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Simulator Evaluations of Assistive Hover Automation Concepts for a Lift Plus Cruise eVTOL Vehicle

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Outline

- Introduction: AEP-2 Study
- Inceptors, Controls, Displays
- Assistive Hover Automation
- AEP-2 Scenarios
- AEP-2 Participants and Procedure
- Performance Metrics
- Conclusions and next steps



Study: Automation Enabled Pilot-2 (AEP-2)



- **Purpose**

- Evaluate challenges associated with transitioning from forward flight to a vertical landing with industry representative eVTOL aircraft and aircraft automation using expected Urban Air Mobility (UAM) operational concepts

- **Primary Objectives:**

- Identify changes needed to existing approach procedures to meet UAM requirements
- Assess whether the automation conditions require exceptional skill under conditions tested.
- Determine whether pilot workload is acceptable for proposed UAM approach procedures under conditions tested

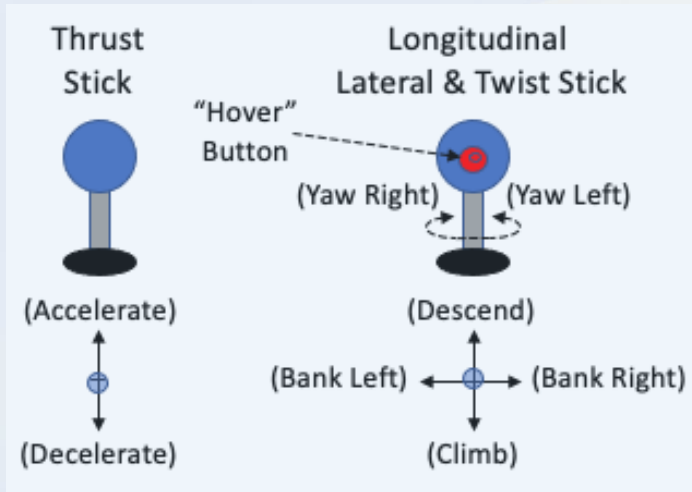
- **Secondary Objectives:**

- Establish baseline for future automation studies
- Highlight potential evaluation areas of concern to regulators

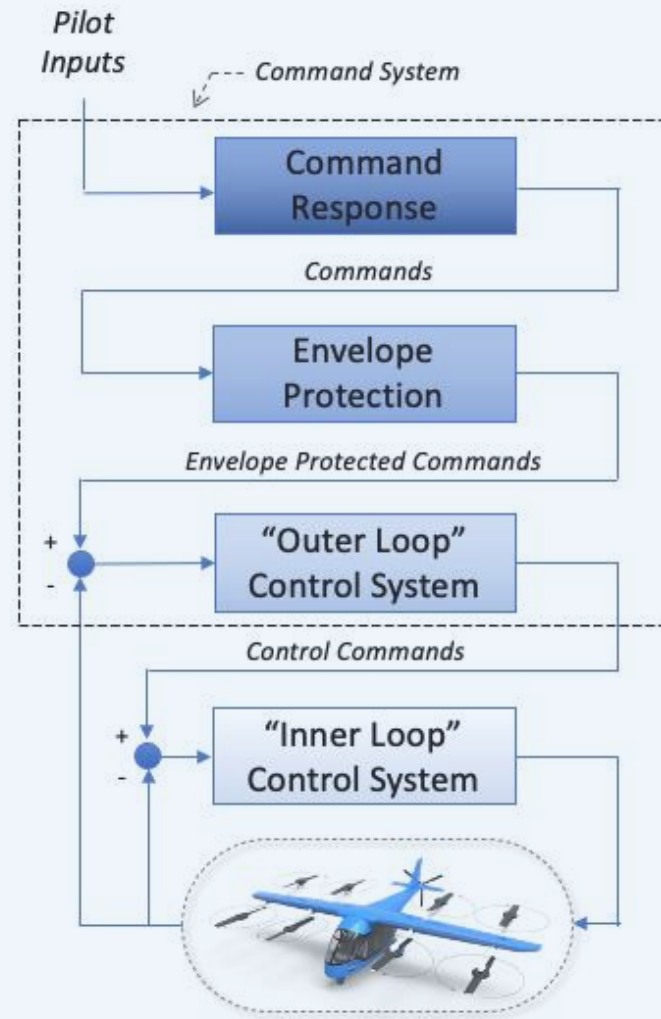
Lift Plus Cruise Vehicle



Dual Inceptors



Controls & Automation



Enhanced/Synthetic Vision Displays



Map with predicted hover symbology



Primary Flight Display

Automation Condition AHA-0

- Hover Button arms Hover mode
- Hover mode engages below 10 KFGS
 - Left stick commands longitudinal and right stick commands lateral velocities (e.g. TRC)
 - Right stick commands vertical acceleration (e.g. RCHH)
- Predicted hover point is not displayed

Automation Condition AHA-1

- Hover Button engages Transition to Hover
 - Automatically commands a 2.5 knot/sec deceleration rate¹
 - Automatically commands a decrab maneuver²
 - Right stick response transitions to command a vector-based FPA and track angle target
- Hover Mode engages below 10 KFGS

Automation Condition AHA-2

- Hover Button engaged Transition to a Hover Point
 - Automatically latches to helipad if “close enough” when transition is engaged
 - Automatically commands a deceleration to the hover point¹
 - Automatically commands a decrab maneuver²
 - Right stick response transitions to command a vector-based FPA target and the computed track angle to the hover point
- Hover Point Mode engages upon hover point capture



Flight Path Vector



Trend Line Only



Commanded
Flight Path Vector



Predicted Hover Point
Along Commanded Track



Commanded/Computed
Flight Path Vector

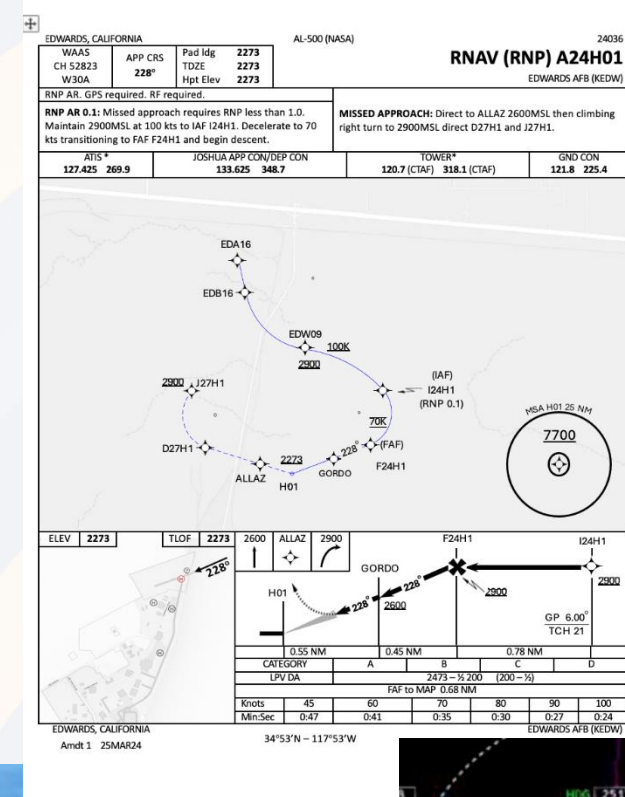


Commanded Hover Point
Along Computed Track

(1) Can be modified with left inceptor inputs
(2) Can be modified with right inceptor twist inputs

AEP-2 Scenarios

- 45 data collection runs, split into 3 scenario blocks
 - Varying automation, glidepath, visibility, wind and traffic
- 1. Full approach, RNP-AR approach segment (6 runs)
 - Only AHA-0, 6-deg GPA
 - Clear and 1 statute mile visibility
 - No wind or 17 kts from west (quartering headwind on final)
- 2. VMC intermediate and final approach segment (24 runs)
 - AHA-0,1,2
 - 6- and 12-degree GPA
 - Unlimited visibility
 - No wind, quartering headwind or quartering tailwind
- 3. IMC final approach segment (15 runs)
 - AHA-0,1,2
 - 6- and 12-degree GPA
 - IMC to 50' above Decision Altitude
 - Quartering tailwind or crosswind
- Secondary Task: Traffic separation and avoidance
 - No intended conflict or customized intrusion (slow preceding, late arrival, late departure, blunder taxi)





Ames Research Center

AEP-2 Participants and Procedure



Participants:

- No qualified pilot pool, previous studies used only formally trained test pilots
 - AEP-2 Participants have evaluation roles with Powered Lift eVTOL:
 - 11 pilots (495 data collection runs)
 - Airworthiness (3 test pilots)
 - Aircraft Evaluation (3)
 - Flight Standards (2)
 - Industry (aircraft manufacturer) (3 test pilots)

Training (1 Day):

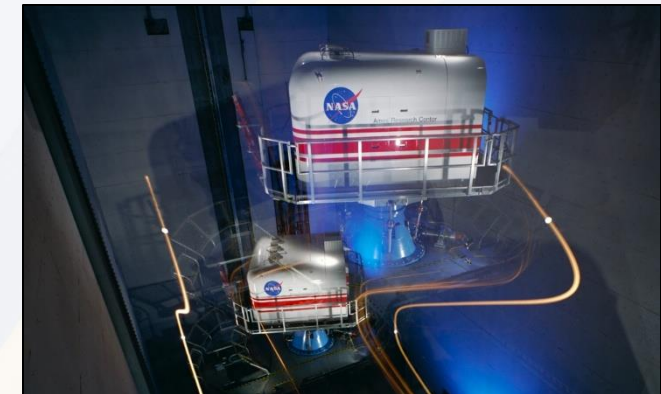
- AFM distributed prior to travel to Ames
- 1 Day in ACEL-RATE simulator
 - Approach procedure, aircraft performance, automation, inceptor strategy, operations, eye tracking, subjective measures
- Post-training questionnaire

Data Collection (1 Day):

- VMS familiarization
- 45 Scenario data runs, pilot ratings
- Eye-tracking
- Post-sim questionnaire and debrief



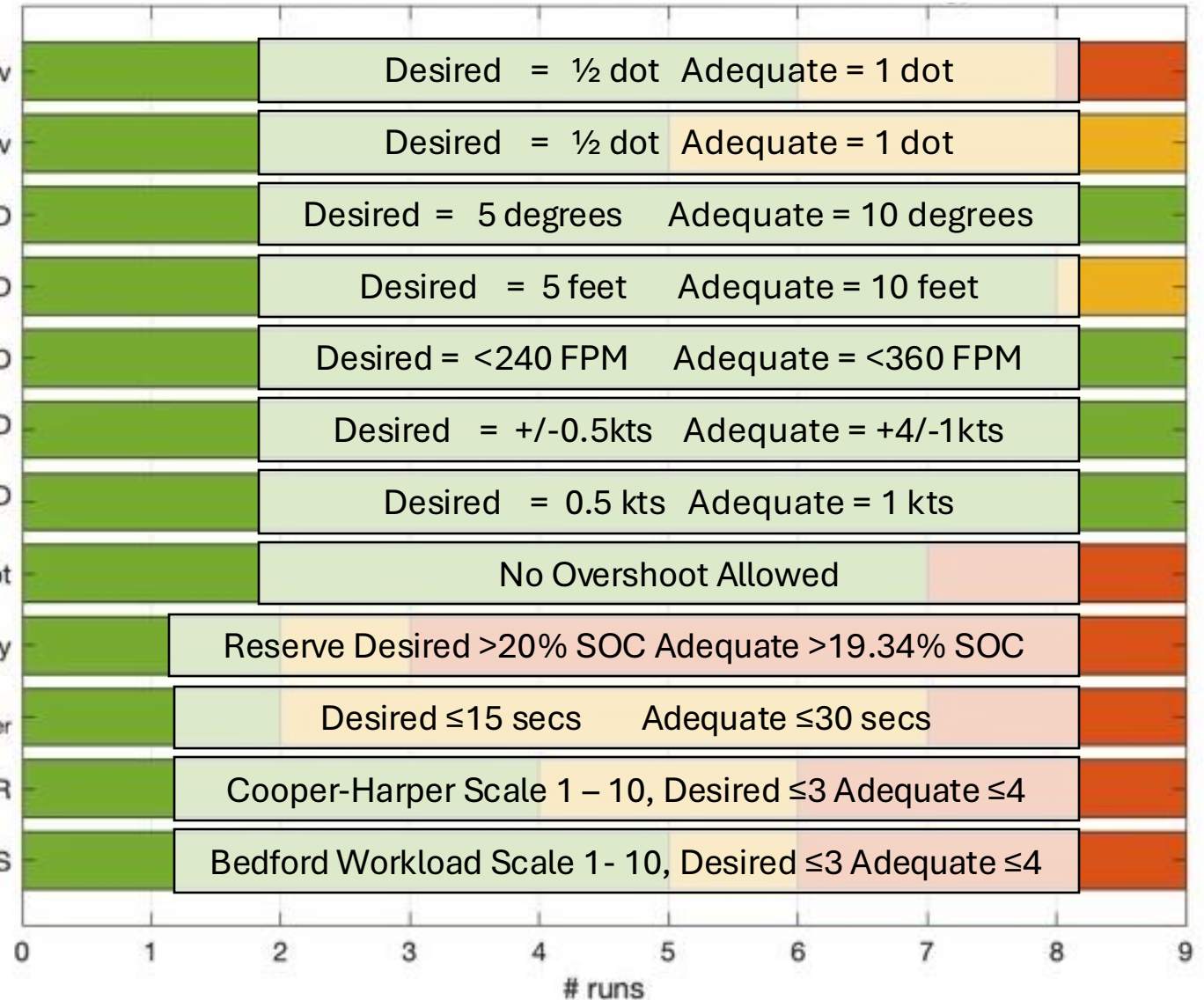
Aerospce Cognitive Engineering Lab
Rapid Automation Test Environment (ACEL-RATE)



Vertical Motion Simulator (VMS)

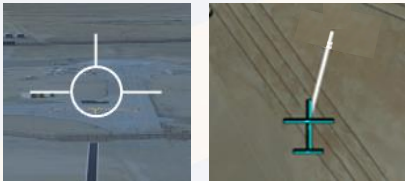
Landing Performance Criteria Visualization

- Approach Glidepath Deviation → ALT dev
- Approach Crosstrack Deviation → XTK dev
- Heading at Touchdown → HDG TD
- Distance to TLOF center at Touchdown → DIST TD
- Vertical Speed at Touchdown → VSPD TD
- Longitudinal Groundspeed at Touchdown → GS_x TD
- Lateral Groundspeed at Touchdown → GS_y TD
- Overshoot of touchdown area → Overshoot
- Energy used for Hover → Battery
- Hover time → t_{hover}
- Handling Quality Rating → CHR
- Workload Rating → BRS

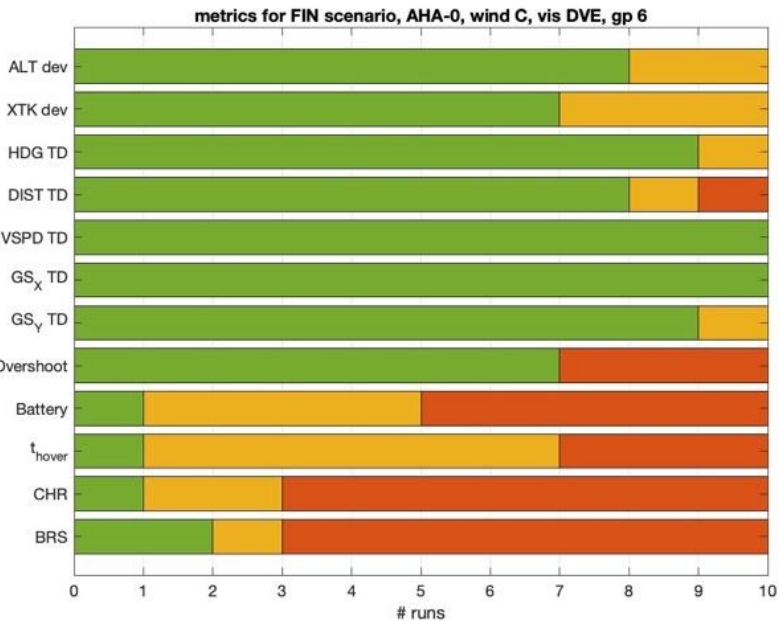


Example: Crosswind 6 deg

AHA-0



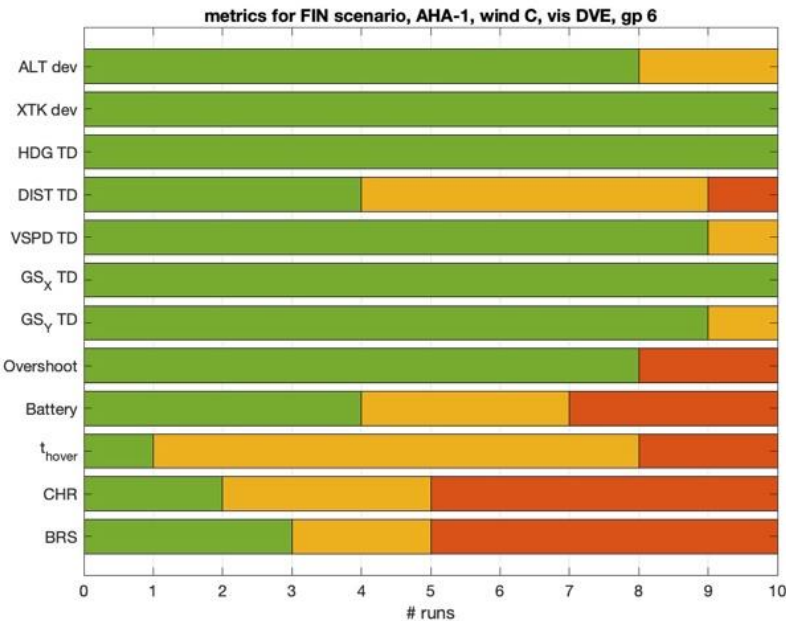
Predicted Track



AHA-1



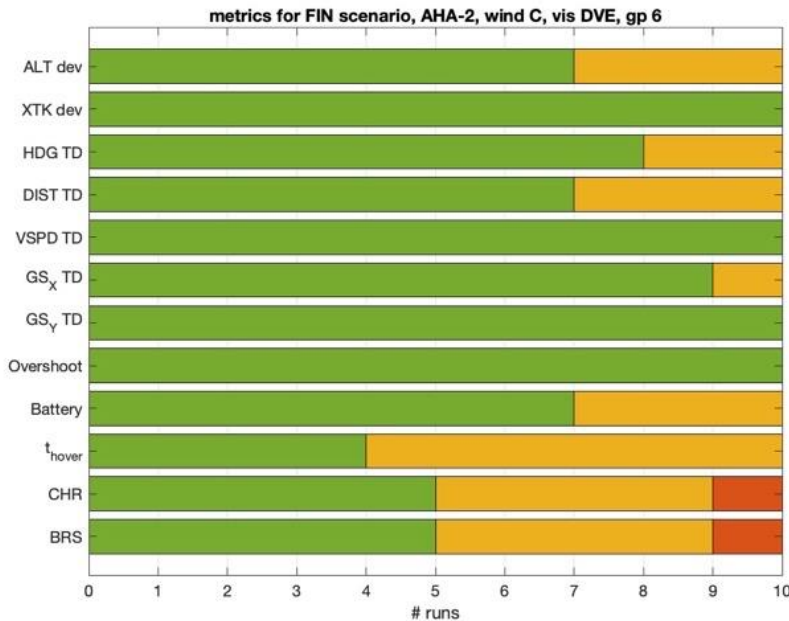
Predicted Hover Point
Along Commanded Track



AHA-2

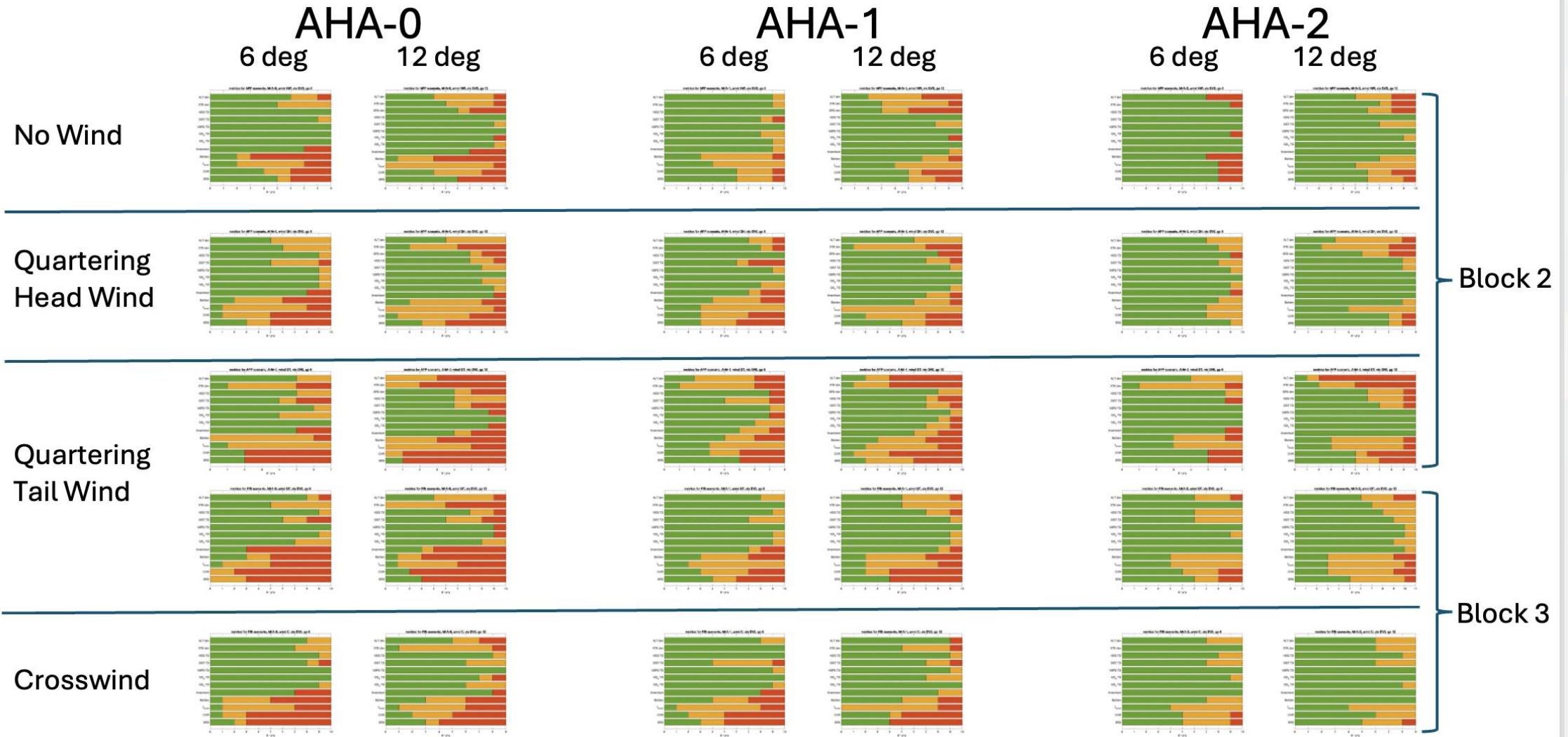


Commanded FPA and Hover Point
Along Computed Track



Results show better conformance and less pilot compensation and workload for higher automation levels

*AHA: Assistive Hover Automation



Results show better conformance and less pilot compensation and workload for higher automation levels

Conclusion and Next Steps

Results:

- Sparse regulatory guidance for evaluation of novel flight deck automation for AAM aircraft
- Automation tools make approach and landing easier, however the tools change pilot behavior...
- Identified safety concern with limitations of proposed hazard detection and avoidance tools near the ground, with some instances of close calls and collisions with other aircraft
- Simplified Flight Controls $\neq$ Simplified Vehicle Operations

Critical Operational Issues:

- FAA UAM ConOps calls for 4D trajectories
- Workload is a concern
 - Timing for transition and landing significantly impacts performance and workload
 - Immature assumptions about required time conformance
 - Immature assumptions about vertiport operations
- Topics for AEP-3 and beyond
 - Incorporate procedure elements based on UAM airspace assumptions
 - Focus on approach, departure for proposed use cases
 - RTA and wind predictions

