National Campaign Initial UAM Surrogate Flight Research Results

Crosscutting AAM Ecosystem Working Group (AEWG)

OCTOBER 26, 2021

Agenda

October 26, 2021

3:00pm - 5:00pm ET

Time (ET)	Topic	Speaker
3:00PM – 3:20PM	**NC Developmental Test Objectives**	• Starr Ginn, NASA
3:20PM – 4:10PM	**Initial UAM Surrogate Flight Research**	• David Webber, NASA
4:10PM – 4:20PM	**Q&A**	• All Above
4:25PM – 4:45PM	**Infrastructure and Procedures**	• David Zahn, NASA
4:45PM – 4:55PM	**Q&A**	• All Above

Platforms and Discussion

Active Participants

- Platform: MS Teams
- Discussion: MS Teams microphone, chat, and "Raise your hand" functions
  - Leave your cameras/webcams off to preserve WiFi bandwidth
  - Use your mute/unmute button (e.g., remain on mute unless you are speaking)
  - Enter comments/questions in the chat
  - Click the "Raise your hand" button if you wish to speak
  - Say your name and affiliation before you begin speaking

Listen Only Participants

- Platform: YouTube Live Stream
  - Go to https://nari.arc.nasa.gov/aam-portal/ for the link, or:
    - Copy and paste https://youtu.be/b74Oo_Aab88 into your browser
- Discussion: Conferences.io
  - Enter https://arc.cnf.io/sessions/c5n1/#!/dashboard into your browser
  - Questions will be addressed *if times permits or at the facilitator's discretion*

MEET OUR NASA TEAM

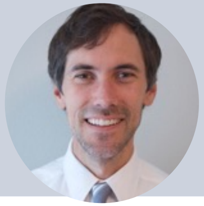
Starr Ginn
National Campaign Lead

Shivanjli Sharma
National Campaign Deputy

Jeff Leigh
Lead Chief Engineer

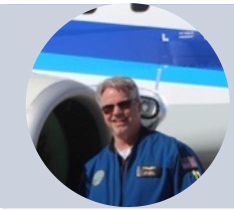
Mike Marston
Lead Operations Engineer

Al Capps
Airspace Operations Management (AOM) Tech Lead



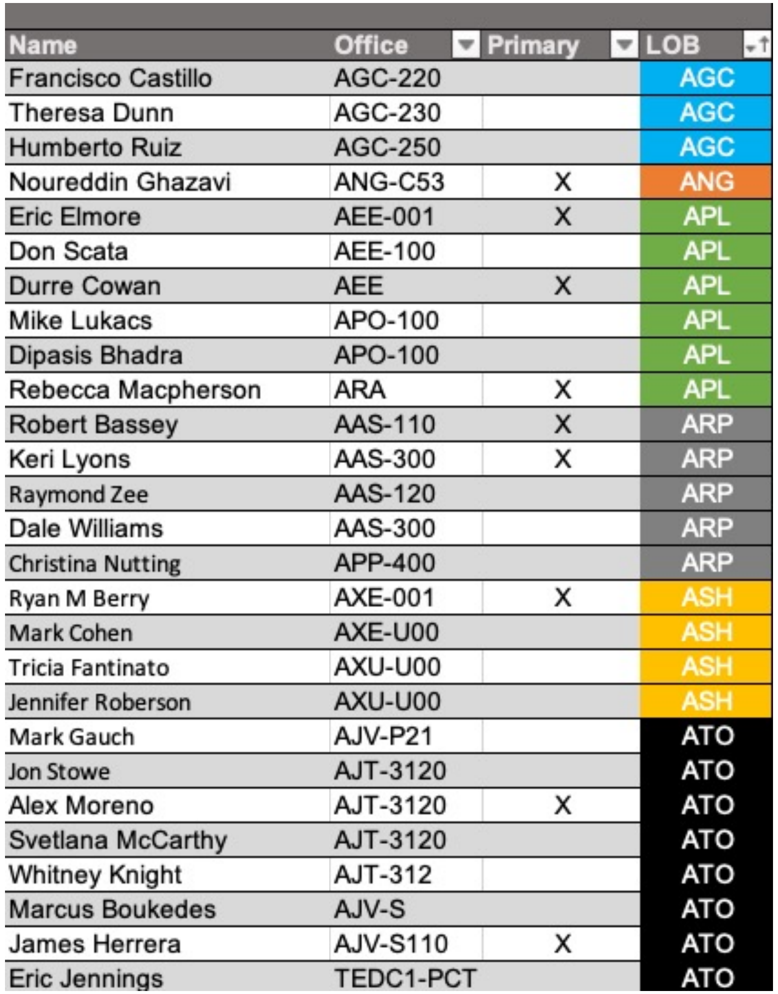
Andrew Guion
Flight Safety Lead

David Zahn
Airspace Procedures PI



David Webber
FAA Flight Test Liaison/Vehicle PI

MEET OUR FAA TEAM



Name	Office	Primary	LOB
Francisco Castillo	AGC-220		AGC
Theresa Dunn	AGC-230		AGC
Humberto Ruiz	AGC-250		AGC
Noureddin Ghazavi	ANG-C53	X	ANG
Eric Elmore	AEE-001	X	APL
Don Scata	AEE-100		APL
Durre Cowan	AEE	X	APL
Mike Lukacs	APO-100		APL
Dipasis Bhadra	APO-100		APL
Rebecca Macpherson	ARA	X	APL
Robert Bassey	AAS-110	X	ARP
Keri Lyons	AAS-300	X	ARP
Raymond Zee	AAS-120		ARP
Dale Williams	AAS-300		ARP
Christina Nutting	APP-400		ARP
Ryan M Berry	AXE-001	X	ASH
Mark Cohen	AXE-U00		ASH
Tricia Fantinato	AXU-U00		ASH
Jennifer Roberson	AXU-U00		ASH
Mark Gauch	AJV-P21		ATO
Jon Stowe	AJT-3120		ATO
Alex Moreno	AJT-3120	X	ATO
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Whitney Knight	AJT-312		ATO
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James Herrera	AJV-S110	X	ATO
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Jonathan Torres	ANG-E261		WJHTC
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Marcus Cunningham	AFS-002B	X	AVS
James Wilborn	AIR-633	X	AVS
James Foltz	AIR-618	X	AVS
Katie Constant-Coup	AIR-670		AVS
George Romanski	AIR-600		AVS
Christopher Swider	AUS-200		AVS
Francisco Capristan	AUS-320		AVS
Aaron VanBuren	AUS-320		AVS
Kerin Olson	AUS-320		AVS
Scott Gore	AUS-410	X	AVS
Jacquelyn Erinne	AUS-420		AVS
David Dunning	AUS-440	X	AVS
Bradford Drake	AUS-440	X	AVS
Randy DeAngelis	AUS-440		AVS
Manny Cruz	AUS-440		AVS

Roles and Engagement

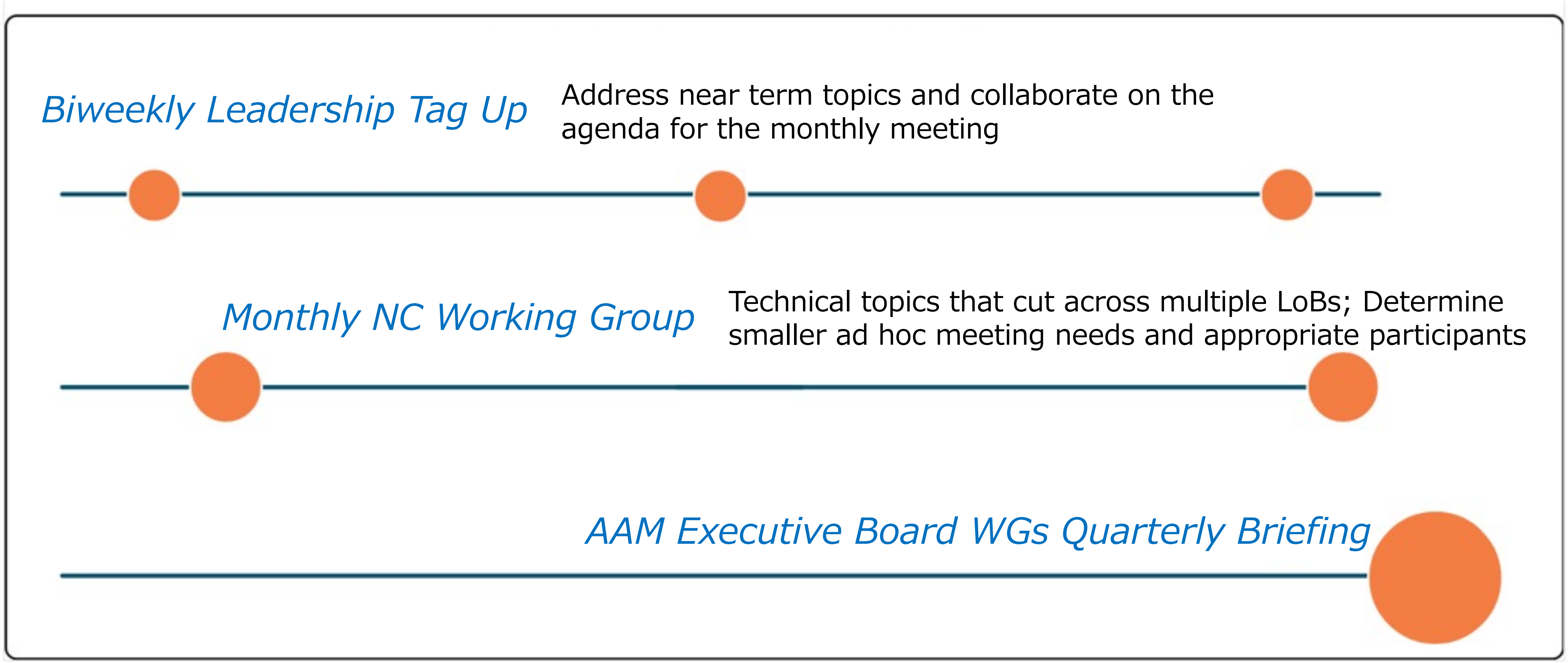
- **Role of FAA:**
  - Develop and refine ConOps with internal and external stakeholders (ConOps v1.0) and is responsible for establishing operational parameters and maintaining oversight
  - Verify where experiments, architectures, and concepts are anchored in existing standards (where feasible)
  - Determine data needs from various LoBs to support evolving standards and policies

- **Role of NASA:**
  - Conduct flight demonstrations that evaluate use cases and develop scenarios that step through the relevant portions of a specific operation
  - Design experiments, architectures, and concepts then develop a system of system ecosystem to enable AAM
    - For example, energy reserves to increase individual aircraft operational performance requirements in order to optimize the capacity utilization of the airspace structure.
  - Collect data, perform analysis, and disseminate to appropriate groups

Objectives of NC/FAA Collaboration in the WG:

- Collaborate throughout all stages of the AAM National Campaign, from planning and scenario validation to AAM National Campaign execution
- FAA lines of business and stakeholders to provide subject matter expertise and technical support where possible to advance AAM National Campaign objectives and ensure information captured from lessons learned informs FAA
- Ensure the data collected will help inform the FAA for development of appropriate policies and procedures to enable integration of Advanced Air Mobility (AAM) concepts into the National Airspace System (NAS)

Meeting Cadence



Biweekly Leadership Tag Up Address near term topics and collaborate on the agenda for the monthly meeting

Monthly NC Working Group Technical topics that cut across multiple LoBs; Determine smaller ad hoc meeting needs and appropriate participants

AAM Executive Board WGs Quarterly Briefing

NASA/FAA Interagency Agreement National Campaign (example)

Objective 1: Collect flight-data during the National Campaign Series to accelerate certification and approval processes

Products	Deliverable Dates	Linkages	Status
• Measure FAA AAM vehicle data parameters utilizing a surrogate vehicle during NC Dry Run	• FAM Flights Dec. 2020 • Dry Run Flights Mar. 2021	• NC Data Teams, AFB-260, AIR-710, AJW-1473	• Complete • Complete
• Provide FAA FIAPA FTE, FAA Vehicle Performance FTE, FAA certified test pilot	• FAM Flights Dec. 2020 • Dry Run Flights Mar. 2021	• AJF-13, AIR-713, AIR-714, AJV-A	• Complete • Complete
• Develop a joint NC Flight Test Report for each NC Series demonstration tests	• FAM Flights Dec. 2020 • Dry Run Flights Mar. 2021	• NC Data Teams • NC Data Teams, AFB-260, AIR-710, AJW-1473, ARP, FTI/STI In Draft NC Flight Test Report	• Complete • In Progress

Objective One example, there are five objectives

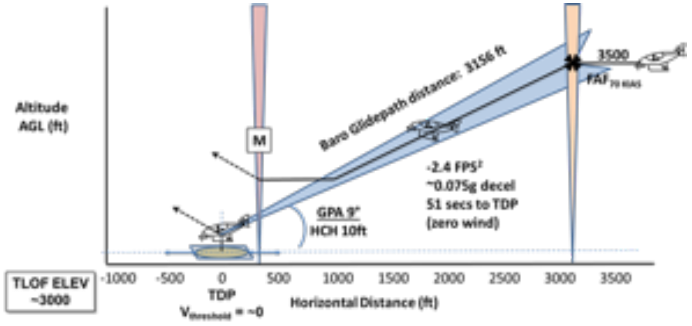
NC Dry Run – Outcomes and Highlights

- ☑ **Operational assessment** and revision of NC flight test plan using a helicopter as a stand in representative UAM vehicle

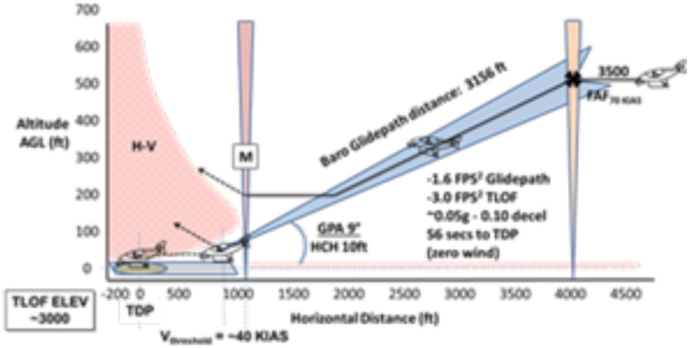

Dry Run at AFRC


ATI LVC & Data Collection

- ☑ **Assess operational processes** for **integrated** operations with vehicle and airspace and data collection in the field



- ☑ Capture **foundational** vehicle and operational data to support **evolutions** in vehicle, infrastructure, and airspace requirements that will enable the advent of UAM in the National Airspace System (NAS)



NC Developmental Test (DT) with eVTOL Flight Partner

NC DT Flights with Joby enables initial assessment and data collection of eVTOL performance characteristics and acoustic testing at Partner Test Site

- Developmental Test (NC DT) with partner Joby Aviation included activities to prepare for NC-1 such as collaborating on objectives, exercising range deployment, and data collection protocols
- Given the unmanned configuration for this flight test, the NC is leveraging a data buy like process that allows for flights under current certifications from the FAA and AFRL

ATI LVC & Data Collection

Acoustics

RVLT

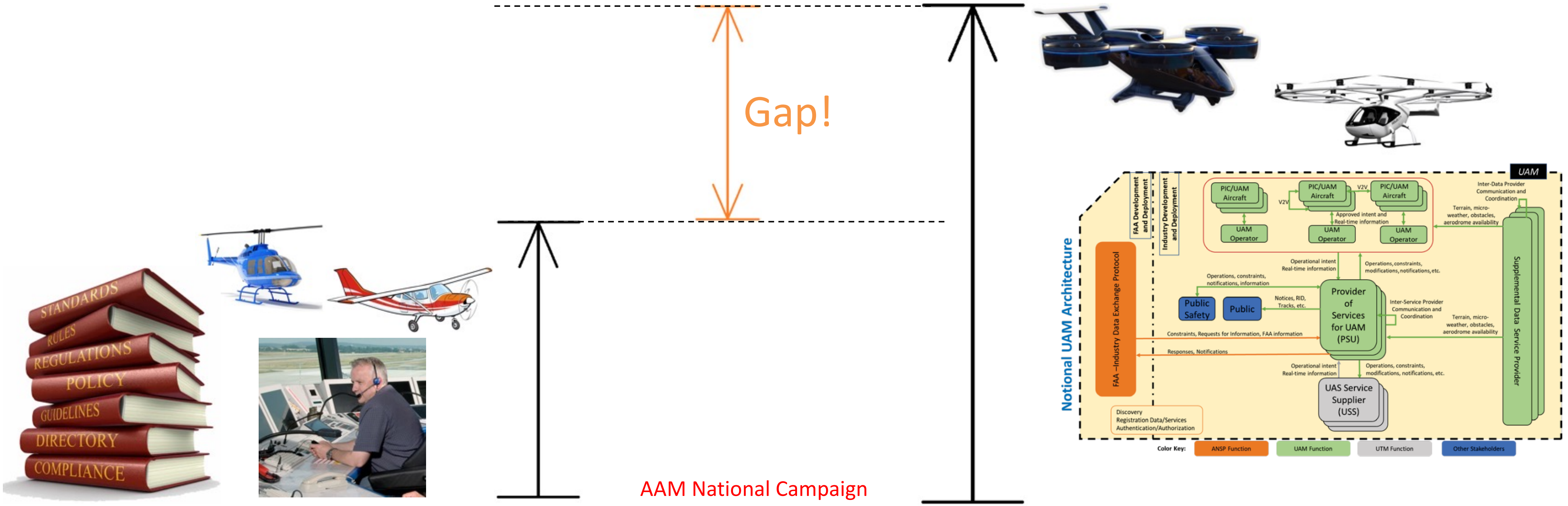
Test Site Infrastructure

What do we mean by "gaps?"

→ Regulatory, policy, or standards gap facing AAM

A new or novel AAM goal/aspect presents a need perhaps not completely addressed by existing regs/policy/standards/MOCs

- AAM presents a new aspect/goal/challenge
- Current regs/policy/standards/MOCs may not completely address that new AAM need/target
- Some effort, product, data, standards development required to fill gap



Current write-up summary fields

Gap Subject:
- Gap category (reg/policy, technical, economic? Aircraft Cert, IFR procedures, ATM? Safety, ops, efficiency, convenience? Priority?)

1) Current/legacy state:

2) Specific applicable regs/policy/guidance/MOCs/standards/forms:

3) AAM requirement/need/target and associated UML:
   - What is new challenge presented by AAM and when?

4) Potential limitation/inadequacy/incompatibility/lacking aspect of current regs/policy:
   - What is perceived/potential shortfall or missing piece of existing regs/policy?

5) Relevant NC/Build 2 test objectives:
   - What related performance or technical parameters were we measuring and why?
   - What were the related data requirements? (What data did/should NC collect?)
   - Who is the customer for the testing/ who requested the data/ who will benefit or be informed by the results? What products will NC deliver to meet their needs?
   - Is the gap related to an FAA ANG UAM Use Case or CONOPS question?

6) Relevant NC/Build 2 test report results, conclusions and recommendations:
   - What were results of tests against the test objectives, and what value-added conclusions & recommendations do we have?

7) Desired end state:
   + Description of effort/product/data/standards development required?
   + How would gap be filled/ current regs be supplemented to address AAM needs?
   + Future work required/recommended? By NC or AAM community?

Questions

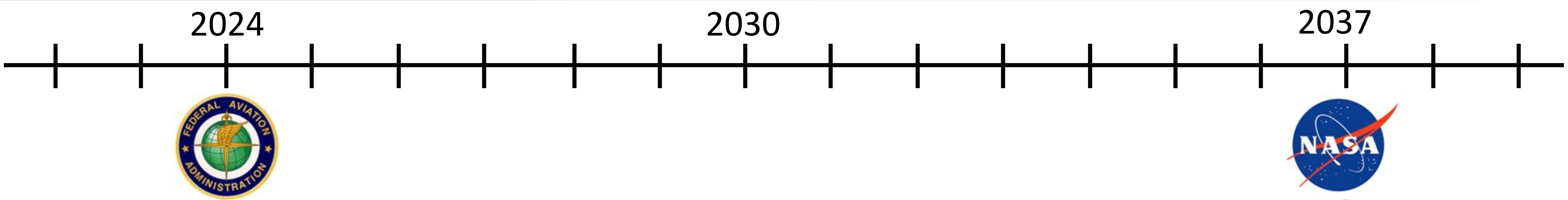
NASA ADVANCED AIR MOBILITY (AAM) NATIONAL CAMPAIGN (NC)

Urban Air Mobility Surrogate Flight Research

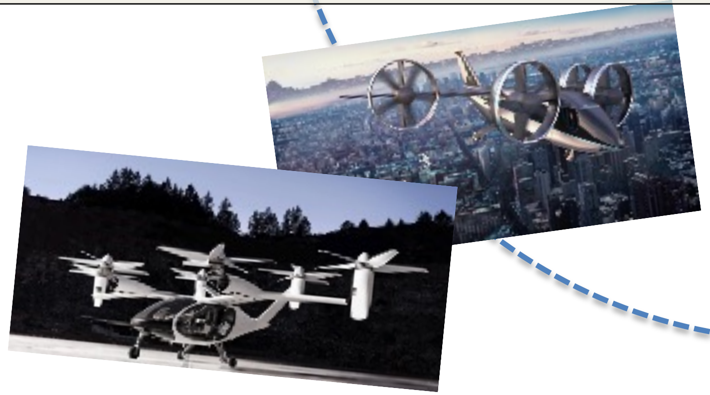
initial observations and assumptions

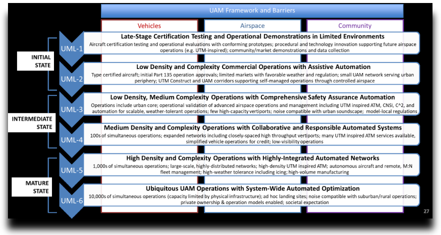
Dave Webber – NASA AAM Vehicle PI & FAA Flight Test/Certification Liaison

FAA/NASA Collaboration on the AAM NC



Current aerospace developments demand that FAA look more forward, and NASA support immediate and near future needs of potentially revolutionary US air transportation





UAM Framework and Barriers

Vehicles | Airspace | Community

INITIAL STATE

UML-1 **Late-Stage Certification Testing and Operational Demonstrations in Limited Environments**
Aircraft certification testing and operational evaluations with conforming prototypes; procedural and technology innovation supporting future airspace operations (e.g. UTM-inspired); community/market demonstrations and data collection

UML-2 **Low Density and Complexity Commercial Operations with Assistive Automation**
Type certified aircraft; initial Part 135 operation approvals; limited markets with favorable weather and regulation; small UAM network serving urban periphery; UTM Construct and UAM corridors supporting self-managed operations through controlled airspace

INTERMEDIATE STATE

UML-3 **Low Density, Medium Complexity Operations with Comprehensive Safety Assurance Automation**
Operations include urban core; operational validation of advanced airspace operations and management including UTM inspired ATM, CNSI, C^2, and automation for scalable, weather-tolerant operations; few high-capacity vertiports; noise compatible with urban soundscape; model-local regulations

UML-4 **Medium Density and Complexity Operations with Collaborative and Responsible Automated Systems**
100s of simultaneous operations; expanded networks including closely-spaced high throughput vertiports; many UTM inspired ATM services available, simplified vehicle operations for credit; low-visibility operations

MATURE STATE

UML-5 **High Density and Complexity Operations with Highly-Integrated Automated Networks**
1,000s of simultaneous operations; large-scale, highly-distributed networks; high-density UTM inspired ATM; autonomous aircraft and remote, M:N fleet management; high-weather tolerance including icing; high-volume manufacturing

UML-6 **Ubiquitous UAM Operations with System-Wide Automated Optimization**
10,000s of simultaneous operations (capacity limited by physical infrastructure); ad hoc landing sites; noise compatible with suburban/rural operations; private ownership & operation models enabled; societal expectation

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FAA is immediately challenged to ensure safety for future technologies (~3 yr), while preserving the existing “rights” and expectations of the aviation industry

FAA seeks empirical “evidence” to support necessary standards development

Advanced Air Mobility (AAM)

Advanced Air Traffic Management

Advanced Airplanes

Urban Air Mobility UAM e/VTOL "Air Taxi"

Utility/Emergency/ Personal Air Vehicles

Advanced Rotorcraft

Cargo Delivery/ Drones

Advanced Air Mobility (AAM) encompasses several nascent "operational use cases" in addition to innovative evolutions in existing aerial mobility/technologies

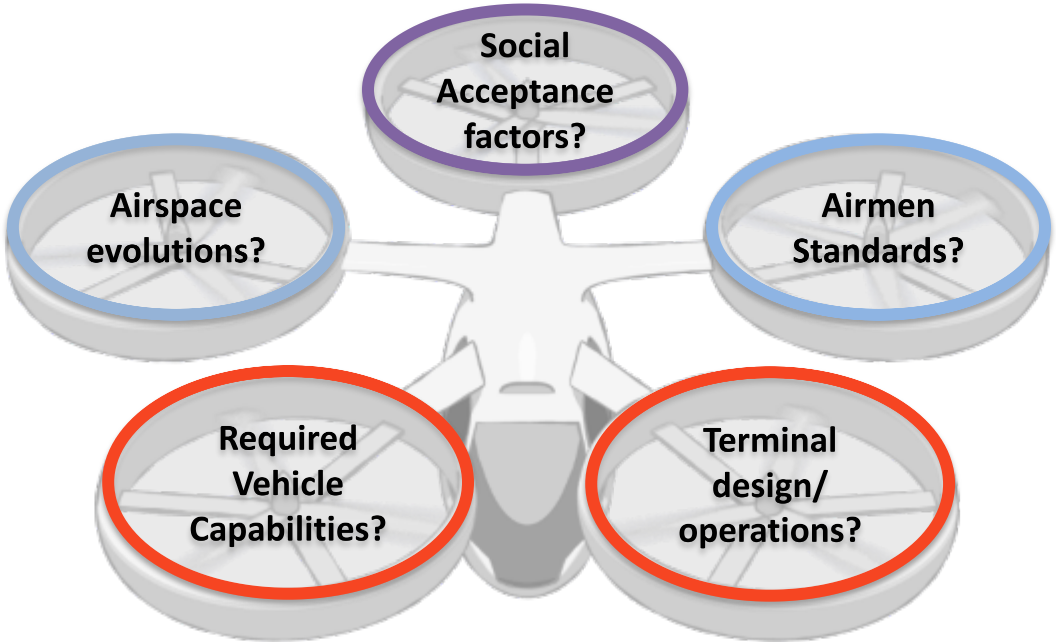
These new *operational use cases* need to be understood in order to develop appropriate regulatory (minimum airworthiness) requirements for vehicles

FAA Perspective

FAA Vehicle Certification recognizes the "holistic" inter-dependence of standards

Example:

If required Vehicle Capabilities are Raised/Lowered – Terminal Ops volumes are Increased/Decreased



FAA seeks the proper **balance of standards** that will enable **new operational use cases** *(solve* ***Urban Air Mobility*** *and you likely solve other operational models)*

Anchoring to today's rotorcraft capabilities/heliport design –
UAM Surrogate flight tests, attempts to capture **foundational data to support evolutionary UAM concepts**

Urban Air Mobility (UAM) configurations

- **Lift + Cruise** *Completely independent thrusters used for cruise vs. for lift without any thrust vectoring*
- **Electric Rotorcraft** *An eVTOL aircraft that utilizes a rotor, such as an electric helicopter or electric autogyro*
- **Wingless (Multicopter)** *No thruster for cruise/only for lift*
- **Vectored Thrust** *An eVTOL aircraft that uses <u>any</u> of its thrusters for lift <u>and</u> cruise.*

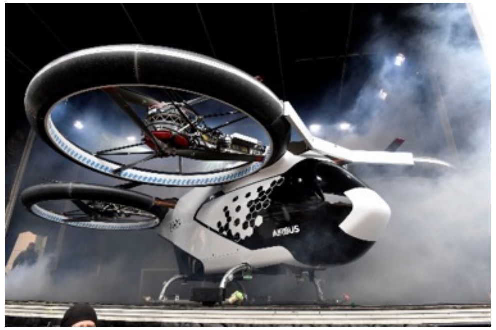
"UAM" is a subset of Advanced Air Mobility (AAM) – intended for ***paid passenger-carrying operations over the urban environment***

Urban Air Mobility (UAM)

- Economic model ($$'s per seat-mile) demands an aviation version of "mass production" and operation that is new to small aircraft
  - 10's of thousands of aircraft operated by a single part 135 operator (in some cases this operator will be the manufacturer) -vs-
  - 100's of aircraft purchased by private parties and operated by several operators running a mixed fleet operation
- Exhibit thrust and system isolation features similar to transport category rotorcraft
  - utilize a critical engine/system failure concept, and;
  - assure adequate designated takeoff/landing and approach/departure surface areas, and;
  - adequate performance capability for continued safe flight in the event of critical (propulsion or systems) failures.
- Utilize "Simplified Vehicle Operations" and autonomy to ease burden on pilot population




Urban Air Mobility (UAM)

- Low speed controllability must account for constraints of the urban landscape
  - Urban “pinnacle” takeoffs and landings
  - Constrained approach and departure paths
  - Unpredictable winds associated with “urban canyons” coupled with an ever changing urban landscape
- Vehicle characteristics must enable condensed IMC ops in the urban environment
  - minimum stability and control characteristics must be established for UAM operations (Approach capability, V_{MIN-I}, V_{Y-I}, V_{NE-I}, etc)
  - highly-augmented, feedback-control, FBW FCS, providing 4-axis Stability Augmentation (*key enabler for low-speed vertical flight instrument operations*) challenges existing vehicle certification standards and test techniques
- UAM Terminal Procedures (TERPS), Infrastructure and Airspace standards need to align with UAM Category/Class Vehicle Airworthiness Requirements*

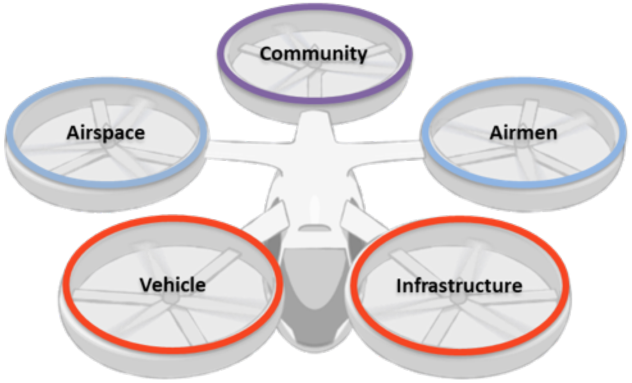
****Category/Class airworthiness standards allow grouping*** *– provides assurance that disparate designs will exhibit minimum capabilities in the National Airspace System*

Birds of a feather… …flock together

- **Shared flight qualities/characteristics**
- **Collision avoidance[1] (maneuvering, separation standards)**
- **Velocity matching[1] (drives terminal operations)**
- **Flock centering[1] (required navigational performance)**

[1] from *Emergent Autonomy – A Step Toward Assurance* 2021 IEEE paper (Lacher, Cook, Oksenhorn) ref. Craig Reynolds, *Flocks, Herds and Schools: A Distributed Behavioral Model, 1987*

Gaps = initial Research Questions



Urban Air Mobility Operational Use Case

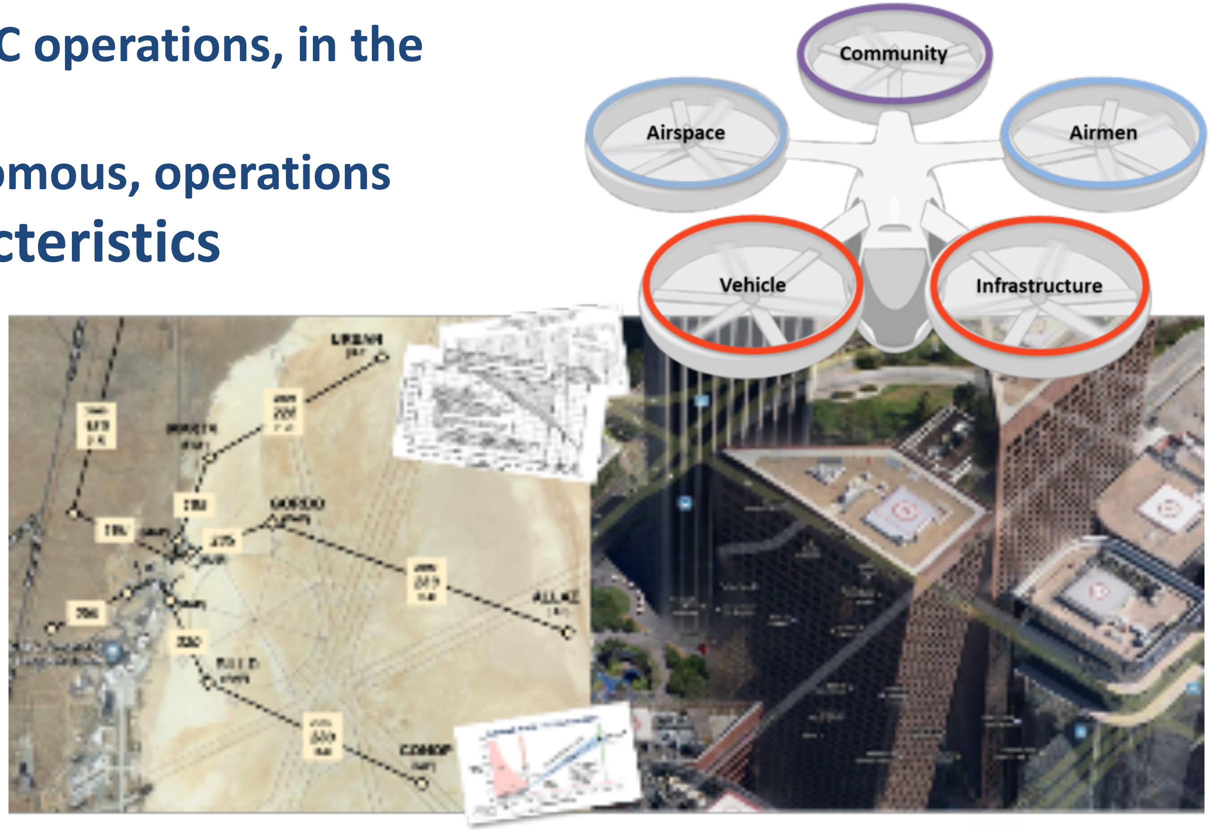
- **What is "UAM" (AAM NC assumptions)**

  paid passenger carrying ops in the urban environment
- **What are physical constraints of UAMs?**
- **What are reasonable airworthiness requirements for UAM?**
  - From Uber Elevate White Paper - Oct 2016 – *UAM must exhibit a four-fold improvement over current part 135 safety in terms of fatalities-per-passenger-mile**

    **current part 135 performance has twice the fatality rate of privately operated cars*
  - Initial focus on: Performance, Stability, Control, Efficiency, Energy Reserves, Airspace design
- **What are physical constraints of UAM Operations?**
- **What are the specifications for viable UAM Airspace constructions**
  - Approach
  - Departure
  - Enroute
  - Contingencies
- **What is required to transform an assumed Special Class Vehicle/Operation into an everyday mode of air travel?**

Building a system of systems

Pouring the foundation for condensed, IMC operations, in the urban environment...
...necessary steps toward complex, autonomous, operations



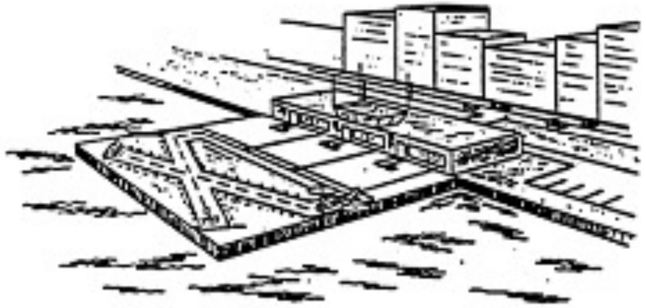
Required UAM Vehicle Flight Characteristics

- Performance
- Stability and Control
- Agility
- Precision
- Collision avoidance

Viable UAM terminal operations

- Approach/Departure capabilities
- Approach constraints
- Appropriate Speeds

Initial Airspace/Infrastructure construction parameters

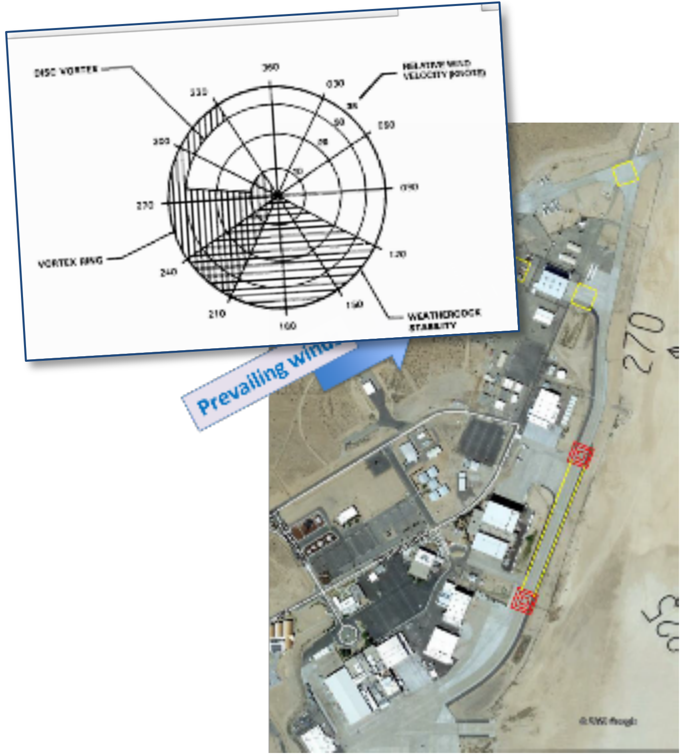


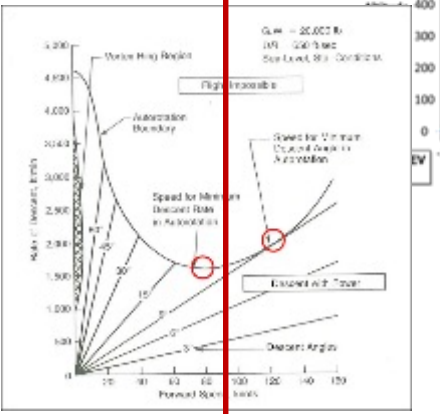
- Touchdown/Liftoff areas
- Proximity to structures
- Approach/Departure surfaces
- Airspace constraints

UAM initial interest areas

Vehicle Characteristics required for Urban Operations

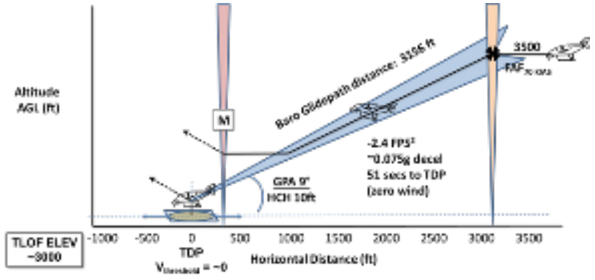
- UAM Performance requirements
- Minimum Stability requirements (IFR)
- All Azimuth Capability (controllability)
- Wind/structure dynamic interface (proximity of landing zone to structures)
- Appropriate Handling Qualities

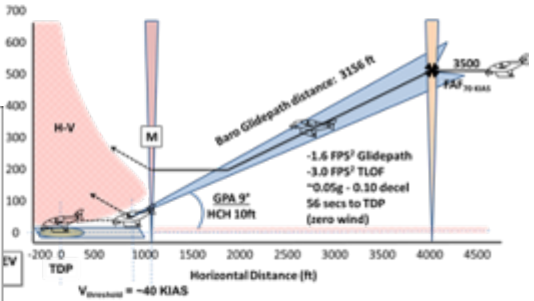


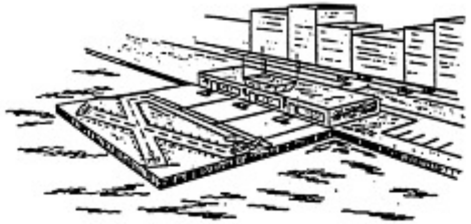


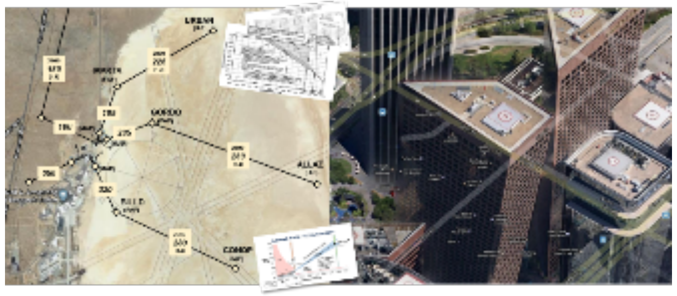
Viable UAM Approaches/Airspace

- Viable UAM IMC approaches
- Heliport and Vertiport ops



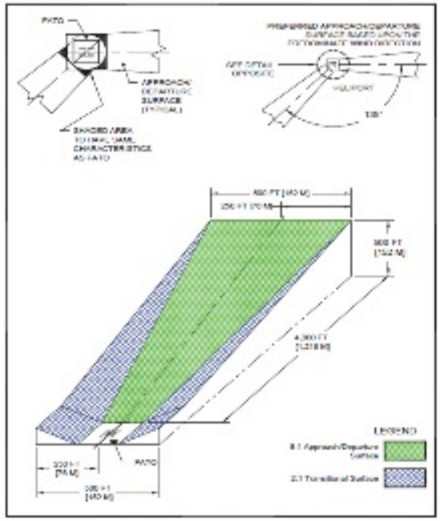






Required evolutions to existing standards to enable UAM

- Airspace
- Infrastructure



March “Build II” UAM Surrogate flight results

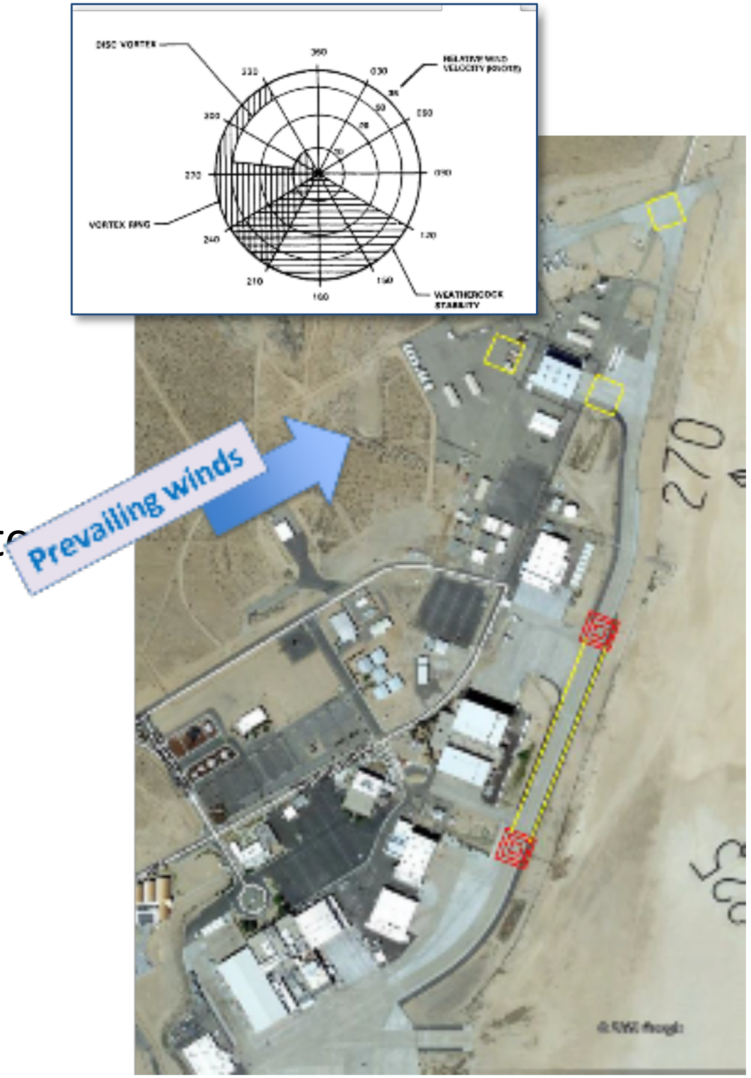
Condensed UAM Approaches/Airspace

- Measured key Vehicle Performance parameters
- Started work on Developmental UAM Task Elements – fed results to VMS etc.
- Started work to determine Dynamic Interface capabilities of a given UAM surrogate
- Determined initial Viable UAM IMC approach constraints
  - Constant Airspeed (V_{FAF})/Deceleration Height (200 ft) technique retained for future testing (UAM Task Elements)
  - 9 degree/60 KIAS V_{FAF} nominal approach appears viable (UAM Task Elements – Approaches)
  - 11 degree/60 KIAS V_{FAF} “calm wind abuse” certification technique appears reasonable (equivalent to 10-20 kt tailwind abuse)
  - Approach Constraints chart constructed (Vehicle Characteristics – Performance)
- Heliport and Vertiport operations
  - Started process to verify hypothesis that existing Approach/Departure Surfaces/design standards are suitable for UAM Operational Use Case
  - Determined Initial design requirements for viable UAM routes

UAM Vehicle Characteristics

Measure discrete Subpart B capabilities of UAM Surrogate

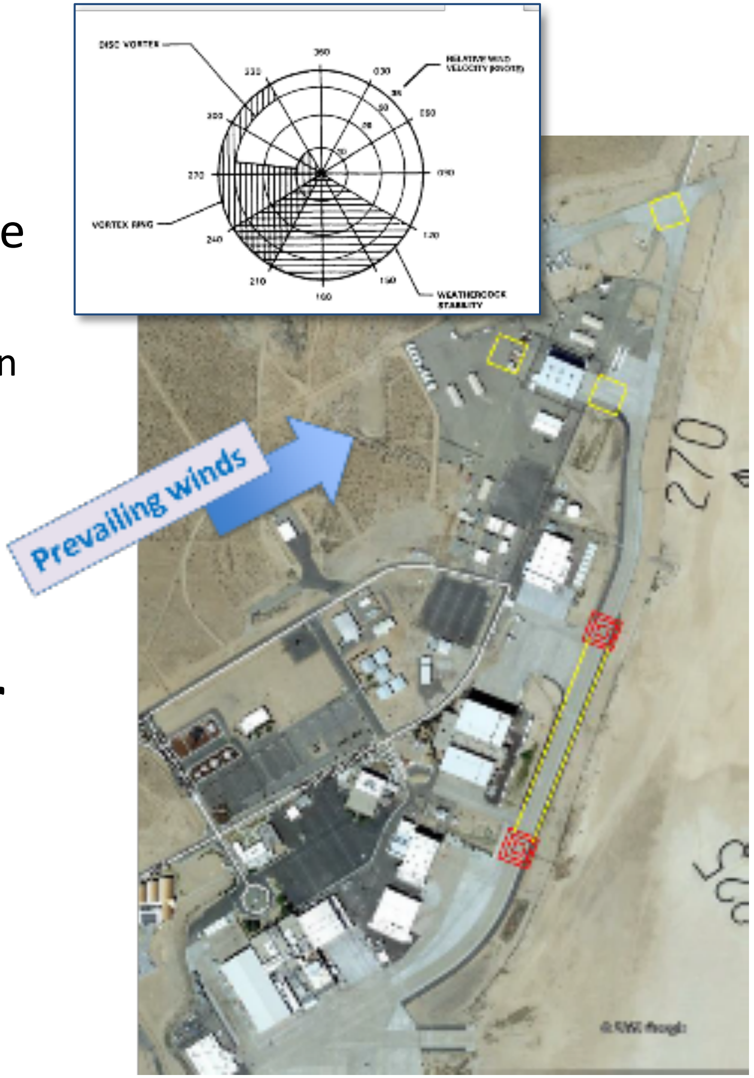
- **UAM Approach Capability/Constraints (performance)**
  - Developed Approach Constraints chart that effectively communicates a given vehicle's ability to fly "UAM" approaches
- **Measure (stability) of UAM surrogate against IFR reqmts**
- **Confirm All Azimuth Capability (controllability)**
  - Current civil rotorcraft requirement is 17 knots – is this appropriate for the UAM operational use case?



UAM Vehicle Characteristics

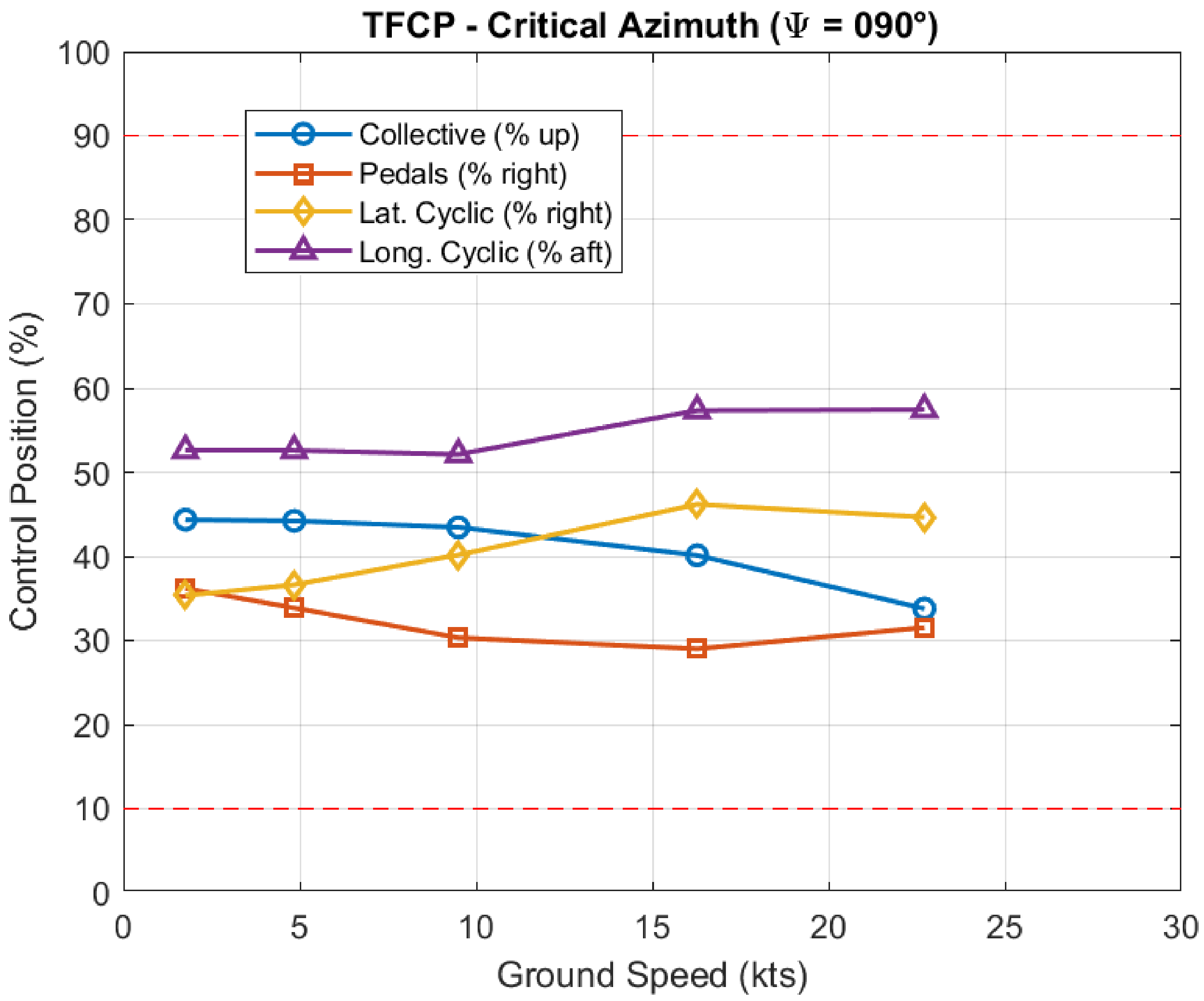
Application of measured characteristics to help answer UAM operational use case questions

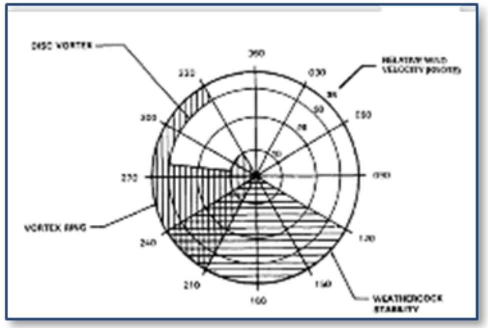
- **Wind/structure *"dynamic interface"* (controllability)**
  - What is relationship between <u>assured</u> all azimuth capability and the ability to fly leeward approaches to a landing zone?
    - proximity of landing zone to building is anchored to current FAA Heliport design criteria
  - Intent is to show relationship between minimum assured All Azimuth capability and ability to safely fly leeward approaches in the urban environment
- **Support development of Handling Qualities standards for highly augmented "UAM mission" vehicles**
  - Appropriate Mission Task Element (MTE) requirements
    - Compare Subpart B (IFR) results against Developmental UAM HQ reqmts
    - "Tune" Desired/Adequate Criteria
    - Test Course tailored to civilian vehicles in the ≤7,000lb weight class

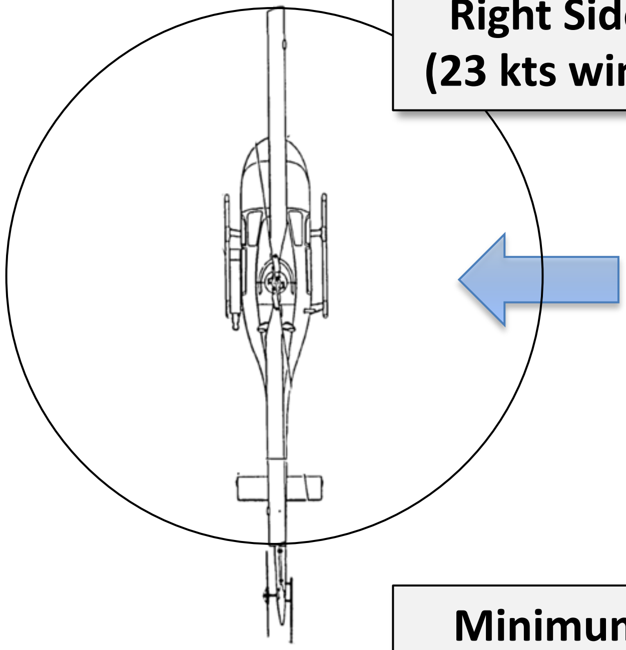


Build II results

Demonstrated All Azimuth Capability





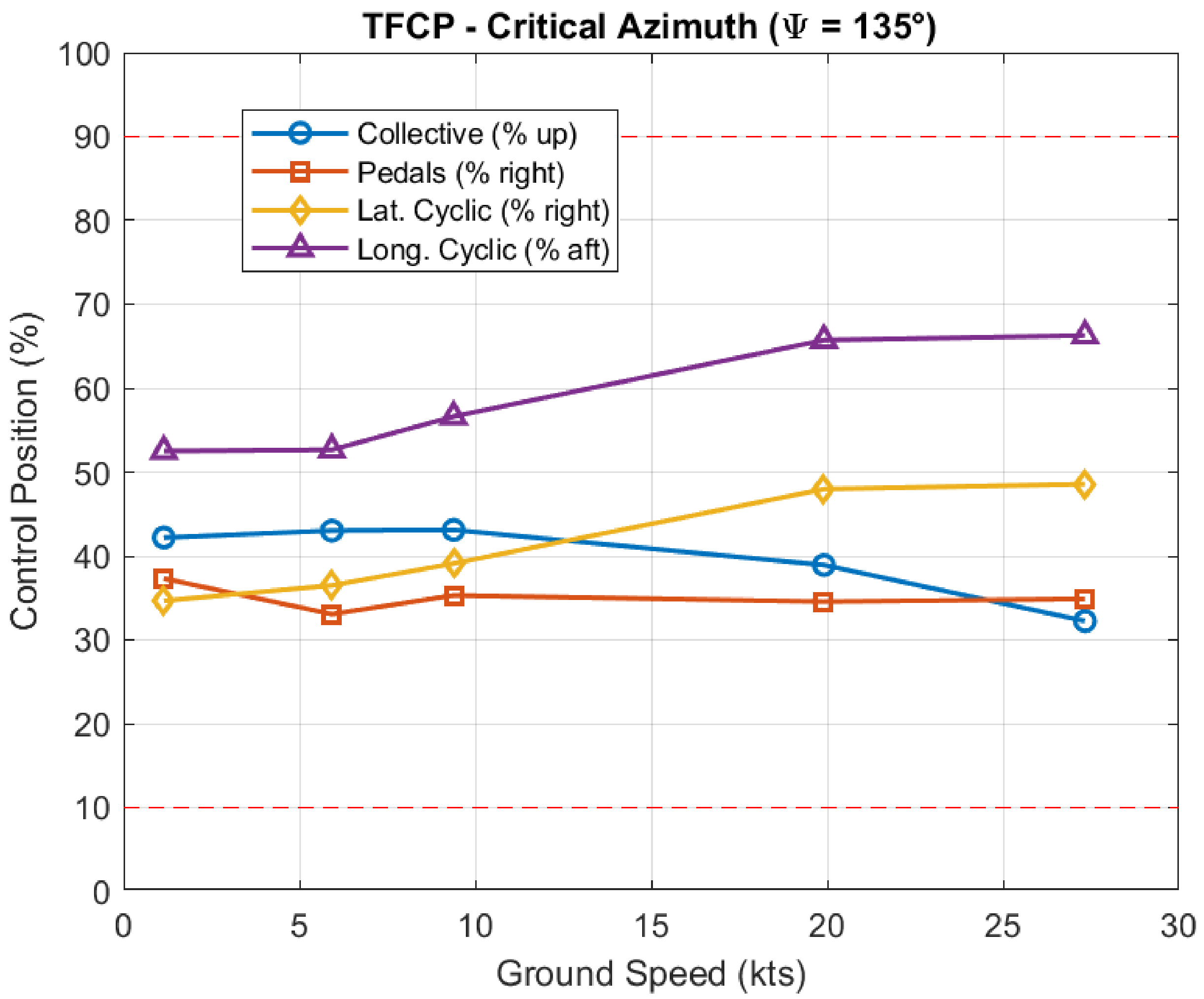


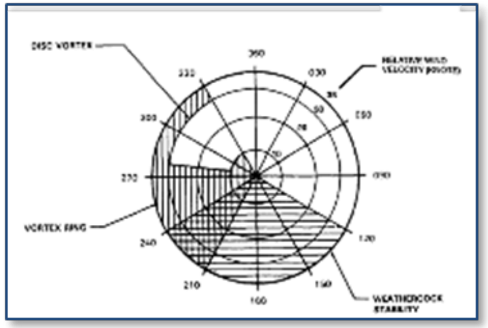
Right Sideward Flight
(23 kts wind from right)

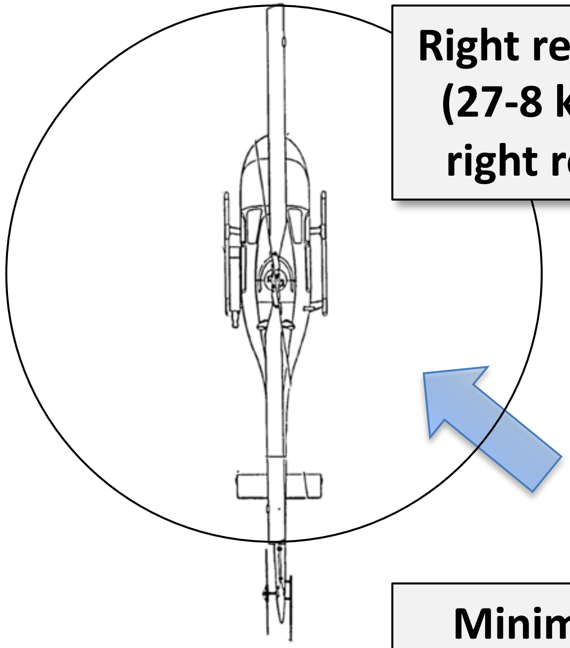
Minimum control margin ~30%
Pedal

Build II results

Demonstrated All Azimuth Capability





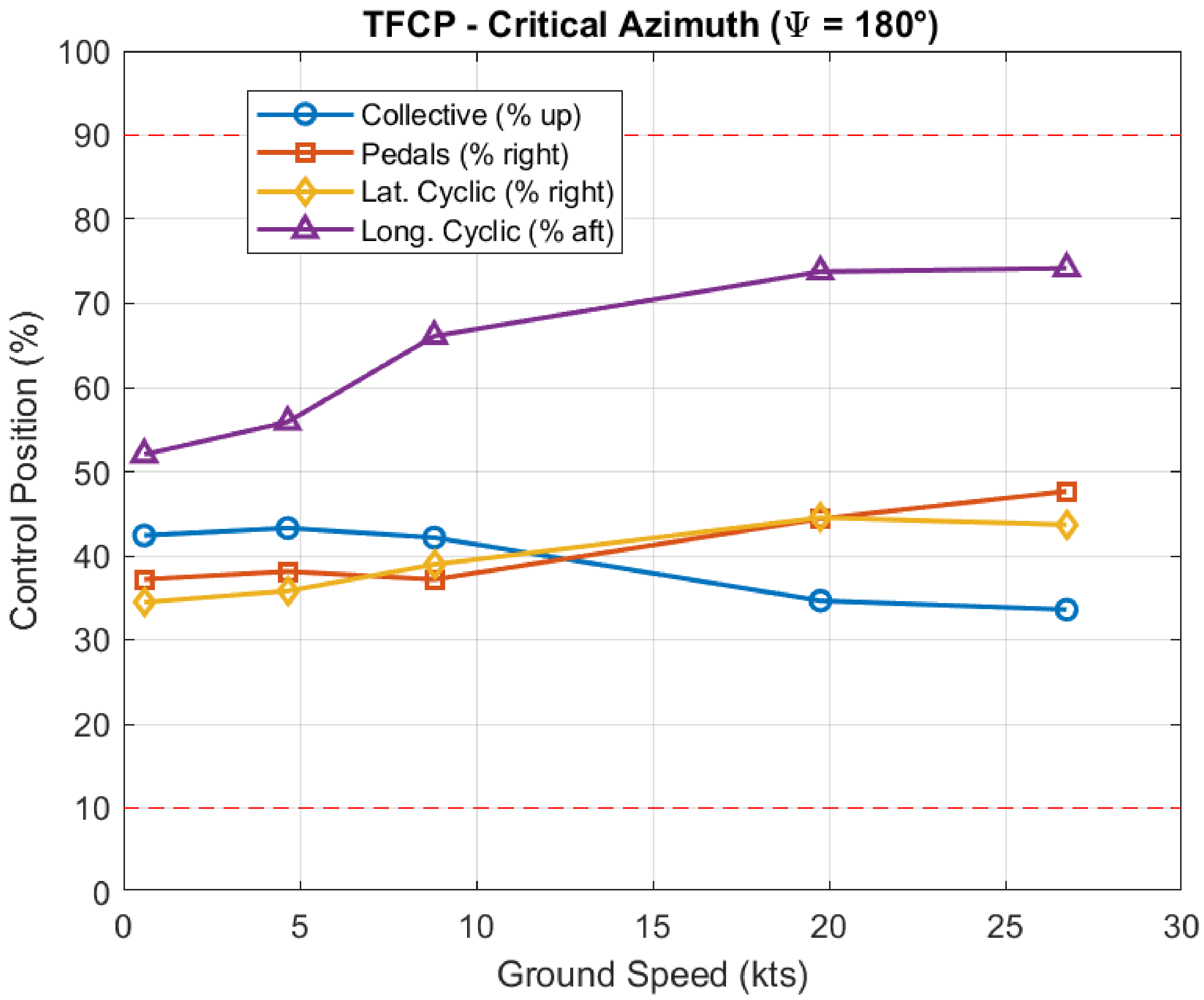


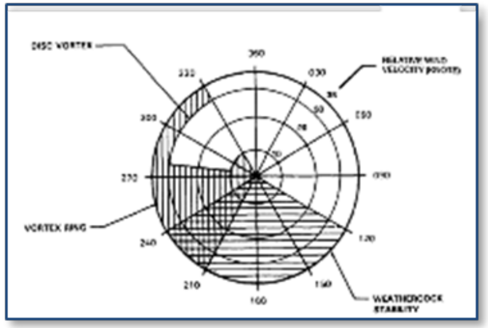
Right rearward Flight (27-8 kt wind from right rear quarter)

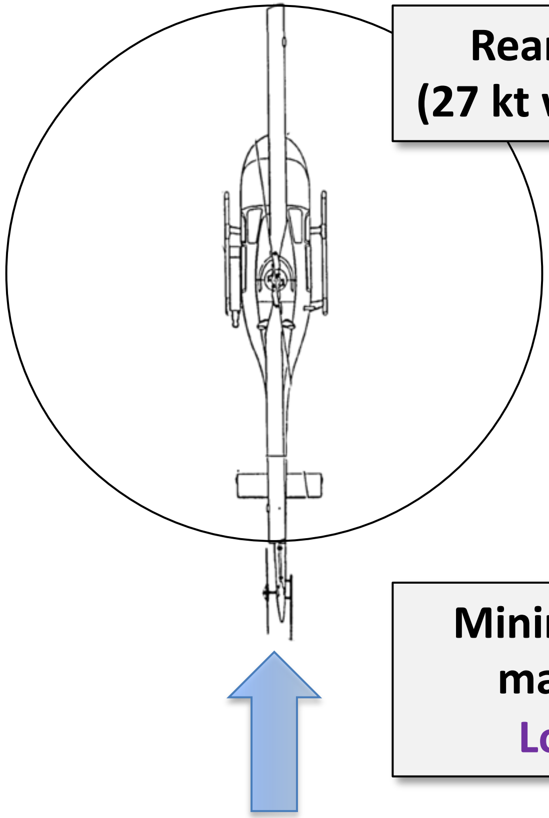
Minimum control margin ~30%
Pedal, Collective

Build II results

Demonstrated All Azimuth Capability





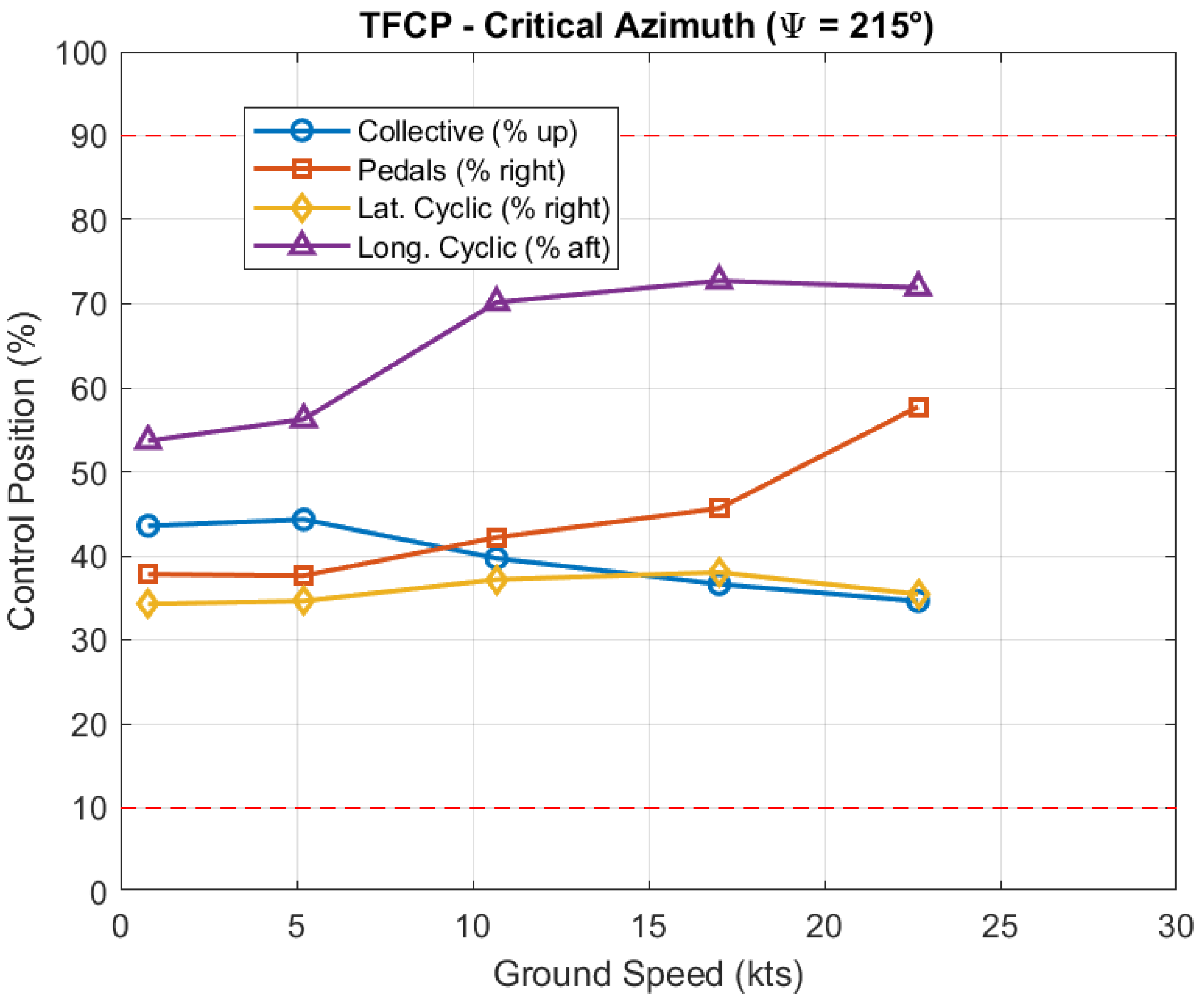


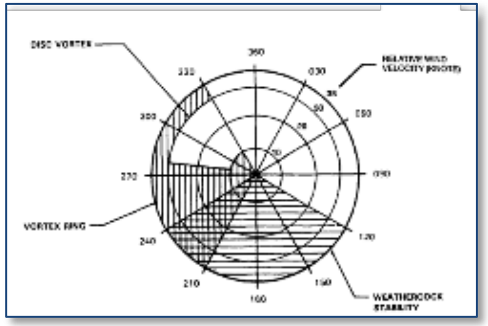
Rearward Flight (27 kt wind from tail)

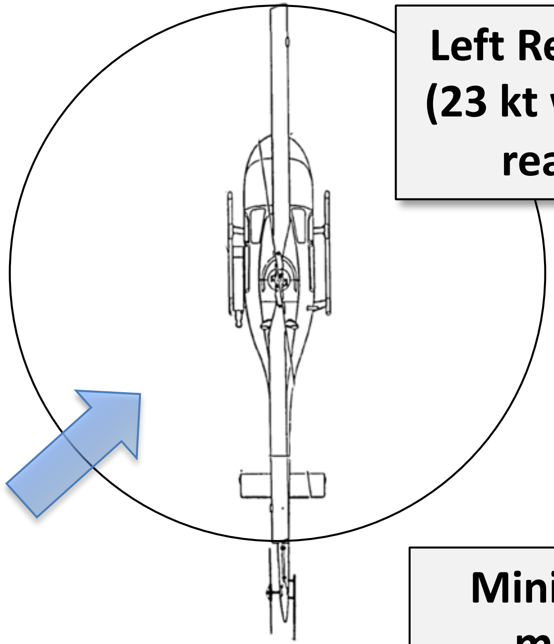
Minimum control margin ~26%
Long Cyclic

Build II results

Demonstrated All Azimuth Capability





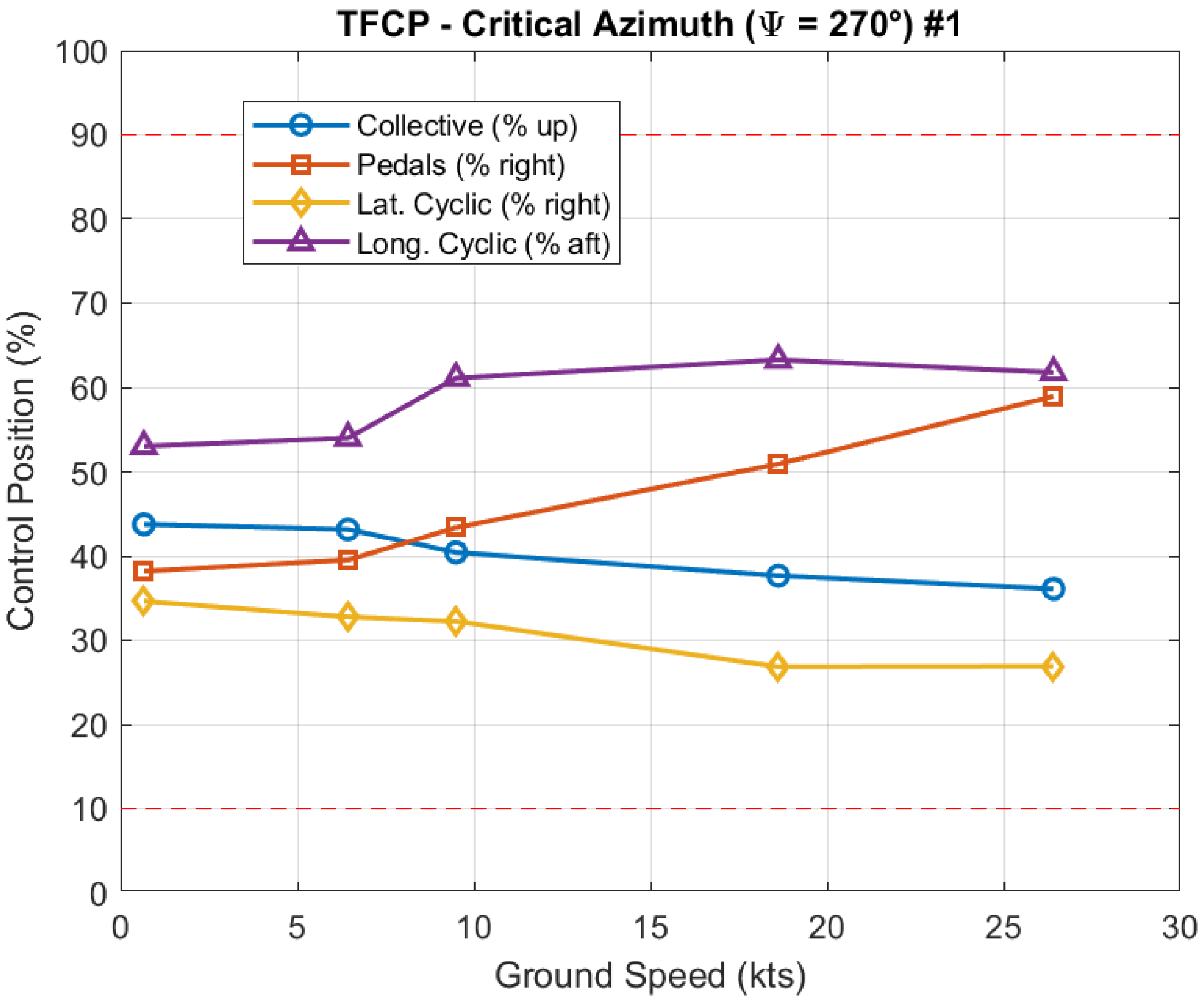


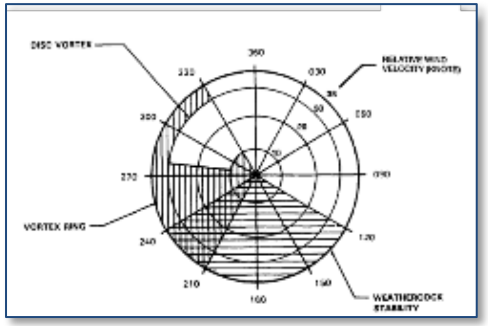
Left Rearward Flight (23 kt wind from left rear quarter)

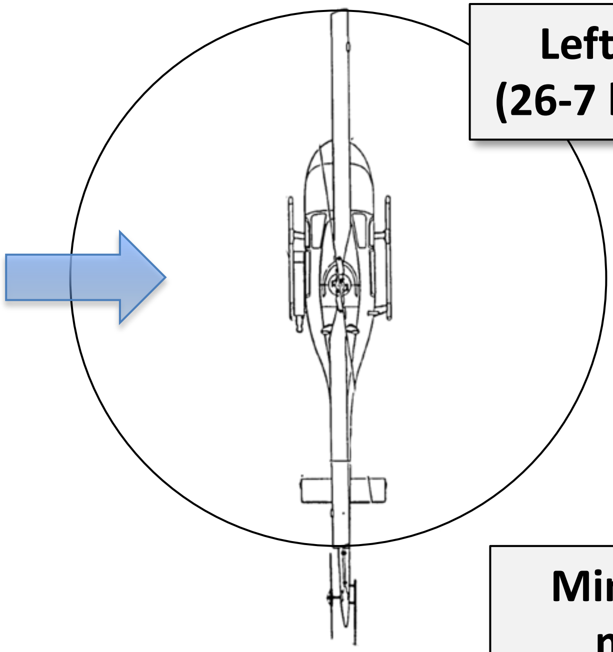
Minimum control margin ~28%
Long Cyclic

Build II results

Demonstrated All Azimuth Capability


TFCP - Critical Azimuth (Ψ = 270°) #1



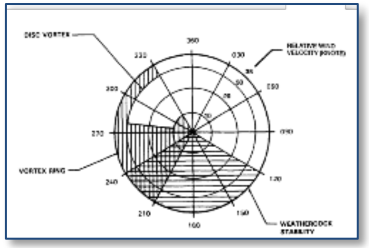


Left Sideward Flight (26-7 kts wind from left)

Minimum control margin ~27%
Lateral Cyclic

Build II results

Vehicle requirements for Urban Air Mobility Operations



- **Verified All Azimuth Capability (Vehicle Characteristics)**
  - **~25 kts* dedicated test at test day weight/altitude/temperature results in at least 26% control margin across all axes**

recommend pace vehicle be incorporated for future all azimuth testing in order to determine UAM limit conditions

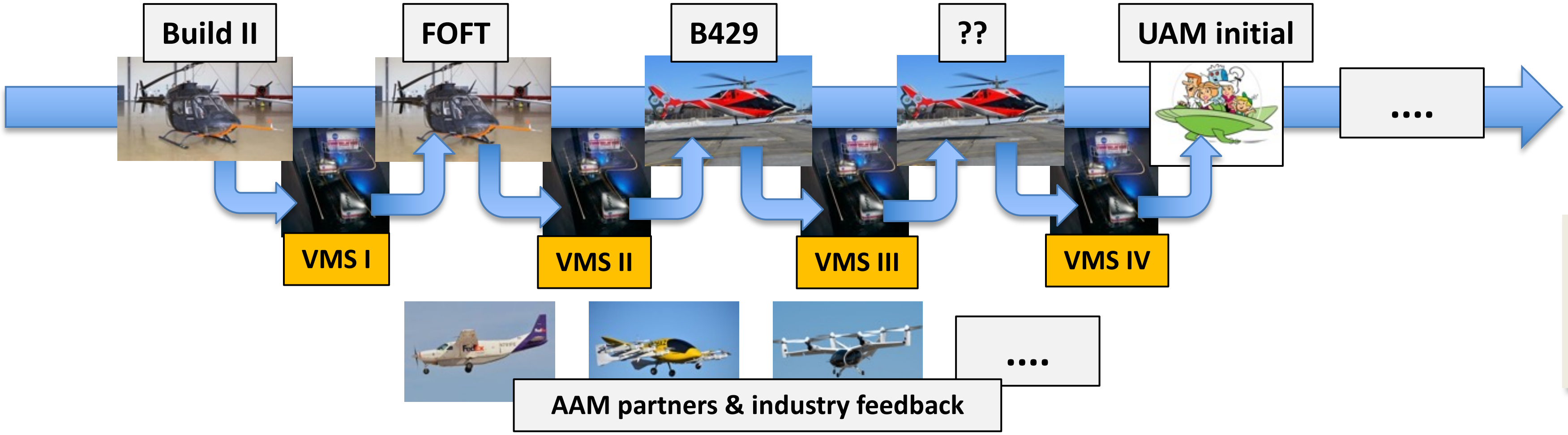
- **Windward/Leeward effects observed during initial "Dynamic Interface" testing (UAM Task Elements)**
  - **Controllability checks are identical between "freestream" (01H) and "windward" (03H) Landing Zones (LZ).**
  - **DI test sequence modified to only compare 01H and "leeward" (02H) LZ prior to commencing DI approaches**
  - **Test sequence modified to fly approaches with wind from the right, prior to wind from the left (Vehicle Characteristics – All Azimuth results)**

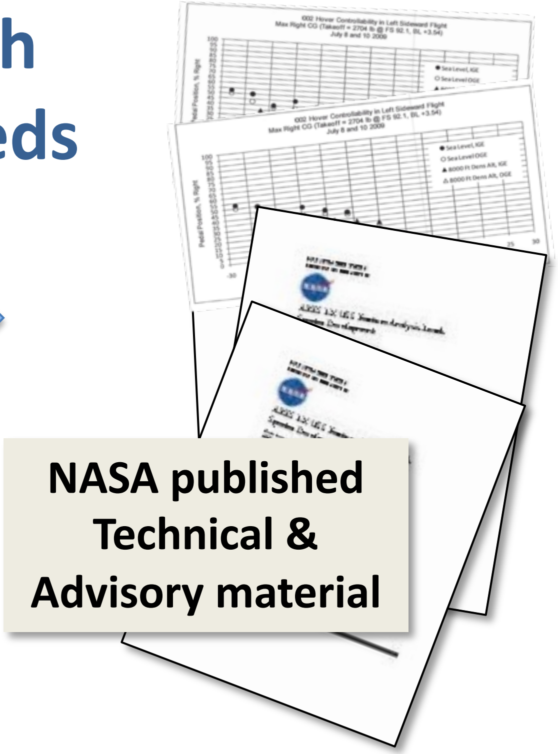
recommend CFD analysis of research building/LZ flight test infrastructure to support technical findings

Required Handling Qualities for UAM

Developmental UAM Task Elements

- AAM NC foundational role in Mission Task Element development
- Utilize UAM Surrogate vehicles as “experiment control” to compare flight results from “traditional” vs “draft civil HQ” FT methods
- Deliver Flight verified Performance constraints (viable UAM approaches)
- Support interagency and industry collaborative sim research
- Collaborate with industry and iterate on flight research needs

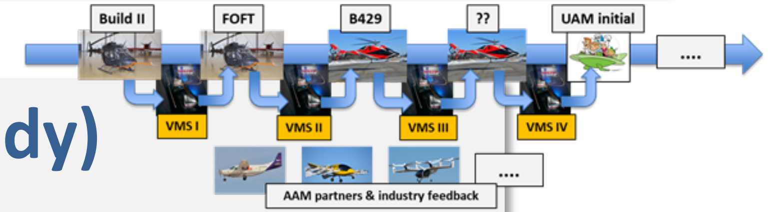




NASA published Technical & Advisory material

June 2021 Study* Ames Vertical Motion Simulator (VMS)


Build II research results



Initial HQTE development (FAA-1A study)

- 54 conditions tested
  - UAM heliport approach with NC
  - “Operational” vs. “Stress Test” UAM Task Elements
  - AAM NC evaluation aircrew participation
- 2 UAM aircraft concept vehicles
- 1 IFCS concept
  - Unified’ FCS and inceptor strategy
- Usable Cue Environment/Test Range Development
- Simulator Infrastructure for future development
- Initial Evaluation methods
- Results/observations used to refine Follow on Flight Test HQ criteria and test range needs


RPM Control

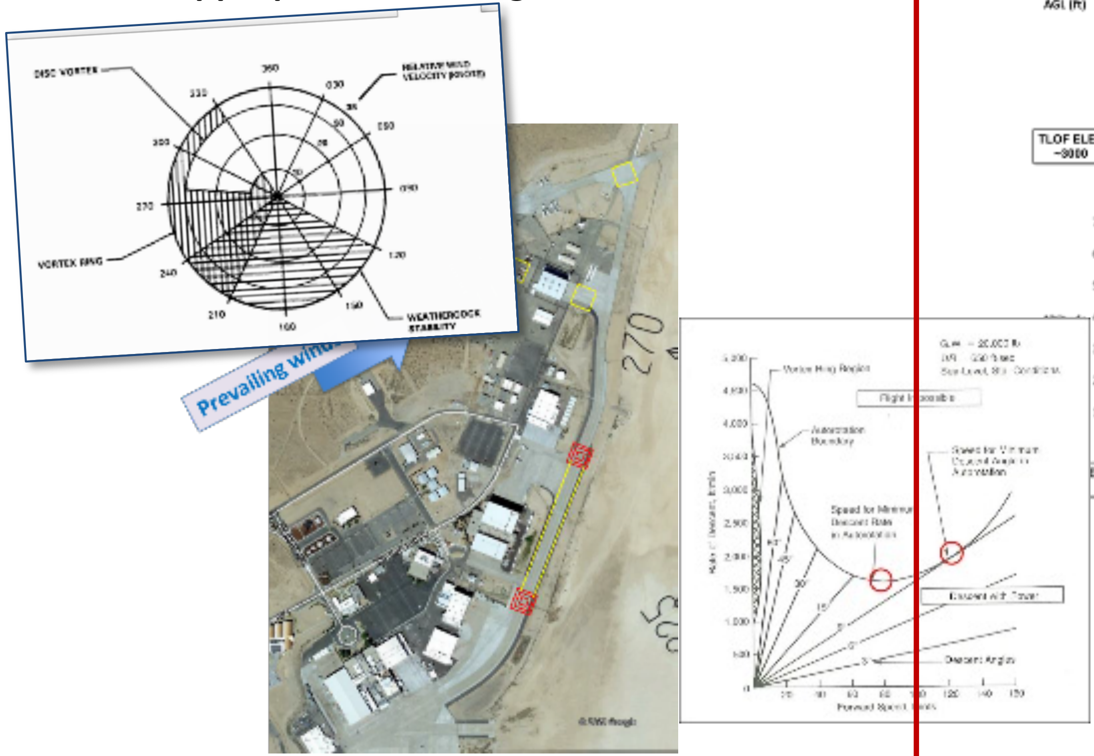

Collective Control

* w/M. Feary – NASA AFCM

UAM initial interest areas

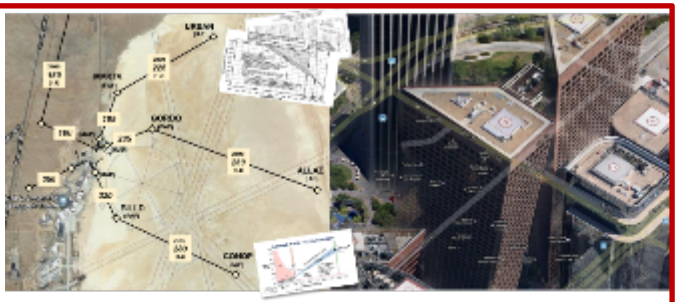
Vehicle Characteristics required for Urban Operations

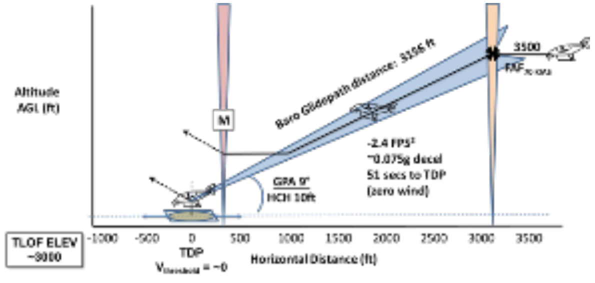
- UAM Performance requirements
- Minimum Stability requirements (IFR)
- All Azimuth Capability (controllability)
- Wind/structure dynamic interface (proximity of landing zone to structures)
- Appropriate Handling Qualities

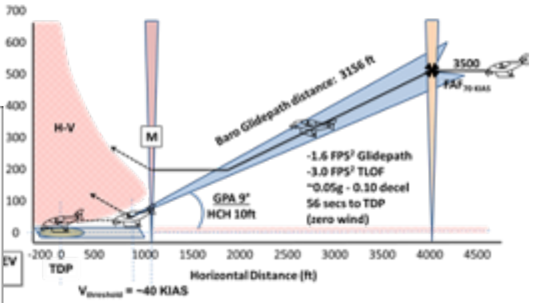


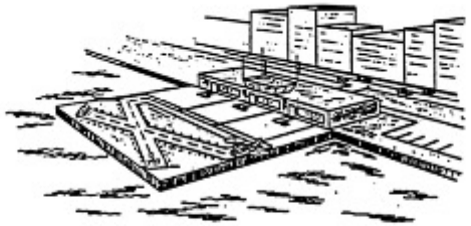
Viable UAM Approaches/Airspace

- Viable UAM IMC approaches
- Heliport and Vertiport ops



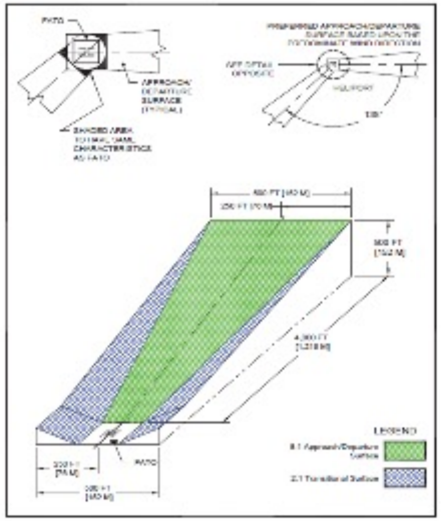






Required evolutions to existing standards to enable UAM

- Airspace
- Infrastructure

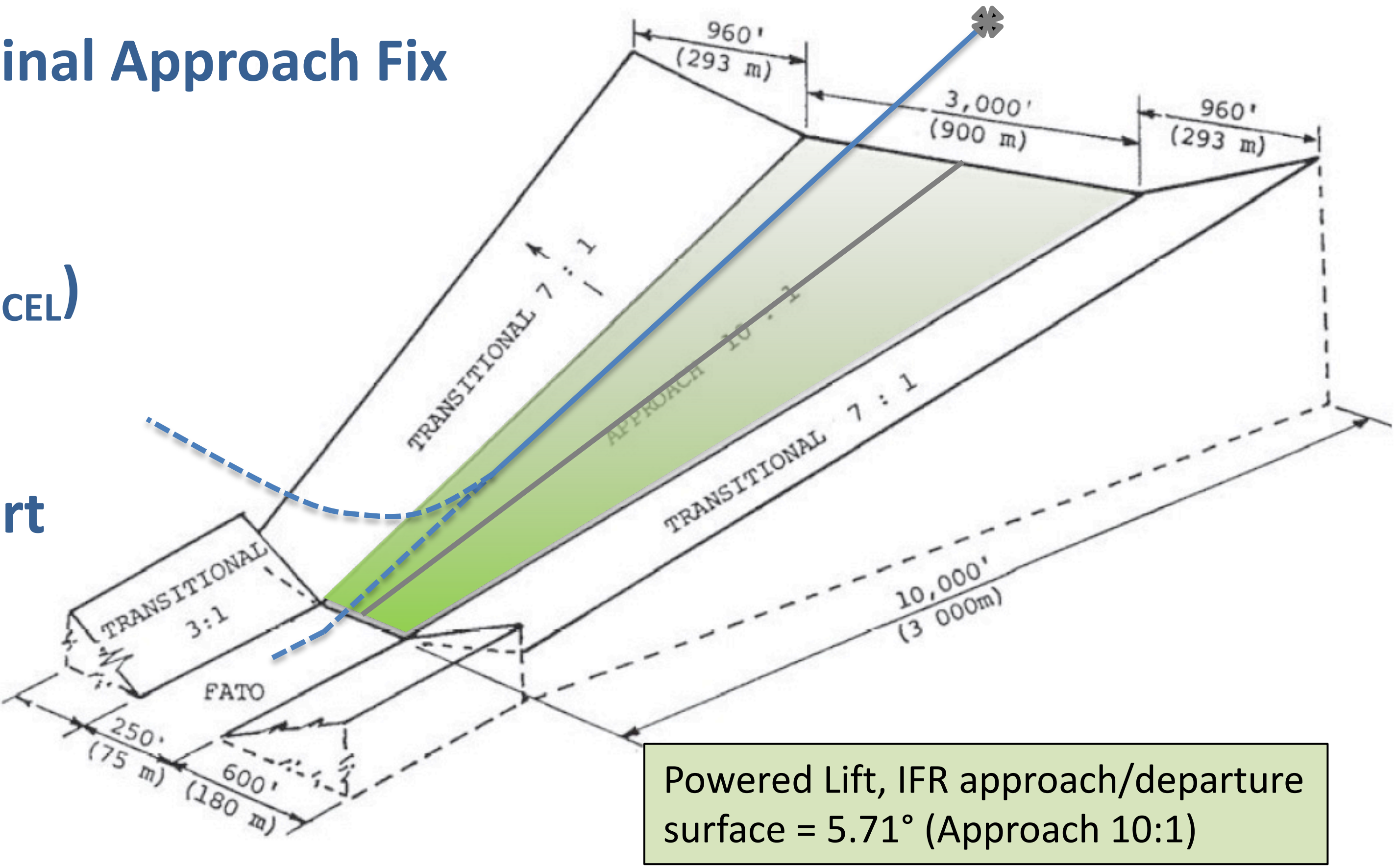


AAM National Campaign

UAM Vertiport approach/departure surface

- Constant speed approach from Final Approach Fix (FAF),
- Fixed glidepath angle (GPA),
- Defined deceleration height (H_{DECEL})
- Missed approach, or;
- Decelerate to a vertical landing,
- Constrained by passenger comfort parameters

(steeper approaches will tend to require powered-lift vehicles to fly their approach in transitional flight)



Powered Lift, IFR approach/departure surface = 5.71° (Approach 10:1)

Figure 3-5. Vertiport 9-degree precision instrument approach surfaces

Ref. FAA AC 150 5390-3 Vertiport Design (cancelled)

Current TERPS Approach Categories

	Threshold Speed, V_{AT}*	**final approach speed, V_{FAF} (3°/4.5°)**	**max descent rate**
A	$\leq$90 knots	70-100 knots	~500/700 fpm
B	91-120 knots	85-130 knots	~650/1050 fpm
C	121-140 knots	115-160 knots	~750/1100 fpm
D	141-165 knots	130-185 knots	~900/1300 fpm
E	166-210 knots	155-230 knots	
H	N/A	60-90 knots	~500/700 fpm

(E usually not published on civil charts – used for military fighters, etc.)

*V_{AT} is based on 1.3V_{SO} or 1.23VS_{1G} (akin to V_{REF})
Instrument approach assumes 3° nominal/4.5° glidepath

UAM Heliport – 120ft^2

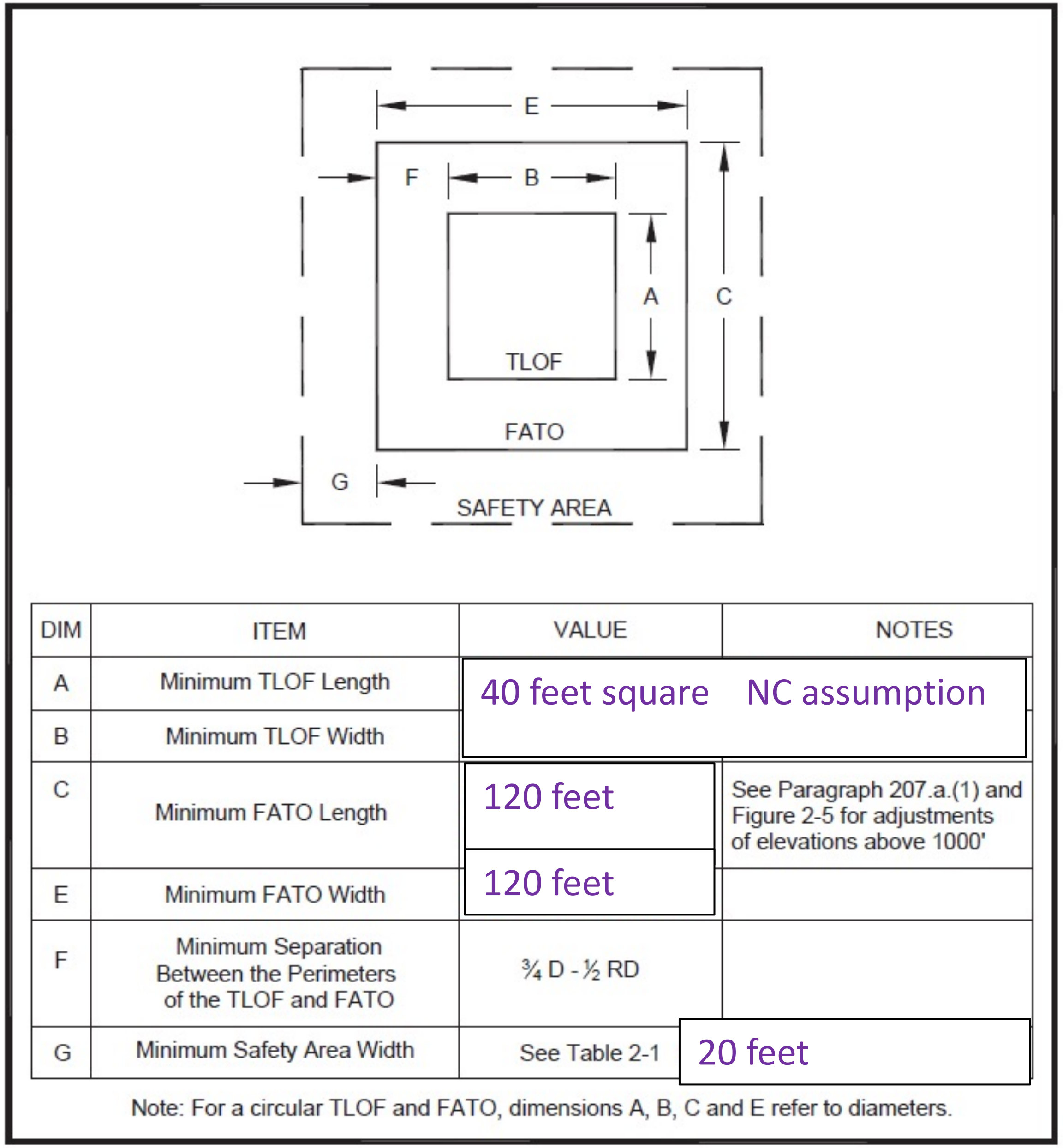
Square TLOF/FATO (and Safety Area) designed in accordance with the FAA's current Heliport Design Advisory Circular*.

Accommodates vehicles that will make a constant decelerating approach on a fixed glidepath to a hover point directly over the touchdown point prior to touchdown.

40 foot nominal Touchdown/Liftoff area (TLOF) (assumes max dimension <40 feet)

Ref. AC 150 5390-2C Heliport Design

(Markings/placement to be IAW Heliport Design AC – FATO length will need to be adjusted dependent on elevation)



DIM	ITEM	VALUE	NOTES
A	Minimum TLOF Length	40 feet square	NC assumption
B	Minimum TLOF Width		
C	Minimum FATO Length	120 feet	See Paragraph 207.a.(1) and Figure 2-5 for adjustments of elevations above 1000'
E	Minimum FATO Width	120 feet	
F	Minimum Separation Between the Perimeters of the TLOF and FATO	¾ D - ½ RD	
G	Minimum Safety Area Width	See Table 2-1	20 feet

Note: For a circular TLOF and FATO, dimensions A, B, C and E refer to diameters.

Figure 2–2. TLOF/FATO Safety Area Relationships and Minimum Dimensions:

AAM NC Terminal Ops

6 AAM NC *"UAM Heliports"*

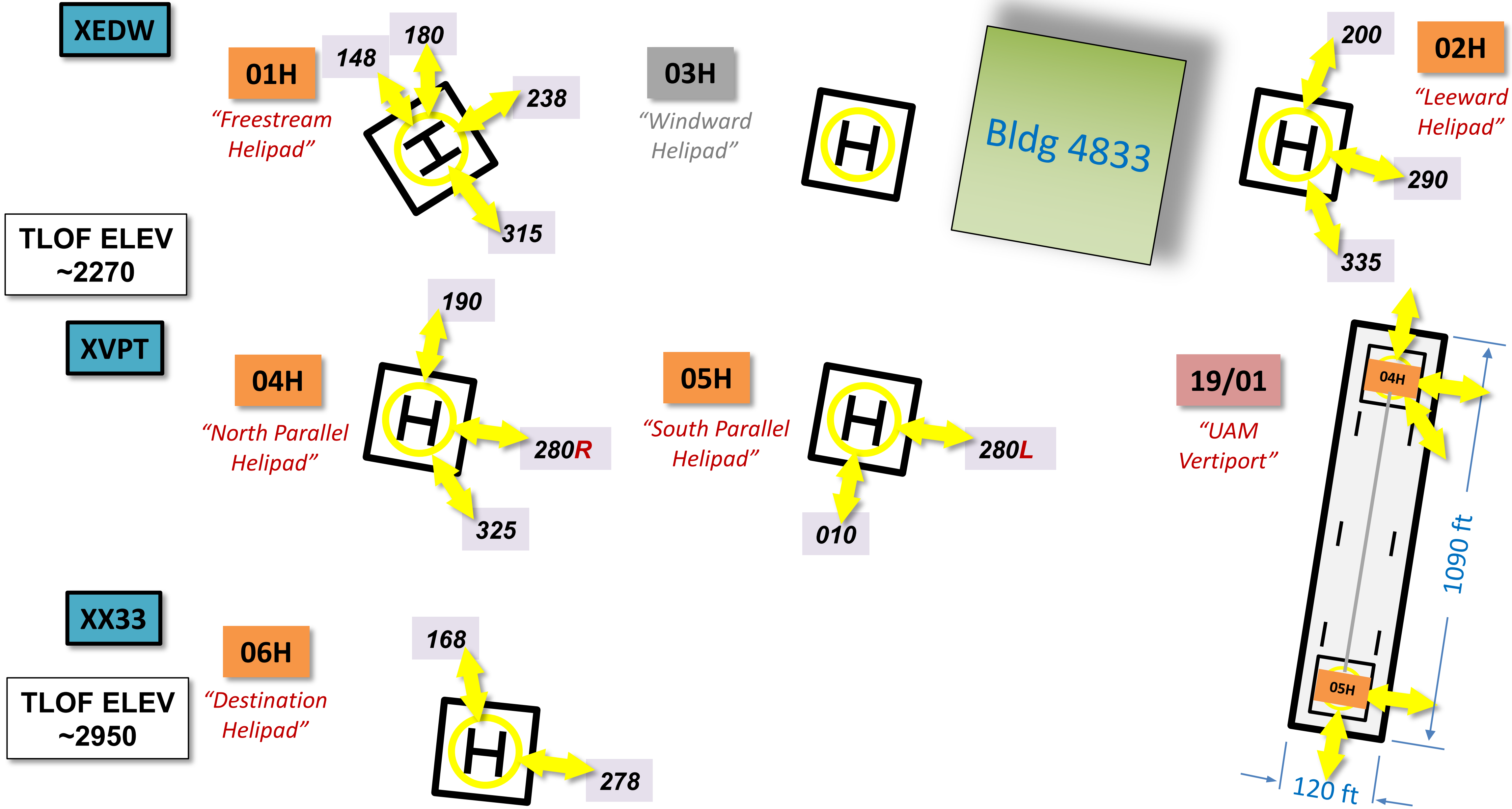
- 40x40ft TLOF
- Northern Heliports suitable for wind/controllability studies
- All Heliport design/placement IAW AC 150/ 5390-2C Heliport Design

1 AAM NC *"UAM Vertiport"*

- 1090ft length x 120ft width TLOF/FATO
- 01H + 02H + 03H = **XEDW** *Research Airport*
- 04H + 05H + 19/01 = **XVPT** *Research Airport*
- 06H = **XX33** *Research Airport*

FATO and Safety Area are off paved surface, and will not be marked

AAM NC Terminal Approaches



XEDW

TLOF ELEV
~2270

01H
"Freestream Helipad"

03H
"Windward Helipad"

02H
"Leeward Helipad"

XVPT

04H
"North Parallel Helipad"

05H
"South Parallel Helipad"

19/01
"UAM Vertiport"

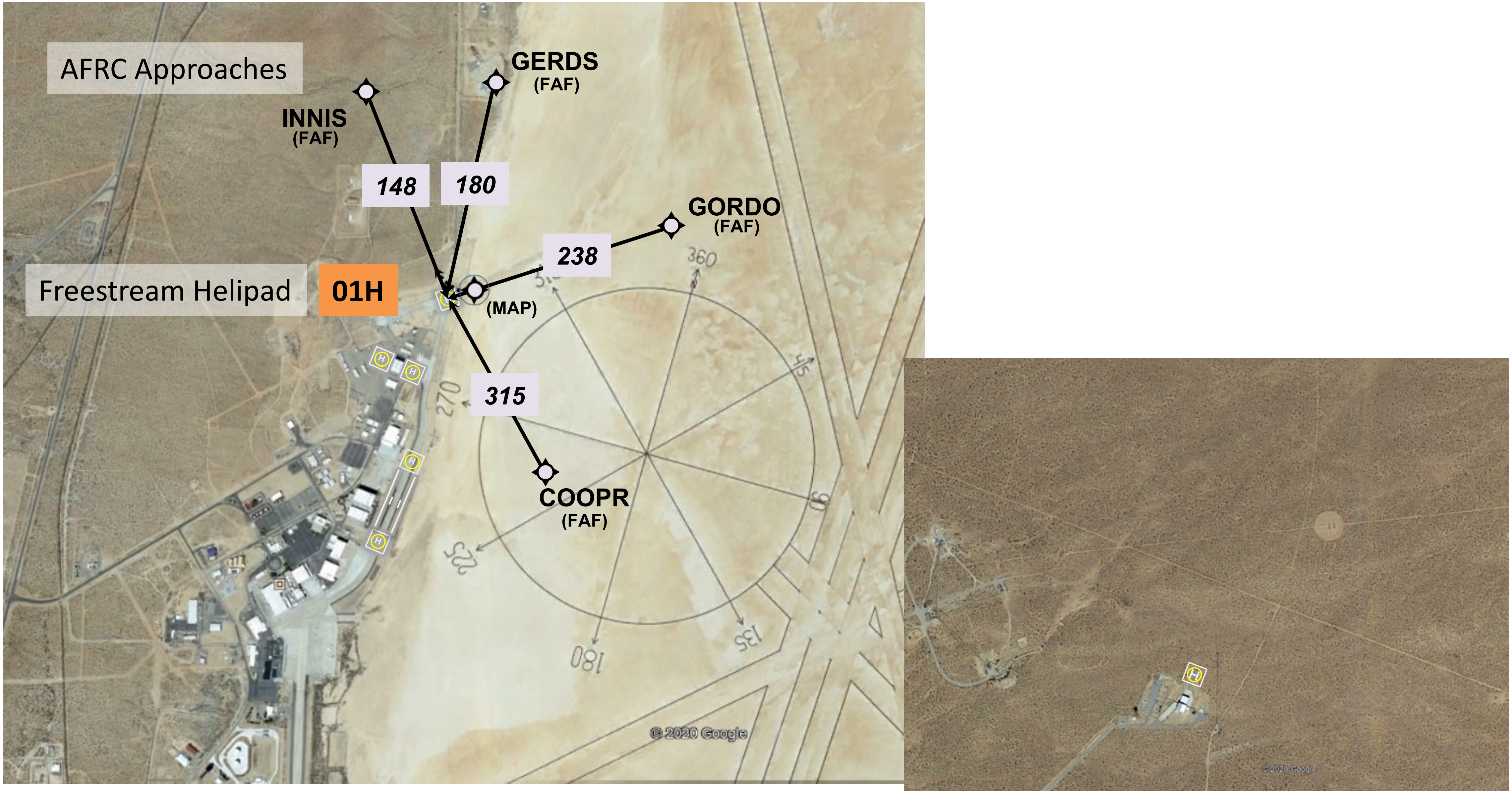
XX33

TLOF ELEV
~2950

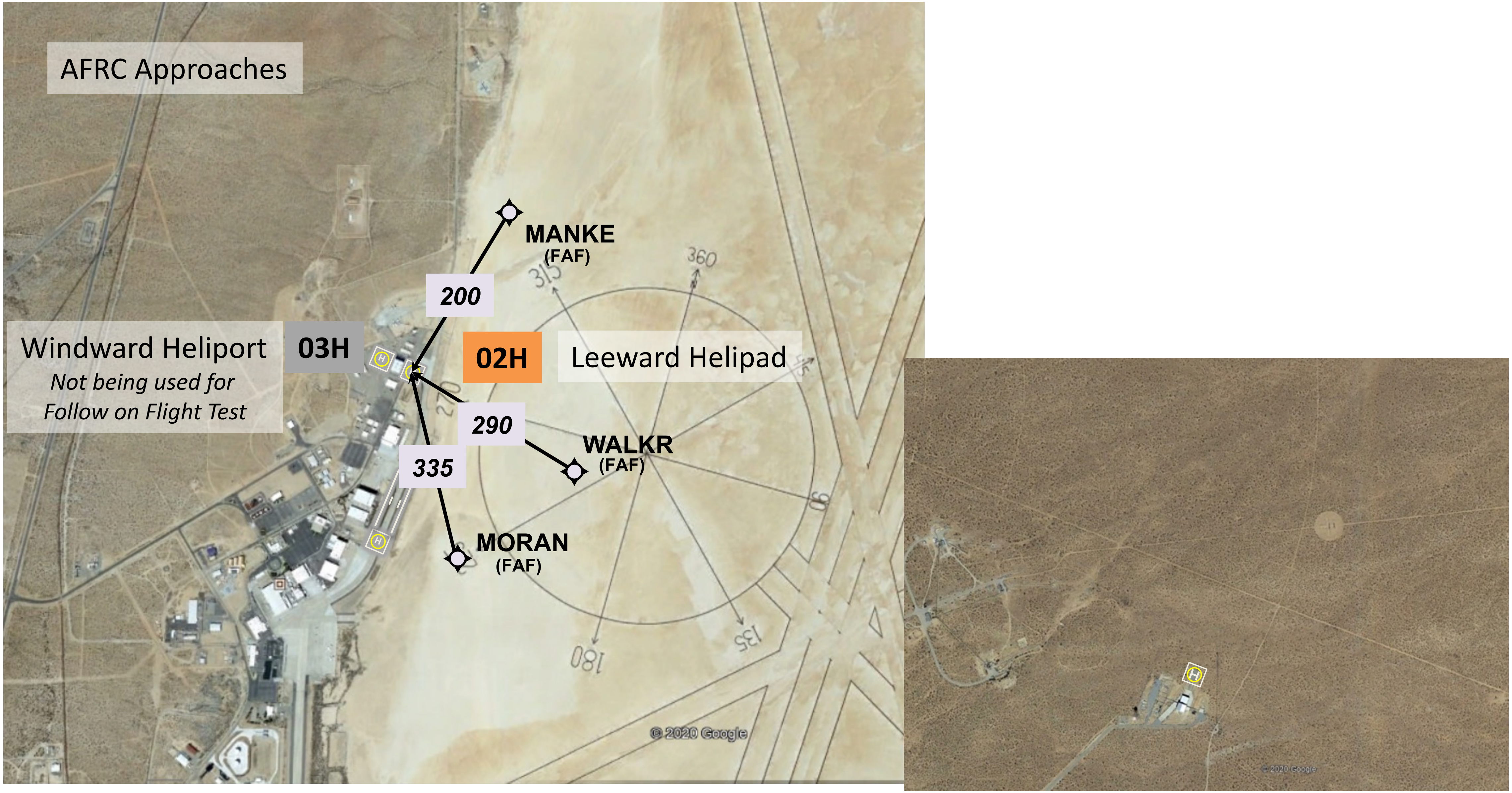
06H
"Destination Helipad"

AAM National Campaign

AAM NC Terminal Approaches



AAM NC Terminal Approaches



AFRC Approaches

Windward Heliport

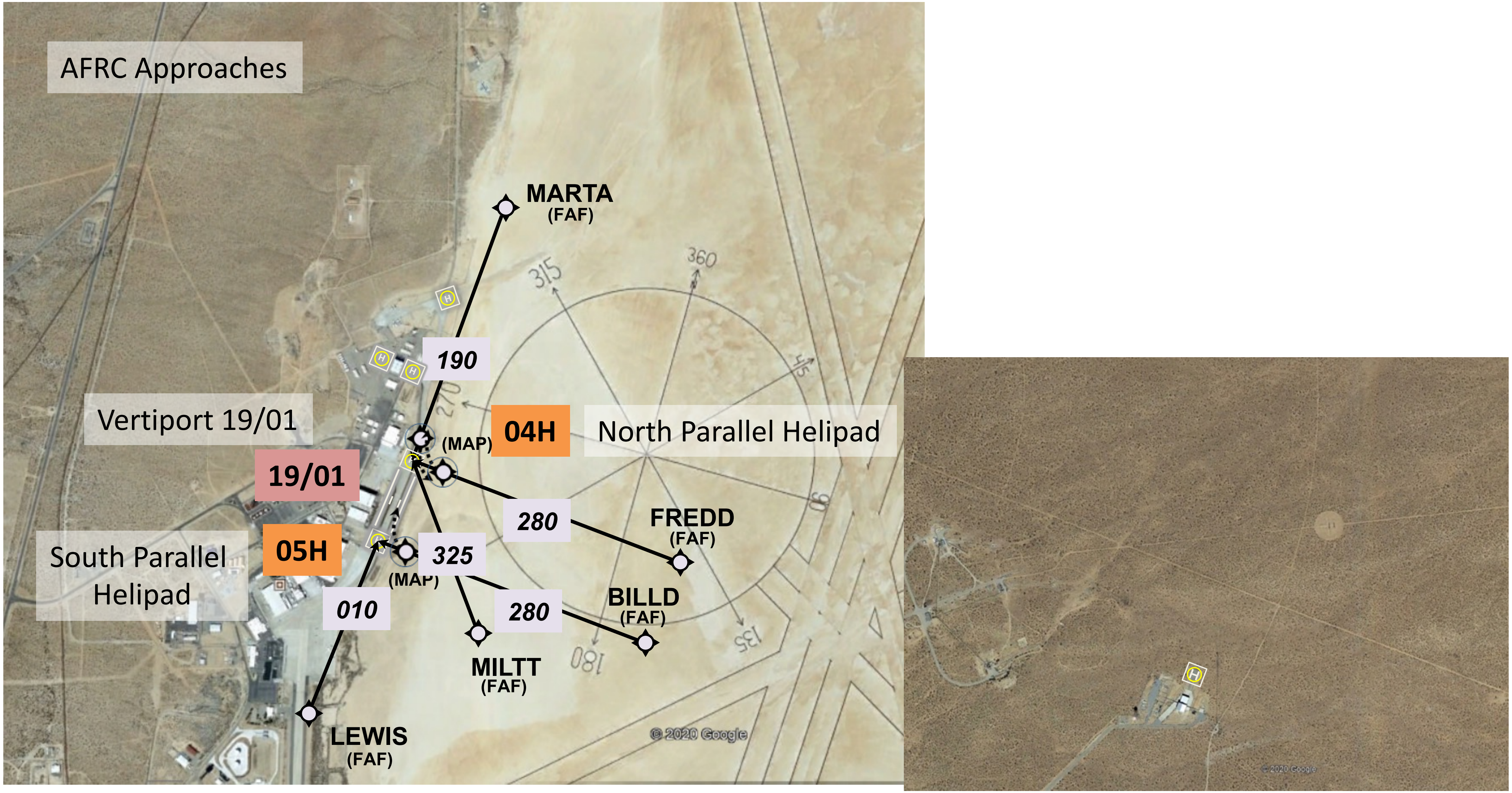
03H

Not being used for Follow on Flight Test

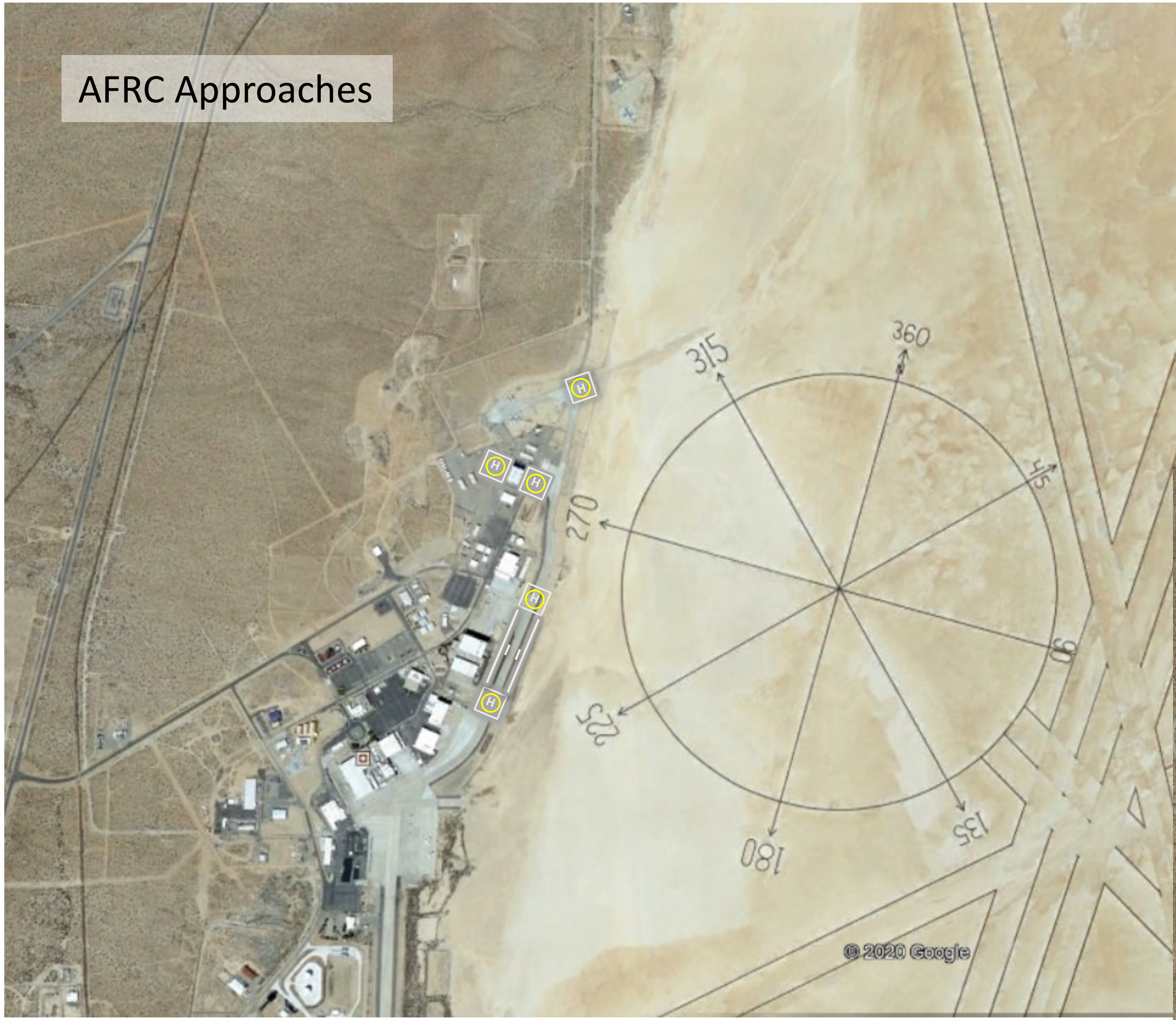
02H

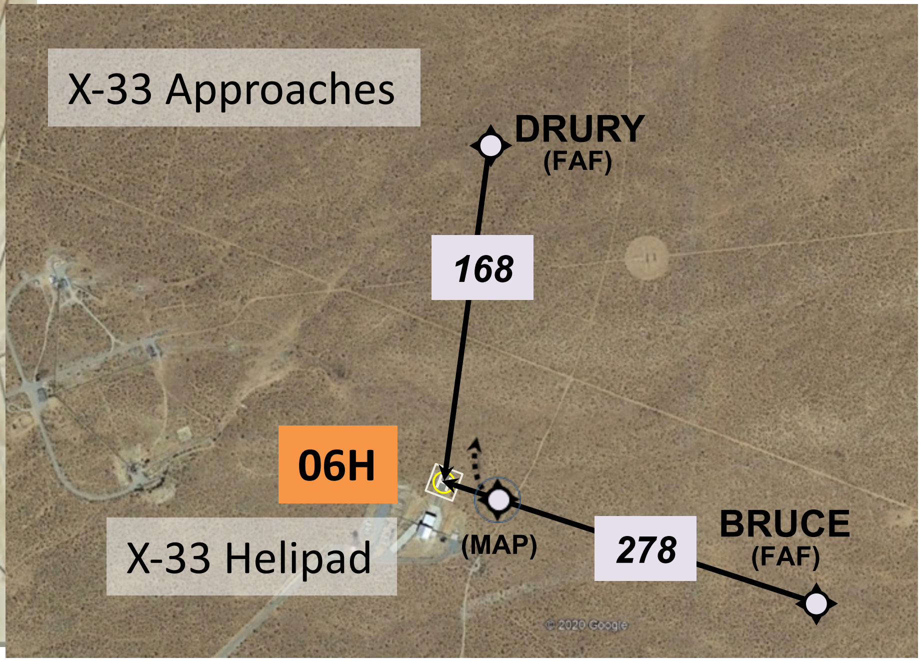
Leeward Helipad

AAM NC Terminal Approaches

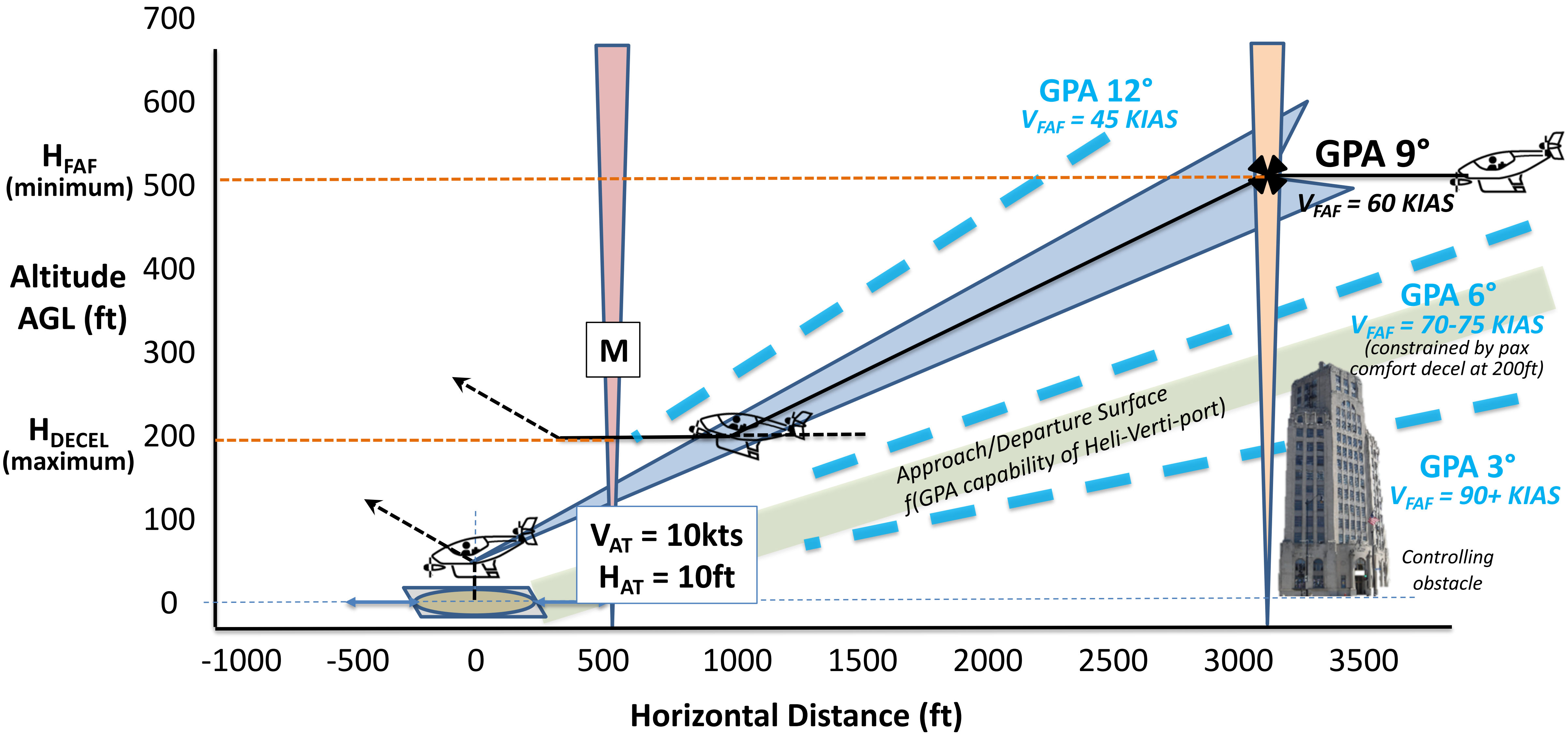


AAM NC Terminal Approaches



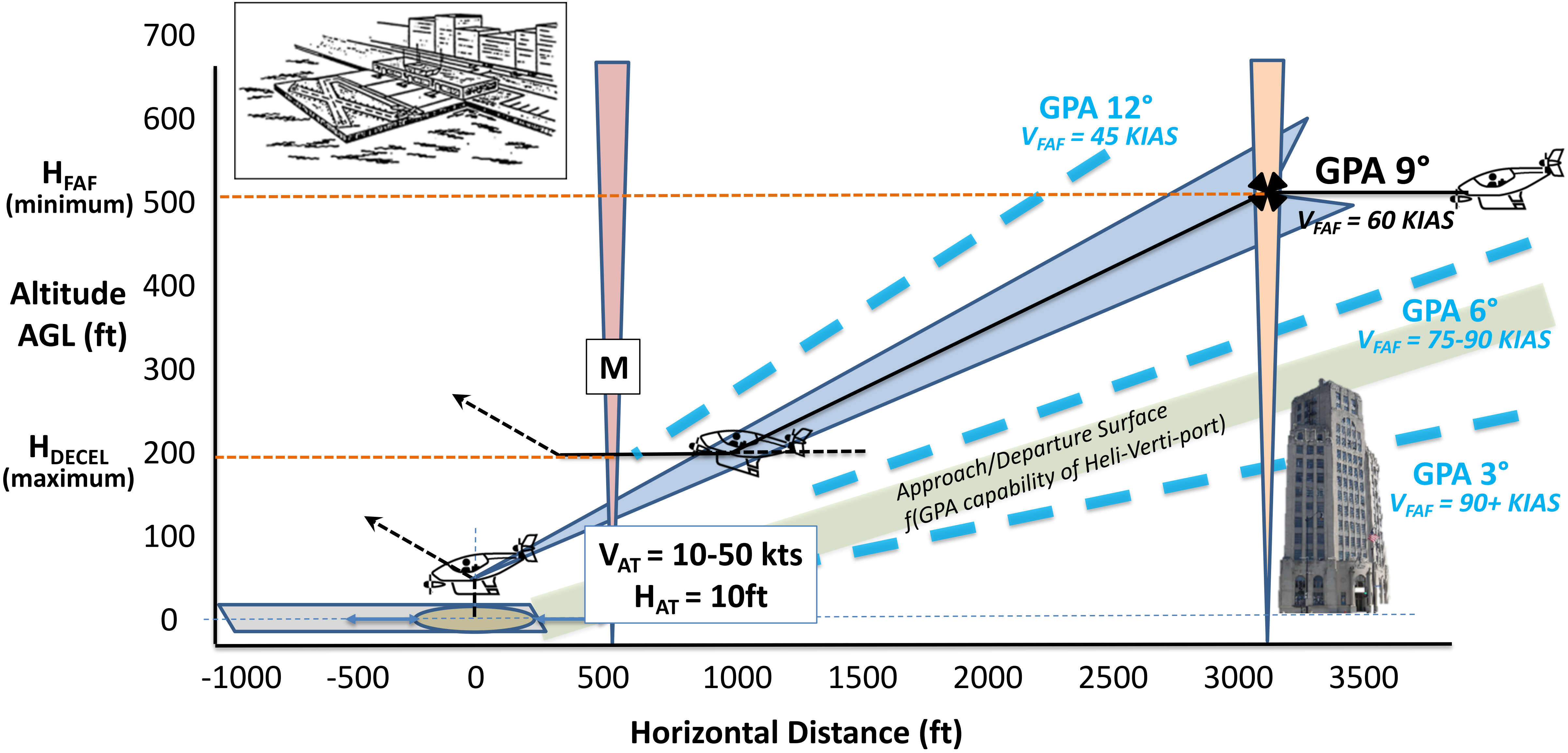


Constant Airspeed* Approach –UAM Heliport



*"constant decel" and "continuous decel" methods were considered not viable without automation/augmentation

Constant Airspeed Approach – NC UAM Vertiport



Approach Constraints –UAM Heli/Vertiport

Approach Constraints

GPA	**App/Dep surface = Obstacle Clearance**	**V_{FAF} KIAS**	**V_{FAF} KTAS**
3 deg	0.875° (66:1-) *Cat III Airport* 2.86° (20:1) *Small Airplane, VFR, some IFR** 3.81° (15:1) *Small Airplane*	Per existing TERPS category V_{SO} *>50kts – Cat B* V_{SO} *<50kts*	

Standard Certification delivers nominal **3-4.5°**
Glidepath Angle capability,
IFR capability NOT assured
(Part 23 and Part 27 baseline)

Aircraft Capability

Infrastructure/Terminal Design/Operations

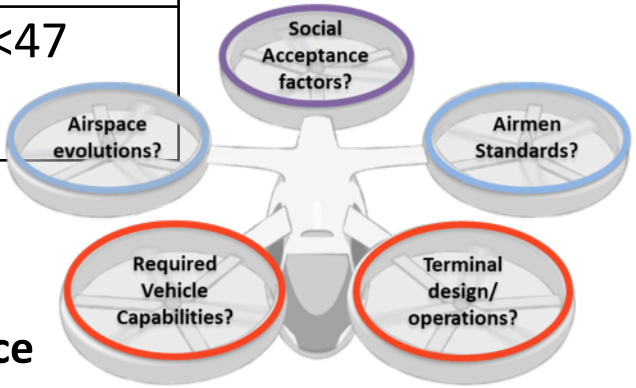
...drives Airspace requirements

*consult AC 150/5300-13A Airport Design for additional details (e.g. threshold reqmts, etc)

Approach Constraints –UAM Heli/Vertiport

Approach Constraints *UAM Heli-[1]/Verti-[2]port* (200 ft H_{DECEL}, [2]varies dependent on V_{AT})

GPA	App/Dep surface = Obstacle Clearance	V_{FAF} KIAS	V_{FAF} KTAS
3 deg	0.875° (66:1) *Cat III Airport*	Per existing TERPS category	
6 deg	3.37° (17:1) *Vertiport IFR*	75[1], ≤90[2]	79[1], ≤94
9 deg	5.71° (10:1) *Vertiport IFR*	60	63
12 deg	8.13° (7:1) *theoretical*	45	47
VTO	2.58° (22:1) to 100 ft AGL, Then 56.3° (6:9) *SC-VTOL MOC*	<45	<47



Aircraft Capability

Infrastructure/Terminal Design/Operations

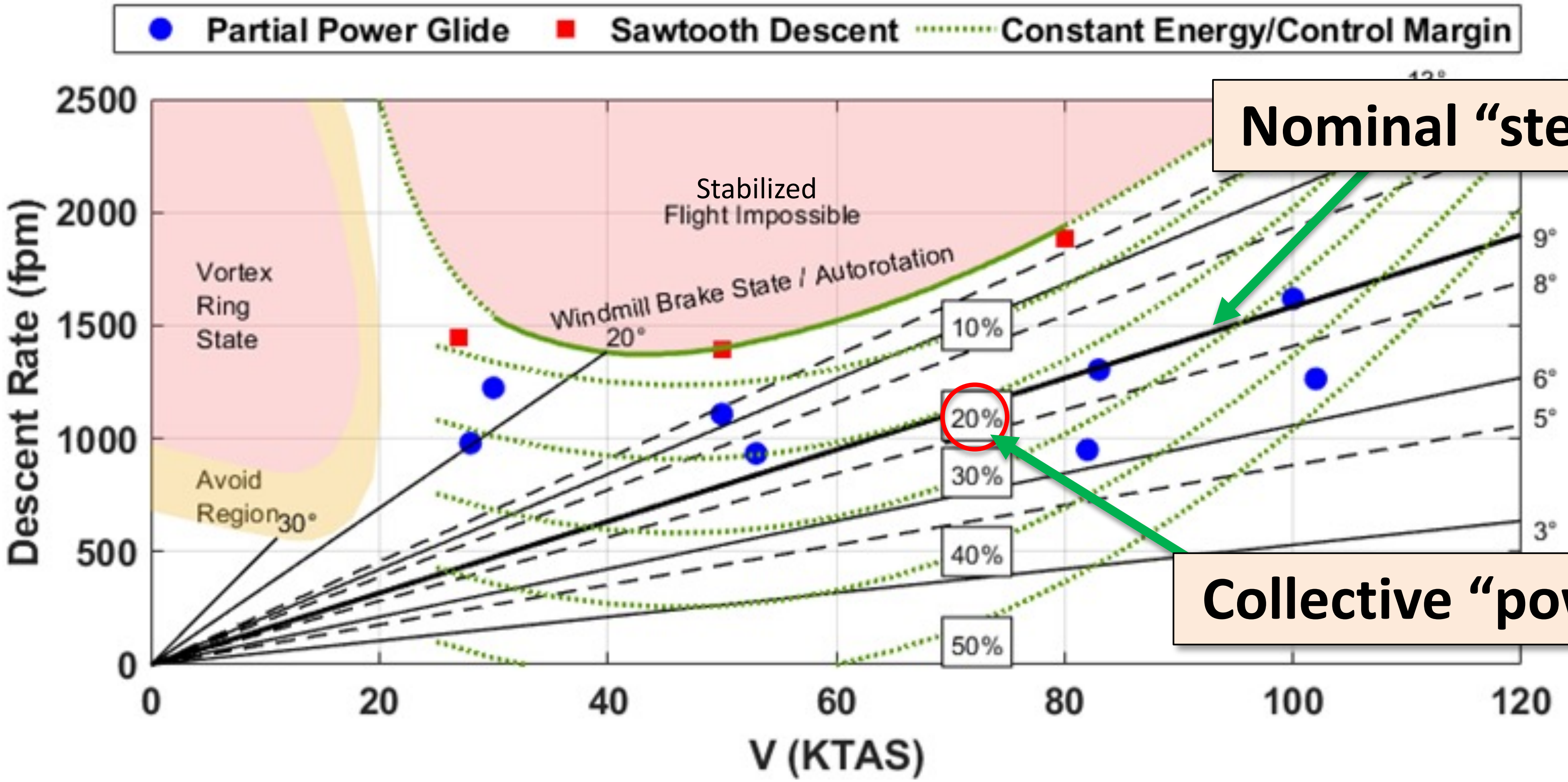
...drives Airspace requirements

- H_{FAF}
- Turn radii
- Inbound leg lengths
- Separation

Initial UAM surrogate results

Approach Constraints charts

Vehicle Characteristics - Performance



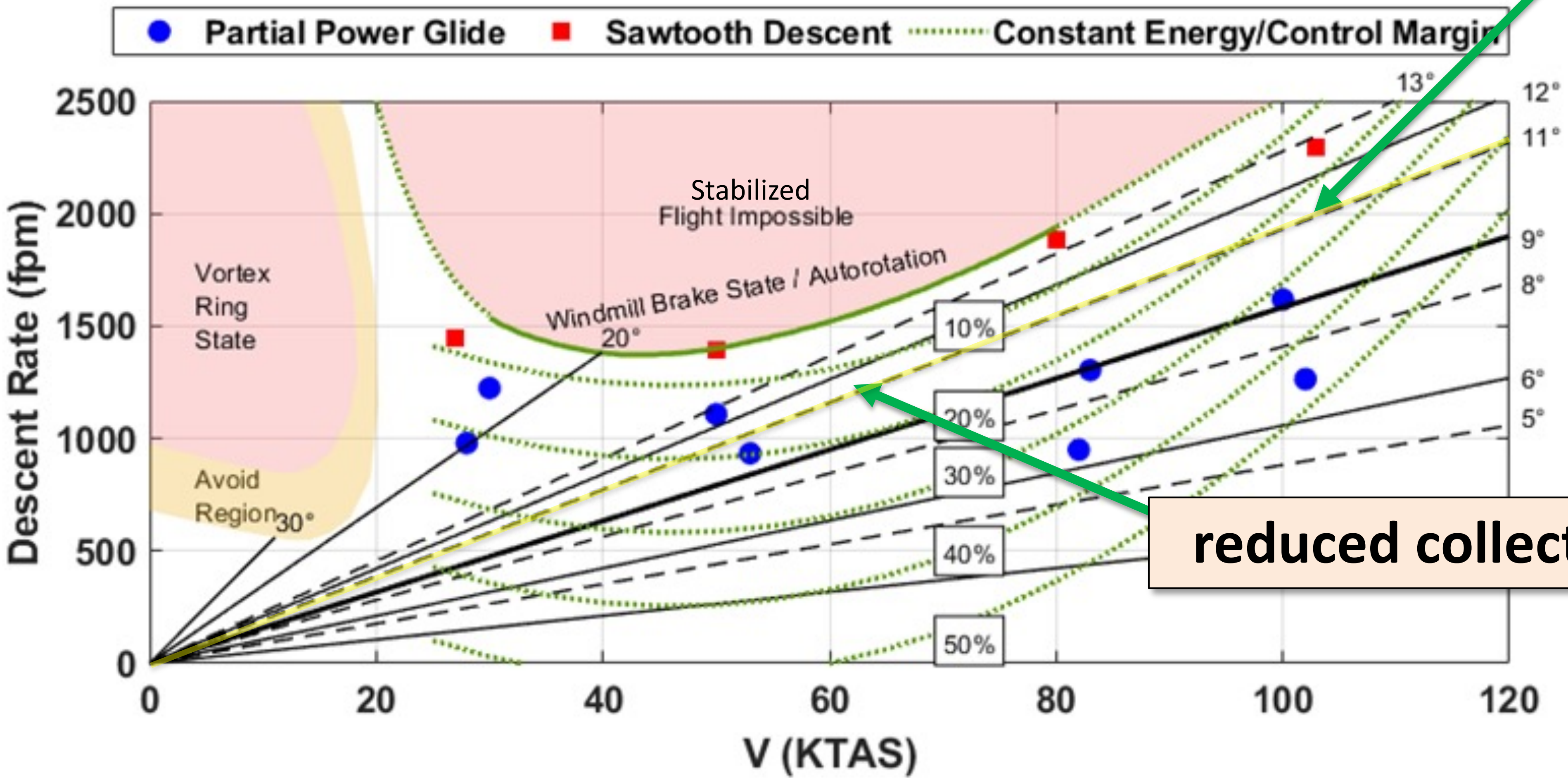
Nominal "steep" approach

Calm Wind

Collective "power margin"

Initial UAM surrogate results

Approach Constraints charts



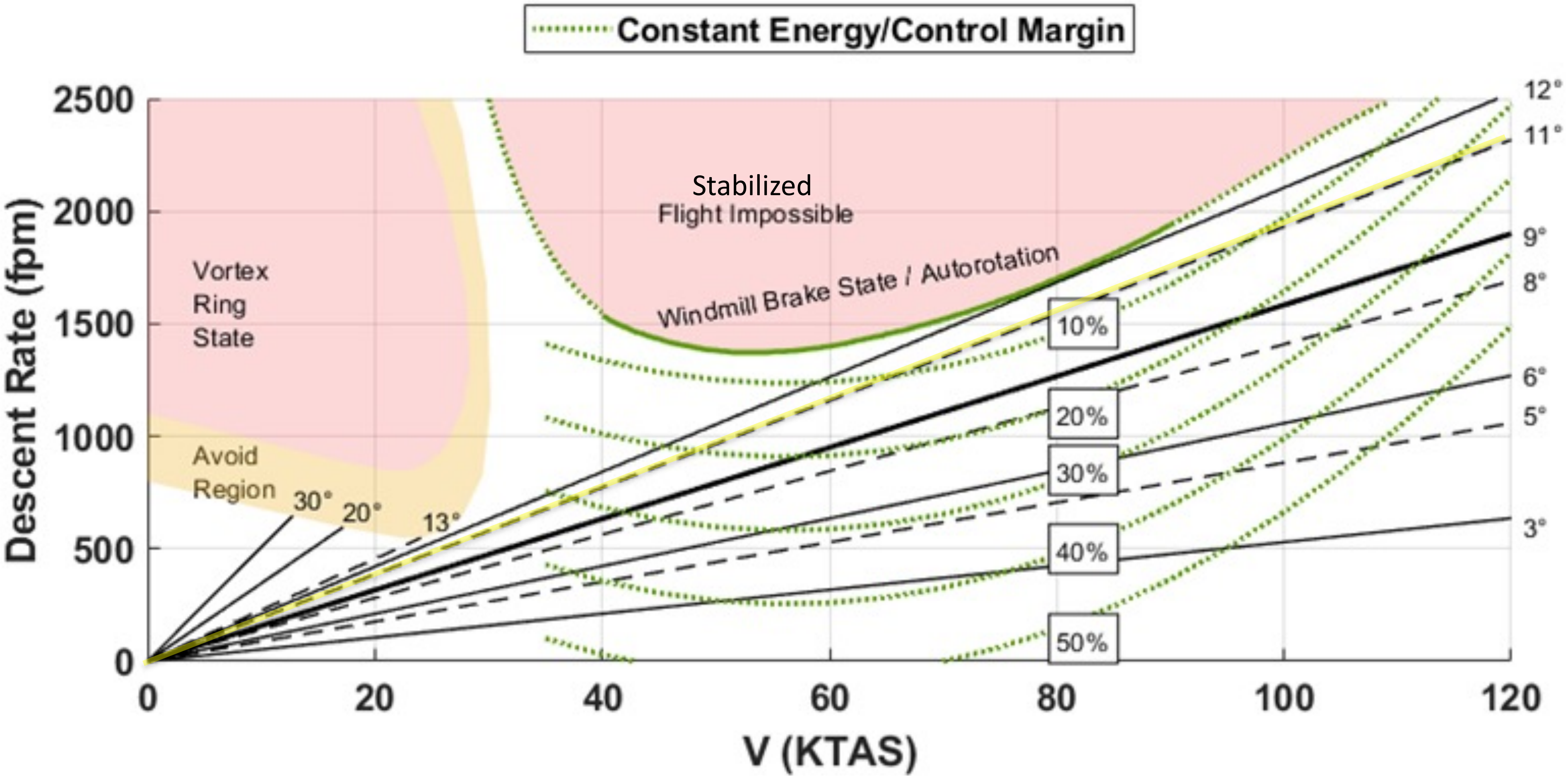
Certification “Abuse” angle = nominal + 2°

Calm Wind

reduced collective margin

Initial UAM surrogate results

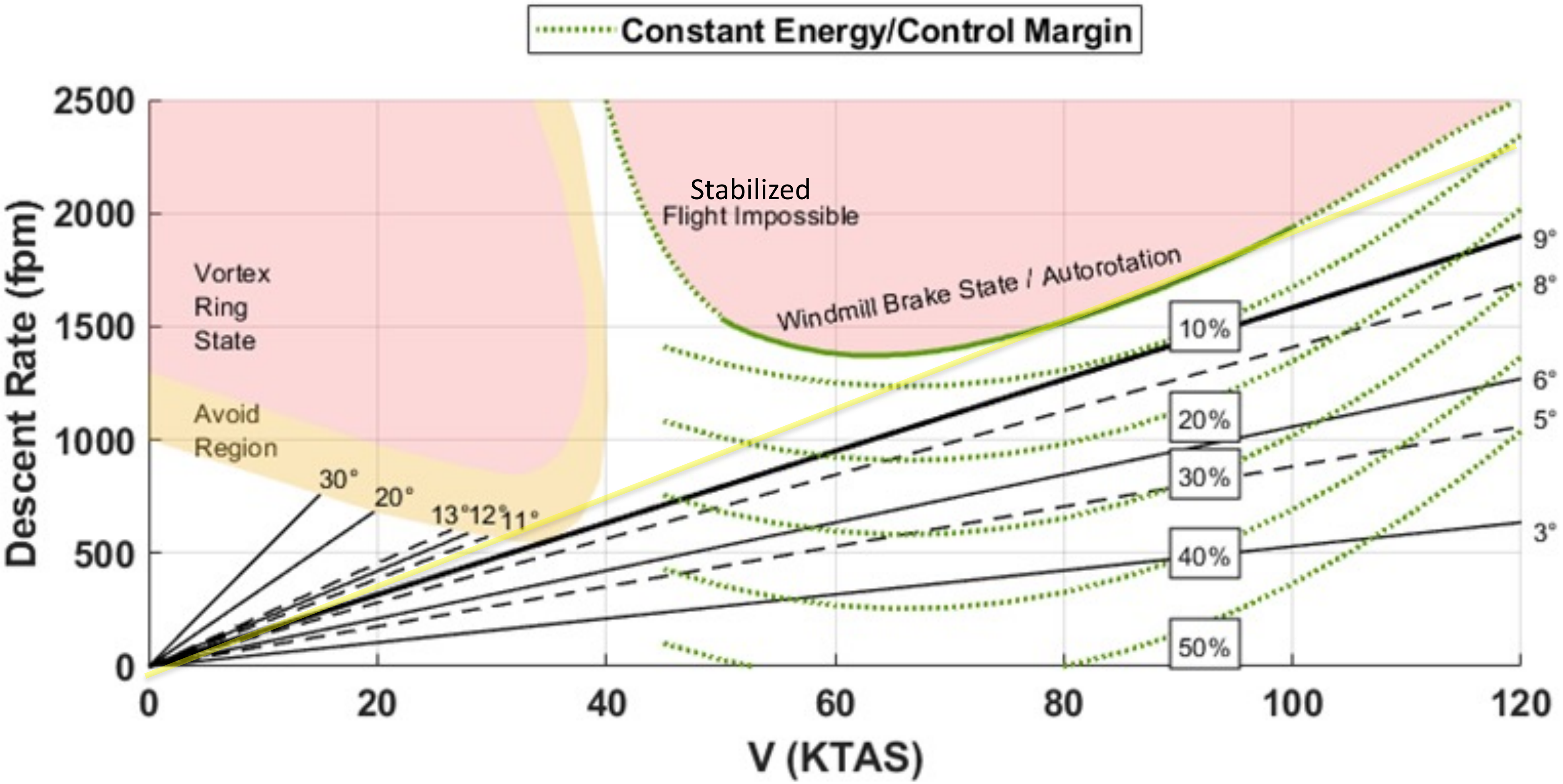
Approach Constraints charts



10 knot Tailwind

Initial UAM surrogate results

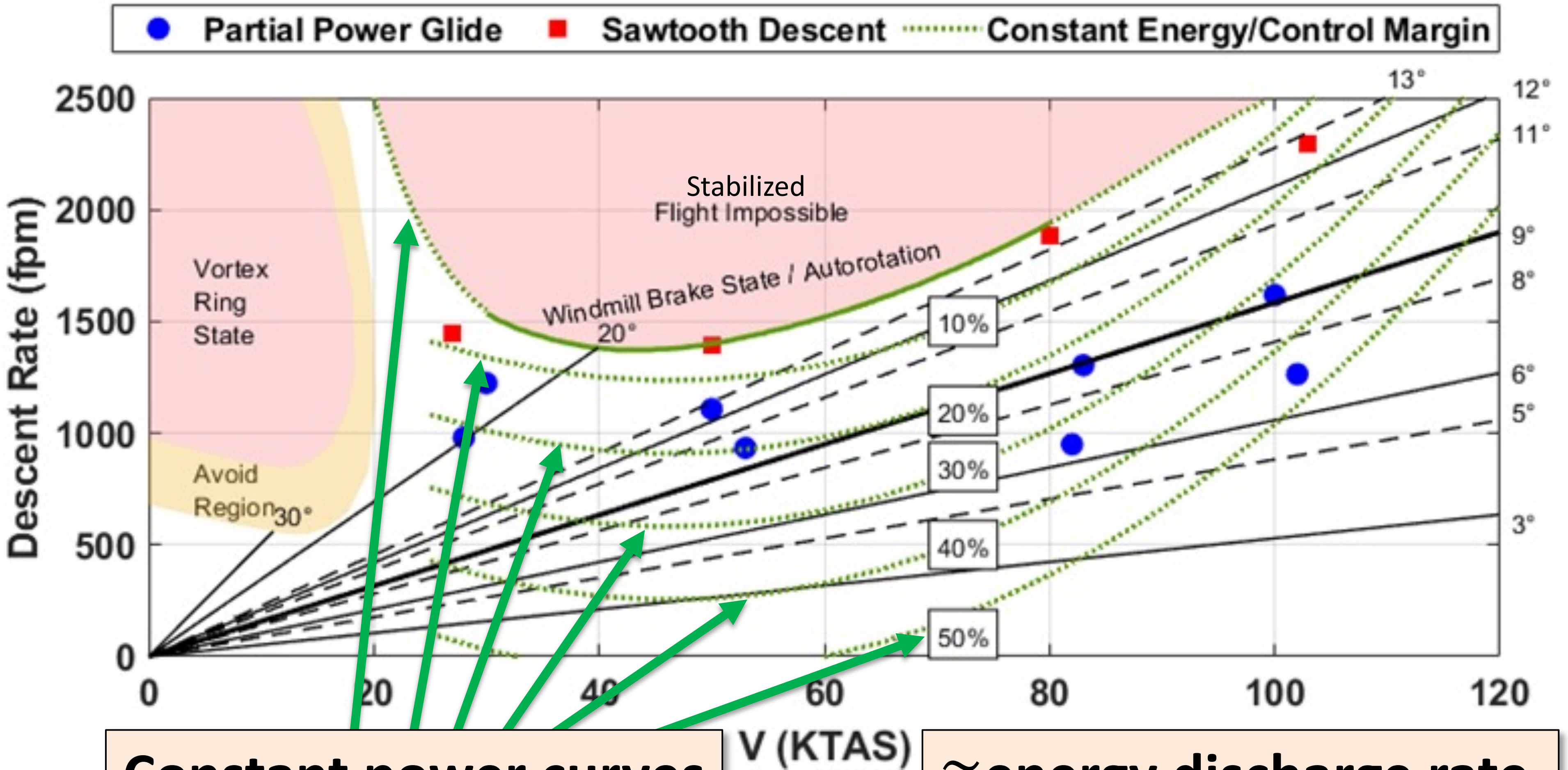
Approach Constraints charts



20 knot Tailwind

Initial UAM surrogate results

Approach Constraints charts



Calm Wind

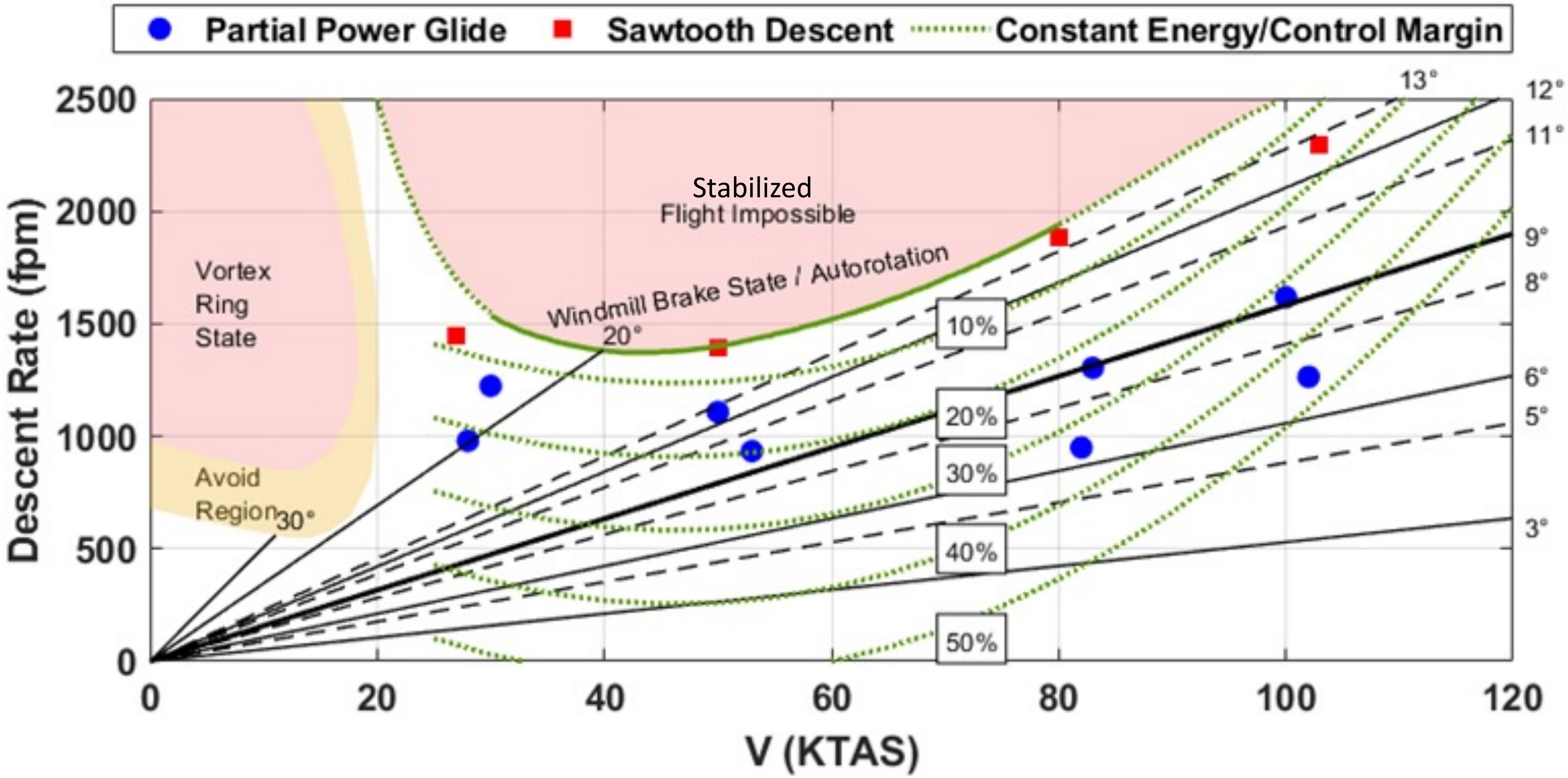
Constant power curves

≅energy discharge rate

Initial UAM surrogate results

Approach Constraints charts

Vehicle Characteristics - Performance



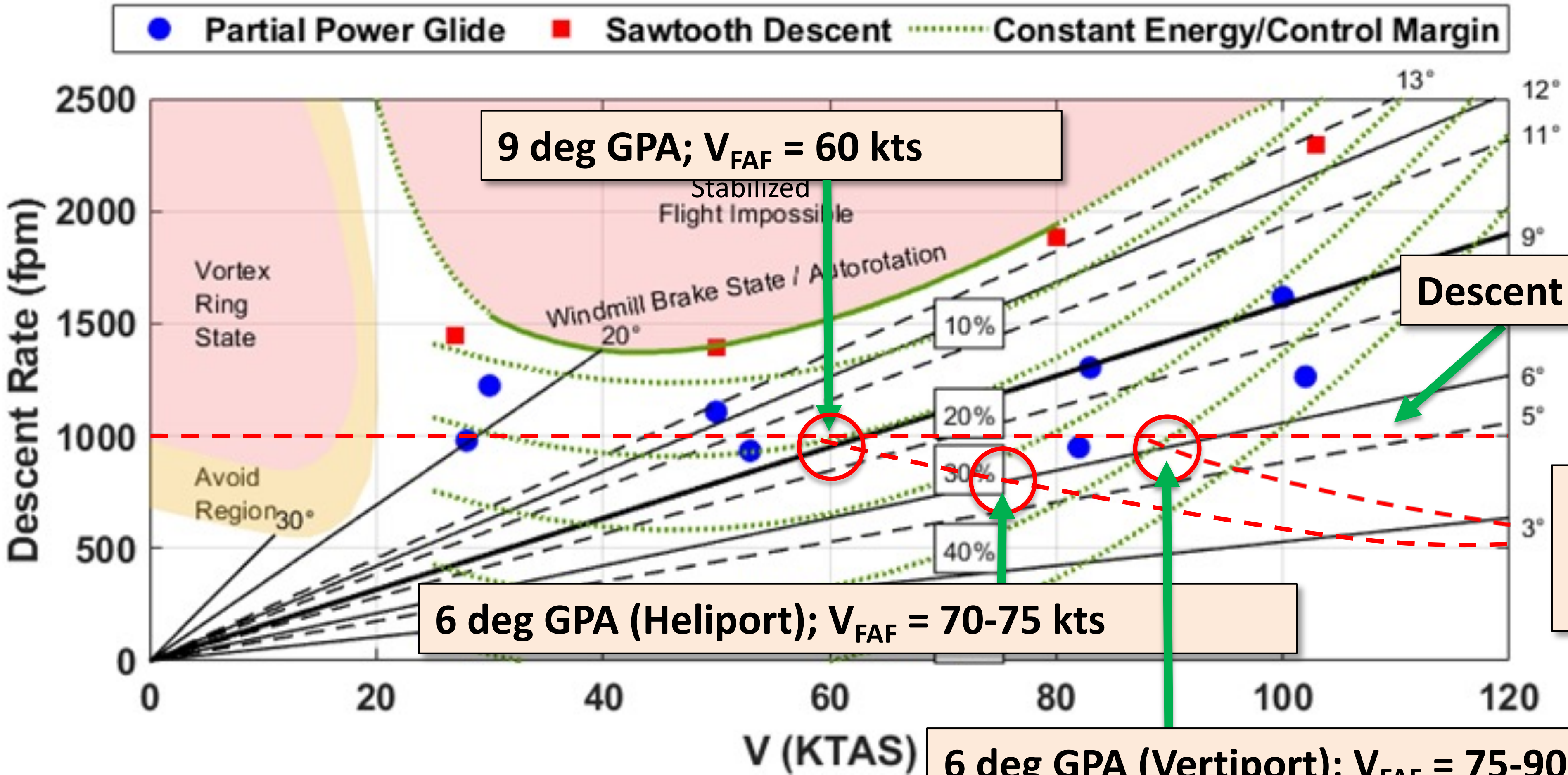
Calm Wind

Initial UAM surrogate results

Approach Constraints charts

Constant V_{FAF} approach to H_{DECEL} = 200ft

“Passenger comfort” constraints



9 deg GPA; V_{FAF} = 60 kts

Descent Rate <1000 fpm

Wind axis Decel rate from H_{DECEL} = 200ft *(NTE N_X average 0.150)*

6 deg GPA (Heliport); V_{FAF} = 70-75 kts

6 deg GPA (Vertiport); V_{FAF} = 75-90 kts (dependent on V_{AT})

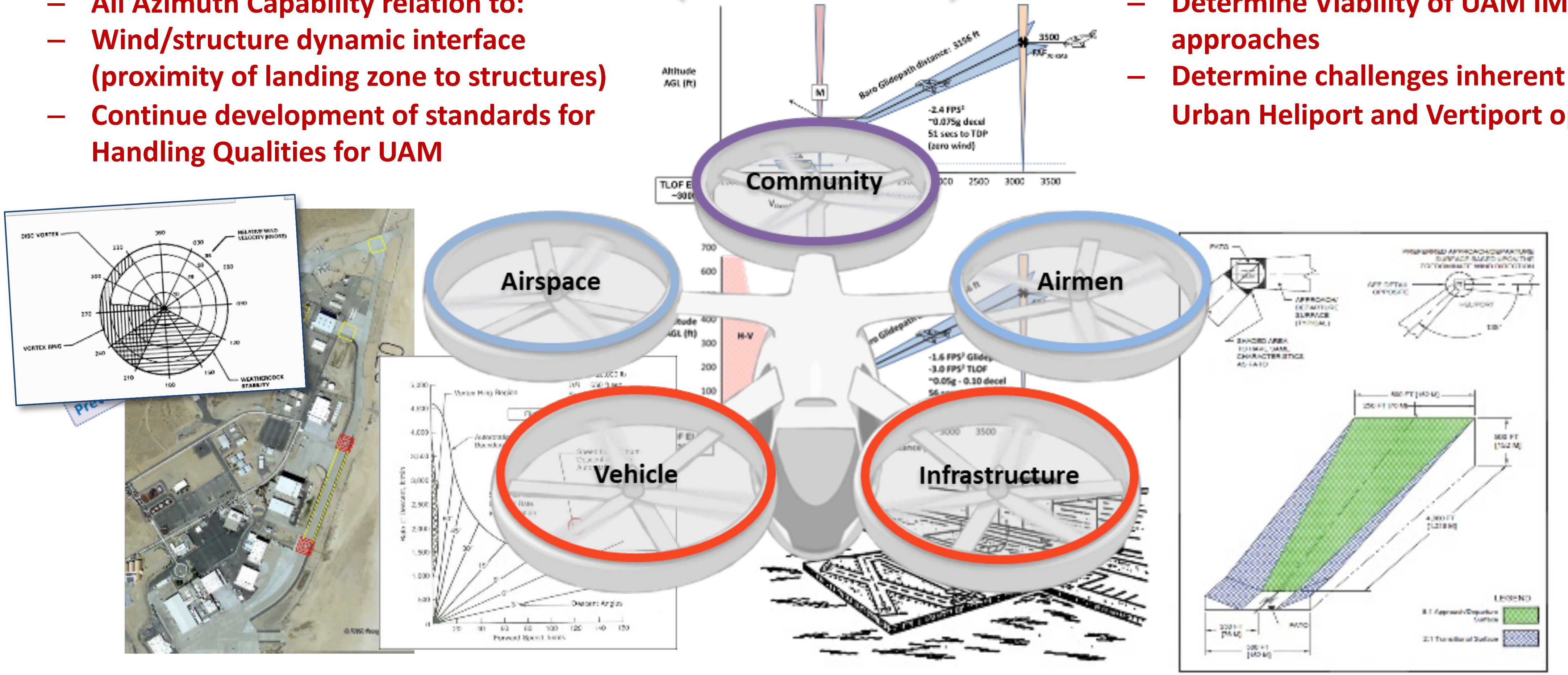
Follow on Flight Test – next steps

Vehicle Characteristics required for Urban Operations

- UAM Performance requirements (lower GPAs)
- All Azimuth Capability relation to:
- Wind/structure dynamic interface (proximity of landing zone to structures)
- Continue development of standards for Handling Qualities for UAM

Viable UAM Approaches/Airspace

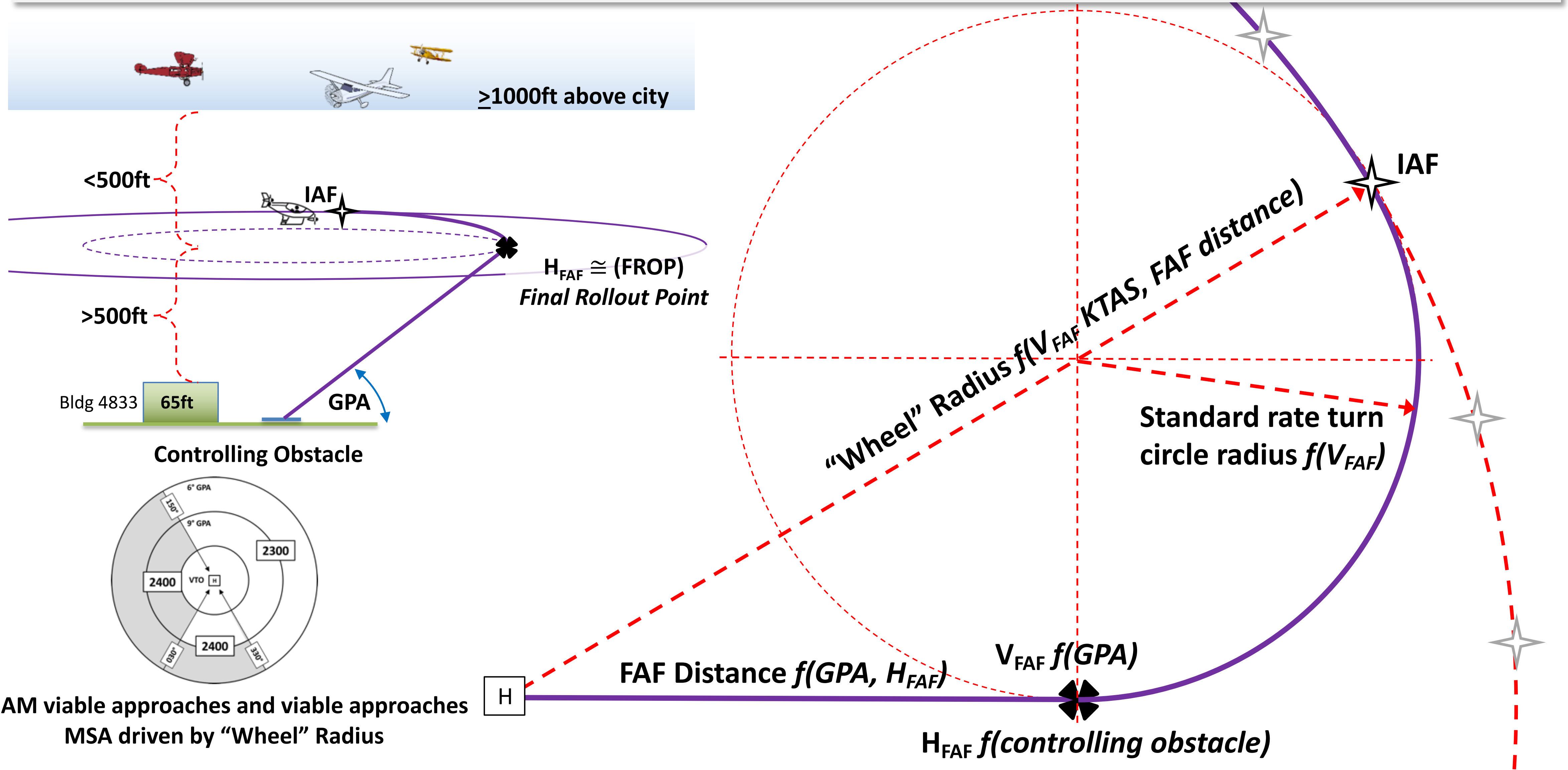
- Apply Vehicle constraints to airspace construction parameters
- Determine Viability of UAM IMC approaches
- Determine challenges inherent in Urban Heliport and Vertiport ops



AAM National Campaign

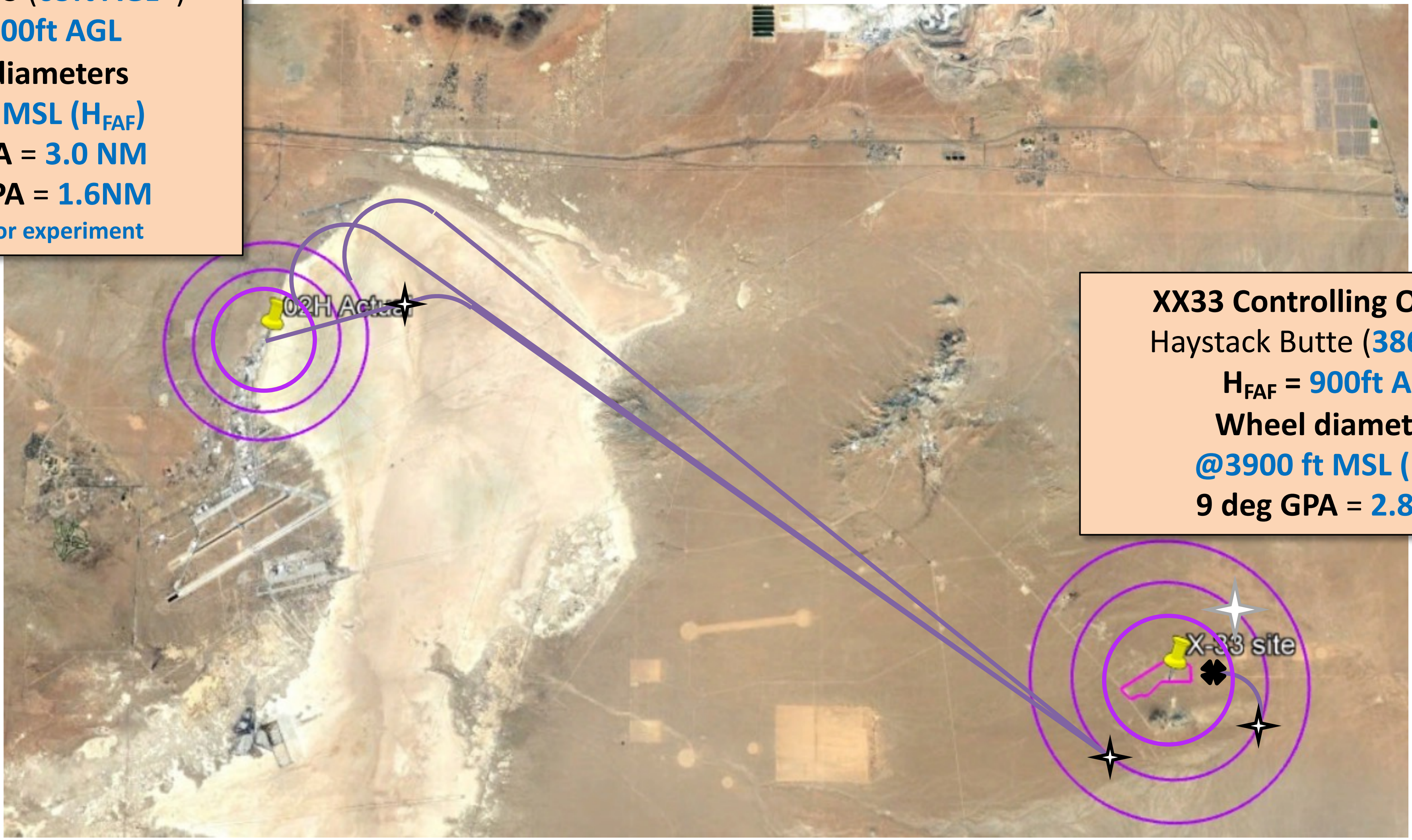
FOFT Infrastructure iterations

Viability of UAM "Wheel" to provide multiple IAFs for UAM Approaches



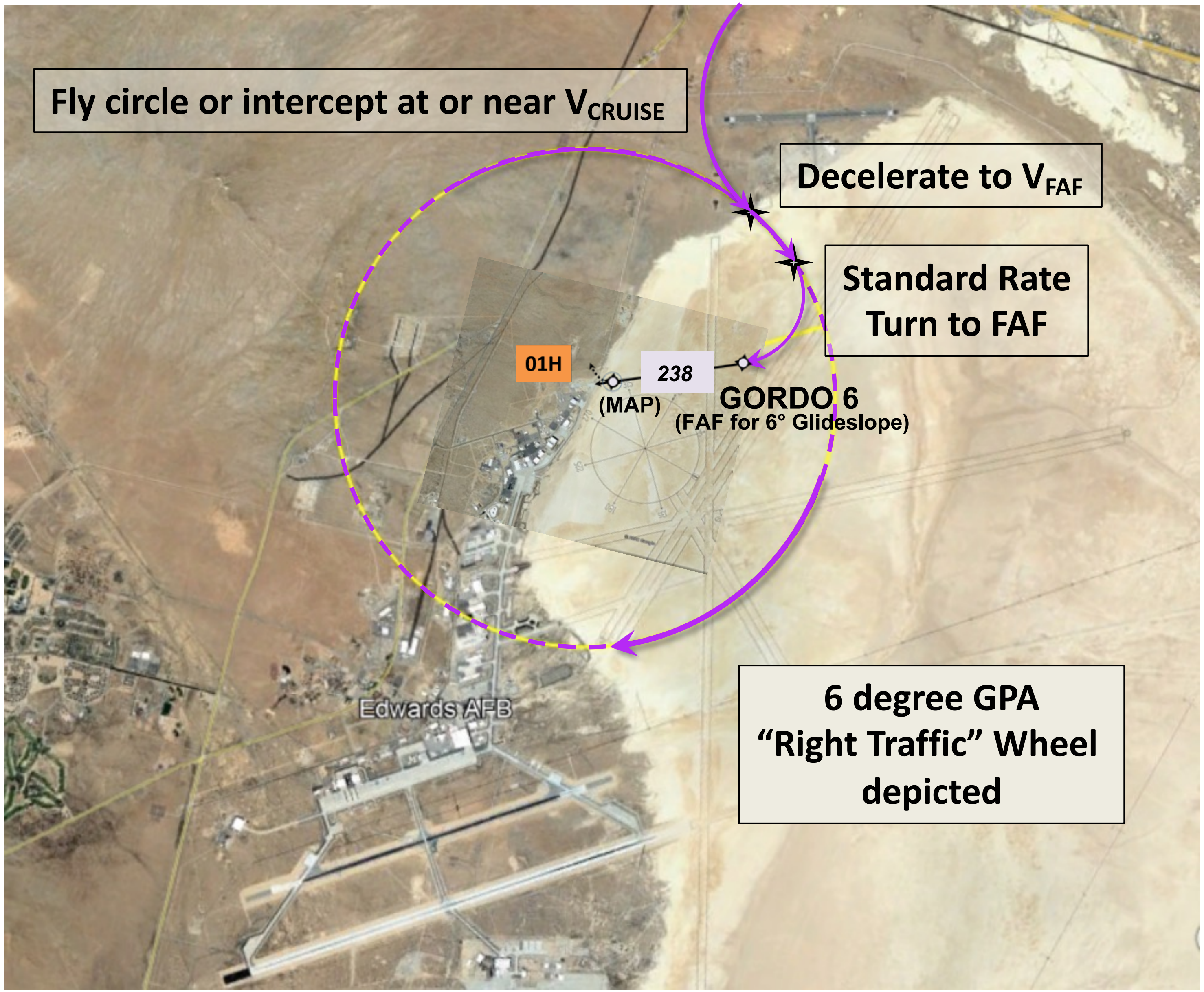
UAM “Wheel” Airspace viability

XEDW Controlling Obstacle
Building 4833 (65ft AGL*)
H_{FAF} = 600ft AGL
Wheel diameters
@2900ft MSL (H_{FAF})
6 deg GPA = 3.0 NM
12 deg GPA = 1.6NM
*assumed for experiment



XX33 Controlling Obstacle
Haystack Butte (386ft AGL)
H_{FAF} = 900ft AGL
Wheel diameters
@3900 ft MSL (H_{FAF})
9 deg GPA = 2.8 NM

UAM “Wheel” Airspace viability



Fly circle or intercept at or near V_{CRUISE}

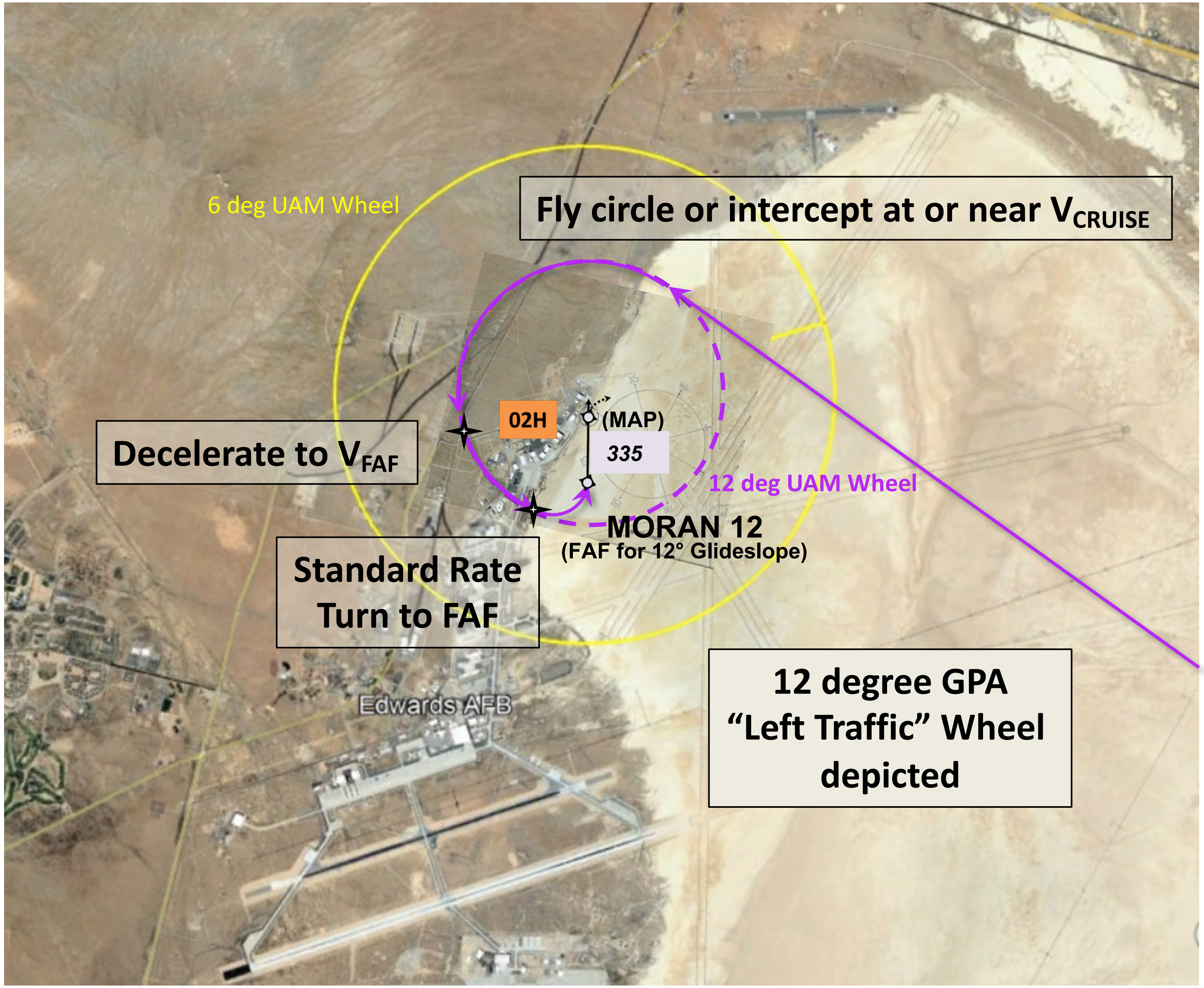
Decelerate to V_{FAF}

Standard Rate Turn to FAF

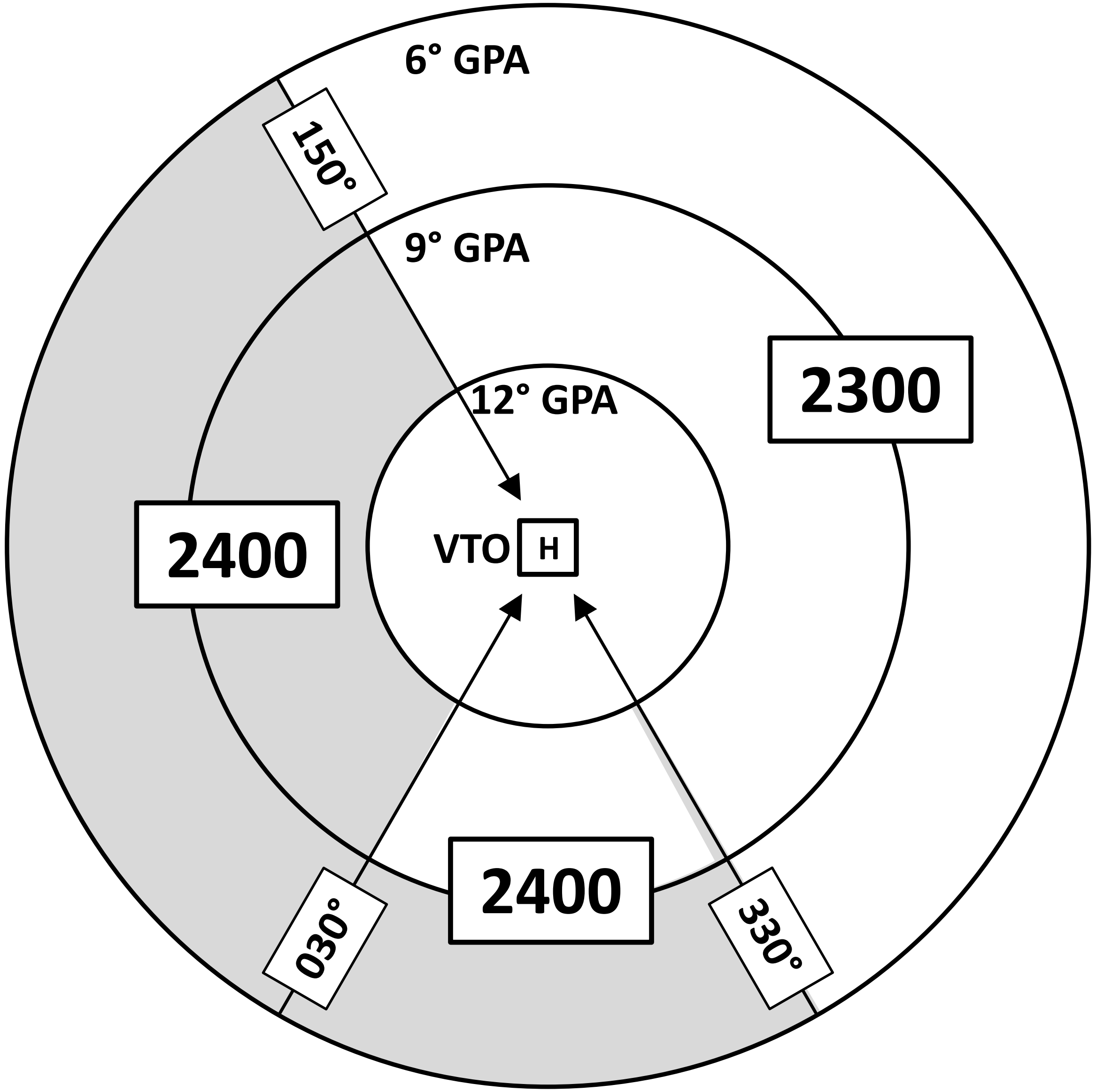
6 degree GPA “Right Traffic” Wheel depicted

AAM National Campaign

UAM “Wheel” Airspace viability



UAM "Wheel" Airspace viability



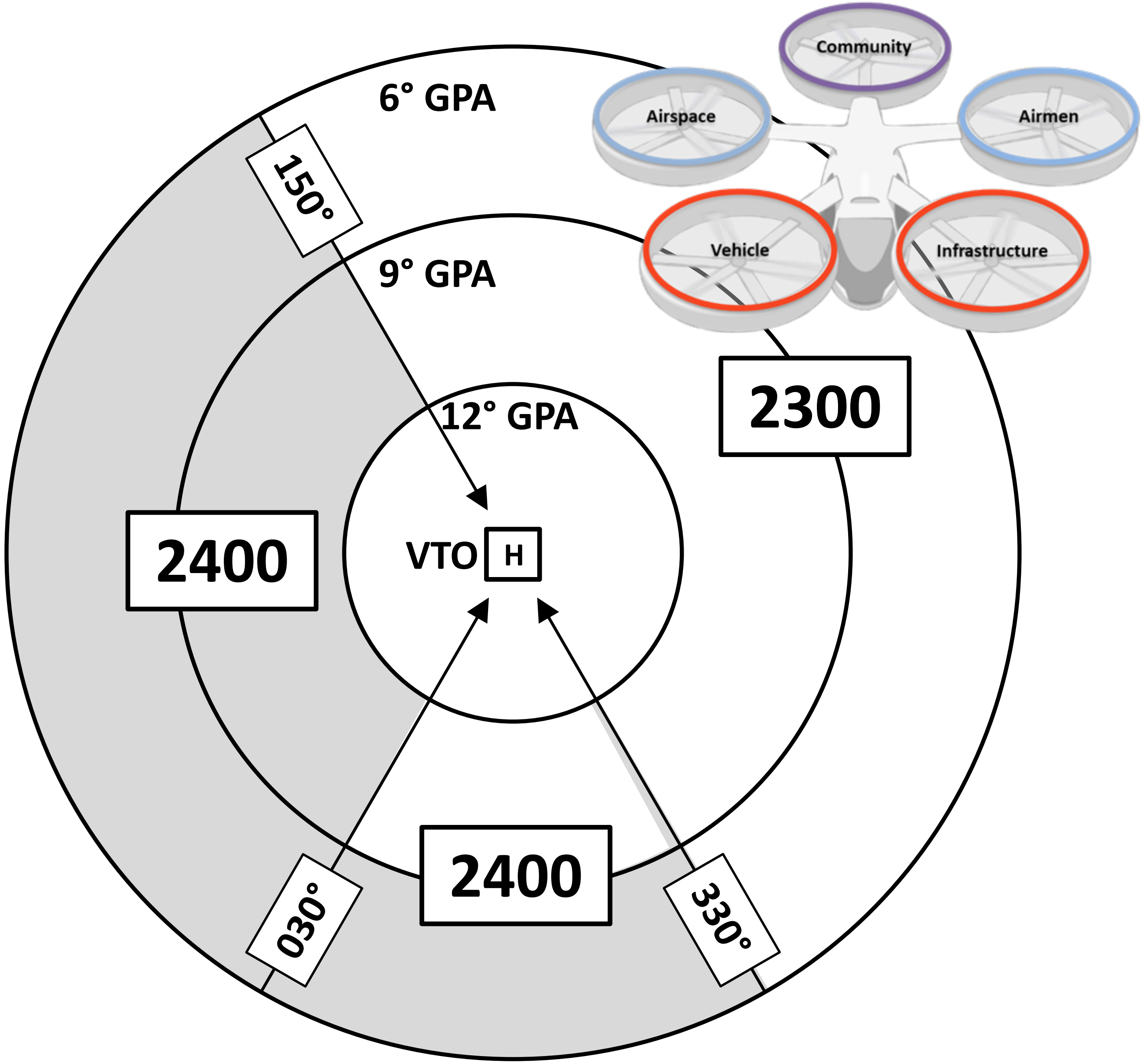
XEDW Aerodrome
6 deg approach Diameter = 3.0NM*
9 deg approach Diameter = 2.1NM*
12 deg approach Diameter = 1.6NM*

***H_{FAF} respects 65 ft Controlling Obstacle:**
H_{FAF} = 600ft/2900ft MSL

Reasonable variations
H_{FAF} = **500**/**1000**ft
6 deg approach Diameter= **2.7**/**4.2**NM
9 deg approach Diameter= **1.9**/**2.9**NM
12 deg approach Diameter = **1.5**/**2.2**NM

However, it is viable to fly at a higher and more UAM economical speed on the "Wheel" without violating standard rate turn constraints
Standard rate turn diameter – 140 KTAS
= 1.5NM

UAM Certification



Standard Certification delivers nominal **3-4.5°** Glidepath Angle capability,
IFR capability NOT assured
(Part 23 and Part 27 baseline)

UAM/*EASA-Enhanced* is expected to require Category A performance "flyaway" capability after failure

Steeper approach capabilities increase operational utility in urban environment

"Flyaway" assurance requirements increase with steeper GPA capabilities

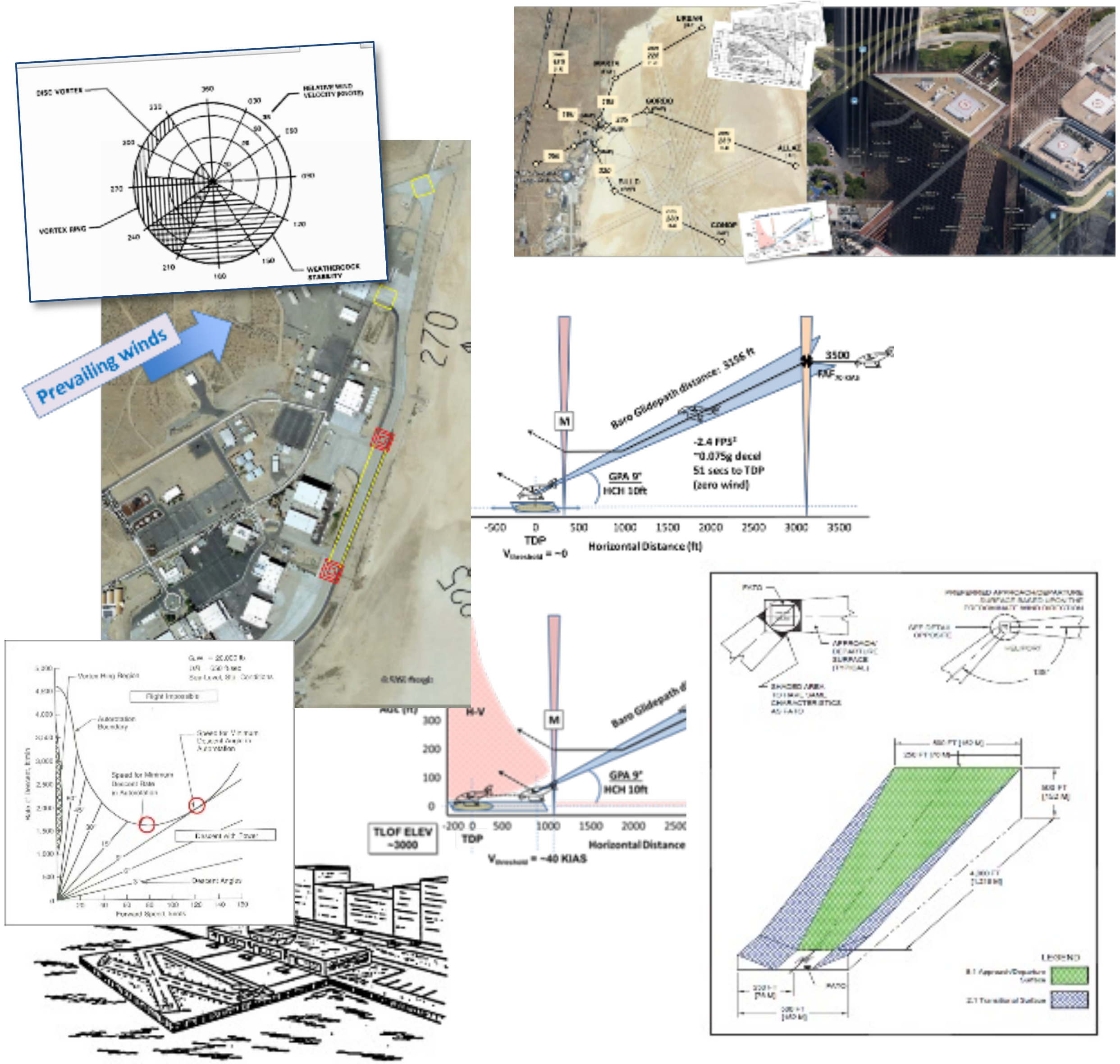
-however-

some business cases may not require same aircraft requirements demanded by the Urban Air Mobility (UAM) business case

Certification Basis should clarify Glidepath Angle/Departure capability

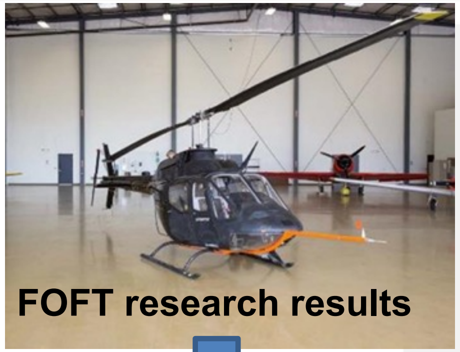
UAM future research areas

- Continue HQ development with more and more augmented vertical lift vehicles
  - B429, single pilot, IFR, CAT A
  - Actual UAM vehicles via NASA partnerships
- Minimum Departure Performance requirements
  - Leverage CAT A capable UAM surrogate
  - Can a “Powered Lift” Departure Requirement that merges Rotorcraft Category A with Commuter Airplane “flyaway capability” requirements be realized?
  - Applicant defines Kinetic Energy (e.g., V_1) or combination of Potential and Kinetic Energy (e.g., Takeoff/Landing Decision Points (T/LDP)) for approach/departure assurance
- Automation research
- Simplified Vehicle Ops (SVO) research

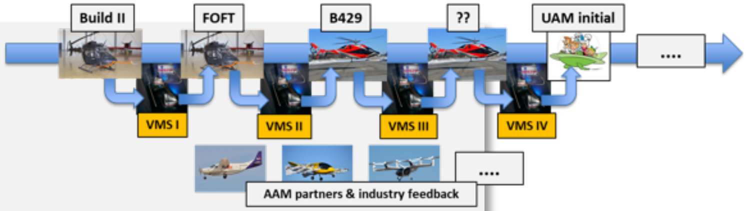


What targeted research are stakeholders interested in?

November 2021 AFCM AEP-1 Study*



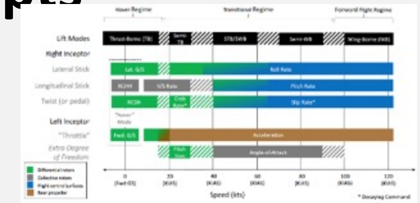
FOFT research results

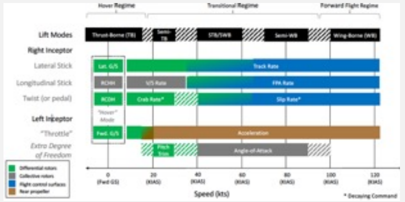


Objectives

RPM Control

- Focus on Automation
  - SVO 1 -3
- 1 UAM aircraft concept (Lift + Cruise)
- Indirect Flight Control System (IFCS) concepts
- Extension to HQTEs developed in FAA -1A
- Explore different levels of aggressiveness
- Environmental Conditions
  - Wind effects on IFCS
- Operational vs Stress Test





- Results/observations can be used to inform AAM NC flight research experiment design/iterations

* w/M. Feary – NASA AFCM

Departure Assurance

EXAMPLE

Consider a Transport Category Aircraft

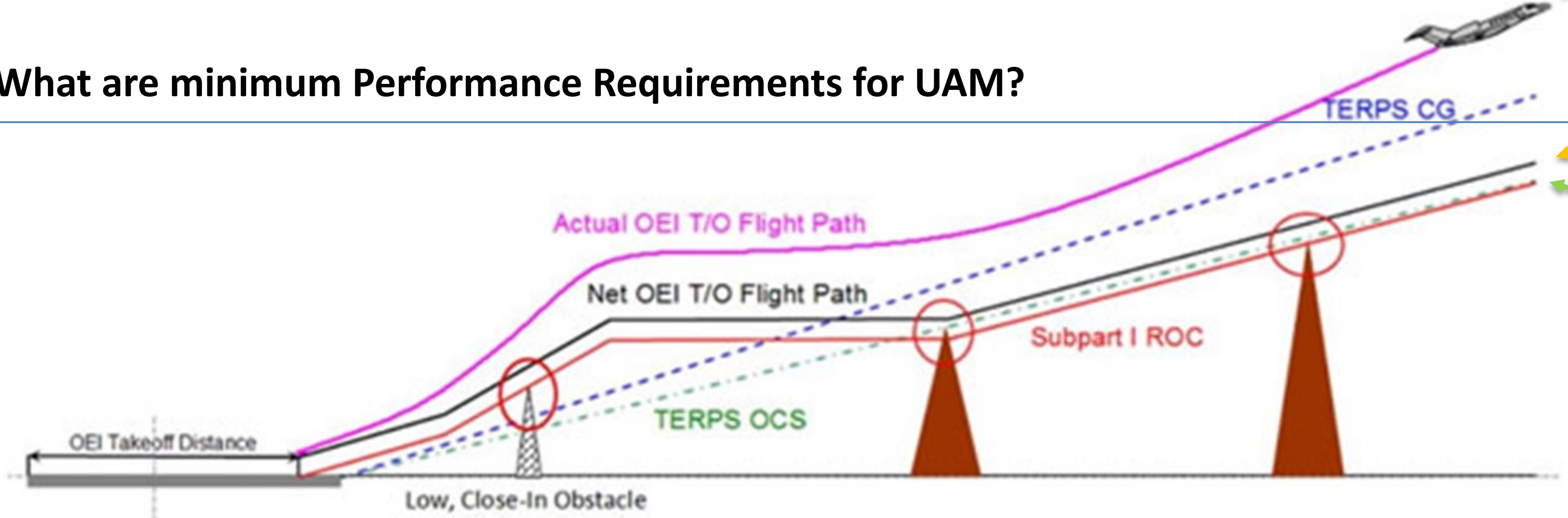
- “Certified” to Part 25 Climb Performance Airworthiness Requirements
- At **WAT** limit, all Transport Airplanes are “assured” to be capable of *“Net **OEI** Takeoff Path”*

Critical Parameter

Critical Parameters

Terminal Instrument Procedures (TERPS) ***<u>builds on Vehicle Assurance</u>*** *by assuring Obstacle Clearance Standards (OCS)*

....What are minimum Performance Requirements for UAM?



Vehicle Capability

Part 25 certification “assurance”*

TERPS Required Obstacle Clearance

***this ASSURANCE becomes a legally enforceable requirement when captured in the Type Certificate Data Sheet – and can then become a <u>foundation</u> for operational, infrastructure planning**

Vehicle *(assured)* capability drives infrastructure design

after critical loss of thrust…
<u>Transport category, airplane class</u>
Certified to 2.4 - 3 percent climb gradient

<u>Normal category, (multi-engine) airplane</u>
Certified to 1 - 2 percent climb gradient - *or* -
no minimum climb rate assurance if
crashworthiness is adequate

after critical loss of thrust…
<u>Transport category A, rotorcraft class</u>
Certified to be capable of returning to the
Point of departure – and/or flyaway with
>100 feet per minute climb rate

<u>Normal category, rotorcraft class</u>
no minimum climb rate assurance

What minimum airworthiness requirements are required to support the Urban Air Mobility Terminal Operations model?

Can we "merge" transport/commuter airplane and rotorcraft Cat A performance requirements to support commercial powered lift requirements?

QUESTIONS/COMMENTS/DISCUSSION

NASA ADVANCED AIR MOBILITY (AAM) NATIONAL CAMPAIGN (NC)

Urban Air Mobility Surrogate Flight Research

Infrastructure and Procedures

David Zahn – NASA AAM Airspace/TERPS PI

Infrastructure and Procedures

National Campaign Developmental Testing

Experimental Landing Surfaces

- Precision Surveys (Conventional & LIDAR)
- Registration & Coding

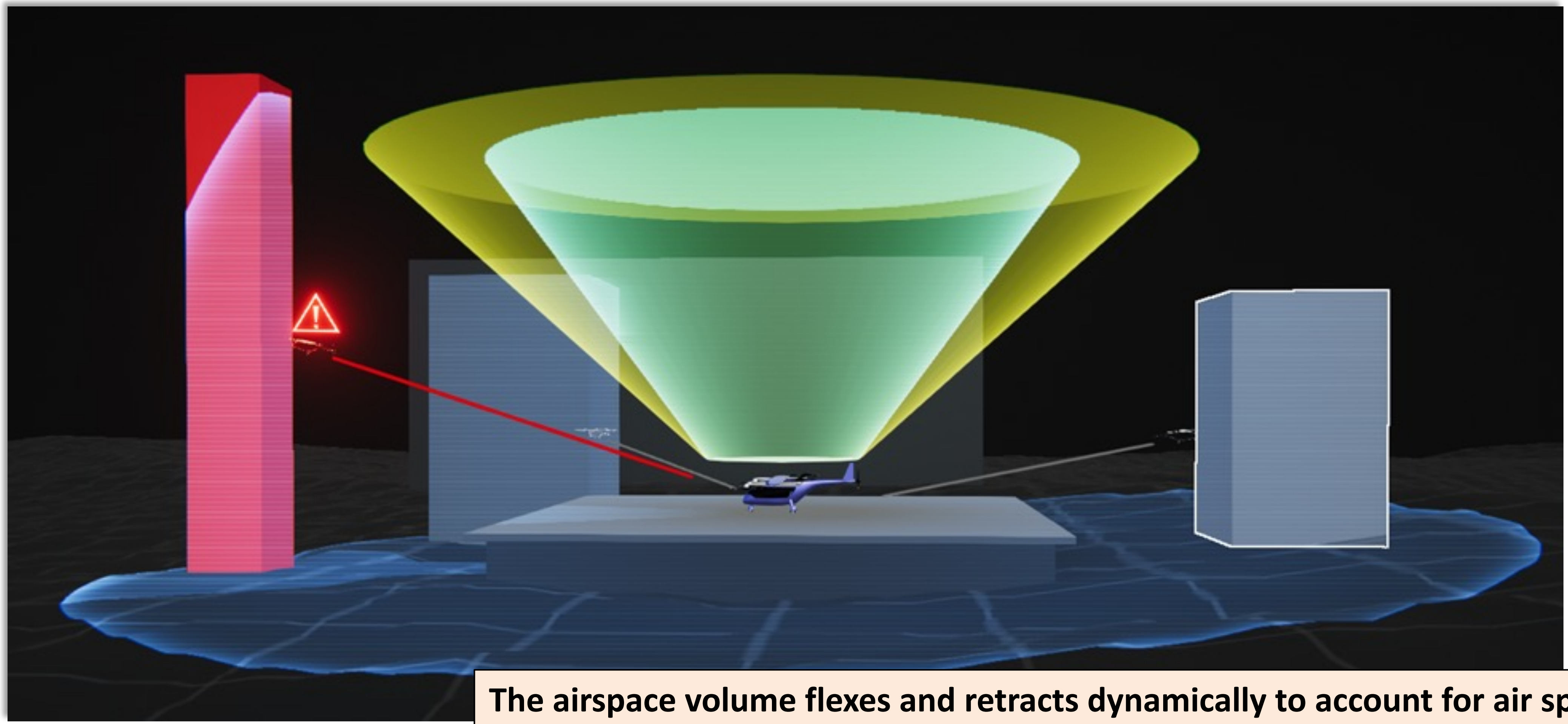
Test Range Routes & Flight Plans

- Test Range Constraints & Routes
- Flight Plan Theories
- Truncated ARINC coding
- Route Tracking

Terminal Operations

- Approach Procedures
- Experimental Flight Inspection software

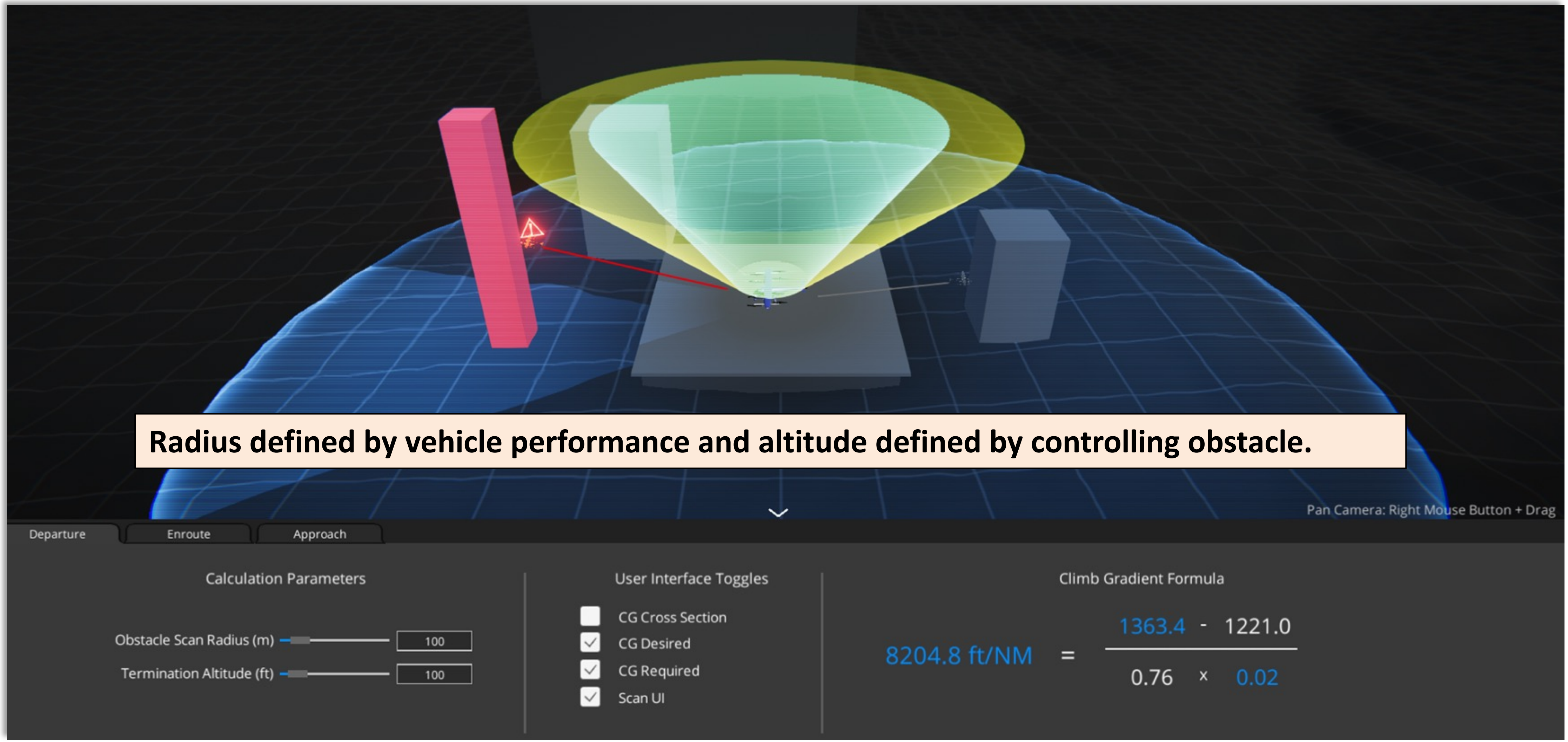
AAM Airspace Architecture Model



The airspace volume flexes and retracts dynamically to account for air speed, obstacles and winds enabling on-demand departure and approach procedures.

NC developed an airspace configurable tool that integrates AAM vehicle performance to obstacle and terrain evaluation.

AAM Airspace Architecture Model



Radius defined by vehicle performance and altitude defined by controlling obstacle.

Calculation Parameters

Obstacle Scan Radius (m): 100
Termination Altitude (ft): 100

User Interface Toggles

☐ CG Cross Section
☑ CG Desired
☑ CG Required
☑ Scan UI

Climb Gradient Formula

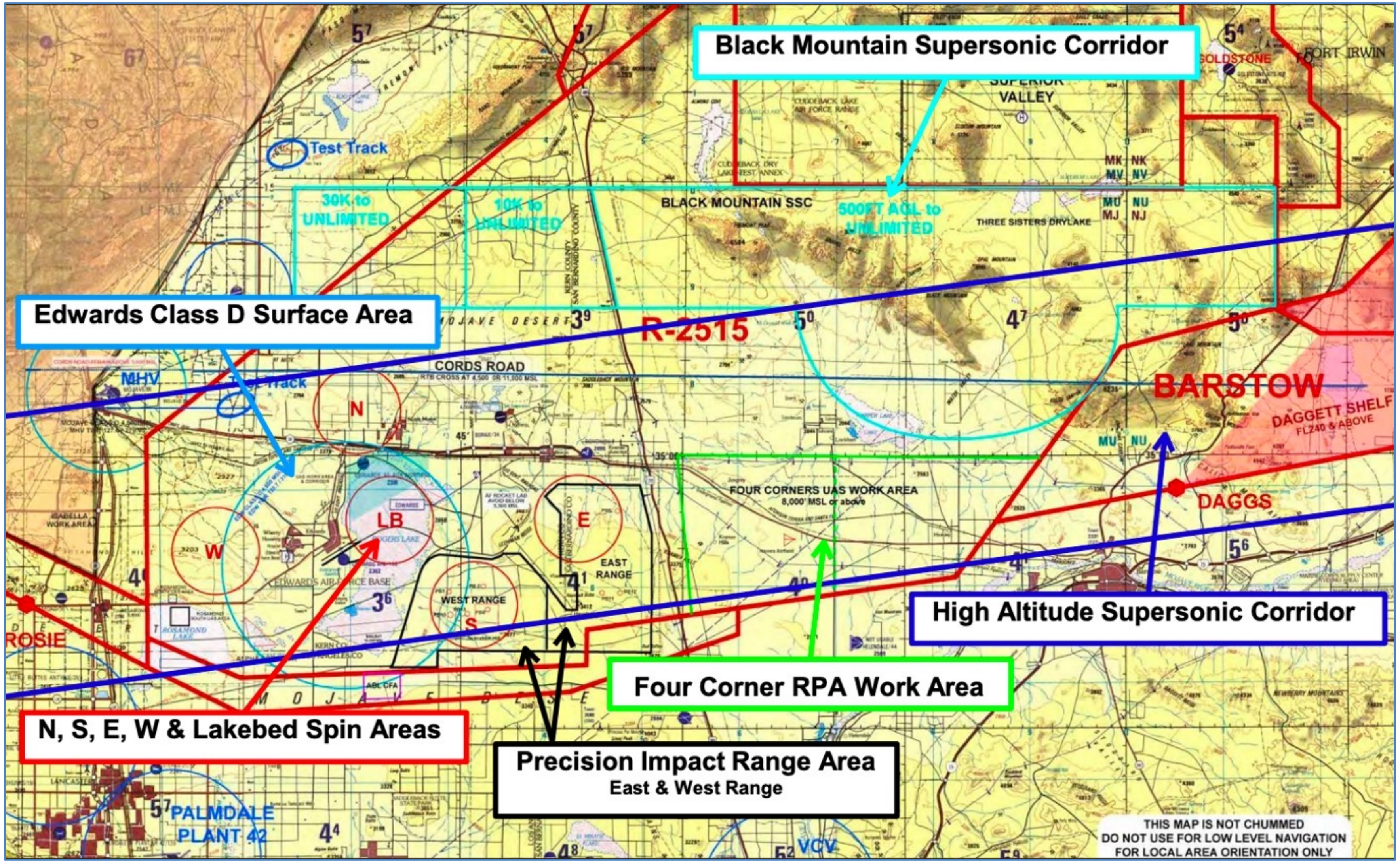
$$8204.8\ \text{ft/NM} = \frac{1363.4 - 1221.0}{0.76 \times 0.02}$$

NC developed an airspace configurable tool that integrates AAM vehicle performance to obstacle and terrain evaluation.

Experimental Landing Surfaces

Advanced Air Mobility (AAM) may require high precision for vertiports, unique coding & novel approach procedures.

Test Range Flight Constraints



Edwards A.F.B. constraints

- fly-over restrictions around buildings & structures
- altitude limitations over UAS workspace
- XX33 Restricted Airspace over Mojave Lakebed R-2515

Build 2 at EAFB mimics urban constrained airspace for unique routes and new approach methods.

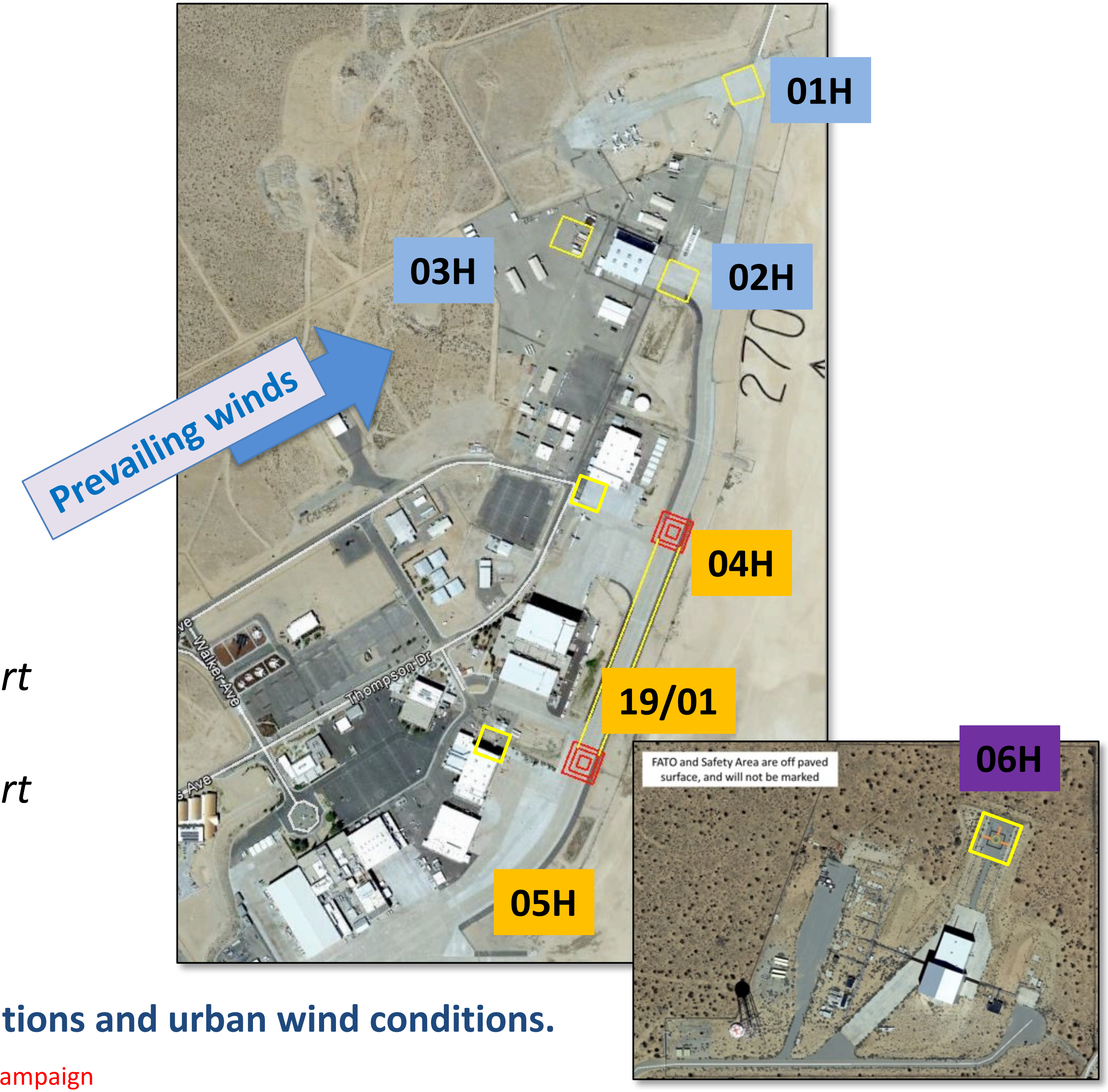
Experimental Landing Surfaces

6 AAM NC “UAM Heliports”

- 40x40ft TLOF
- Northern Heliports suitable for wind/controllability studies
- All Heliport design/placement IAW AC 150/ 5390-2C Heliport Design

1 AAM NC “UAM Vertiport”

- 1090ft length x 120ft width TLOF/FATO
- 01H + 02H + 03H = **XEDW** *Research Airport*
- 04H + 05H + 19/01 = **XVPT** *Research Airport*
- 06H = **XX33** *Research Airport*



FATO and Safety Area are off paved surface, and will not be marked

AAM landing surfaces may operate with different configurations and urban wind conditions.

Conventional Geodetic Survey Method

RNAV - XEDW (01H)

Facility Search

Identifier	XEDW

AIRNAV Data

Airport

AIRPORT ID	XEDW
STATE	CA
COUNTRY	US
MVAR	E12
STATUS	Active

Runway

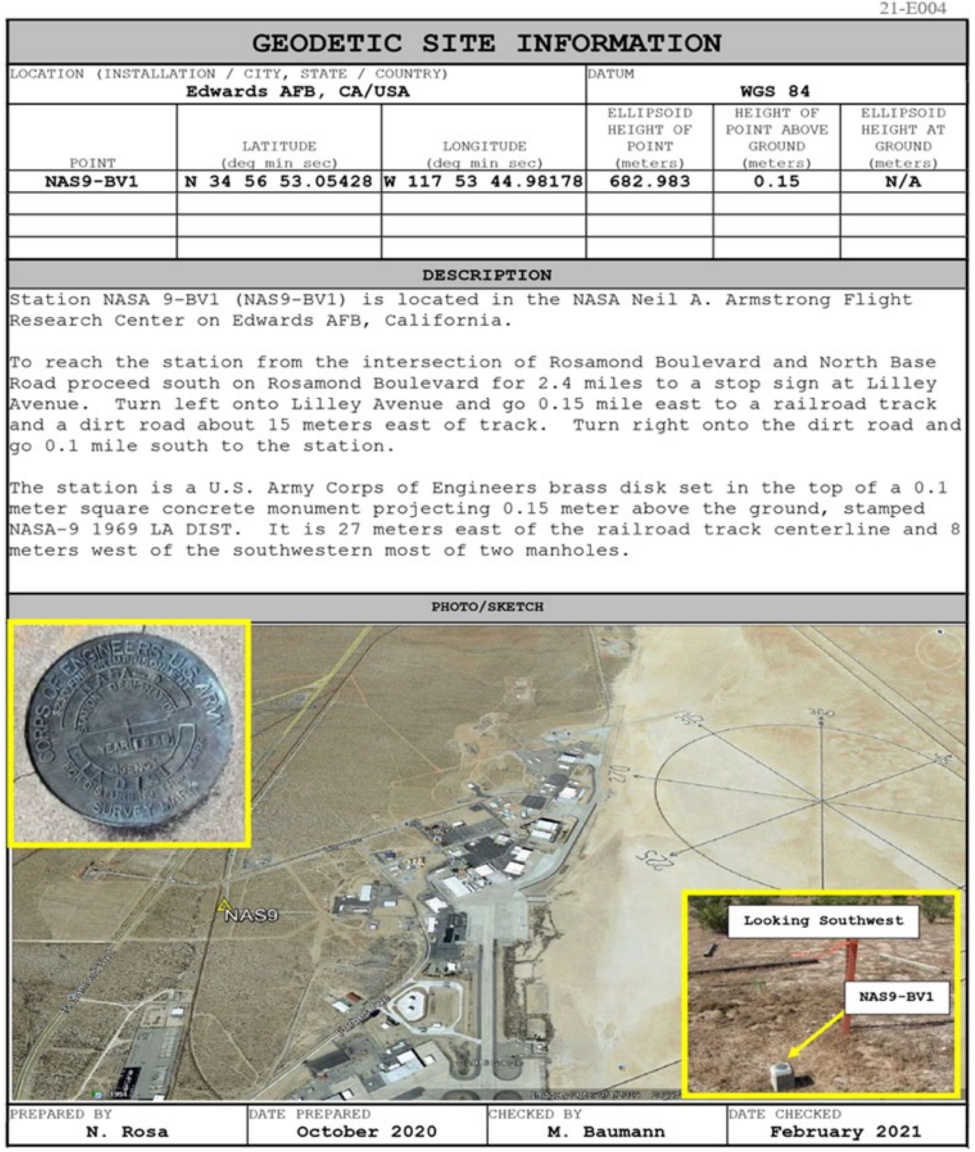
◄ 01H (A) ►

General

LANDING LENGTH	96 FT
TRUE BEARING	250.35°
PUB DATE	09/28/2020
FI RWY LENGTH	
FI RWY HEIGHT	

Helipad

LATITUDE	N34° 57' 32.8320"
LONGITUDE	W117° 52' 54.1200"
ELEVATION	2276.0 FT
ELLIPSOID ELEV.	2170.7 FT
MODEL / SOURCE	WGS84 / E
HORZ. DATUM	WGS84
VERT. DATUM	EGM_96
CALC ELLIP HT	2170.8 FT
IS DISPLACED	



21-E004

GEODETIC SITE INFORMATION

LOCATION (INSTALLATION / CITY, STATE / COUNTRY)	DATUM
Edwards AFB, CA/USA	WGS 84

POINT	LATITUDE (deg min sec)	LONGITUDE (deg min sec)	ELLIPSOID HEIGHT OF POINT (meters)	HEIGHT OF POINT ABOVE GROUND (meters)	ELLIPSOID HEIGHT AT GROUND (meters)
NAS9-BV1	N 34 56 53.05428	W 117 53 44.98178	682.983	0.15	N/A

DESCRIPTION

Station NASA 9-BV1 (NAS9-BV1) is located in the NASA Neil A. Armstrong Flight Research Center on Edwards AFB, California.

To reach the station from the intersection of Rosamond Boulevard and North Base Road proceed south on Rosamond Boulevard for 2.4 miles to a stop sign at Lilley Avenue. Turn left onto Lilley Avenue and go 0.15 mile east to a railroad track and a dirt road about 15 meters east of track. Turn right onto the dirt road and go 0.1 mile south to the station.

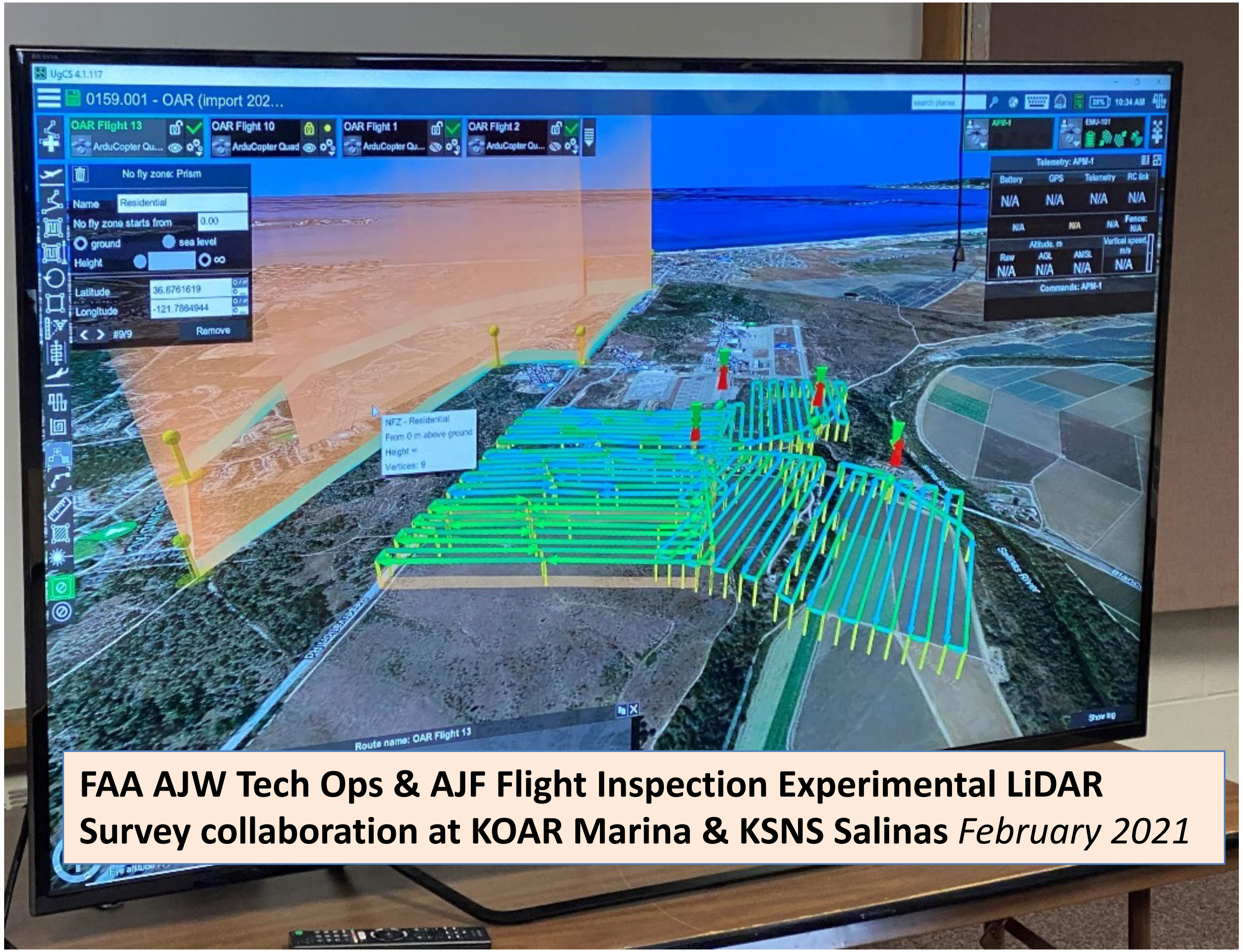
The station is a U.S. Army Corps of Engineers brass disk set in the top of a 0.1 meter square concrete monument projecting 0.15 meter above the ground, stamped NASA-9 1969 LA DIST. It is 27 meters east of the railroad track centerline and 8 meters west of the southwestern most of two manholes.

PHOTO/SKETCH

PREPARED BY	DATE PREPARED	CHECKED BY	DATE CHECKED
N. Rosa	October 2020	M. Baumann	February 2021

Geodetic survey data is populated in the FAA RNAV database for coding to/from locations.

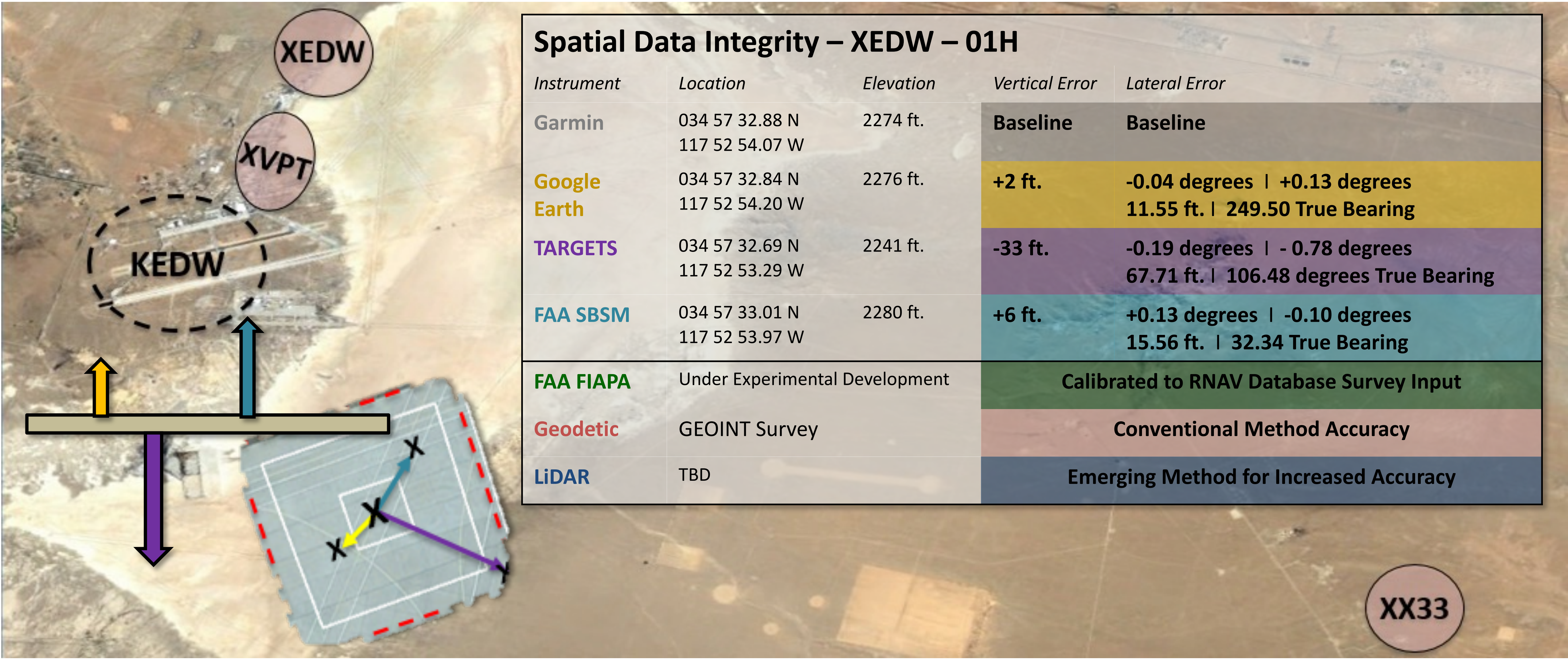
Emerging LIDAR Survey Method Collaboration



FAA AJW Tech Ops & AJF Flight Inspection Experimental LiDAR Survey collaboration at KOAR Marina & KSNS Salinas *February 2021*

Drones equipped with LiDAR demonstrate high-precision fidelity survey results for future precise operations & safety.

Landing Surface Surveys



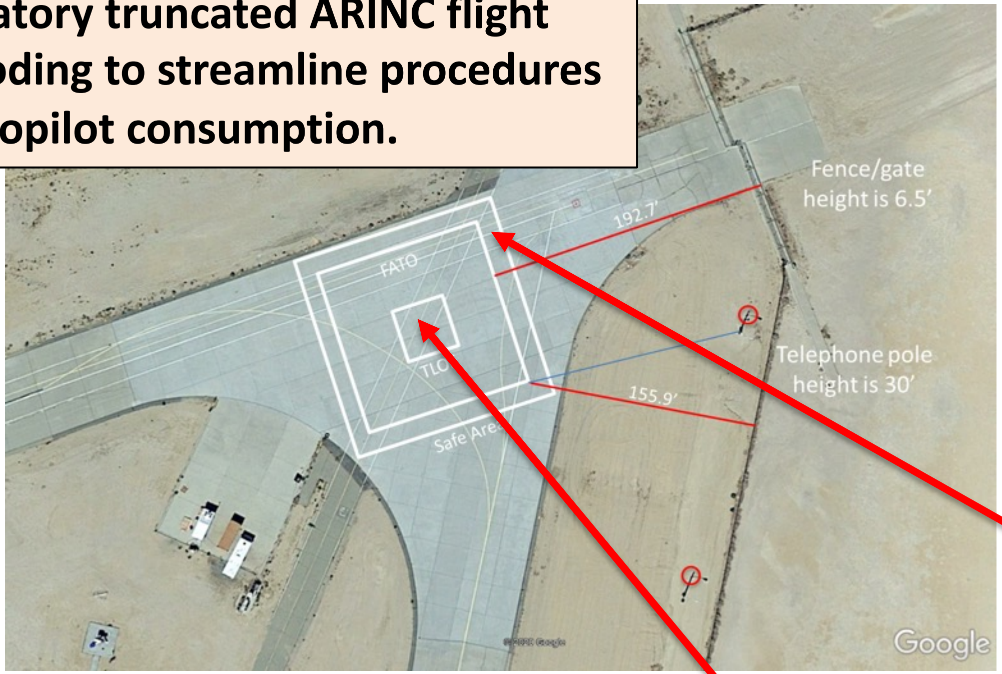
Spatial Data Integrity – XEDW – 01H

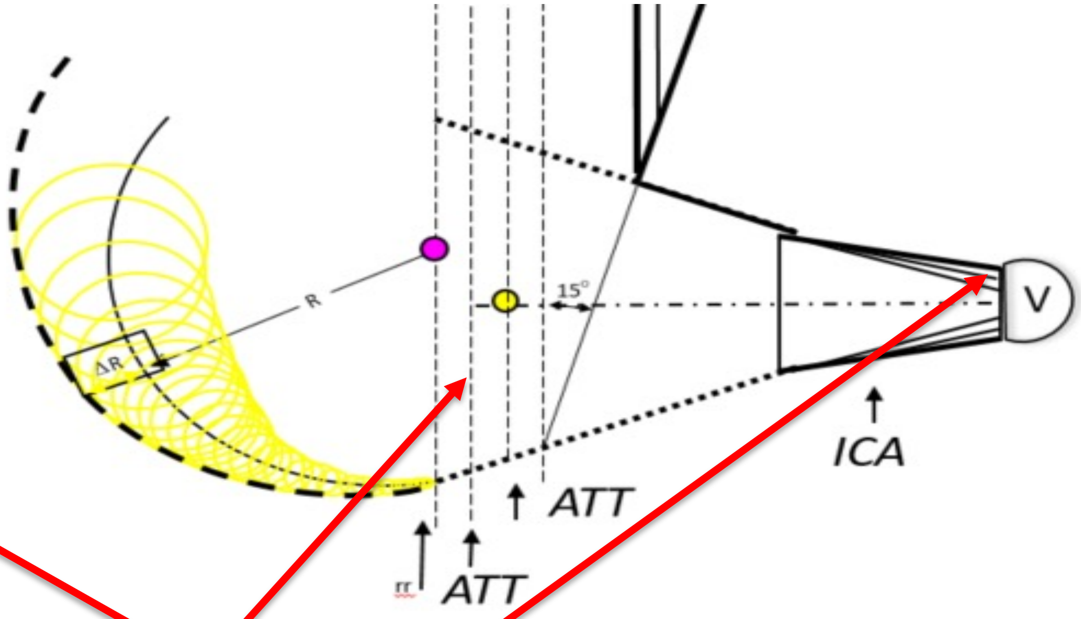
Instrument	*Location*	*Elevation*	*Vertical Error*	*Lateral Error*
Garmin	034 57 32.88 N 117 52 54.07 W	2274 ft.	**Baseline**	**Baseline**
Google Earth	034 57 32.84 N 117 52 54.20 W	2276 ft.	**+2 ft.**	**-0.04 degrees I +0.13 degrees** **11.55 ft. I 249.50 True Bearing**
TARGETS	034 57 32.69 N 117 52 53.29 W	2241 ft.	**-33 ft.**	**-0.19 degrees I - 0.78 degrees** **67.71 ft. I 106.48 degrees True Bearing**
FAA SBSM	034 57 33.01 N 117 52 53.97 W	2280 ft.	**+6 ft.**	**+0.13 degrees I -0.10 degrees** **15.56 ft. I 32.34 True Bearing**
FAA FIAPA	Under Experimental Development		**Calibrated to RNAV Database Survey Input**	
Geodetic	GEOINT Survey		**Conventional Method Accuracy**	
LiDAR	TBD		**Emerging Method for Increased Accuracy**	

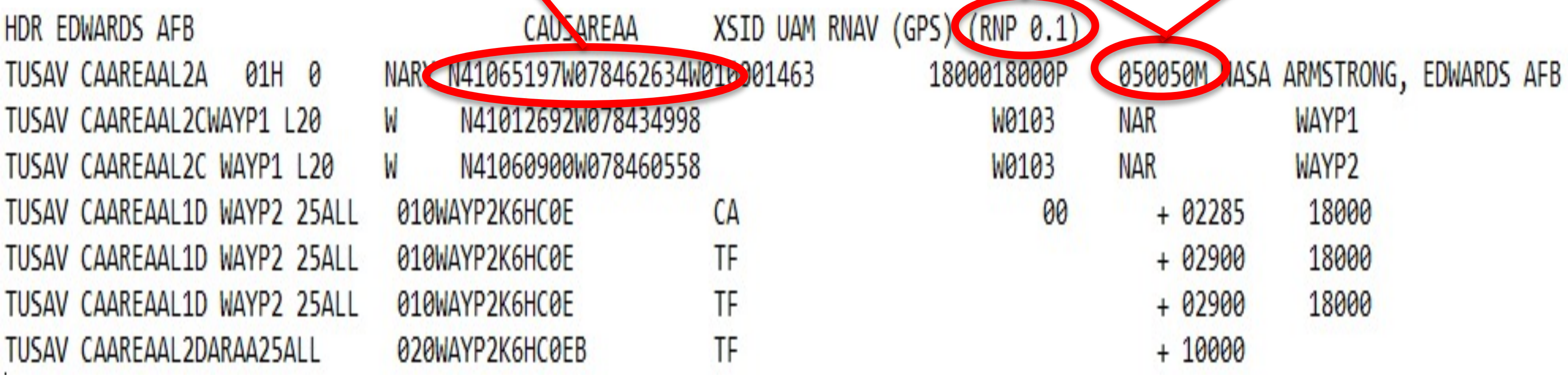
AAM may require new survey methods to ensure precise landing surfaces given automation in constrained airspace.

Flight Plan Coding ‘Deproach’ Theory

Exploratory truncated ARINC flight plan coding to streamline procedures for autopilot consumption.







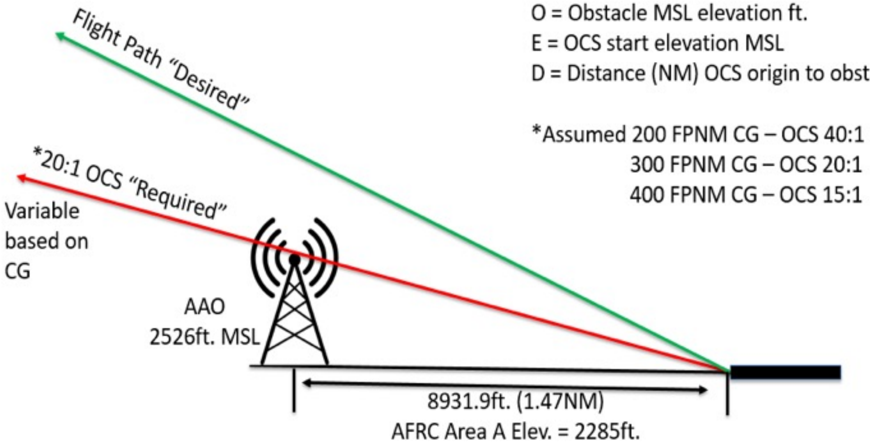
```
HDR EDWARDS AFB                    CAUSAREAA     XSID UAM RNAV (GPS) (RNP 0.1)
TUSAV CAAREAAL2A   01H  0      NARY N41065197W078462634W01001463          1800018000P   050050M NASA ARMSTRONG, EDWARDS AFB
TUSAV CAAREAAL2CWAYP1 L20      W      N41012692W078434998                   W0103     NAR            WAYP1
TUSAV CAAREAAL2C WAYP1 L20     W      N41060900W078460558                   W0103     NAR            WAYP2
TUSAV CAAREAAL1D WAYP2 25ALL    010WAYP2K6HC0E          CA                      00      + 02285     18000
TUSAV CAAREAAL1D WAYP2 25ALL    010WAYP2K6HC0E          TF                              + 02900     18000
TUSAV CAAREAAL1D WAYP2 25ALL    010WAYP2K6HC0E          TF                              + 02900     18000
TUSAV CAAREAAL2DARAA25ALL       020WAYP2K6HC0EB         TF                              + 10000
```

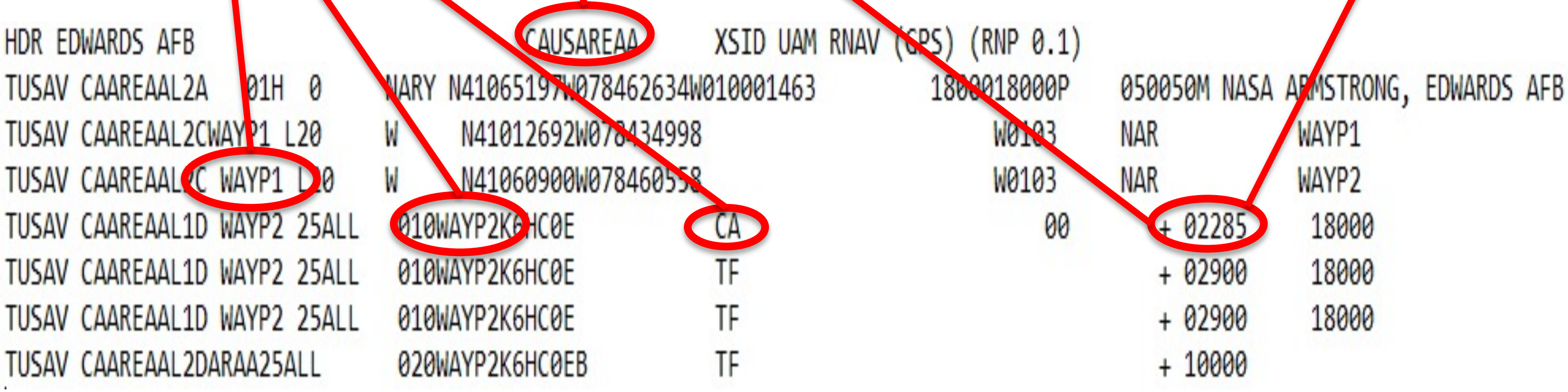
Flight Plan Coding ‘Deproach’ Theory

CG = $\frac{O - E}{0.76D} = \frac{2526 - 2285}{0.76 \times 1.47}$ = 215.71 ~ 216ft./NM

O = Obstacle MSL elevation ft.
E = OCS start elevation MSL
D = Distance (NM) OCS origin to obstacle

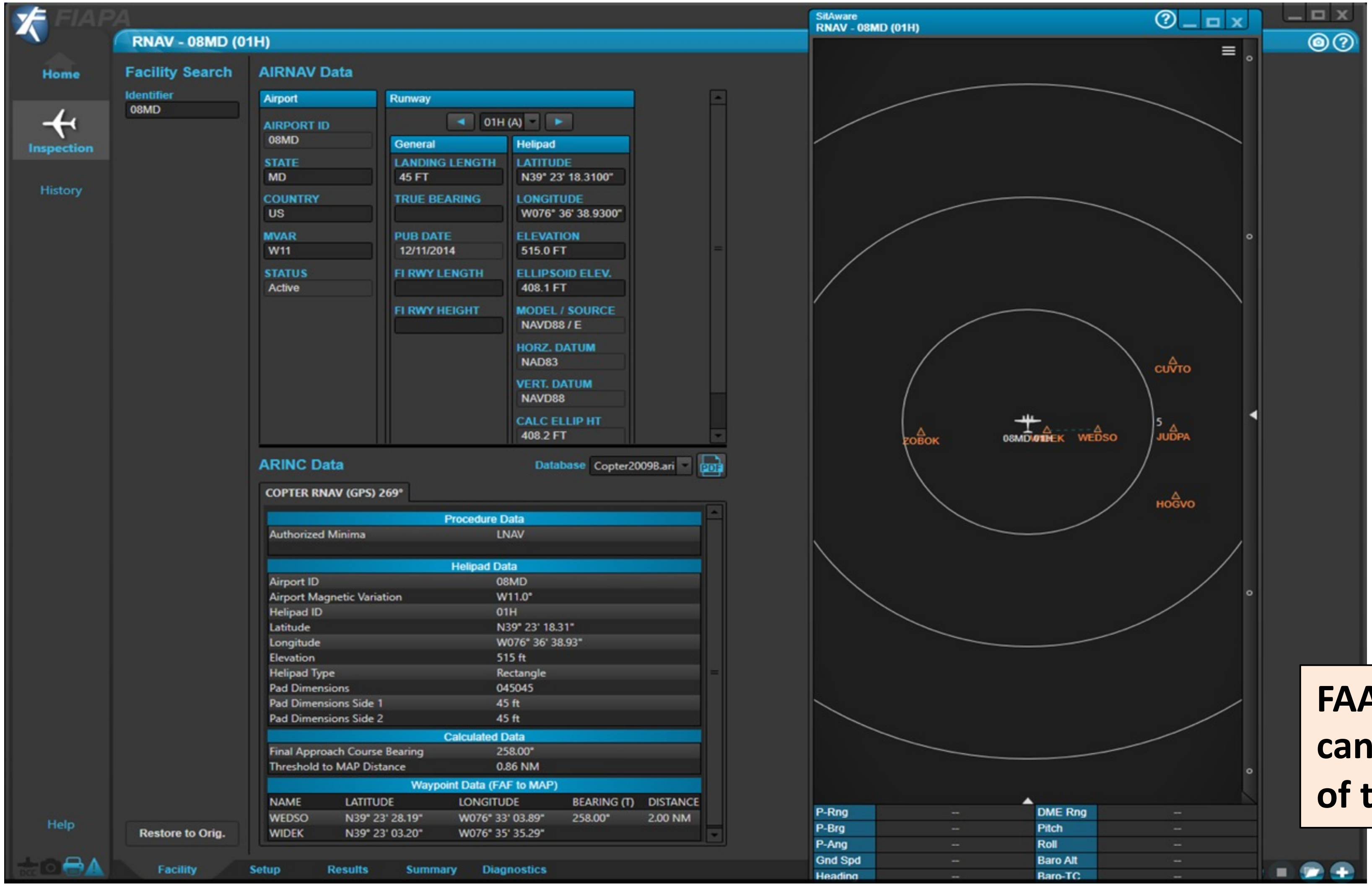
*Assumed 200 FPNM CG – OCS 40:1
300 FPNM CG – OCS 20:1
400 FPNM CG – OCS 15:1





```
HDR EDWARDS AFB                 CAUSAREAA     XSID UAM RNAV (GPS) (RNP 0.1)
TUSAV CAAREAAL2A   01H  0     WARY N41065197W078462634W010001463      1800018000P   050050M NASA ARMSTRONG, EDWARDS AFB
TUSAV CAAREAAL2CWAYP1 L20     W     N41012692W078434998                      W0103    NAR              WAYP1
TUSAV CAAREAAL2C WAYP1 L20    W     N41060900W078460558                      W0103    NAR              WAYP2
TUSAV CAAREAAL1D WAYP2 25ALL   010WAYP2K6HC0E           CA                      00     + 02285     18000
TUSAV CAAREAAL1D WAYP2 25ALL   010WAYP2K6HC0E           TF                             + 02900     18000
TUSAV CAAREAAL1D WAYP2 25ALL   010WAYP2K6HC0E           TF                             + 02900     18000
TUSAV CAAREAAL2DARAA25ALL      020WAYP2K6HC0EB          TF                             + 10000
```

Flight Inspection (FIAPA) Collaboration



RNAV - 08MD (01H)

Facility Search

Identifier: 08MD

AIRNAV Data

Airport

AIRPORT ID	08MD
STATE	MD
COUNTRY	US
MVAR	W11
STATUS	Active

Runway 01H (A)

General

LANDING LENGTH	45 FT
TRUE BEARING	
PUB DATE	12/11/2014
FI RWY LENGTH	
FI RWY HEIGHT	

Helipad

LATITUDE	N39° 23' 18.3100"
LONGITUDE	W076° 36' 38.9300"
ELEVATION	515.0 FT
ELLIPSOID ELEV.	408.1 FT
MODEL / SOURCE	NAVD88 / E
HORZ. DATUM	NAD83
VERT. DATUM	NAVD88
CALC ELLIP HT	408.2 FT

ARINC Data

Database: Copter2009B.ari

COPTER RNAV (GPS) 269°

Procedure Data	
Authorized Minima	LNAV

Helipad Data	
Airport ID	08MD
Airport Magnetic Variation	W11.0°
Helipad ID	01H
Latitude	N39° 23' 18.31"
Longitude	W076° 36' 38.93"
Elevation	515 ft
Helipad Type	Rectangle
Pad Dimensions	045045
Pad Dimensions Side 1	45 ft
Pad Dimensions Side 2	45 ft

Calculated Data	
Final Approach Course Bearing	258.00°
Threshold to MAP Distance	0.86 NM

Waypoint Data (FAF to MAP)

NAME	LATITUDE	LONGITUDE	BEARING (T)	DISTANCE
WEDSO	N39° 23' 28.19"	W076° 33' 03.89"	258.00°	2.00 NM
WIDEK	N39° 23' 03.20"	W076° 35' 35.29"		

P-Rng	--	DME Rng	--
P-Brg	--	Pitch	--
P-Ang	--	Roll	--
Gnd Spd	--	Baro Alt	--
Heading	--	Baro-TC	--

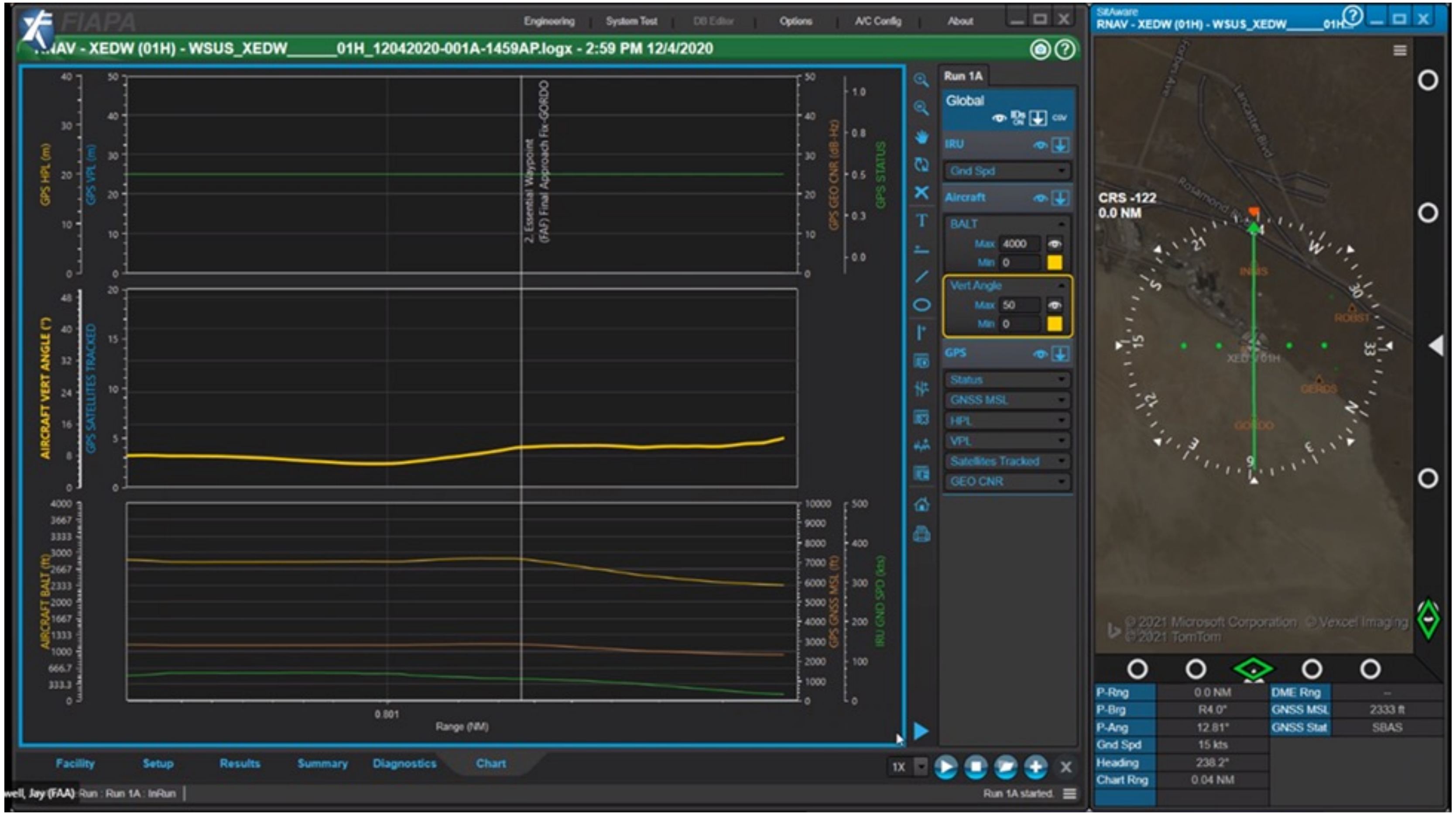
Flight Inspection Airborne Processing Application

- KEDW pending data
- AFRC Waypoint and Route Information
- Performs spatial data accuracy checks
- Post flight Analysis
- Expanding for Helicopter and UAM operations

FAA AJF-013 collaboration for exploratory candidate software for new AAM entrants of the future

AAM NC provides opportunity to explore and calibrate antenna, receivers and software for candidate flight inspection.

Flight Inspection (FIAPA) Collaboration



..NAV - XEDW (01H) - WSUS_XEDW_____01H_12042020-001A-1459AP.logx - 2:59 PM 12/4/2020

RNAV - XEDW (01H) - WSUS_XEDW_____01H

P-Rng	0.0 NM	DME Rng	--
P-Brg	R4.0°	GNSS MSL	2333 ft
P-Ang	12.81°	GNSS Stat	SBAS
Gnd Spd	15 kts		
Heading	238.2°		
Chart Rng	0.04 NM		

..well, Jay (FAA) Run : Run 1A : InRun

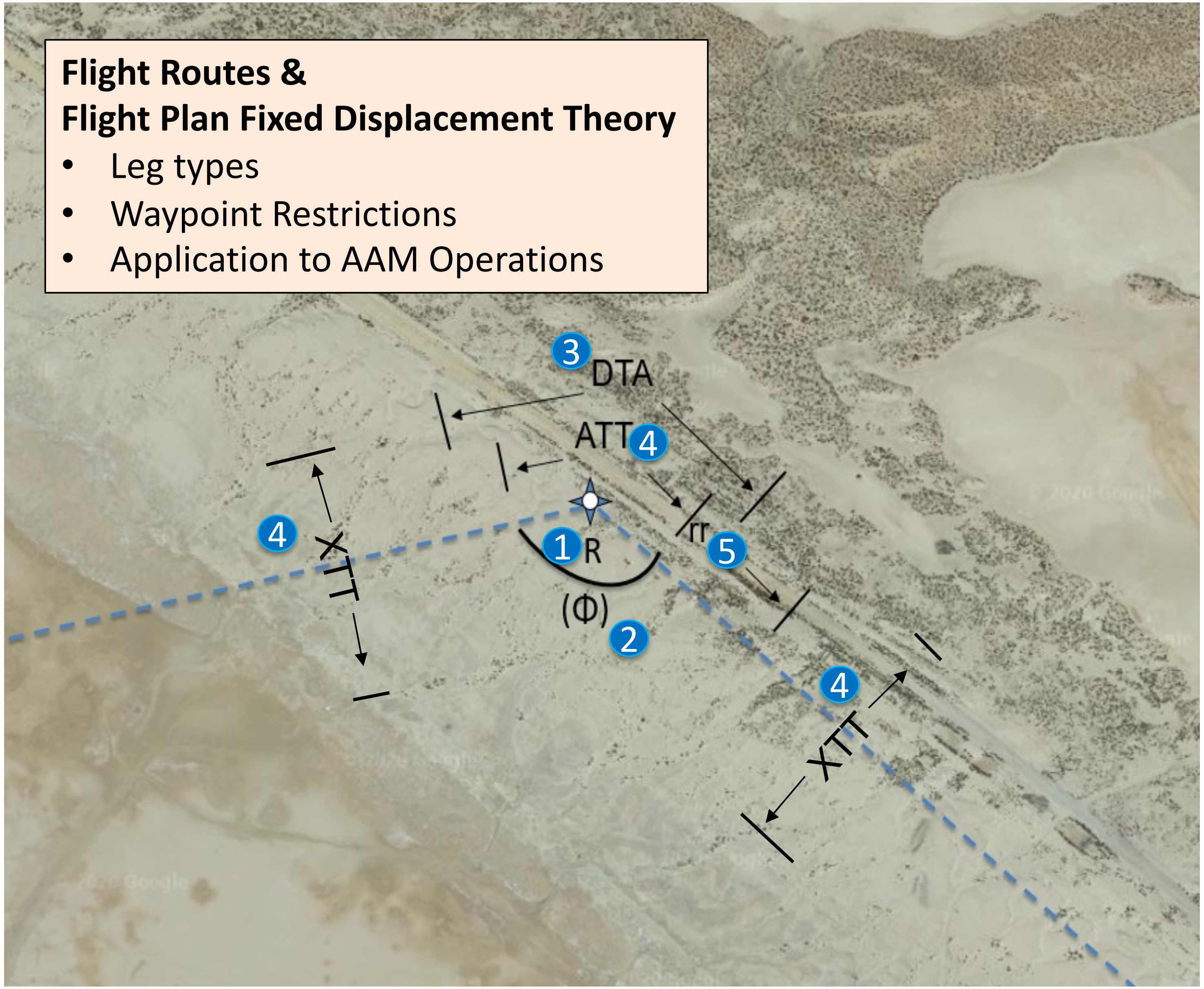
Run 1A started.

Flight Inspection Airborne Processing Application

- Range
- Vertical Angle
- Height MSL
- Horizontal RMS
- Vertical RMS
- Lat/Long
- GPS Status

AAM NC provides opportunity to explore and calibrate antenna, receivers and software for candidate flight inspection.

Fixed Displacement Theory Overview



Flight Routes &
Flight Plan Fixed Displacement Theory

- Leg types
- Waypoint Restrictions
- Application to AAM Operations

① Turn Radius $R = \dfrac{V_{ground2}}{\tan(\phi) \times 68625.4}$

② RF Bank Angle $\phi = \operatorname{atan}\left(\dfrac{V_{ground2}}{R \times 68625.4}\right)$

③ Distance Turn Anticipation

$DTA = R \times \tan\left(\frac{\beta}{2}\right)$

④

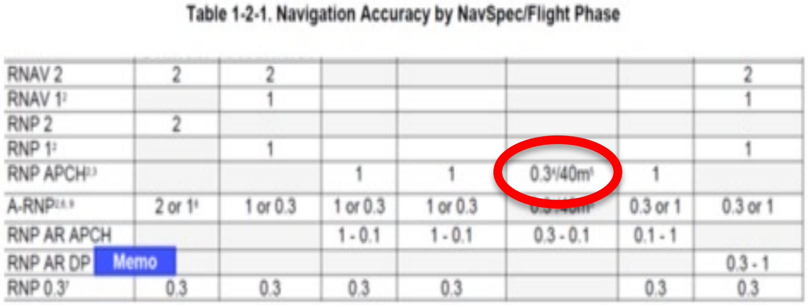


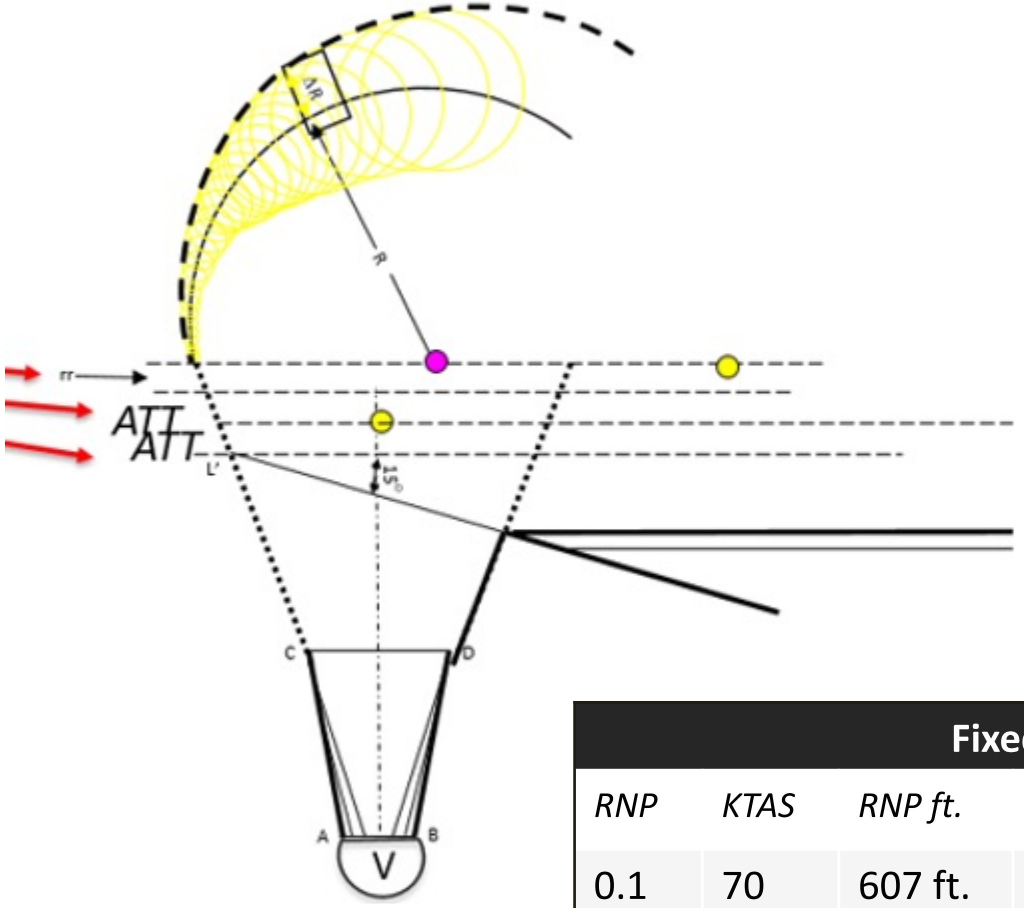
Table 1-2-1. Navigation Accuracy by NavSpec/Flight Phase

RNAV 2	2	2					2
RNAV 1[2]		1					1
RNP 2	2						
RNP 1[2]		1					1
RNP APCH[2,3]			1	1	0.3[4]/40m[5]	1	
A-RNP[2,6,9]	2 or 1[8]	1 or 0.3	1 or 0.3	1 or 0.3	0.3[4]/40m[5]	0.3 or 1	0.3 or 1
RNP AR APCH			1 - 0.1	1 - 0.1	0.3 - 0.1	0.1 - 1	
RNP AR DP Memo							0.3 - 1
RNP 0.3[7]	0.3	0.3	0.3	0.3		0.3	0.3

Formula 1-2-12. **Reaction and Roll Distance** (D_{rr})

⑤ $D_{rr} = \dfrac{V_{KTAS} \times 6}{3600}$

Fixed Displacement Theory Drr



Formula 1-2-12. **Reaction and Roll Distance** (Drr)

$$D_{rr} = \frac{V_{KTAS} \times 6}{3600}$$

70 KTAS x 6 sec./3600 x 6076.12 NM in ft. = 708.8807 ft.

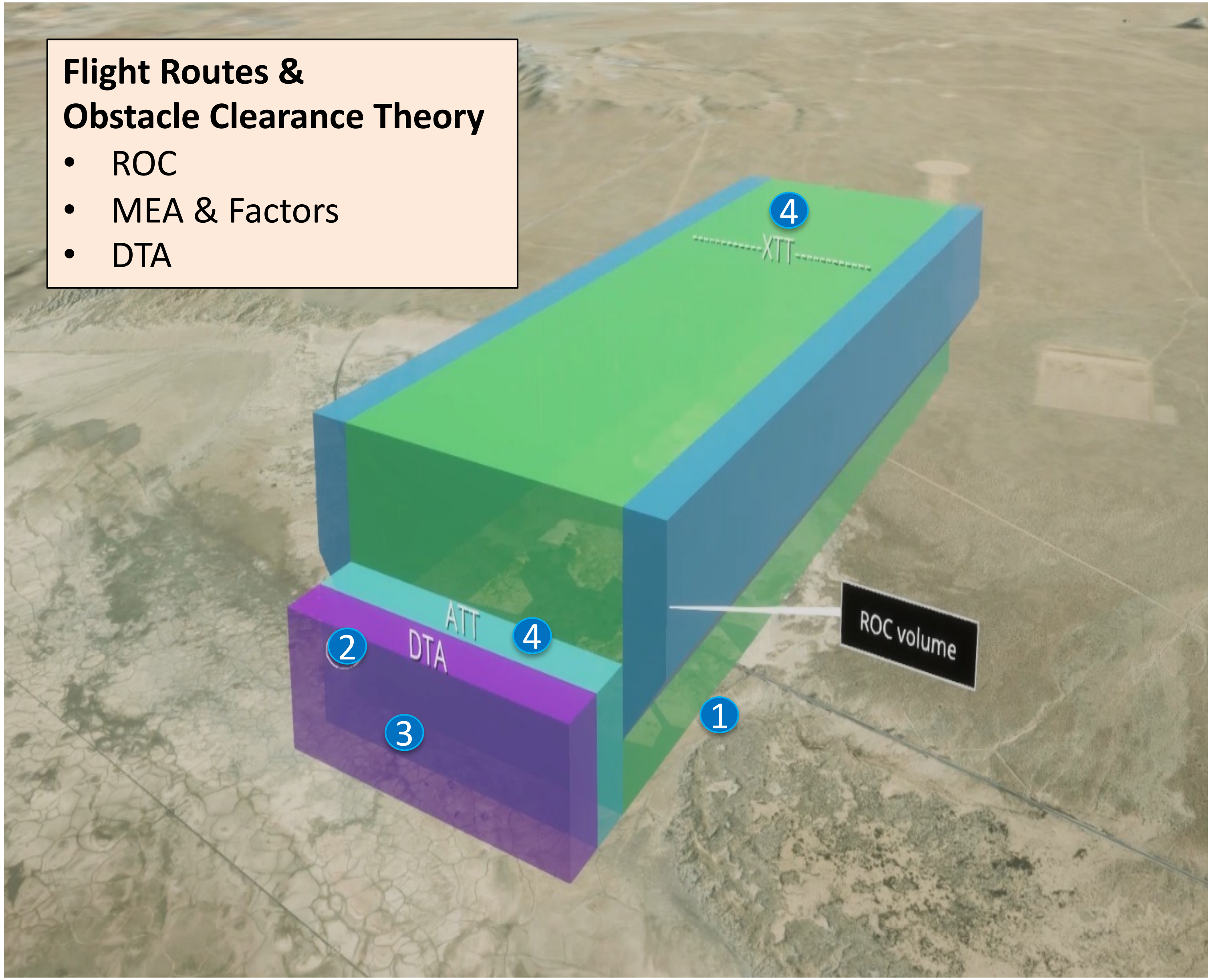
70 KTAS x 3 sec./3600 x 6076.12 NM in ft. = 354.4403 ft.

Fixed Displacement Theory for Distance Reaction & Roll (Drr)

RNP	*KTAS*	*RNP ft.*	*Drr Error*	*Containment Area*	*Time for Drr*	*NAVAID*	*Pilot*	*Autopilot*
0.1	70	607 ft.	708 ft.	1315 ft. **CONSERVATIVE**	6 sec. **CONSERVATIVE**	3 sec.	3 sec.	NA
0.05	70	304 ft.	354 ft.	658 ft. **AGGRESSIVE**	3 sec. **AGGRESSIVE**	3 sec.	NA	TBD

AAM automation may enable reduced reaction and roll displacement allowances to condense flight paths.

Obstacle Clearance Theory Overview



Flight Routes &
Obstacle Clearance Theory

- ROC
- MEA & Factors
- DTA

① Required Obstacle Clearance (ROC)

-Terrain + Airspace + Obstructions

② Minimum Enroute Altitude (MEA)

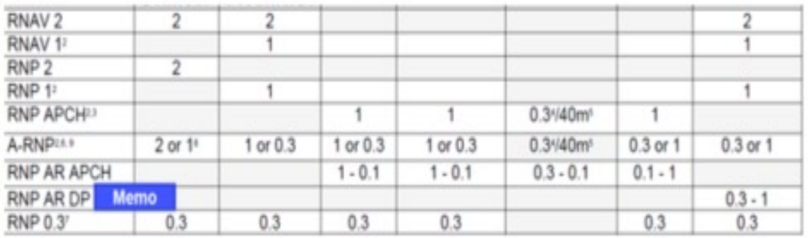
- Obstacle Clearance
- Radio Reception
- NAVAID Reception
- Gust Rejection Tolerance *

③ Distance Turn Anticipation

$$DTA = R \times \tan\left(\frac{\beta}{2}\right)$$

④

Table 1-2-1. Navigation Accuracy by NavSpec/Flight Phase



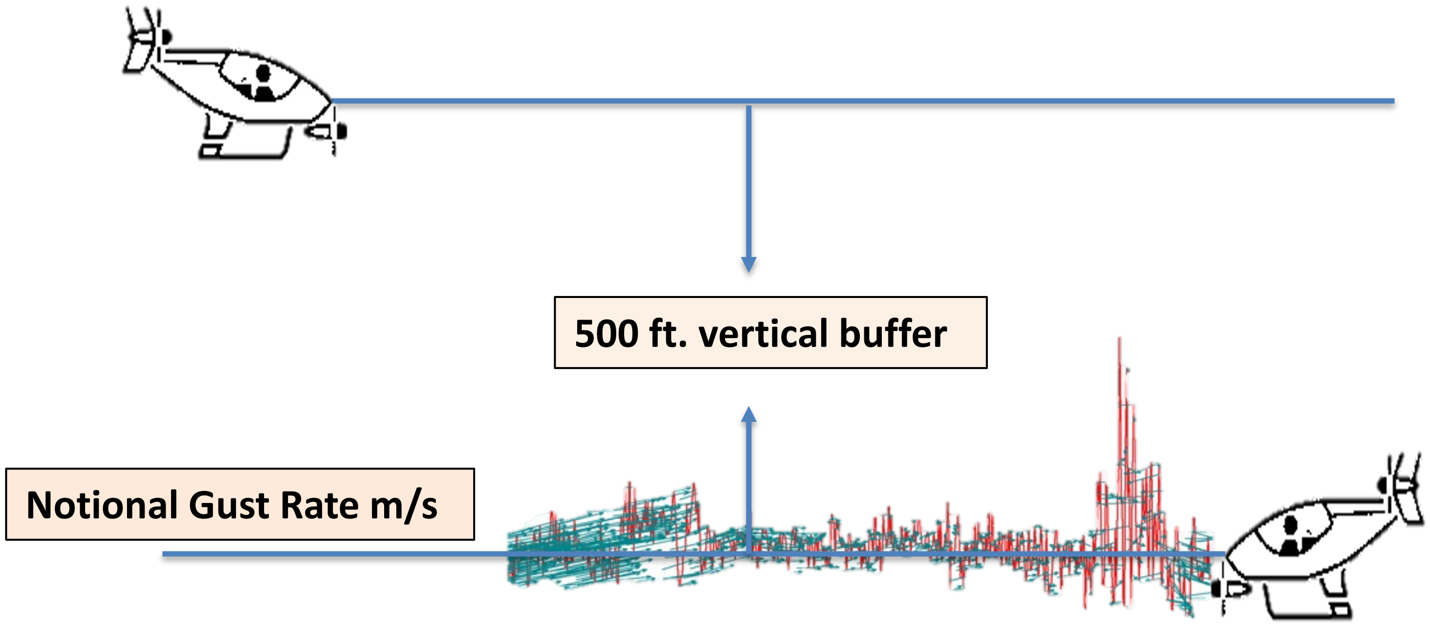
RNAV 2	2	2					2
RNAV 1[2]		1					1
RNP 2	2						
RNP 1[2]		1					1
RNP APCH[2,3]			1	1	0.3[4]/40m[5]	1	
A-RNP[2,6,9]	2 or 1[8]	1 or 0.3	1 or 0.3	1 or 0.3	0.3[4]/40m[5]	0.3 or 1	0.3 or 1
RNP AR APCH			1 - 0.1	1 - 0.1	0.3 - 0.1	0.1 - 1	
RNP AR DP	Memo						0.3 - 1
RNP 0.3[7]	0.3	0.3	0.3	0.3		0.3	0.3

Vertical Separation Theory

Altimetry System Error (ASE) = 1000 ft Buffer
(300 ft Acceptable Error)

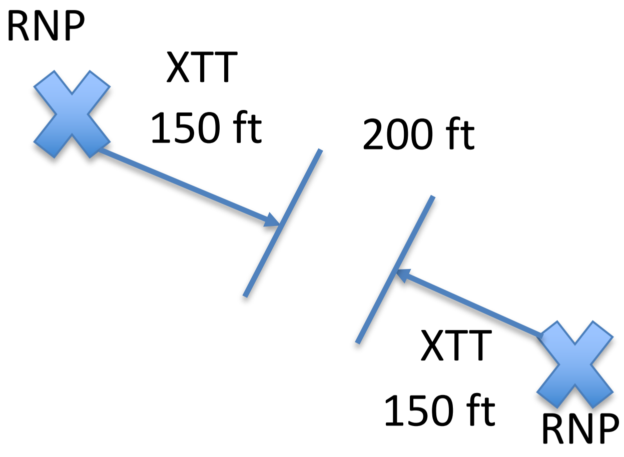
Example AAM ASE = ~500 ft Buffer
(100 ft Acceptable Error or 150 ft Same Ratio)

Vertical Separation			
Gust Updraft	*Feet per second*	*100 ft.*	*150 ft.*
1000 fpm	**16.7**	**5.9**	**8.9**
1500 fpm	**25**	**4.0**	**6.0**
2000 fpm	**33.3**	**3.0**	**4.5**



500 ft. vertical buffer

Notional Gust Rate m/s



RNP

XTT
150 ft

200 ft

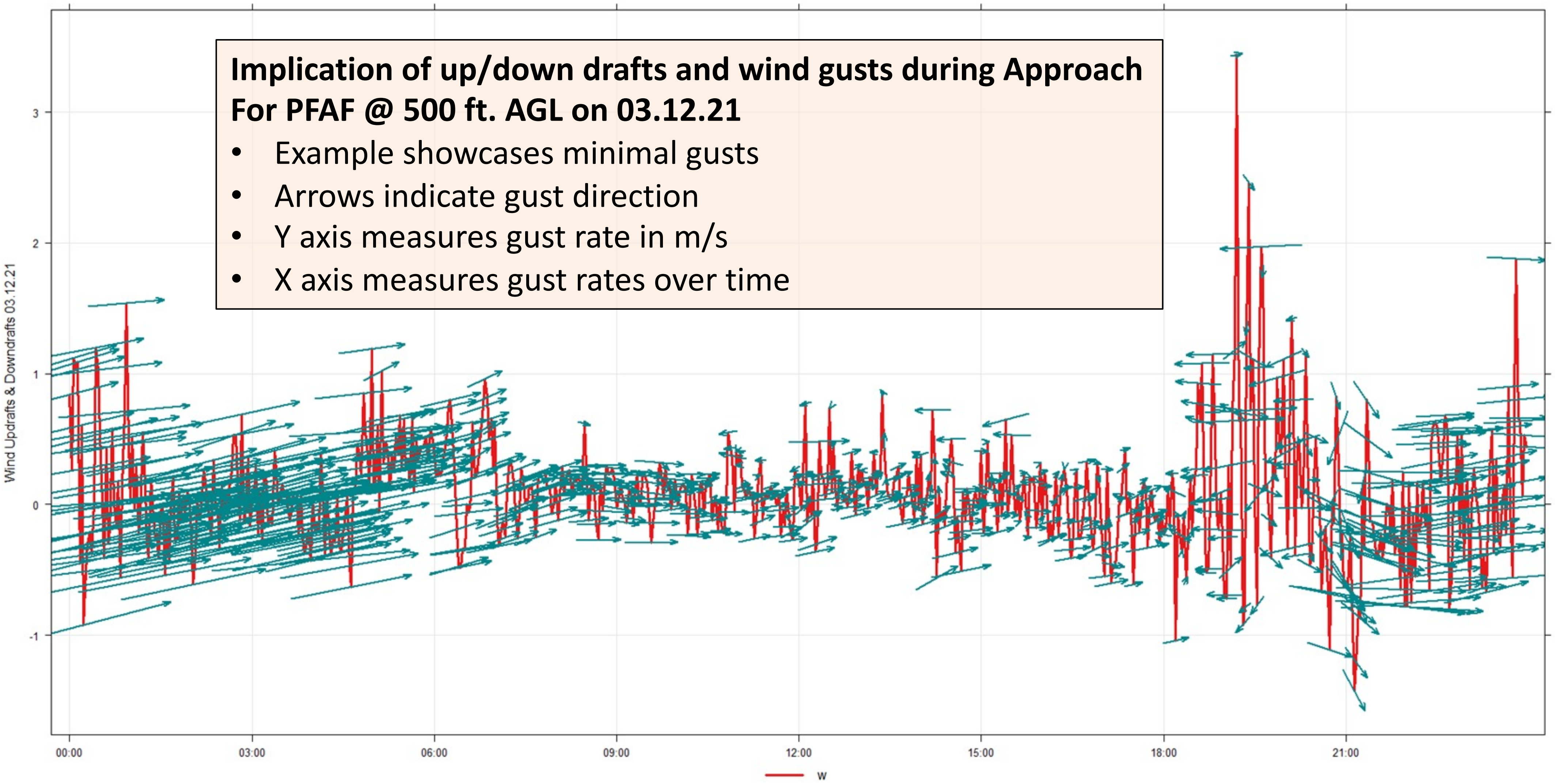
XTT
150 ft

RNP

Wind drafts and gusts may have a greater effect on AAM vertical separation.

Gust Rejection Tolerance Theory

Gust Rate m/s



Implication of up/down drafts and wind gusts during Approach For PFAF @ 500 ft. AGL on 03.12.21

- Example showcases minimal gusts
- Arrows indicate gust direction
- Y axis measures gust rate in m/s
- X axis measures gust rates over time

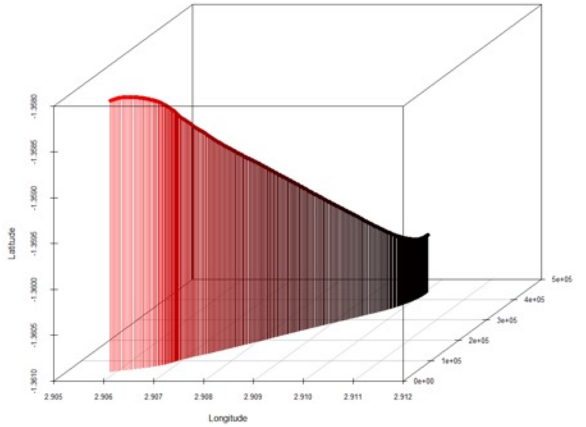
Wind drafts and gusts may impact light class vehicles with fan rotors upon approach.

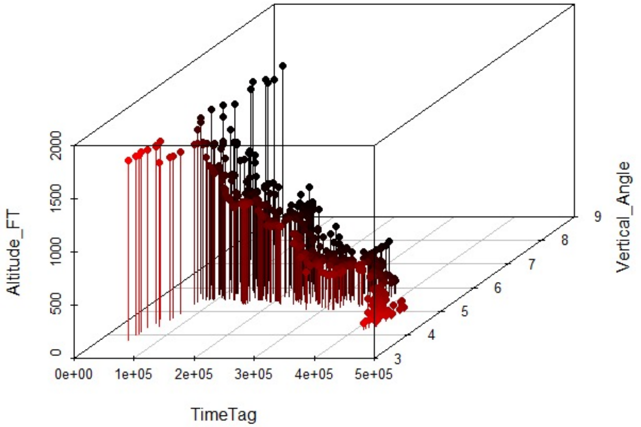
Flight Path Conformance Collaboration

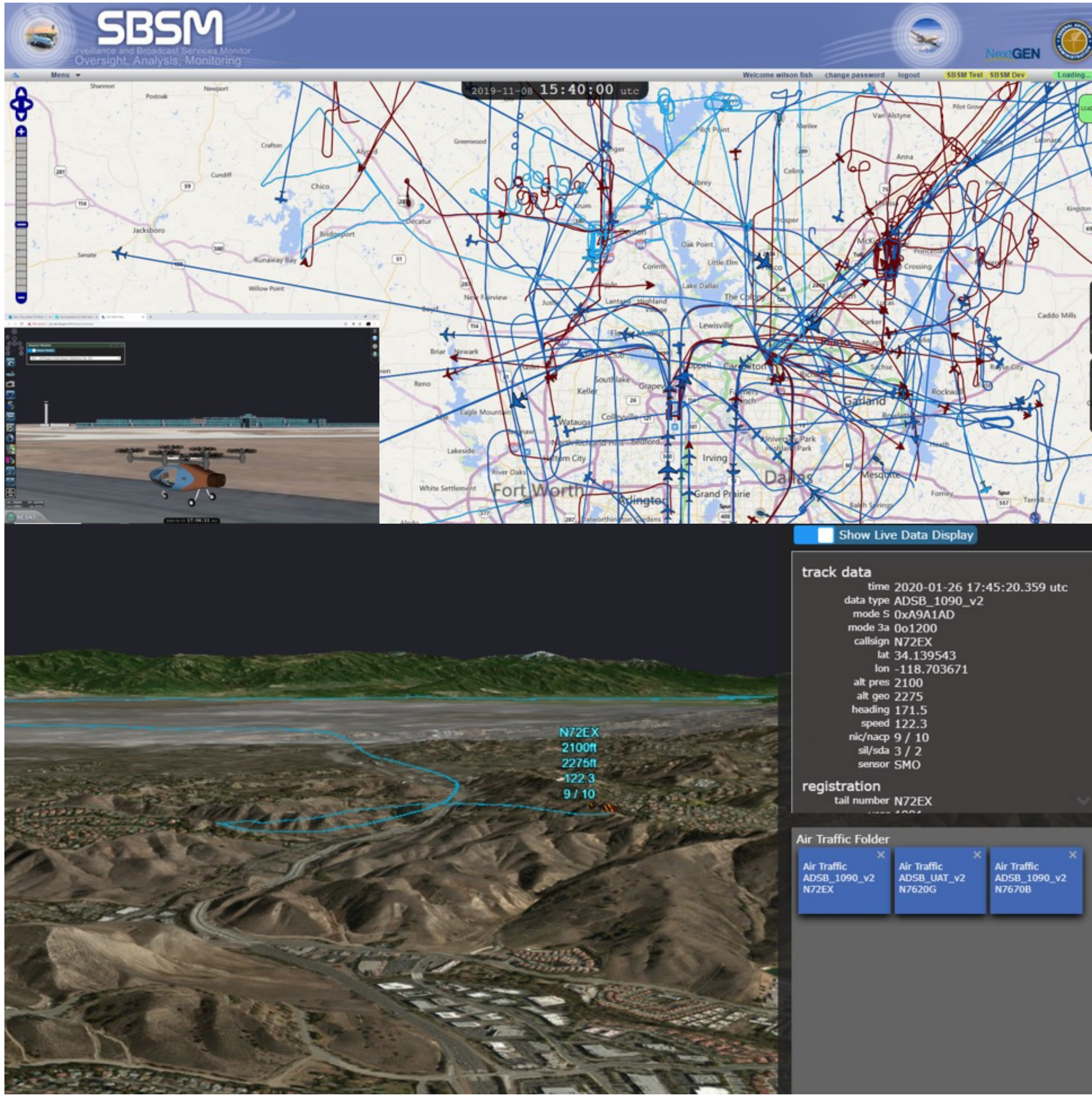
Data Fusion

- Real time (<1 sec refresh rate) ADS-B
- Pilot deviations
- Route tracking and conformance
- Enforcement/Contingency Management
- Post flight data analysis

Collaboration with FAA Surveillance Broadcast Services Monitor AJW -147







track data
time 2020-01-26 17:45:20.359 utc
data type ADSB_1090_v2
mode S 0xA9A1AD
mode 3a 0o1200
callsign N72EX
lat 34.139543
lon -118.703671
alt pres 2100
alt geo 2275
heading 171.5
speed 122.3
nic/nacp 9 / 10
sil/sda 3 / 2
sensor SMO

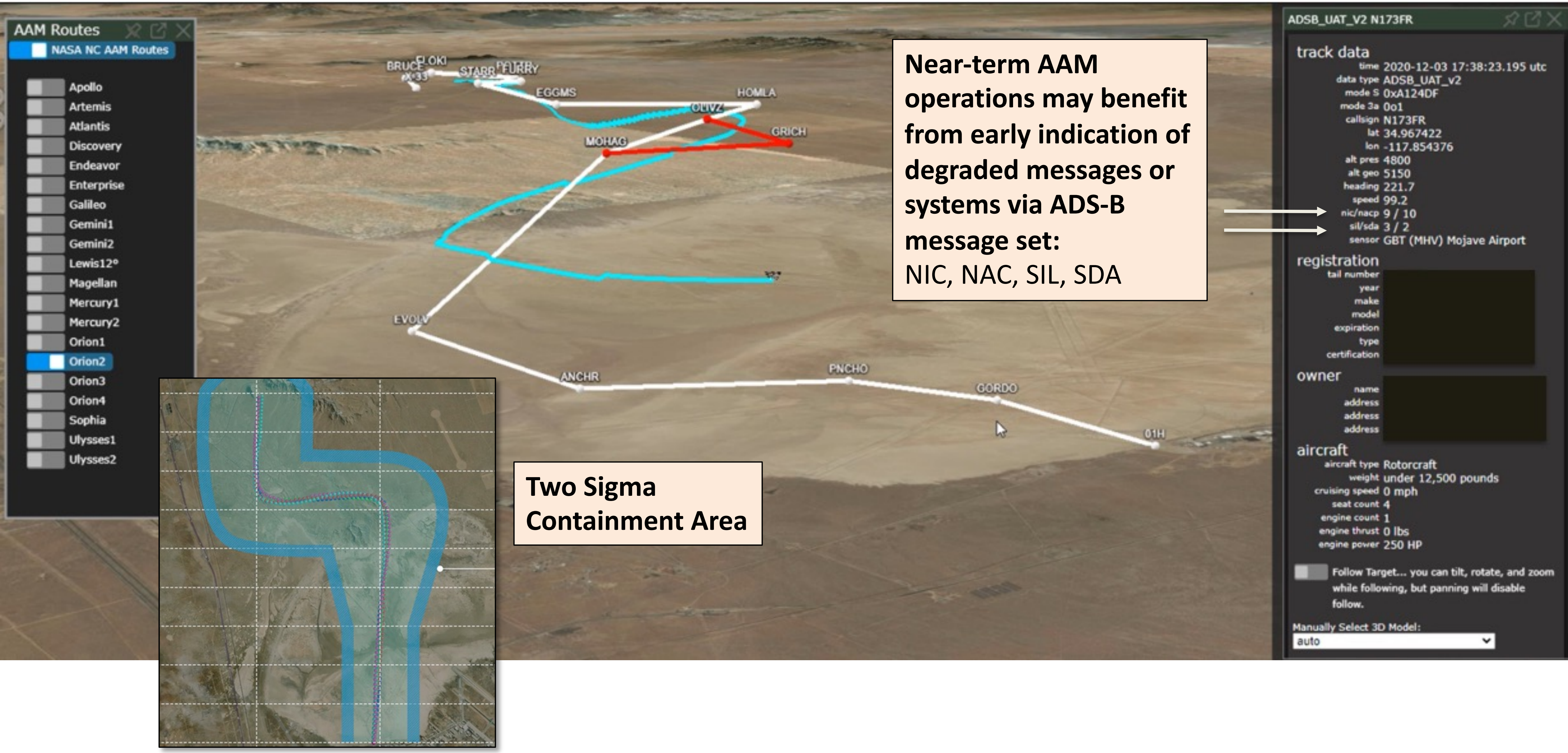
registration
tail number N72EX

Air Traffic
ADSB_1090_v2
N72EX

Air Traffic
ADSB_UAT_v2
N7620G

Air Traffic
ADSB_1090_v2
N7670B

Flight Path Conformance Collaboration



track data
time 2020-12-03 17:38:23.195 utc
data type ADSB_UAT_v2
mode S 0xA124DF
mode 3a 0o1
callsign N173FR
lat 34.967422
lon -117.854376
alt pres 4800
alt geo 5150
heading 221.7
speed 99.2
nic/nacp 9 / 10
sil/sda 3 / 2
sensor GBT (MHV) Mojave Airport

registration
tail number
year
make
model
expiration
type
certification
[redacted]

owner
name
address
address
address
[redacted]

aircraft
aircraft type Rotorcraft
weight under 12,500 pounds
cruising speed 0 mph
seat count 4
engine count 1
engine thrust 0 lbs
engine power 250 HP

☐ Follow Target... you can tilt, rotate, and zoom while following, but panning will disable follow.

Manually Select 3D Model: auto

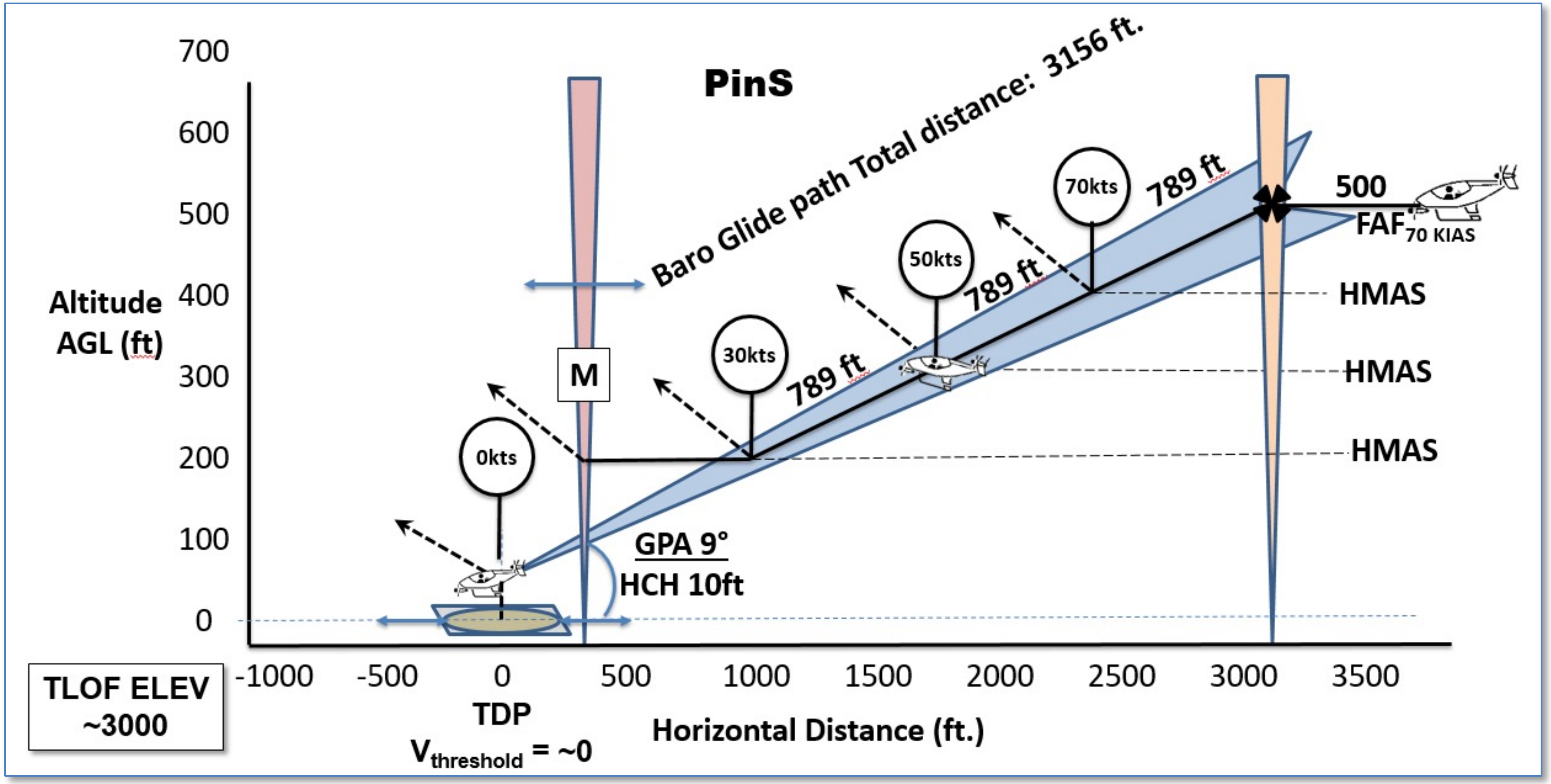
Near-term AAM operations may benefit from early indication of degraded messages or systems via ADS-B message set:
NIC, NAC, SIL, SDA

Two Sigma Containment Area

Flight Following for Quad Zero (PinS) Approaches

A descending / decelerating method may be tested in future flight events:

- Dynamic missed approach opportunities given:
    - Time
    - Speed
    - Altitude
    - Descent Rate
- Speed gateways for deceleration
- Message set updates & latencies
- Impact of wind & gusts



AAM may require novel approach methods to accommodate automation, maintain message integrity, and address shifting wind conditions in constrained airspace.

Flight Following for Quad Zero (PinS) Approaches

A descending / decelerating method may be tested in future flight events:

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- Speed gateways for deceleration
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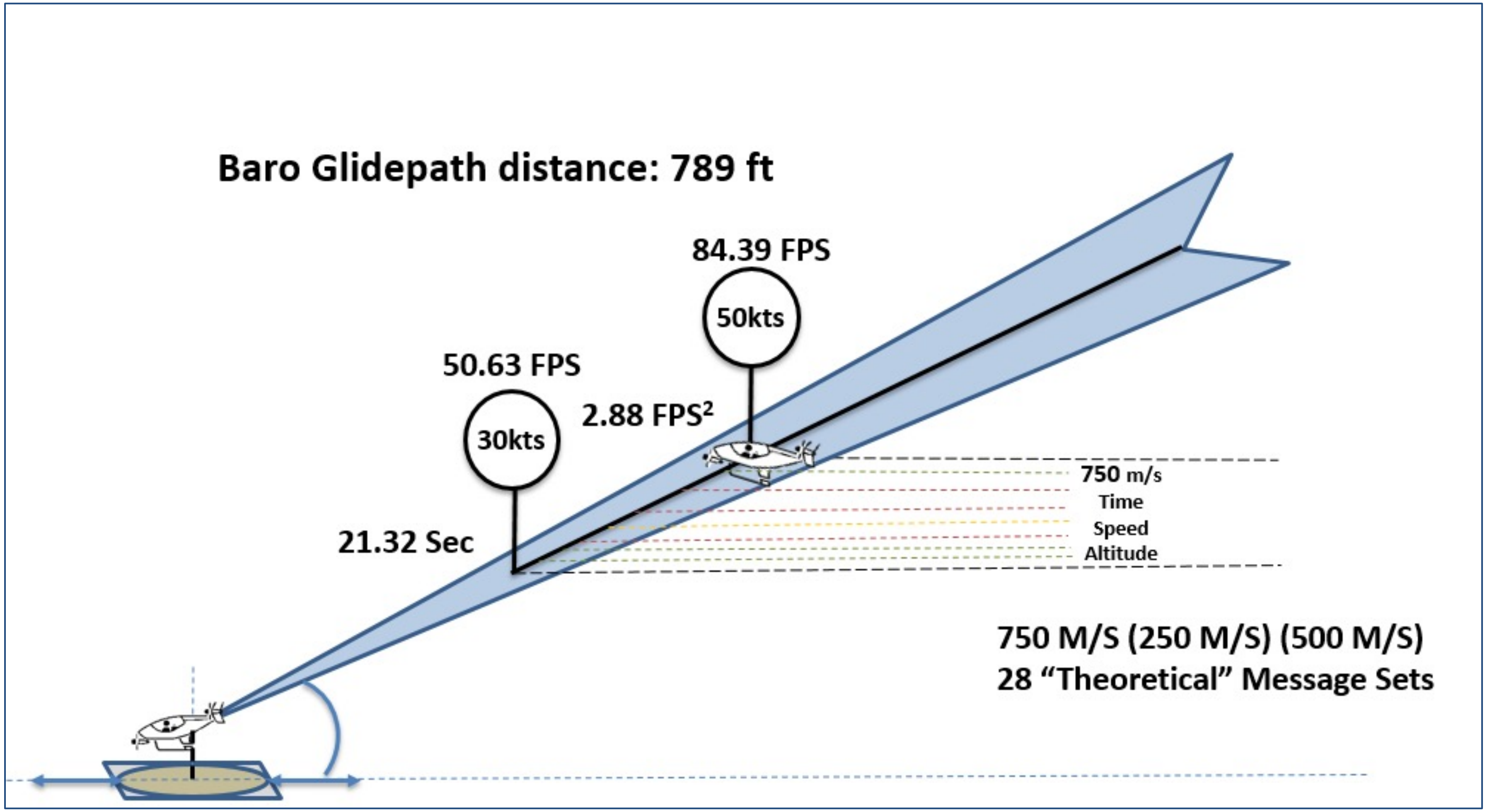
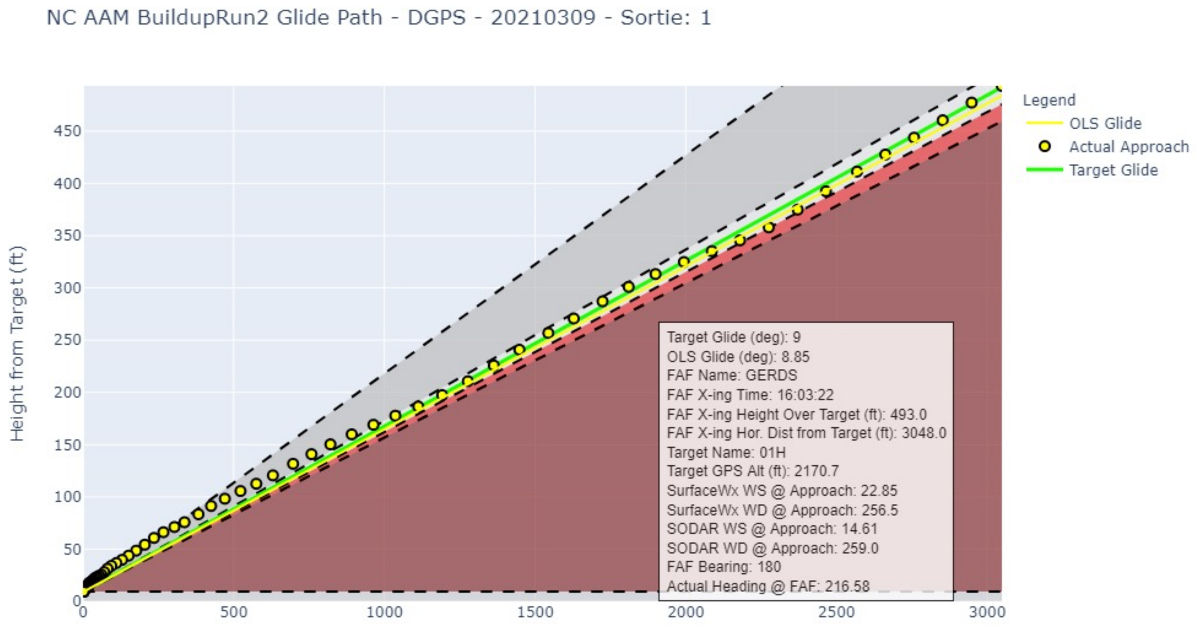


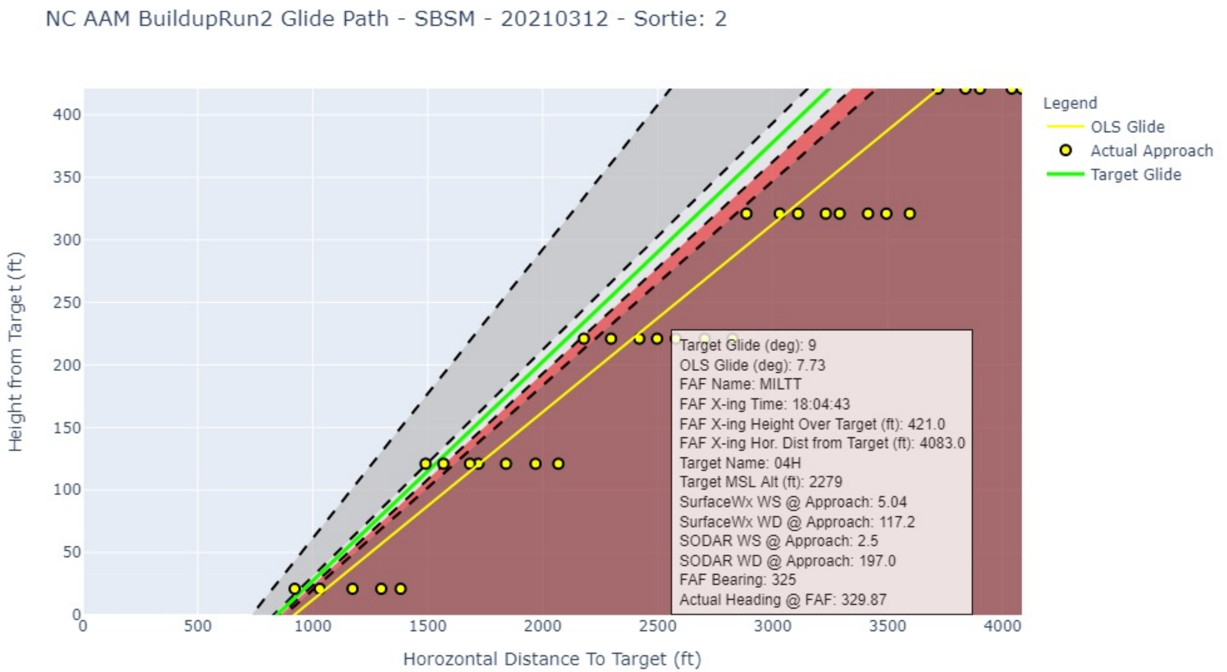
AAM may require novel approach methods to accommodate automation, maintain message integrity, and address shifting wind conditions in constrained airspace.

Time Space Position Information Overview

NC TSPI Instrumentation			
Provider	**Monitor Type**	**Instrument**	**Notes**
Vehicle	Vehicle Sensor	Interactive Authoring Display Software (IADS)	
NASA	Unit affixed to vehicle	ADS-B Pingstation	
FAA	Remote Monitor	ADS-B SBSM	
NASA	Unit affixed to vehicle	d-GPS	NC Primary Truth Source
FAA	Unit affixed to vehicle	Flight Inspection Airborne Processor Application	Approaches only
EDW	Local Monitor	Primary Radar	For reserve


NC AAM BuildupRun2 Glide Path - DGPS - 20210309 - Sortie: 1

Target Glide (deg): 9
OLS Glide (deg): 8.85
FAF Name: GERDS
FAF X-ing Time: 16:03:22
FAF X-ing Height Over Target (ft): 493.0
FAF X-ing Hor. Dist from Target (ft): 3048.0
Target Name: 01H
Target GPS Alt (ft): 2170.7
SurfaceWx WS @ Approach: 22.85
SurfaceWx WD @ Approach: 256.5
SODAR WS @ Approach: 14.61
SODAR WD @ Approach: 259.0
FAF Bearing: 180
Actual Heading @ FAF: 216.58

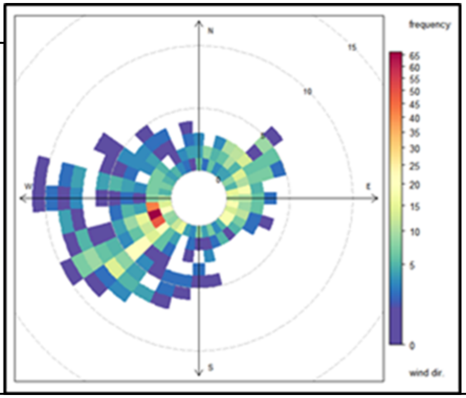

NC AAM BuildupRun2 Glide Path - SBSM - 20210312 - Sortie: 2

Target Glide (deg): 9
OLS Glide (deg): 7.73
FAF Name: MILTT
FAF X-ing Time: 18:04:43
FAF X-ing Height Over Target (ft): 421.0
FAF X-ing Hor. Dist from Target (ft): 4083.0
Target Name: 04H
Target MSL Alt (ft): 2279
SurfaceWx WS @ Approach: 5.04
SurfaceWx WD @ Approach: 117.2
SODAR WS @ Approach: 2.5
SODAR WD @ Approach: 197.0
FAF Bearing: 325
Actual Heading @ FAF: 329.87

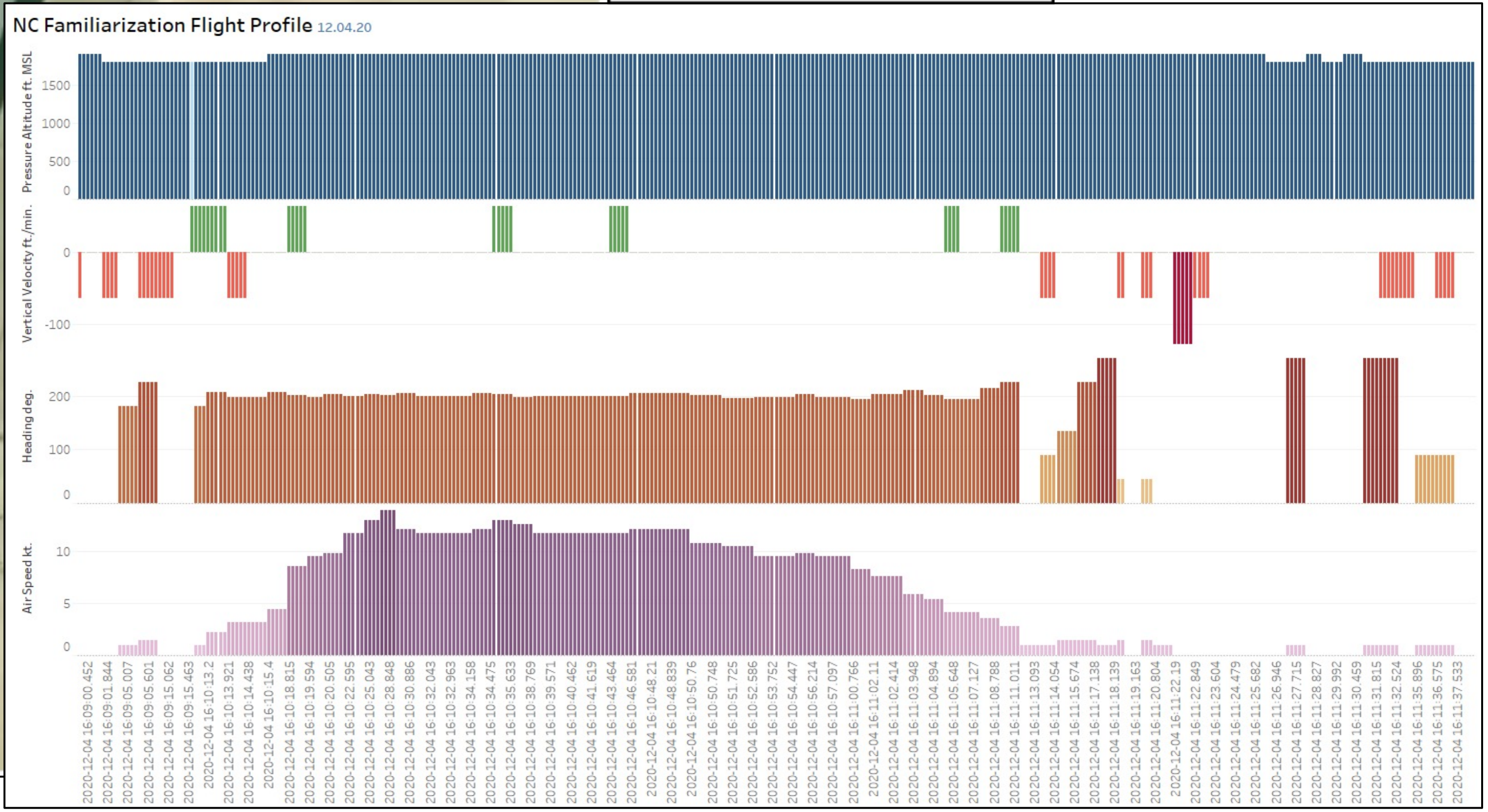
AAM NC tests the latency and signal qualities of multiple instrumentation sources.

UAM Dep/App Theory

Work Underway: Fusing data to apply to approach



Data Element Planning

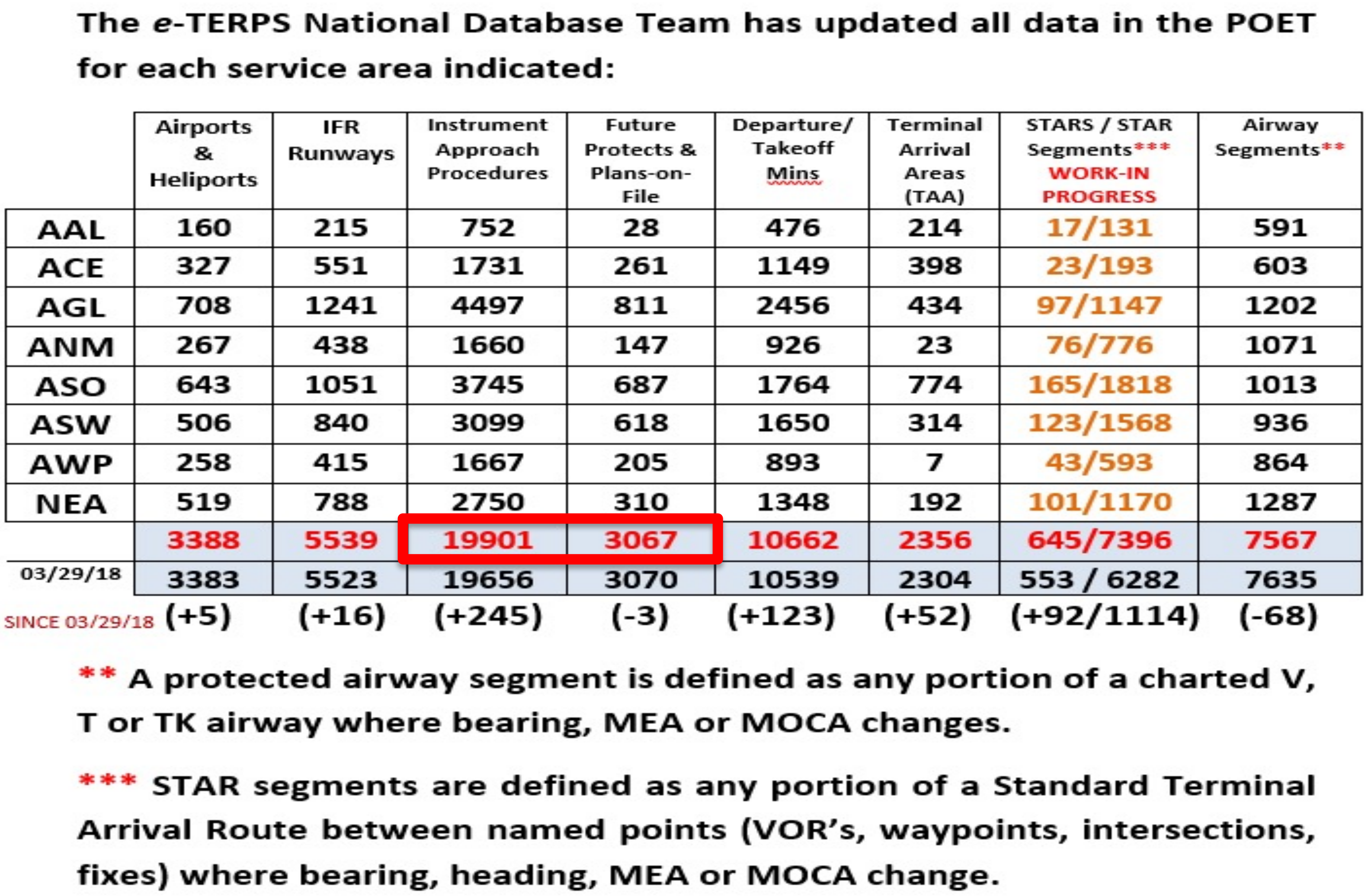


AAM National Campaign

Coded Instrument Flight Procedures

CIFP Timeline

- IFP Wait time 24-60 months
- Priority Levels 1-4
- Priority Level 1, 2 Current Production
- $ 5,000 per procedure/year
- 22,000 Procedures



The *e*-TERPS National Database Team has updated all data in the POET for each service area indicated:

	Airports & Heliports	IFR Runways	Instrument Approach Procedures	Future Protects & Plans-on-File	Departure/ Takeoff Mins	Terminal Arrival Areas (TAA)	STARS / STAR Segments*** WORK-IN PROGRESS	Airway Segments**
AAL	160	215	752	28	476	214	17/131	591
ACE	327	551	1731	261	1149	398	23/193	603
AGL	708	1241	4497	811	2456	434	97/1147	1202
ANM	267	438	1660	147	926	23	76/776	1071
ASO	643	1051	3745	687	1764	774	165/1818	1013
ASW	506	840	3099	618	1650	314	123/1568	936
AWP	258	415	1667	205	893	7	43/593	864
NEA	519	788	2750	310	1348	192	101/1170	1287
	3388	5539	19901	3067	10662	2356	645/7396	7567
03/29/18	3383	5523	19656	3070	10539	2304	553 / 6282	7635
SINCE 03/29/18	(+5)	(+16)	(+245)	(-3)	(+123)	(+52)	(+92/1114)	(-68)

** A protected airway segment is defined as any portion of a charted V, T or TK airway where bearing, MEA or MOCA changes.

*** STAR segments are defined as any portion of a Standard Terminal Arrival Route between named points (VOR's, waypoints, intersections, fixes) where bearing, heading, MEA or MOCA change.

What is the economical impact of AAM integration?

NC is addressing technological, regulatory and economical hurdles for AAM integration.

QUESTIONS/COMMENTS/DISCUSSION

Future Meetings

The Crosscutting Working Group's meeting dates and times vary depending on the needs of the AAM community.

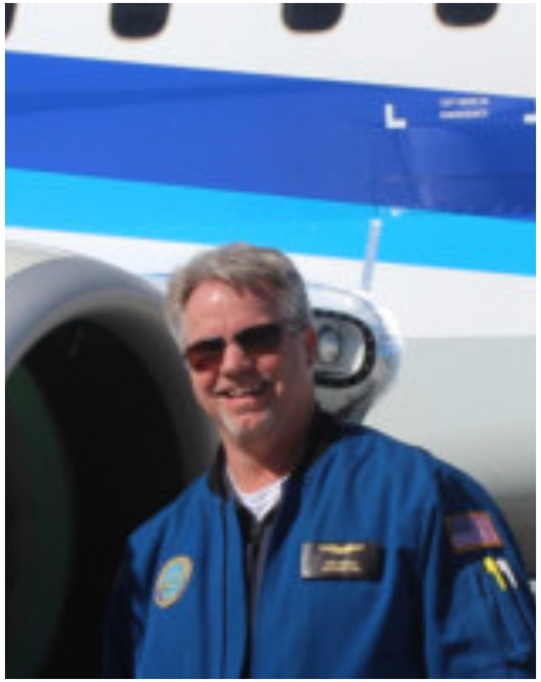
- Nov & Dec 2021 Holiday Break

Crosscutting Working Group POCs

- Technical Lead:
  - Dr. Misty Davies (misty.d.davies@nasa.gov)
- Coordinator:
  - Rajan Shankara (Rajan.shankara@nasa.gov)

Comments, questions, suggestions for future topics, and other workgroup information:

- Email us at: arc-cal-nari@mail.nasa.gov; or
- Visit the new AEWG Portal: https://nari.arc.nasa.gov/aam-portal/.



David Webber is a Research/Flight Test Engineer for the FAA's Aircraft Certification Service, supporting standards development, certification, and international validations across all aircraft product lines. He is deeply involved in a variety of flight research projects designed to support the development, certification and advent of new and novel aircraft technologies, and is technical lead for the NASA Advanced Air Mobility UAM Surrogate Helicopter flight research efforts. He recently accepted a detail to NASA to support Advanced Air Mobility research on a full time basis.

David Zahn is the Principal Investigator of UAM Airspace Procedures for NASA's (Sim Labs) Advanced Air Mobility National Campaign (AAM-NC) located at the Mike Monroney Aeronautical Center, Oklahoma City, OK. Served as a UH-60 Blackhawk pilot in the U.S. Army with previous experience in airfield operations, safety, terminal procedures (TERPS), accident investigation and international flight instruction. David’s background in low-level Air Assault/MEDEVAC/Firefighting operations combined with his TERPS experience helped the NASA team develop UAM specific approach/departure procedures and airspace infrastructure models for UAM research, certification, and integration. David Zahn graduated from Oral Roberts University in Tulsa, OK where he was also an NCAA Division I athlete.