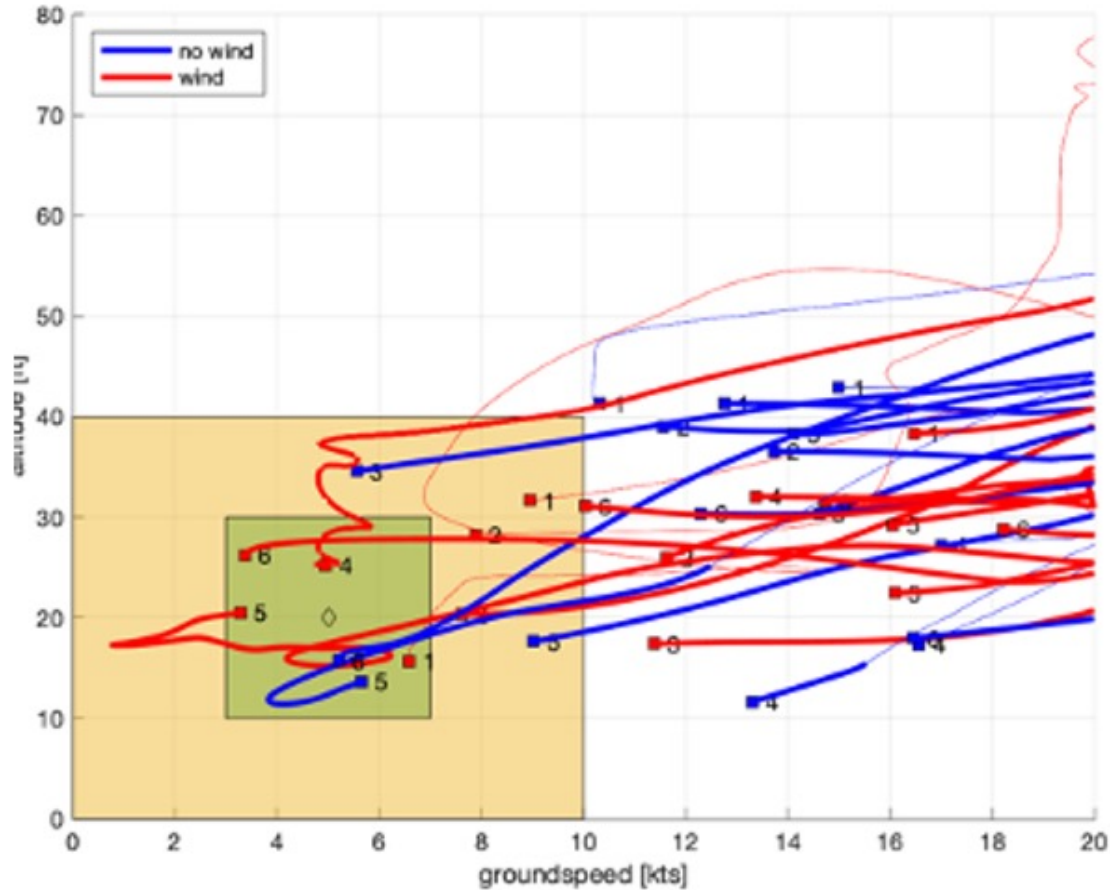
Approach Procedure



Heliport Approach



AEP -1 Heliport Approach Results

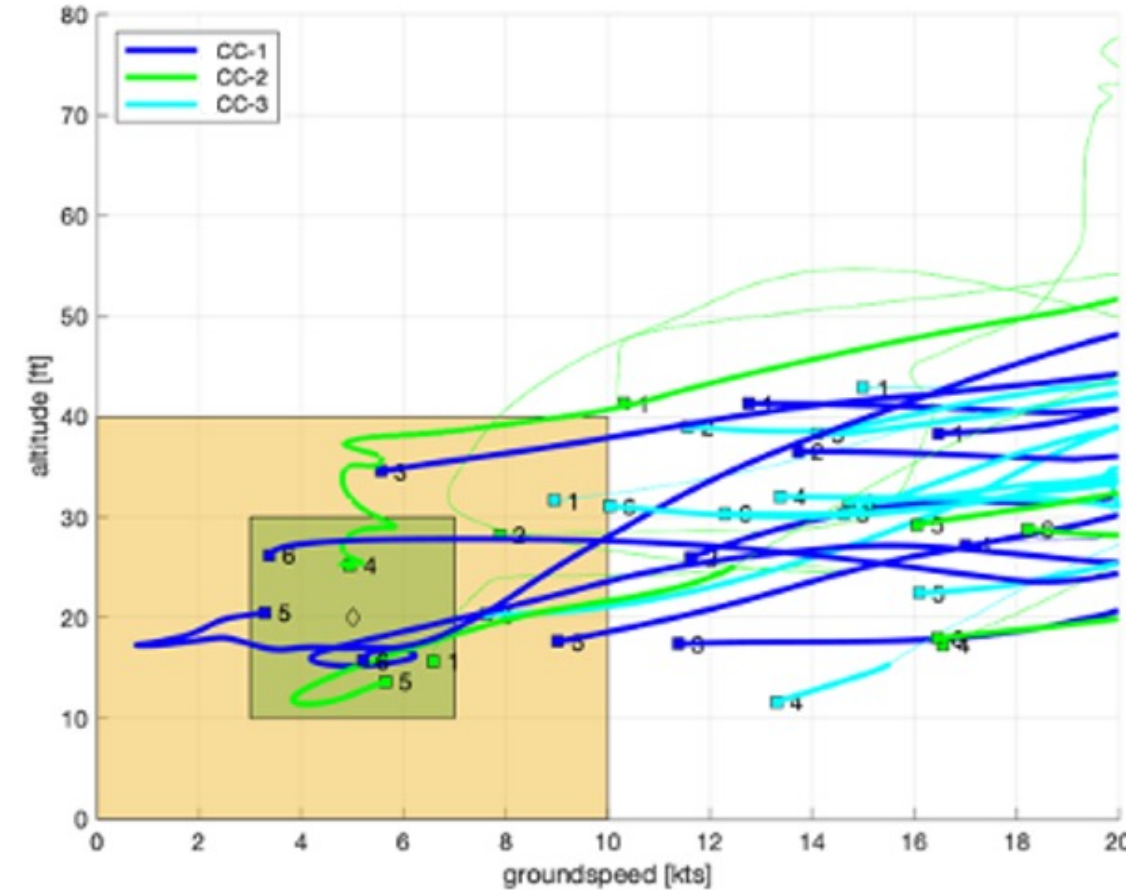


CC-2

“had to learn to get out of the way of the automation...”

“Automation changes the task”

“had to change inceptor strategy during the approach, once TRC mode engaged”



CC-3

“desired performance but I feel like it was luck, it was uncontrollable through the transition”

“ couldn’t predict the behavior of the aircraft...”



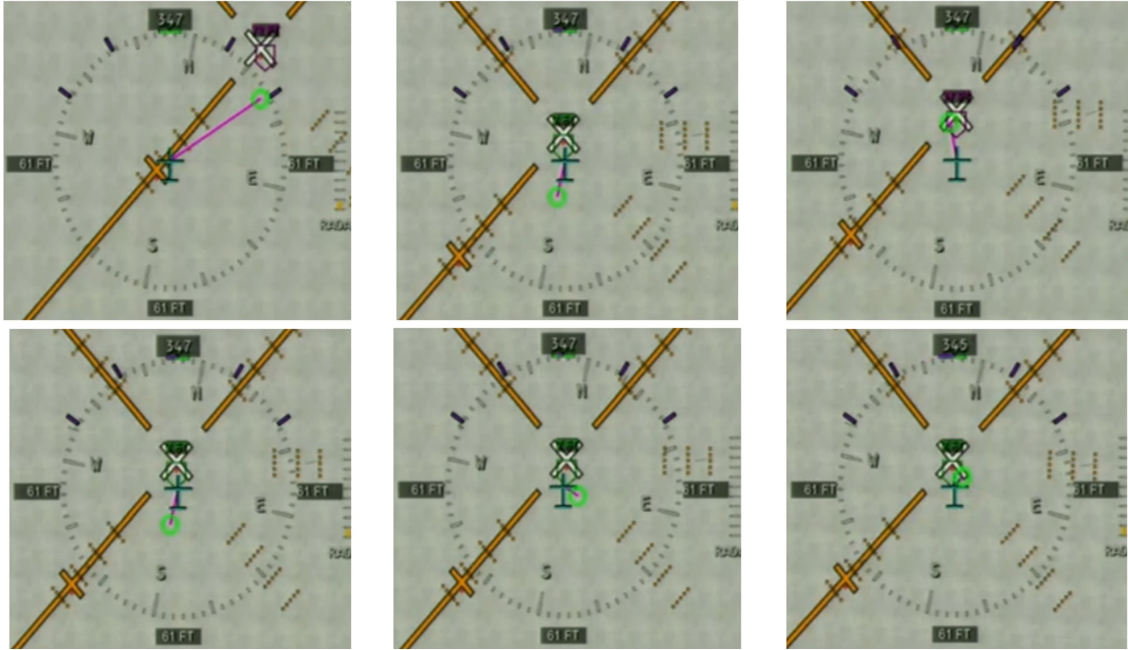
Bell XV-3 (experimental tilt rotor)

"A primary deficiency concerned the multiplicity of controls the pilot was required to manipulate for flightpath and airspeed control during the deceleration to hover, particularly under instrument meteorological conditions"

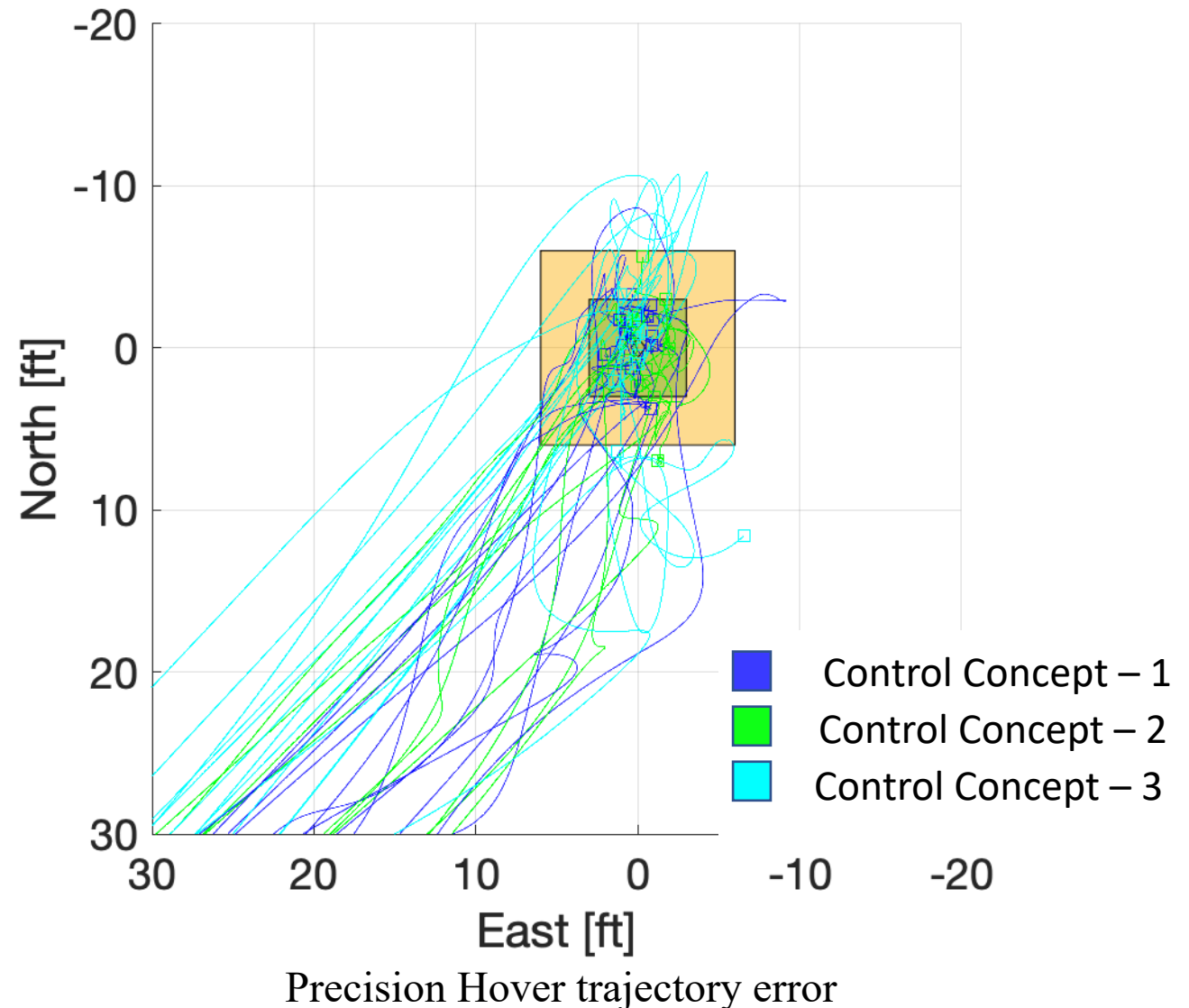
Precision Hover



Precision Hover Results (Automation Condition)



- Winds had little impact on automation
- CC-3 added lag to create a handling deficiency
- CC-3 quote
 - “Not possible to meet the performance criteria without using the display...”



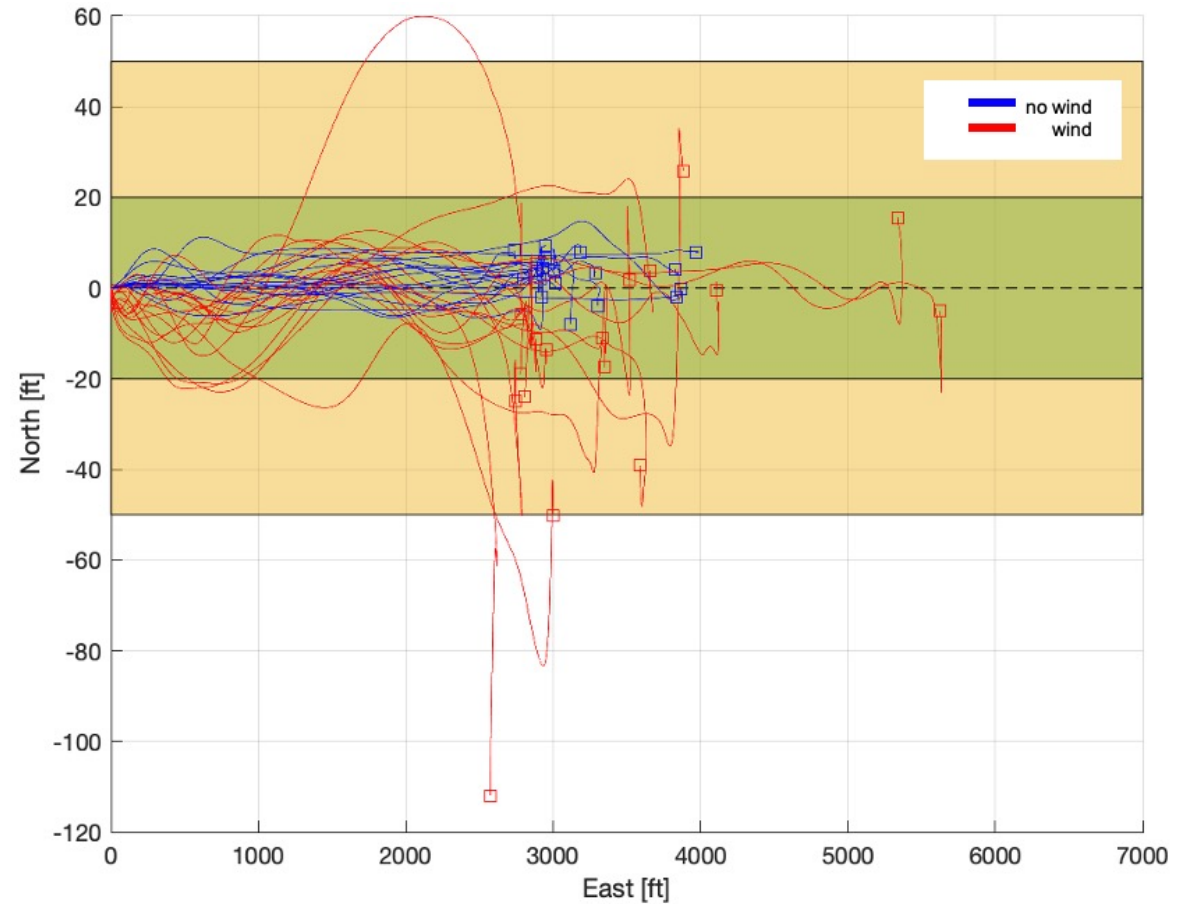
Rejected Takeoff



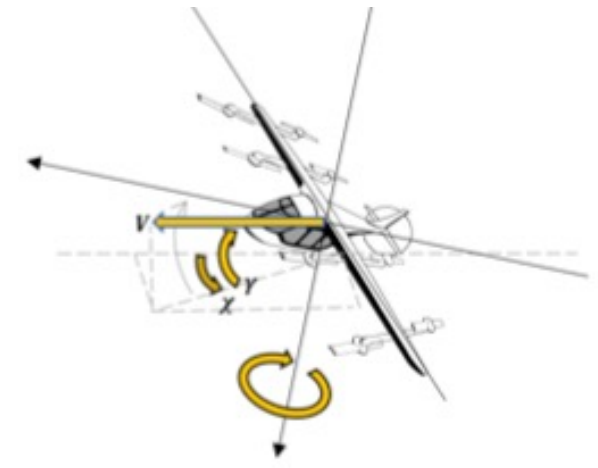
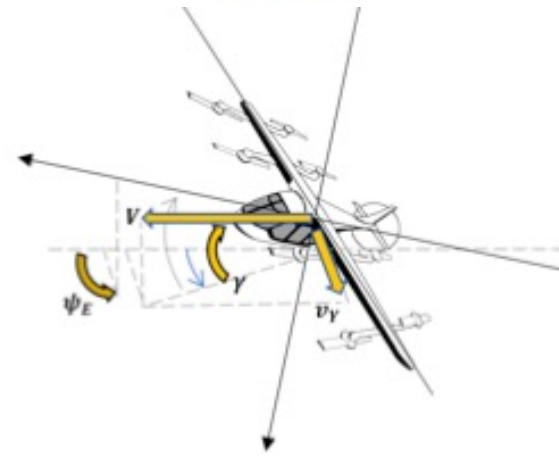
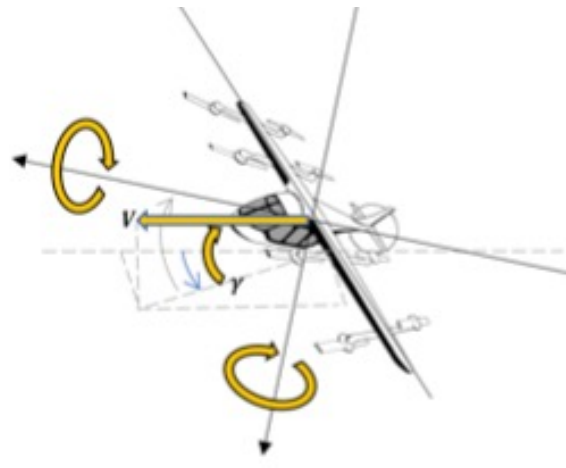
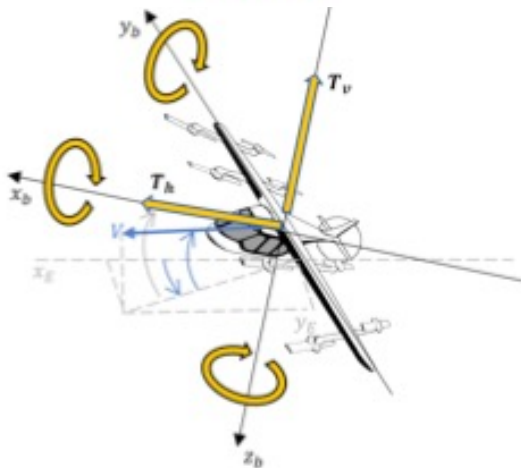
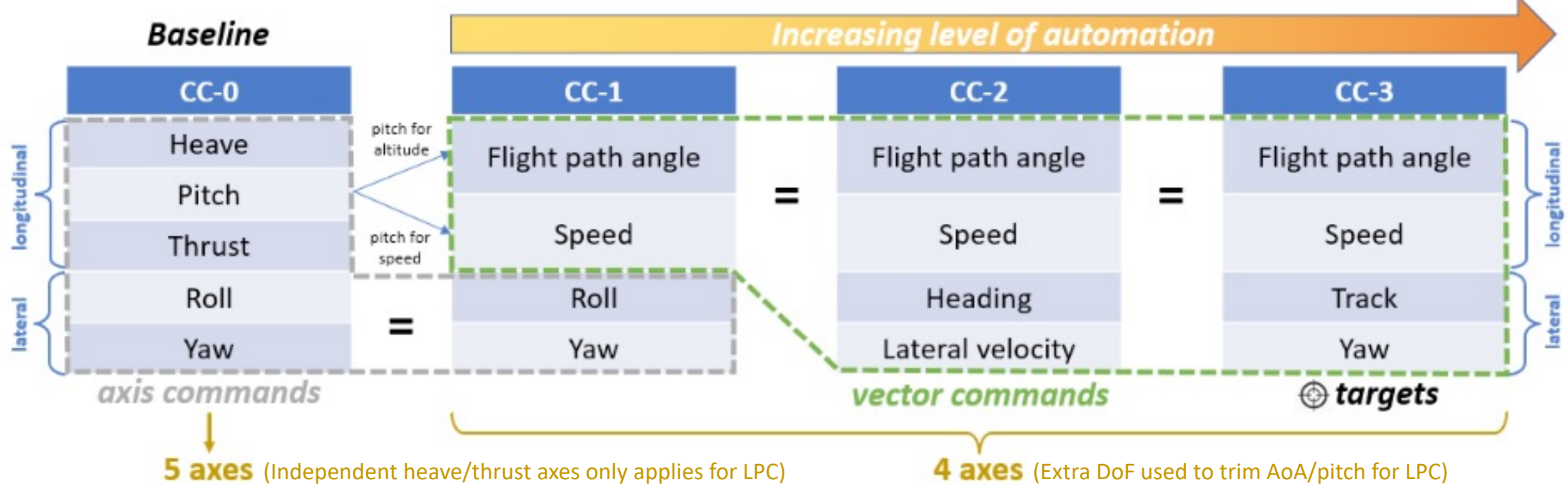
Autopilot flying Rejected Takeoff in crosswind

Rejected Takeoff (Wind Condition)

- Winds were a challenge in all automation configurations, due to vehicle limitations
- Quotes
 - “This is a completely different task with winds”
 - “My company’s aircraft may struggle with this maneuver”



Command Concepts



Lift Plus Cruise (LPC) Concept Vehicle

The RVLТ turboelectric Lift Plus Cruise (LPC) concept model was designed and developed using the NASA Design and Analysis of Rotorcraft (NDARC) tool.

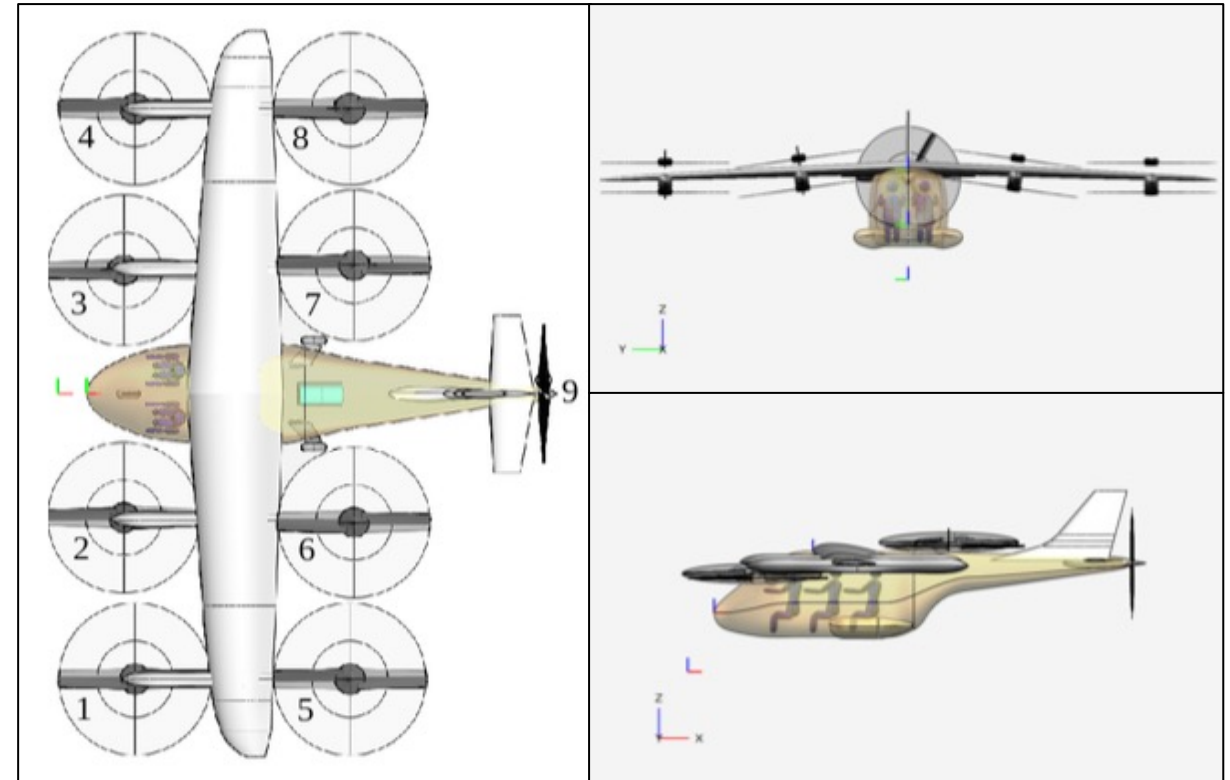
Vehicle Design

- Vehicle Configuration

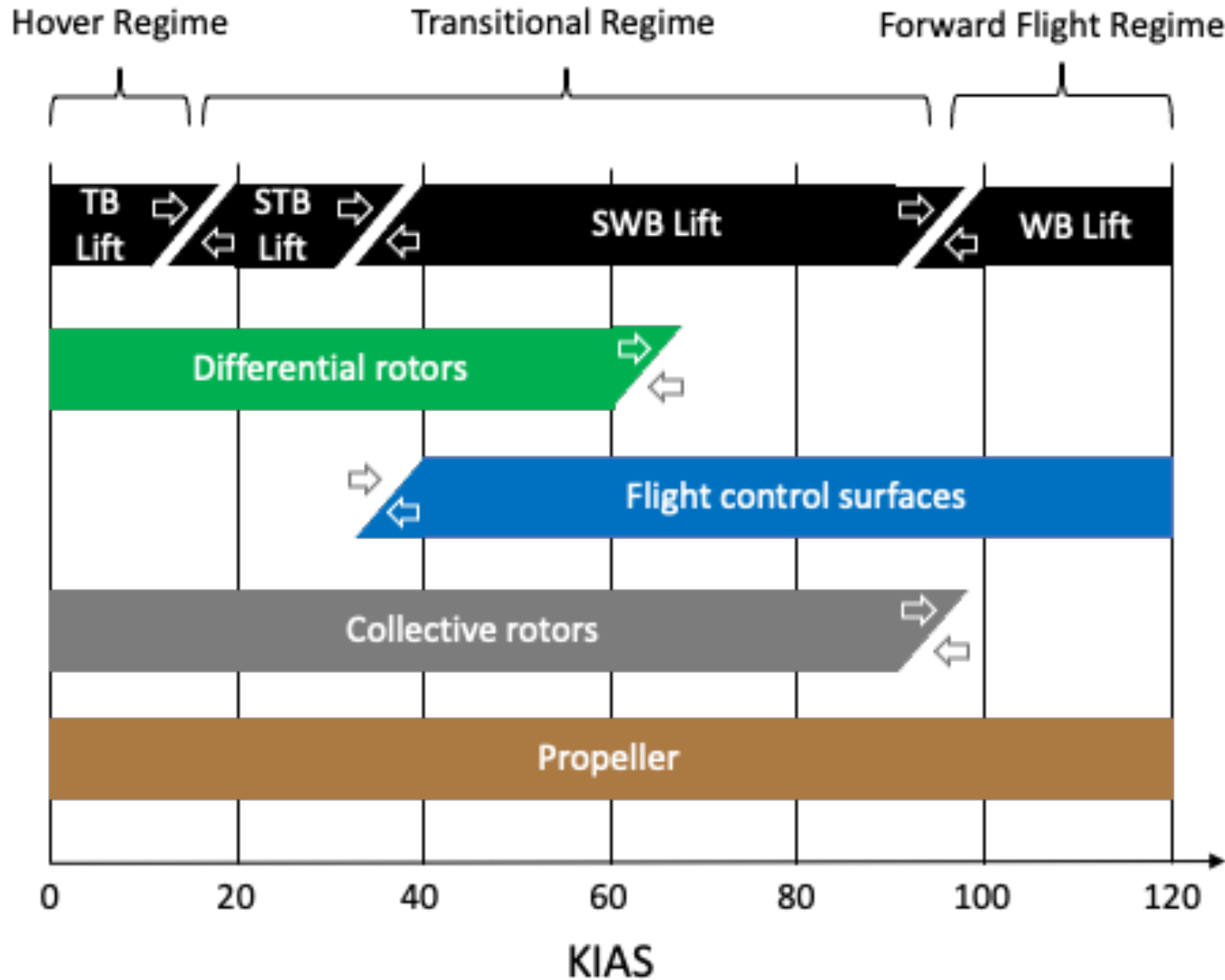
- Designed Gross Weight = 6013 lbs
- Payload = 1200 lbs
- 8 RPM controlled lifting rotors
- 1 collective controlled pusher propeller
- 2 ailerons, 1 elevator, 1 rudder

- Performance Parameters

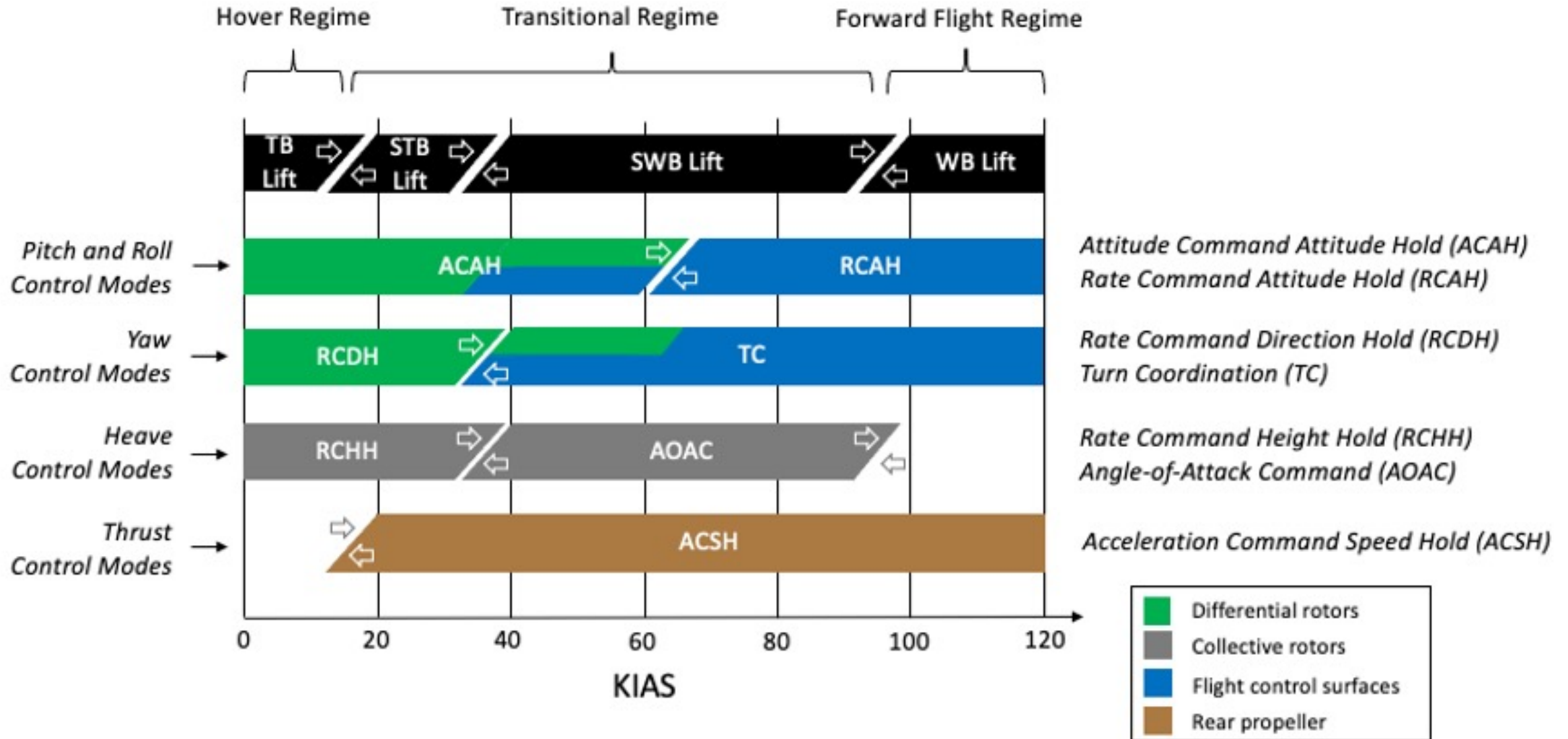
- Range = 50nm
- Best endurance speed (@ 6,000 ft) = 90 kts
- Best range speed (@ 6,000 ft) = 122 kts
- Maximum speed (@ 6,000 ft) = 123 kts



LPC Control Allocation Schedule



LPC Control Mode Schedule



LPC Command Concept 0 (CC-0)

CC-0	Collective Lever	Thrust Lever	Pedal	Longitudinal Stick	Lateral Stick
Hover (0-20 KGS)	ALT Rate Cmd ALT Hold	---	HDG Rate Cmd HDG Hold Sideslip Cmd Sideslip Hold	Lon Rate Cmd Lon Posn Hold	Lat Rate Cmd Lat Posn Hold
TB Lift (0-20 KIAS)	(Heave Cmd)	(Thrust Cmd)		Pitch Cmd Pitch Hold	Bank Cmd Bank Hold
STB Lift (15-40 KIAS)					
SWB Lift (35-100 KIAS)				Pitch Rate Cmd Pitch Hold	Bank Rate Cmd Bank Hold
WB Lift (90-120 KIAS)					

Axes of Control: Heave Axis Thrust Axis Yaw Axis Pitch Axis Roll Axis
--

LPC Command Concept 1 (CC-1)

CC-1	(Auto Trim)	Thrust Stick	Pedal	Longitudinal Stick	Lateral Stick
Hover (0-20 KGS)	↑ (Pitch Trim) ↓	Lon Rate Cmd Lon Posn Hold	HDG Rate Cmd HDG Hold	ALT Rate Cmd ALT Hold	Lat Rate Cmd Lat Posn Hold
TB Lift (0-20 KIAS)		V/S Cmd V/S Hold		Bank Cmd Bank Hold	
STB Lift (15-40 KIAS)		SPD Rate Cmd SPD Hold	Sideslip Cmd Sideslip Hold		FPA Rate Cmd FPA Hold
SWB Lift (35-100 KIAS)	(AoA Trim)	↓			
WB Lift (90-120 KIAS)	- - -				

Axes of Control: Heave Axis Thrust Axis Yaw Axis Pitch Axis Roll Axis

LPC Command Concept 2 (CC-2)

CC-2	(Auto Trim)	Thrust Stick	Pedal Stick	Longitudinal Stick	Lateral Stick
Hover (0-20 KGS)	↑ (Pitch Trim) ↓	Lon Rate Cmd Lon Posn Hold	Lat Rate Cmd Lat Posn Hold	ALT Rate Cmd ALT Hold	↑ HDG TGT Rate Cmd HDG TGT Hold ↓
TB Lift (0-20 KIAS)		↑ SPD Rate Cmd SPD Hold ↓	↑ Lat Rate Cmd Lat Rate Hold ↓	V/S Cmd V/S Hold	
STB Lift (15-40 KIAS)				FPA Rate Cmd FPA Hold	
SWB Lift (35-100 KIAS)	(AoA Trim)				
WB Lift (90-120 KIAS)	---				

Axes of Control: Heave Axis Thrust Axis Yaw Axis Pitch Axis Roll Axis

LPC Command Concept 3 (CC-3)

CC-3	(Auto Trim)	Thrust Stick	Pedal	Longitudinal Stick	Lateral Stick
Hover (0-20 KGS)	↑ (Pitch Trim) ↓	Lon TGT Rate Cmd Lon TGT Hold	HDG Rate Cmd HDG Hold	ALT TGT Rate Cmd ALT TGT Hold	Lat TGT Rate Cmd Lat TGT Hold
TB Lift (0-20 KIAS)		↑ SPD TGT Rate Cmd SPD TGT Hold ↓		V/S TGT Rate Cmd V/S TGT Hold	LatVel TGT Rate Cmd LatVel TGT Hold
STB Lift (15-40 KIAS)				V/S TGT Rate Cmd FPA TGT Hold	LatVel TGT Rate Cmd TRK TGT Hold
SWB Lift (35-100 KIAS)	(AoA Trim)	↓	Sideslip Cmd Sideslip Hold	FPA TGT Rate Cmd FPA TGT Hold	TRK TGT Rate Cmd TRK TGT Hold
WB Lift (90-120 KIAS)	- - -				

Axes of Control: Heave Axis Thrust Axis Yaw Axis Pitch Axis Roll Axis

LPC Command Concept Response Types

CC-0	Collective Lever	Thrust Lever	Pedal	Longitudinal Stick	Lateral Stick
Hover (0-20 KGS)	ALT Rate Cmd ALT Hold	---	HDG Rate Cmd HDG Hold	Lon Rate Cmd Lon Posn Hold	Lat Rate Cmd Lat Posn Hold
TB Lift (0-20 KIAS)	(Heave Cmd)	(Thrust Cmd)		Pitch Cmd Pitch Hold	Bank Cmd Bank Hold
STB Lift (15-40 KIAS)					
SWB Lift (35-100 KIAS)				Sideslip Cmd Sideslip Hold	Pitch Rate Cmd Pitch Hold
WB Lift (90-120 KIAS)					

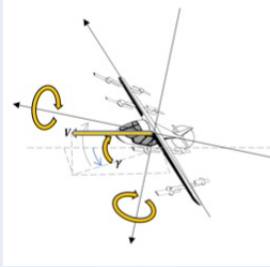
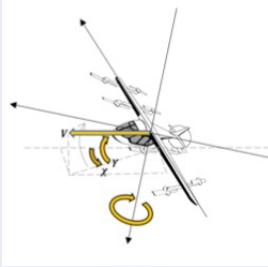
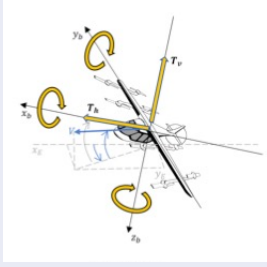
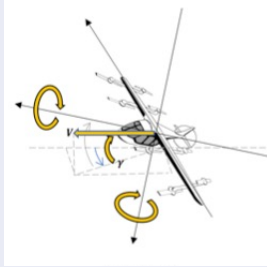
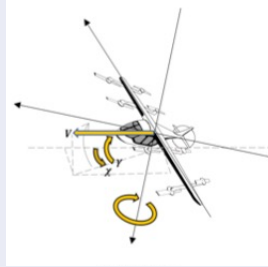
CC-2	(Auto Trim)	Thrust Stick	Pedal Stick	Longitudinal Stick	Lateral Stick
Hover (0-20 KGS)	↑	Lon Rate Cmd Lon Posn Hold	Lat Rate Cmd Lat Posn Hold	ALT Rate Cmd ALT Hold	↑
TB Lift (0-20 KIAS)	(Pitch Trim)	↑	↑	V/S Cmd V/S Hold	↑
STB Lift (15-40 KIAS)	↓	SPD Rate Cmd SPD Hold	Lat Rate Cmd Lat Rate Hold	FPA Rate Cmd FPA Hold	HDG TGT Rate Cmd HDG TGT Hold
SWB Lift (35-100 KIAS)	(AoA Trim)	↓	↓		↓
WB Lift (90-120 KIAS)	---				

CC-1	(Auto Trim)	Thrust Stick	Pedal	Longitudinal Stick	Lateral Stick
Hover (0-20 KGS)	↑ (Pitch Trim)	Lon Rate Cmd Lon Posn Hold	HDG Rate Cmd HDG Hold	ALT Rate Cmd ALT Hold	Lat Rate Cmd Lat Posn Hold
TB Lift (0-20 KIAS)		↑		V/S Cmd V/S Hold	Bank Cmd Bank Hold
STB Lift (15-40 KIAS)	↓	SPD Rate Cmd SPD Hold	Sideslip Cmd Sideslip Hold	FPA Rate Cmd FPA Hold	
SWB Lift (35-100 KIAS)	(AoA Trim)	↓		Bank Rate Cmd Bank Hold	
WB Lift (90-120 KIAS)	---				

CC-3	(Auto Trim)	Thrust Stick	Pedal	Longitudinal Stick	Lateral Stick
Hover (0-20 KGS)	↑	Lon TGT Rate Cmd Lon TGT Hold	HDG Rate Cmd HDG Hold	ALT TGT Rate Cmd ALT TGT Hold	Lat TGT Rate Cmd Lat TGT Hold
TB Lift (0-20 KIAS)	(Pitch Trim)	↑		V/S TGT Rate Cmd V/S TGT Hold	LatVel TGT Rate Cmd LatVel TGT Hold
STB Lift (15-40 KIAS)	↓	SPD TGT Rate Cmd SPD TGT Hold	Sideslip Cmd Sideslip Hold	V/S TGT Rate Cmd FPA TGT Hold	LatVel TGT Rate Cmd TRK TGT Hold
SWB Lift (35-100 KIAS)	(AoA Trim)	↓		FPA TGT Rate Cmd FPA TGT Hold	TRK TGT Rate Cmd TRK TGT Hold
WB Lift (90-120 KIAS)	---				

Axes of Control:
 Heave Axis
 Thrust Axis
 Yaw Axis
 Pitch Axis
 Roll Axis

Simulation Test Matrix

	FAAVE-1 (June 2021)		FAAVE-2 (June 2022)		
Vehicles	 				
Command Concepts	CC-1 	CC-3 	CC-0 	CC-1 	CC-3 
HQTEs (wind on/off)	Hover Focused HQTEs VR HT LR P PH HA S		Approach Focused HQTEs Transition Focused HQTEs HA OA BL MA RT DT HA₂		

AEP-1 (February 2022): Vehicle=LPC, Command Concepts=CC-1, CC-2, CC-3; HQTEs=HA, PH, RT

Kaneshige, J., Lombaerts, T., Shish, K., Feary, M., "Control Concepts for a Lift Plus Cruise Electric Vertical Takeoff and Landing Vehicle", AIAA 2023-TBD, June 2023.

- Industry representative aircraft, interface and automation concepts
 - See Kaneshige et al. 2023 for Flight Technical Performance
- “Flyable but not certifiable”
 - Many task – inceptor combinations were not certifiable as implemented
- Precision Hover
 - CC-3 (highest automation condition) “Not possible to meet the performance criteria without using the display...”
- Rejected Takeoff
 - Automation could not keep up in the wind condition as the aircraft had marginal controllability and the automation could not predict the wind effects
 - Some pilots flying manually could reach desired performance
- Heliport Approach
 - “couldn’t predict the behavior of the aircraft...”
 - “had to learn to get out of the way of the automation...”

Thank You

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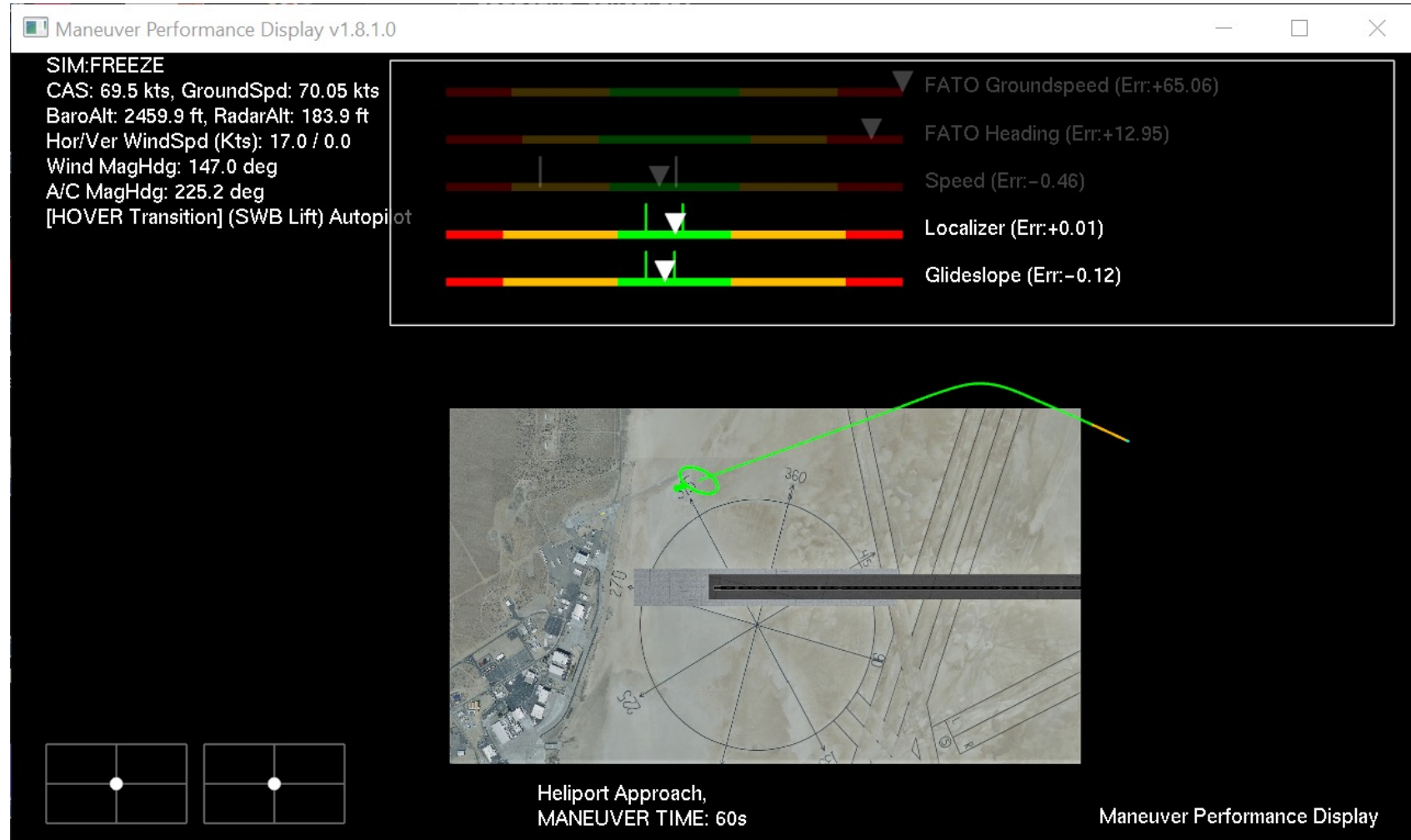
thomas.lombaerts@nasa.gov

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Loran.Haworth@nasa.gov

EXTRA SLIDES

Performance Evaluation



Heliport Approach (Automation Condition)

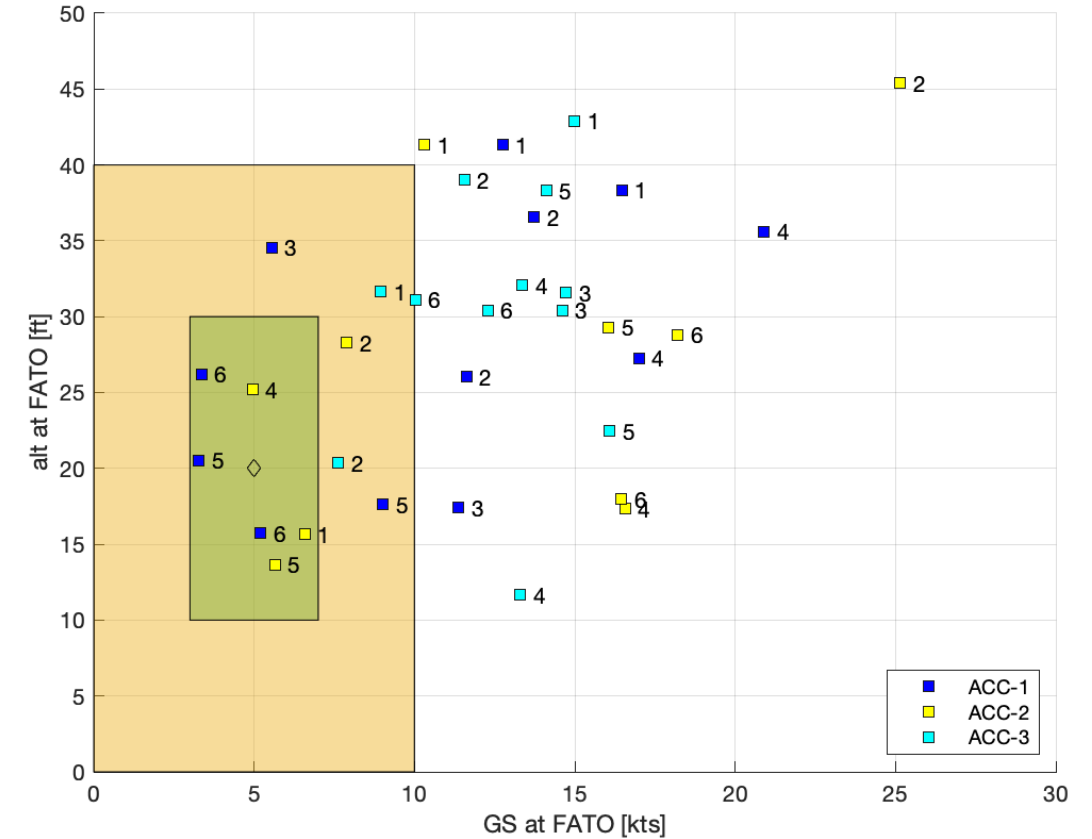
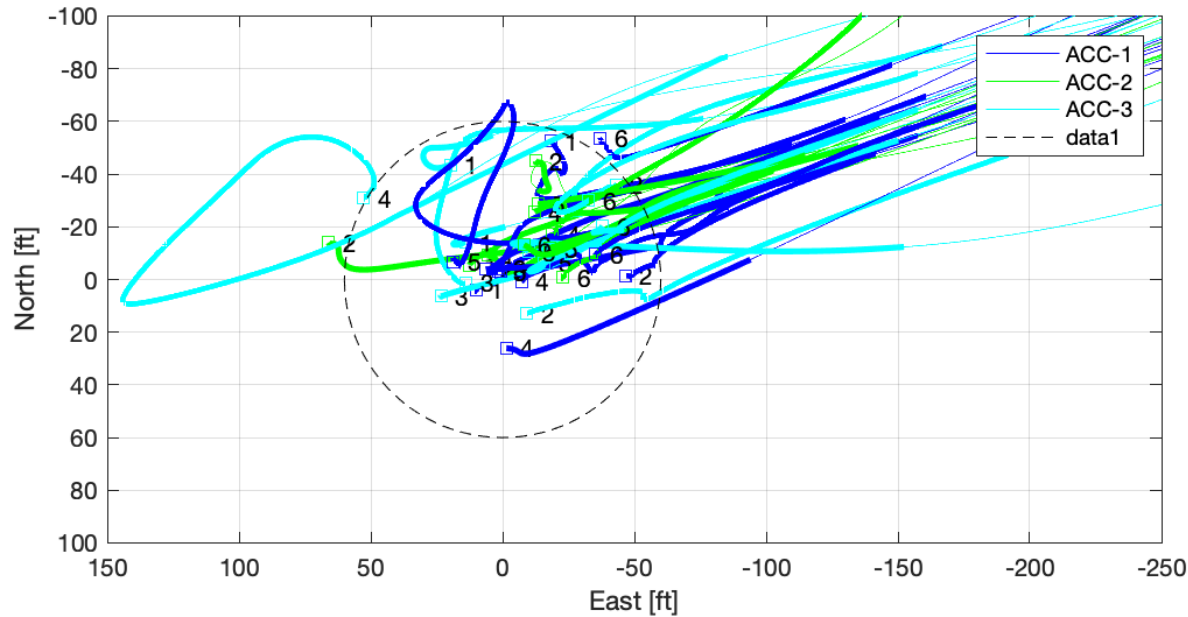


Figure . Distance from FATO boundary at end of Heliport Approach (automation configuration)

- Aircraft, automation concepts developed and used in the study were industry representative
 - Feedback from industry test pilots with similar aircraft
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“had to learn to get out of the way of the automation...”

“Automation changes the task”

“negative habit transfer...”

CC -2

“had to change inceptor strategy during the approach, once TRC mode engaged”

CC-3

“desired performance but I feel like it was luck, it was uncontrollable through the transition”

“ couldn’t predict the behavior of the aircraft...”

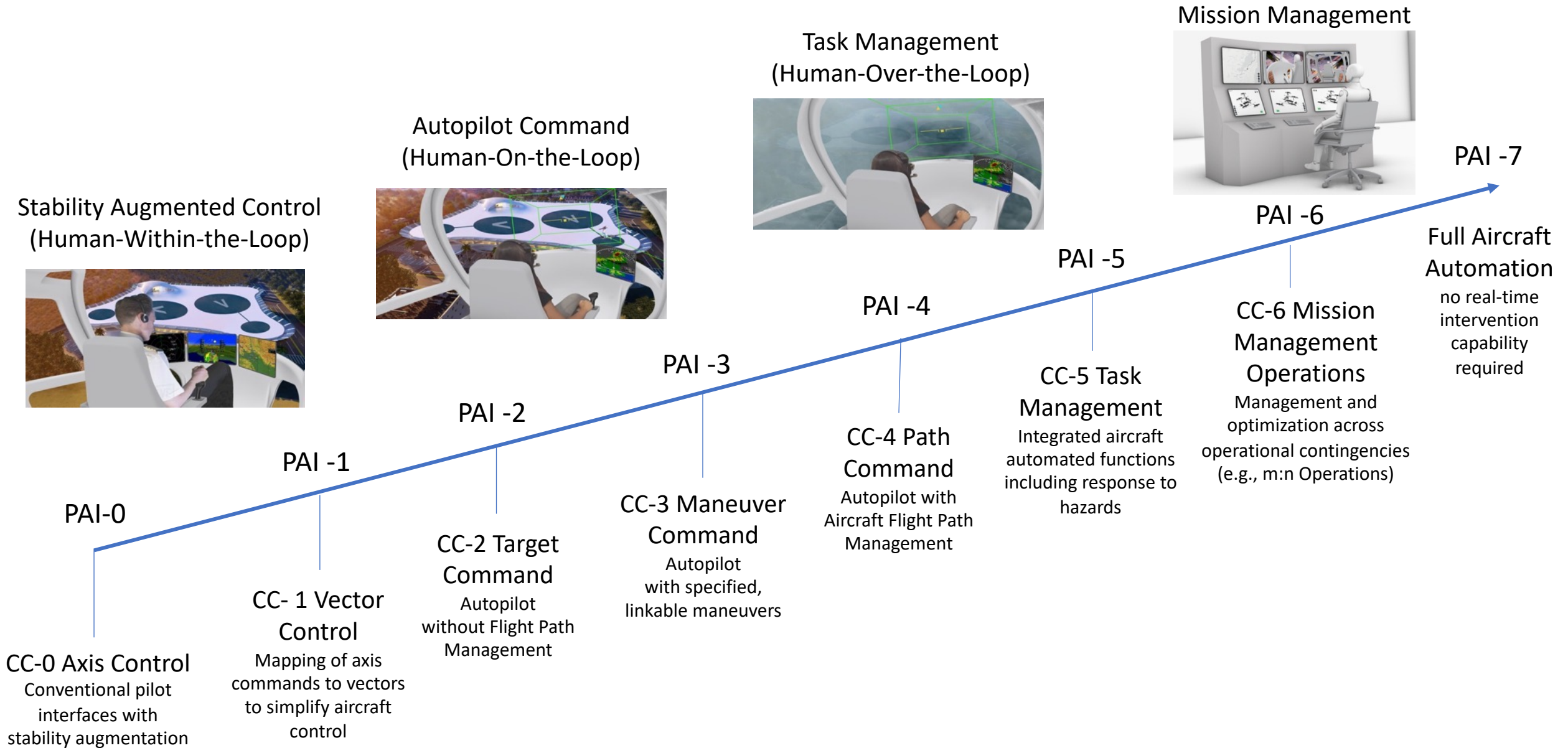


Precision

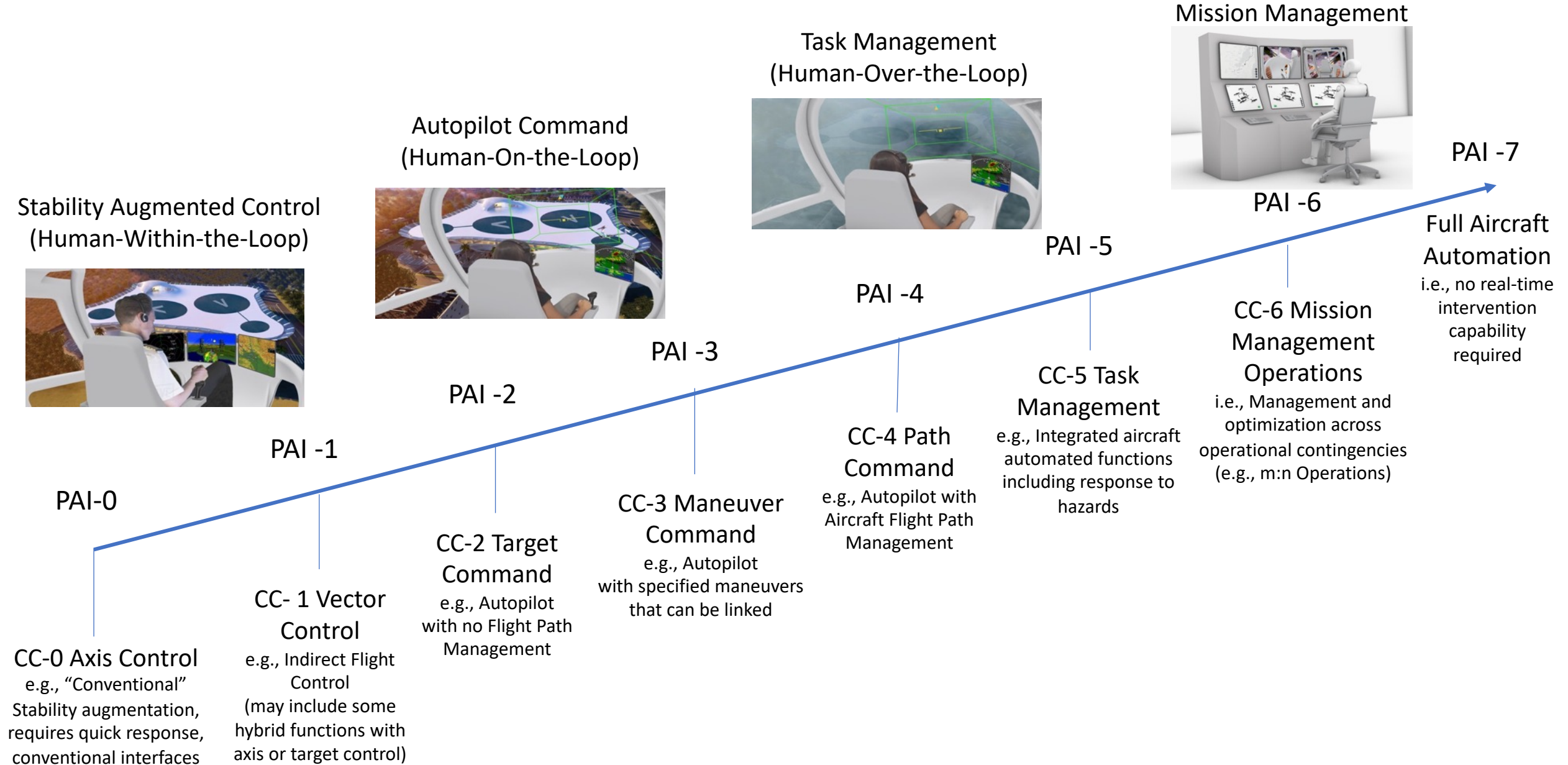


Aggressiveness

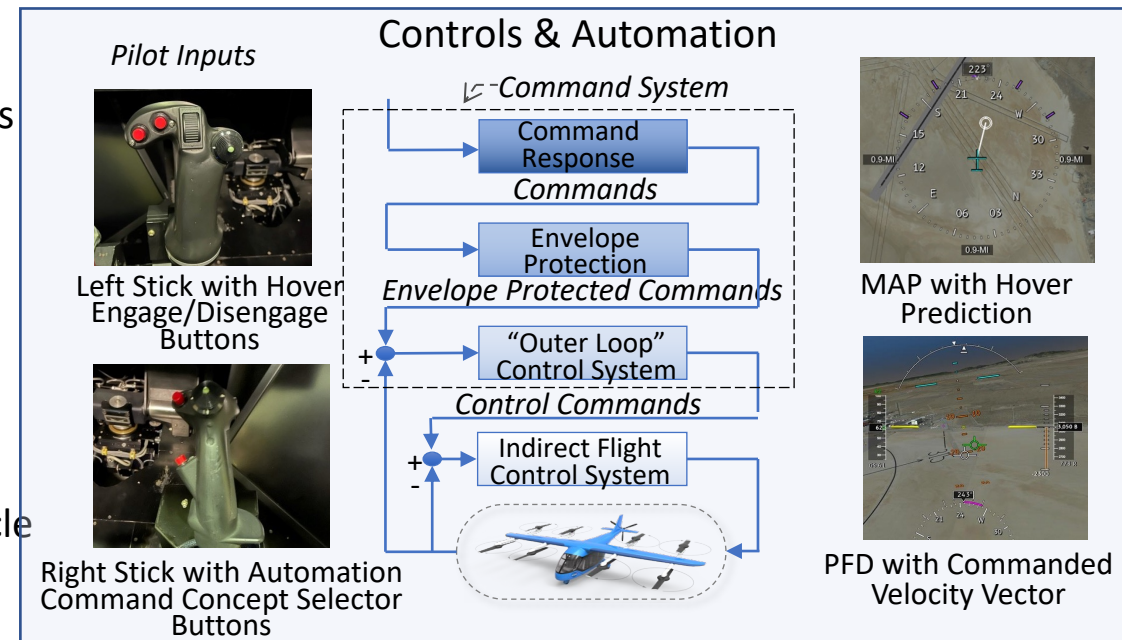
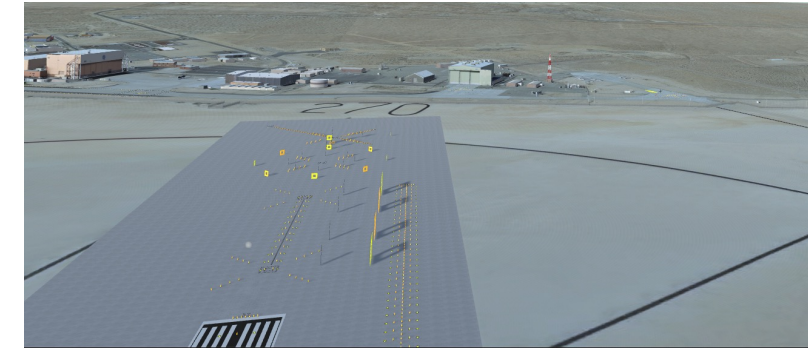
Pilot Automation Interaction (PAI) Framework



Pilot Automation Interaction (PAI) Framework



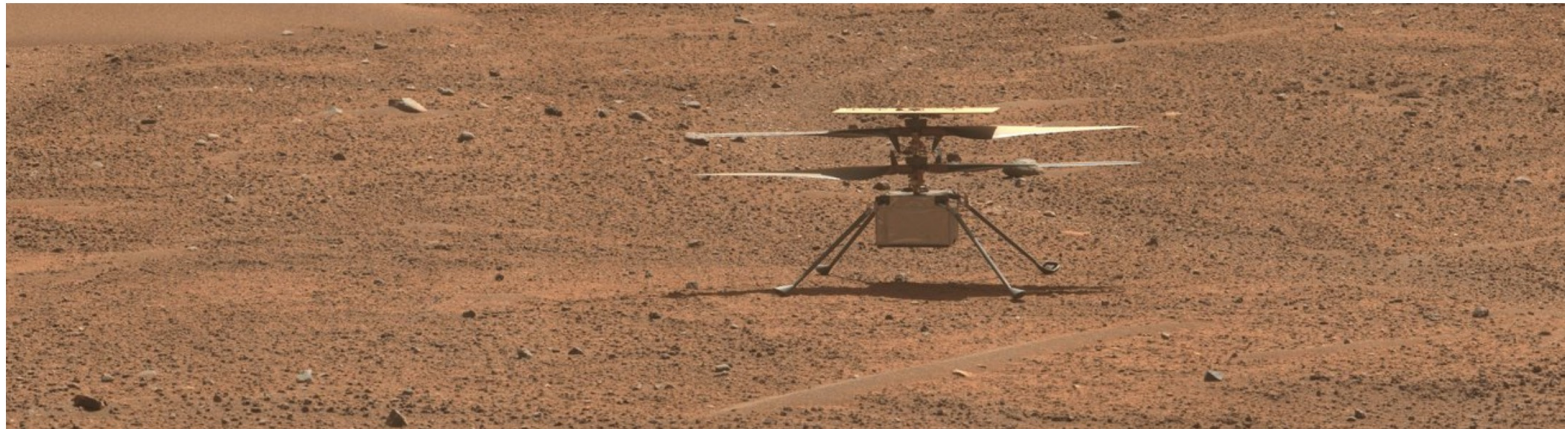
- **Challenge:**
 - No civilian requirements for simulated VTOL test environment
- **Accomplishment:**
 - Developed visual environments, including virtual test course with enhanced Usable Cue Environment (UCE) with additional furniture (e.g. Hover Boards) as a baseline for FAA applicants
- **Challenge:**
 - No existing industry representative VTOL aircraft performance and flight control system for developing evaluation methods
- **Accomplishment**
 - Developed IFCS flight control system for RVL T VTOL performance models
- **Challenge:**
 - Industry representative aircraft automation and pilot interfaces
- **Accomplishment**
 - Developed multiple industry representative control and inceptor configurations
 - Developed baseline Primary Flight Display, Map display, prototype vehicle health display and flight test performance display
 - Developed evaluation framework and supporting test materials



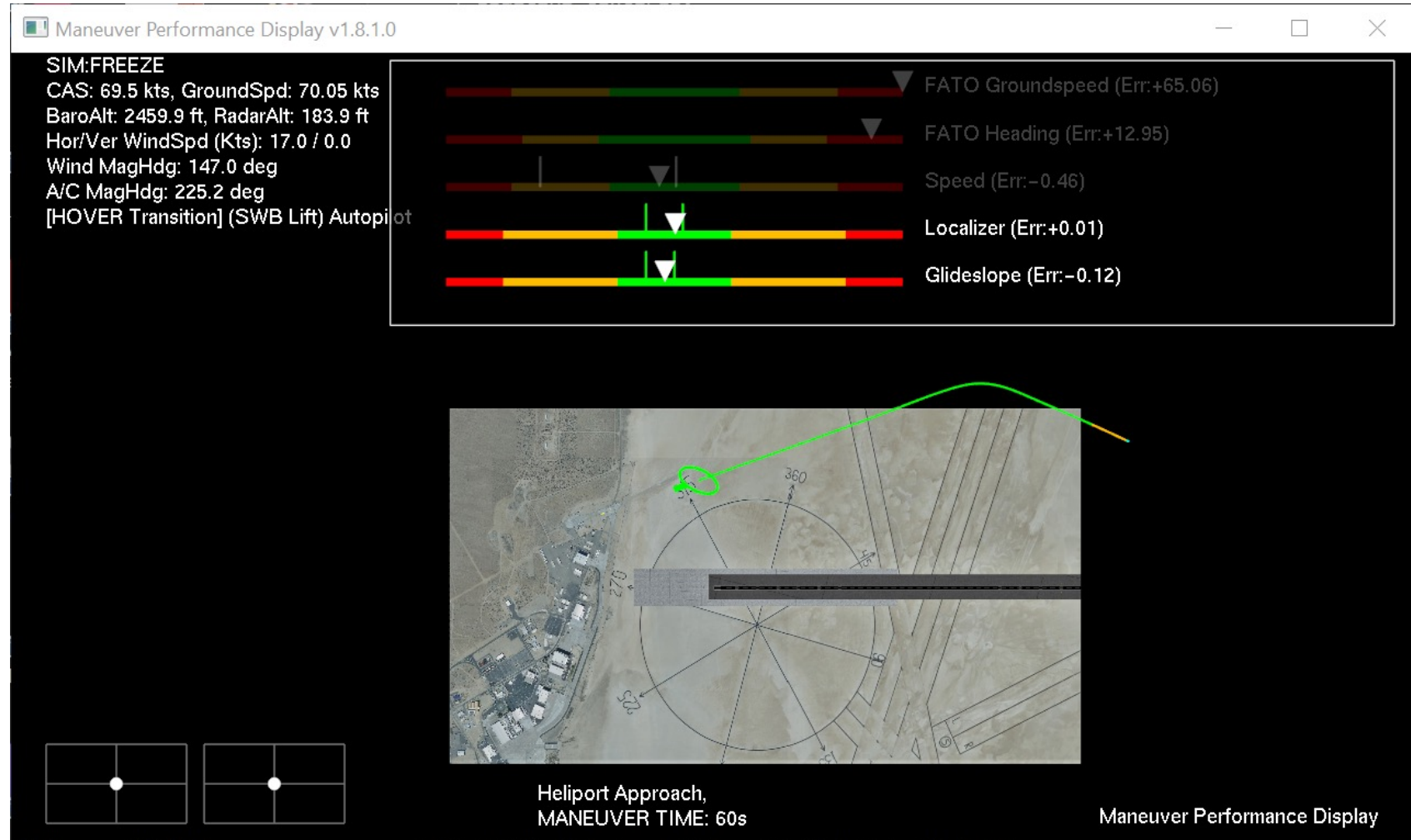
MARS

NASA's Ingenuity Mars Helicopter Flies Again After Unscheduled Landing

Aug. 7, 2023



Performance Evaluation



Heliport Approach (Automation Condition)

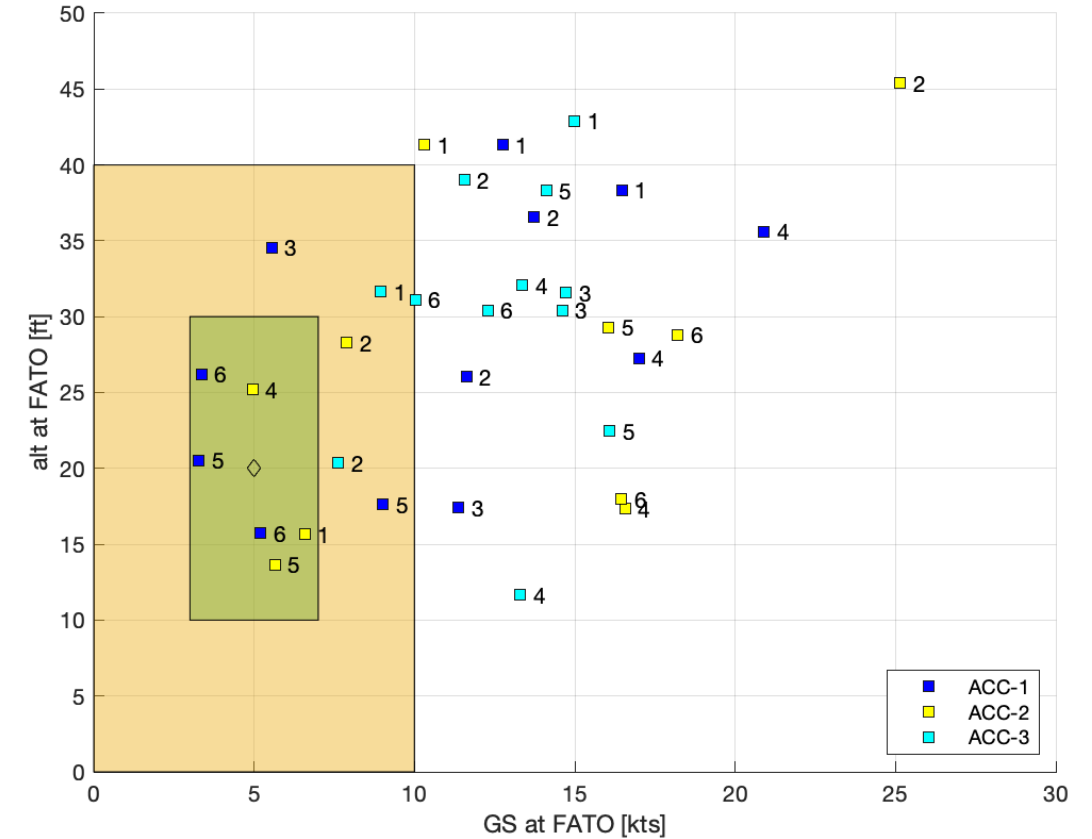
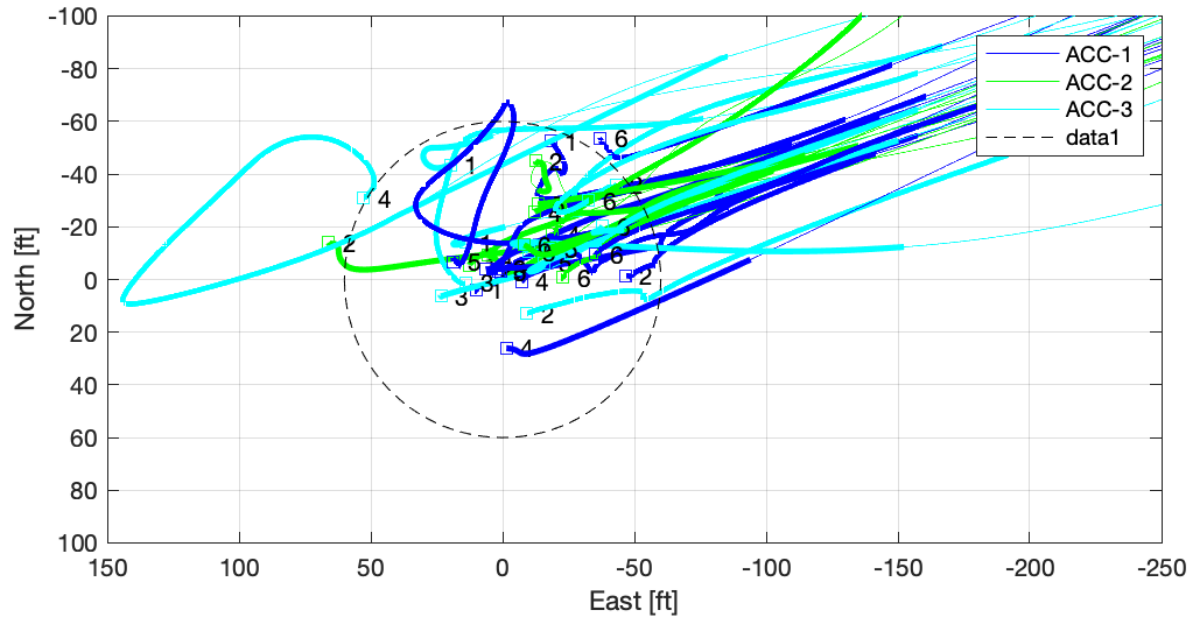
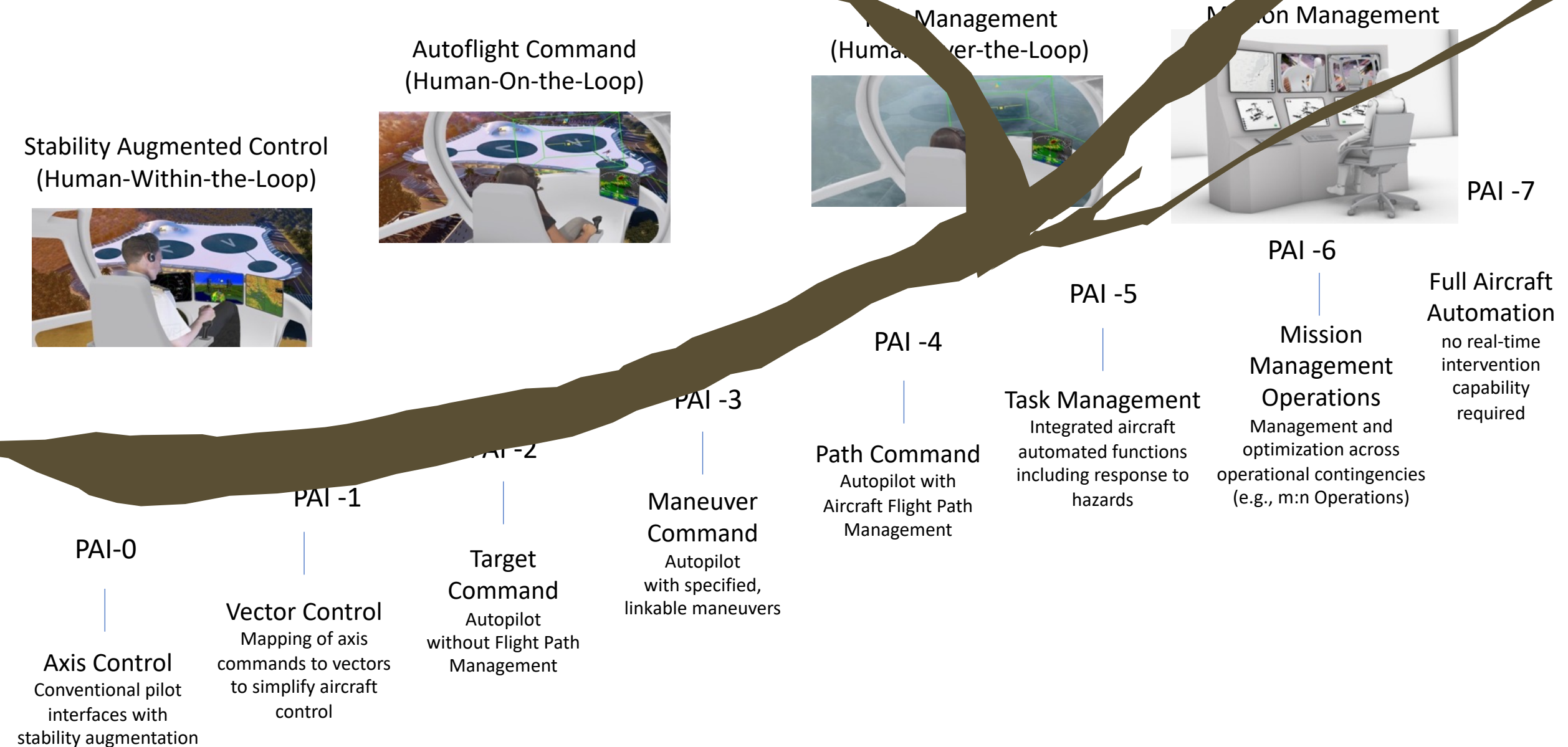


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Heliport Approach Quotes

“had to learn to get out of the way of the automation...”

“Automation changes the task”

“negative habit transfer...”

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CC-3

“desired performance but I feel like it was luck, it was uncontrollable through the transition”

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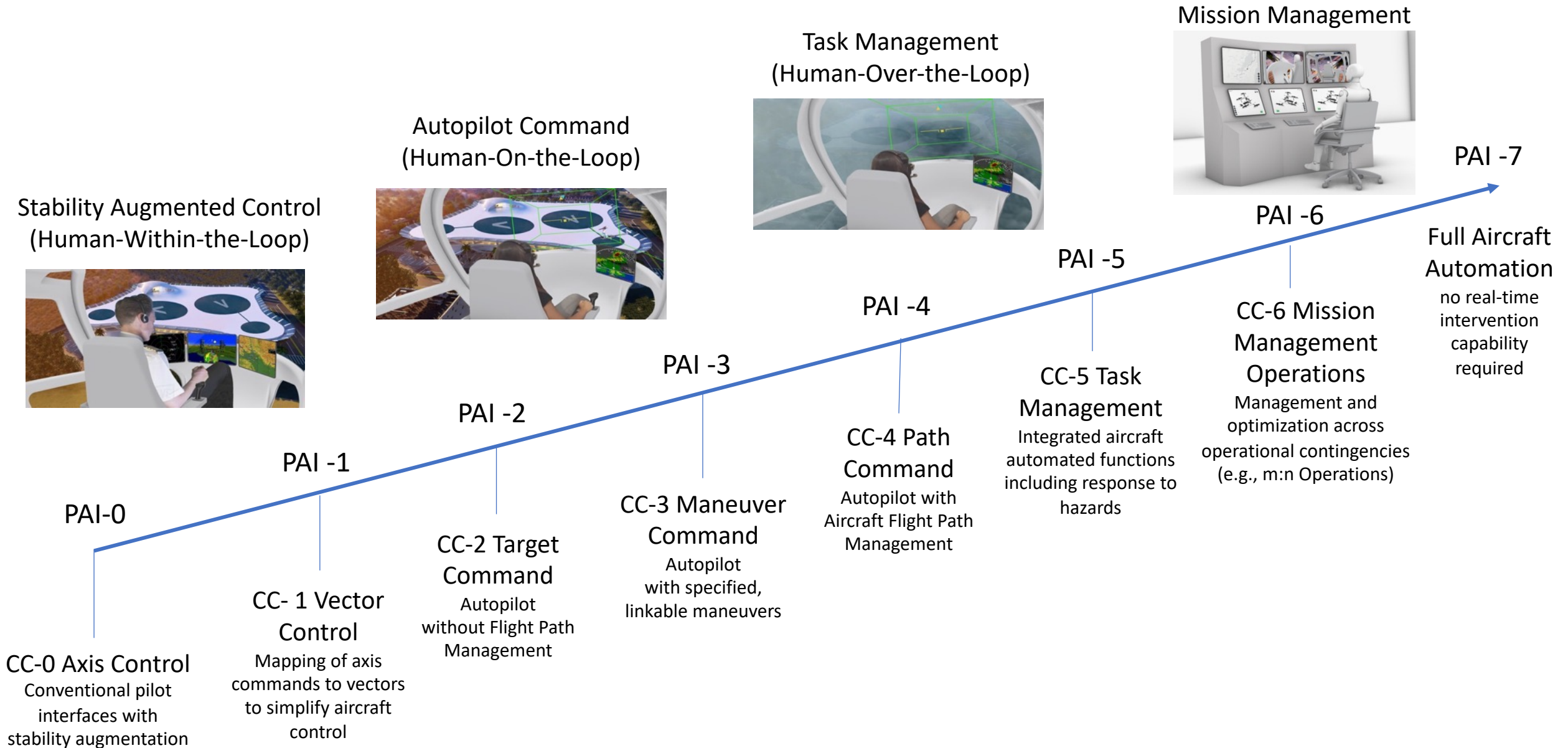


Precision

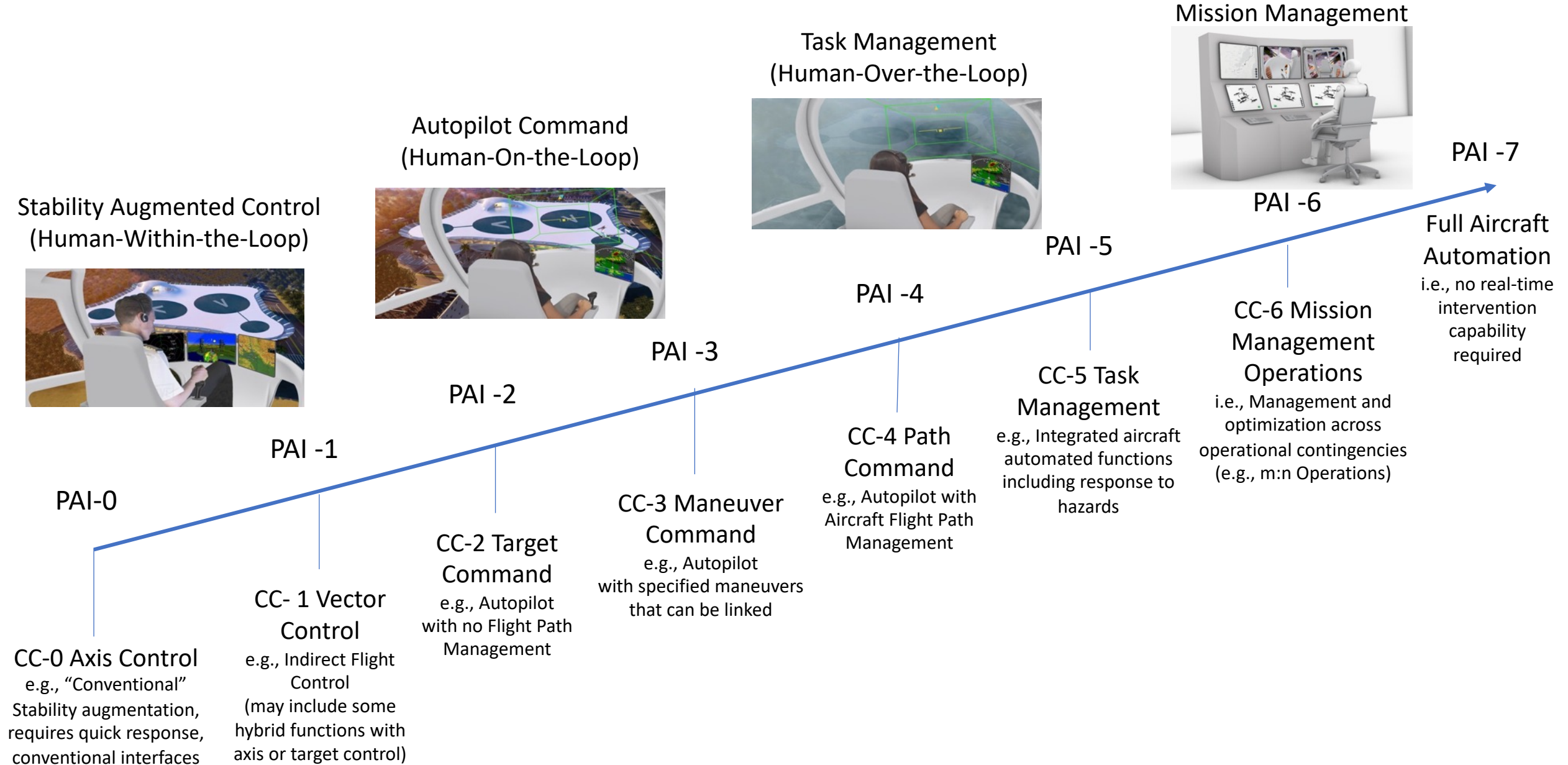


Aggressiveness

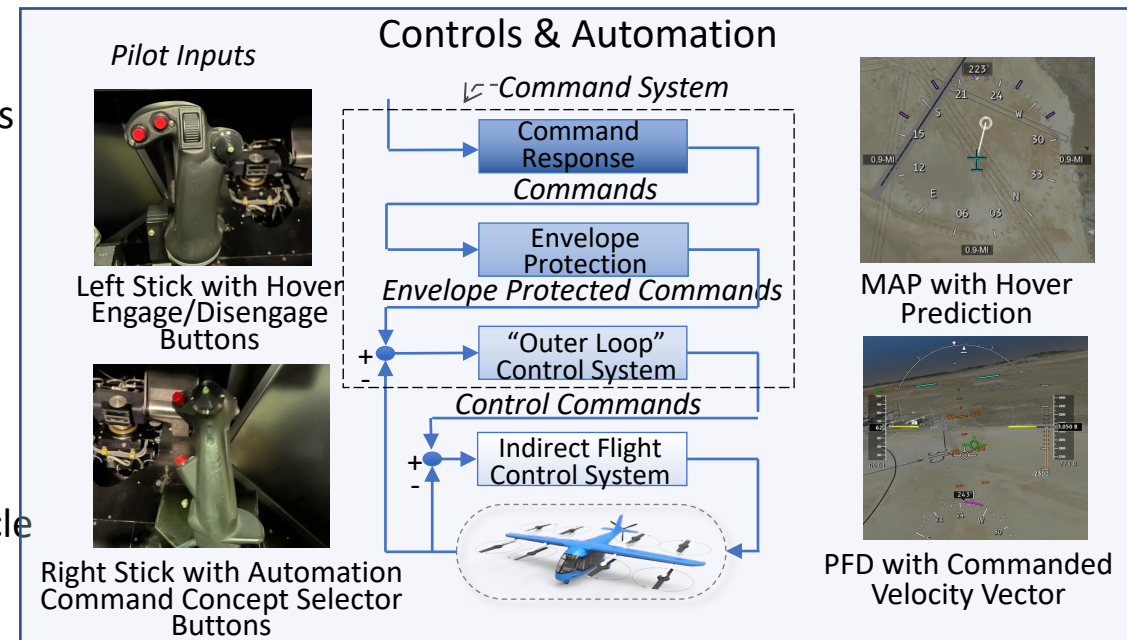
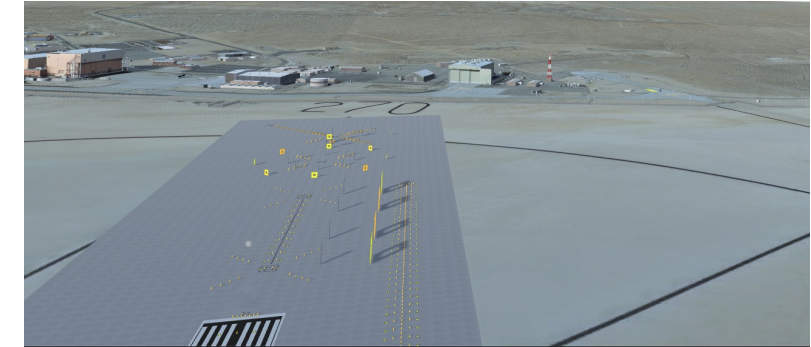
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AERONAUTICAL DESIGN STANDARD PERFORMANCE SPECIFICATION HANDLING QUALITIES REQUIREMENTS FOR MILITARY ROTORCRAFT

- **Scope**

- This specification contains the requirements for the flying and ground handling qualities of rotorcraft. It is
- intended that the specification should cover land based rotorcraft which have primary missions ranging
- from scout and attack to utility and cargo. Additional requirements or modified standards may be required
- for rotorcraft that have to operate from small ships in sea states resulting in more than small ship motion.
- Intended use is described in 6.1.

- **Application**

- The requirements of this specification are intended to assure that no limitations on flight safety or on the
- capability to perform intended missions will result from deficiencies in flying qualities. Flying qualities for
- the rotorcraft shall be in accordance with the provisions of this specification unless specific deviations are
- authorized by the Government. Additional or alternate special requirements may be specified by the
- procuring activity. For example, if the form of a requirement should not fit a particular vehicle
- configuration or control mechanization, the Government may, at its discretion, agree to a modified
- requirement that will maintain an equivalent degree of acceptability.



The Aerospace Cognitive Engineering Lab Rapid Automation Test Environment at Ames showing out-the-window views of San Francisco for an Advanced Air Mobility ride quality simulation project.

NASA / Dominic Hart

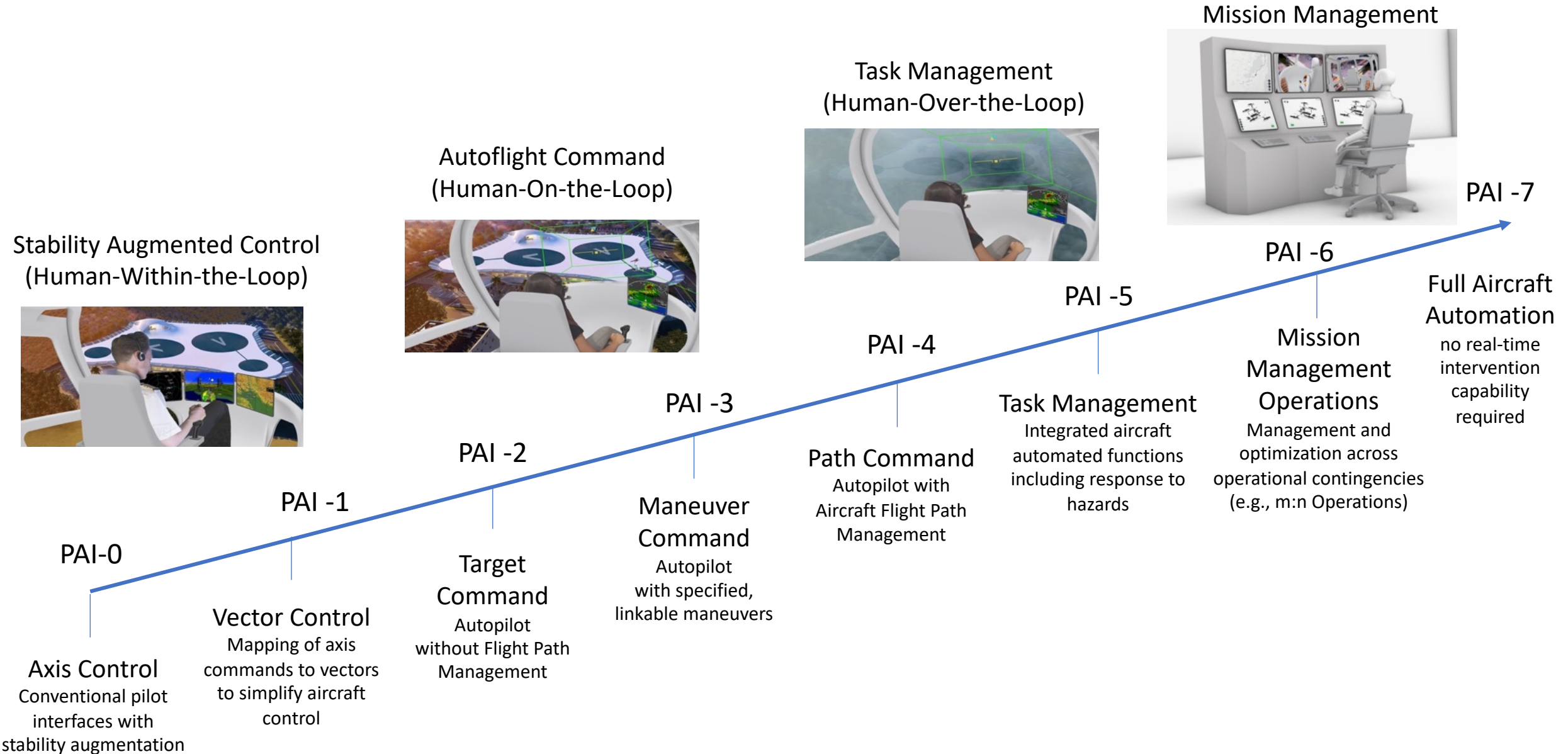
Vertical Motion Simulator Cab



The Vertical Motion Simulator plays a vital role in the advancement of aerospace vehicle design, development, and training.

NASA / Dominic Hart

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