National Aeronautics and Space Administration

Assistive Detect and Avoid Technology in Urban Air Mobility Environments

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Motivation and Outline of Presentation

Motivation:

- Assistive Detect and Avoid (Assistive DAA or **ADAA**) technology may enhance the **efficiency** and conflict avoidance **safety** of Urban Air Mobility (**UAM**) operations conducted under Visual Flight Rules (**VFR**), beyond that with only pilot See and Avoid capability.
- This paper reports **initial observations** of ADAA use in simulated UAM environments.

Outline:

- Brief overviews of DAA and ADAA
- Brief overviews of UAM and the simulation environment
- Sample UAM encounter geometries and ADAA guidance
- Challenges: wind, turns, tight spacing, intersections, rotorcraft
- Initial lessons learned to date

DAA and ADAA

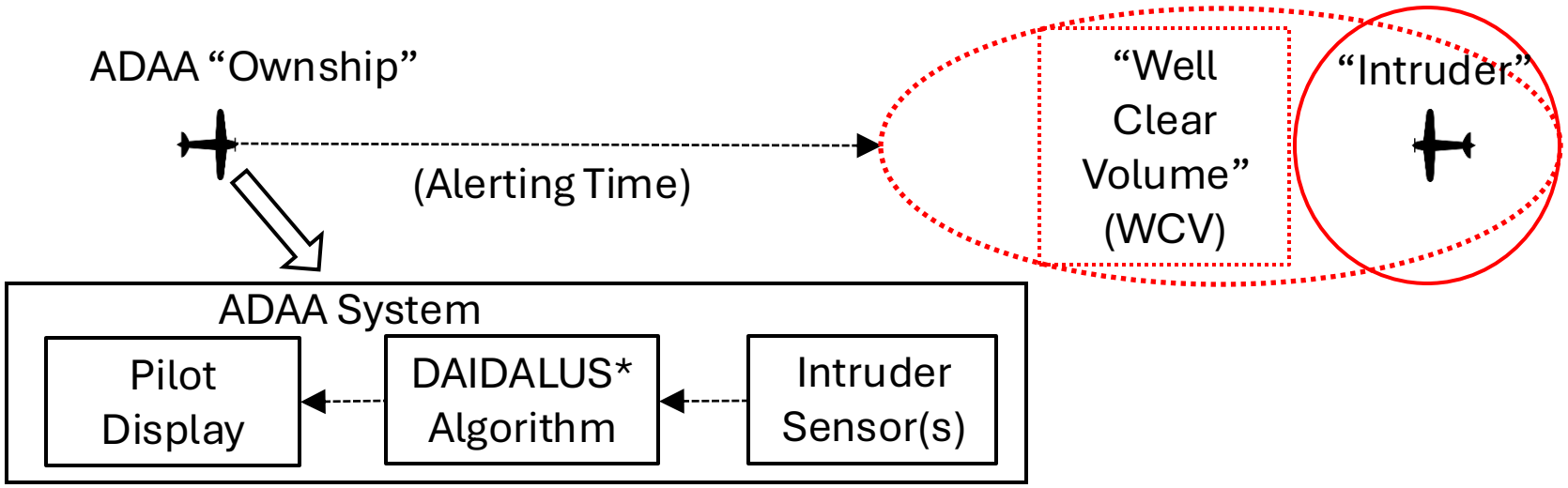
DAA is **Safety-Critical** emerging technology for **remotely-piloted** aircraft:

- 14 CFR 91.111: “No person may operate an aircraft so close to another aircraft as to create a **collision hazard**.”
- 14 CFR 91.113(b): “…vigilance shall be maintained by each person operating an aircraft so as to **see and avoid** other aircraft. … may not pass over, under, or ahead of it unless **well clear**.”
- DAA is intended as an alternative means of compliance to 14 CFR 91.111 and 91.113.

ADAA is **Safety-Enhancing** use of DAA technology by **onboard pilots** to augment their See and Avoid capabilities:

- Implies increased traffic awareness and safety with a lower regulatory approval burden
- DAA changes for ADAA may include simpler interface, shorter alert times, and smaller **Well Clear Volumes (WCV)**.

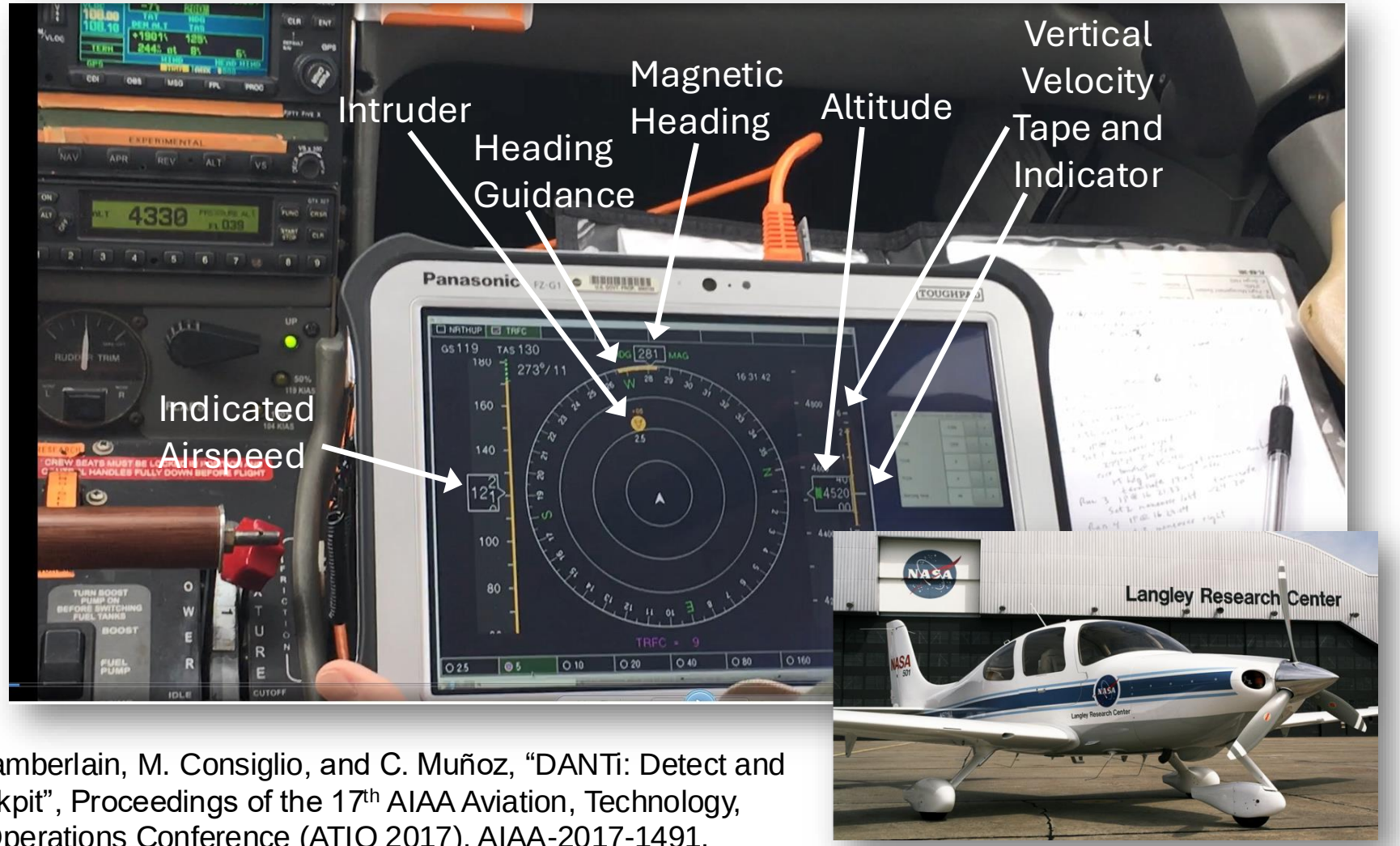
(DAA and) ADAA Concept of Use



- Parametrically-defined WCV around each Intruder
- ADAA provides alerts and guidance within alerting time of WCV
- See-and-Avoid (SAA) is still the primary collision mitigation
  - ADAA alerts/guidance are analogous to ATC advisories/vectors
  - Visually clear in direction of guidance, then maneuver

* NASA-developed Detect and Avoid Alerting Logic for Unmanned Systems

NASA ADAA Initial Flight Prototype (“DANTi”)



Reference: J. Chamberlain, M. Consiglio, and C. Muñoz, “DANTi: Detect and Avoid iN The Cockpit”, Proceedings of the 17th AIAA Aviation, Technology, Integration, and Operations Conference (ATIO 2017), AIAA-2017-1491, Denver, CO, June 2017.

NASA Subsequent ADAA Research Tool (“DANTi 2.0”)

Reference: P. Masci, C. Muñoz, M. Consiglio, and J. Chamberlain, “DANTi: A Tool for Assistive Detect and Avoid Research”, 43rd Digital Avionics System Conference (DASC), IEEE, San Diego, CA, October 2024, in press.

UAM and the NFLITE Simulation Environment

UAM is part of the Advanced Air Mobility (AAM) concept:

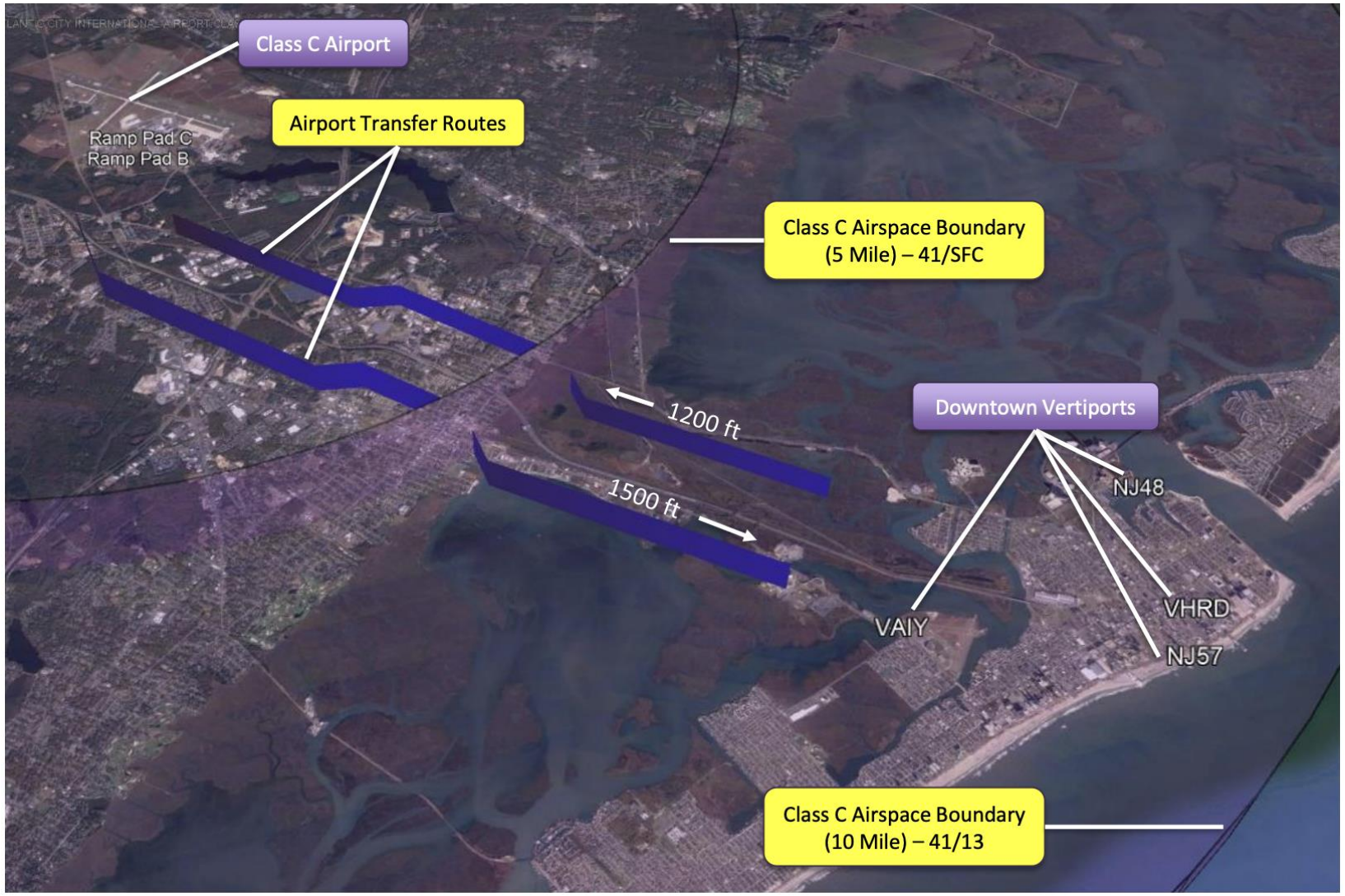
- Moving people and cargo in urban/suburban areas using innovative technologies, operations, and aircraft, including electric Vertical Takeoff and Land (eVTOL) aircraft
- Operations characterized by low altitudes, high traffic tempos/densities, and limited ATC separation services, implying higher collision risk without further mitigations like ADAA

NFLITE is the NASA-FAA Laboratory Integrated Test Environment:

- Enables distributed, realistic human-in-the-loop UAM air traffic simulations
- Pilot and ATC tower participants with out-the-window views, voice and data comm., realistic equipage (e.g., ATC STARS, ERAM; UAM eVTOL sims.), UAM Mission Planner and Vertiport Scheduler stations
- Numerous UAM scenarios with various procedures and traffic densities jointly simulated from 2022-2024, including at ACY, NYC and LAX
- ADAA operations were observed and refined in 2023-2024 simulations

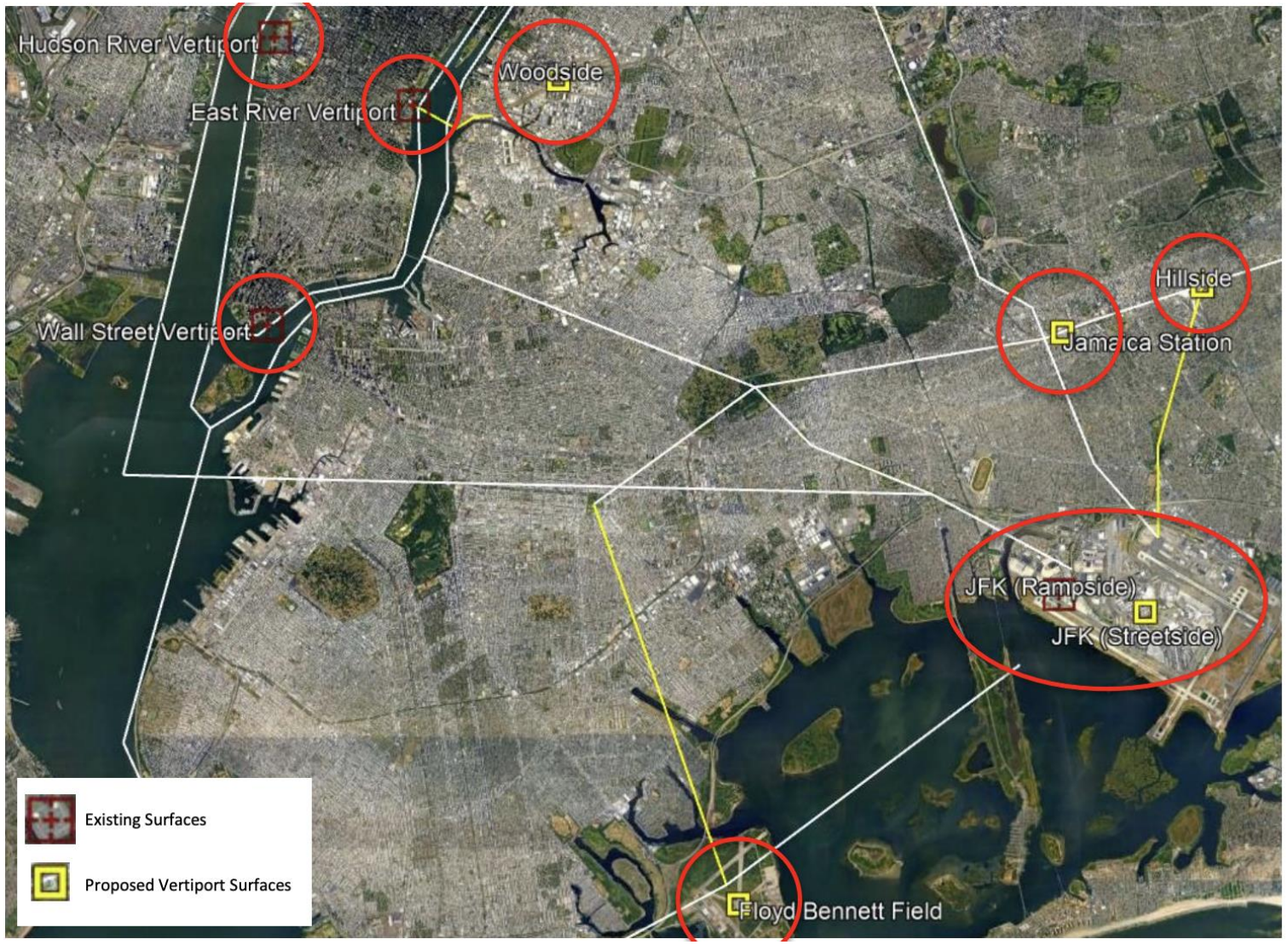
NFLITE UAM Flyer with ADAA Display

UAM Airport Transfer Scenario: Atlantic City (ACY)



Base image credit: Google Earth © 2024

UAM Airport Transfer Scenario: New York City (NYC)



Base image credit: Google Earth © 2024

Staging+
- Floyd Bennett Field
- Woodside

Airport
- JFK (Rampside, Streetside)
- Jamaica Station (Intermodal)

Downtown
- East River
- Hudson River
- Wall Street

Charging
- Hillside

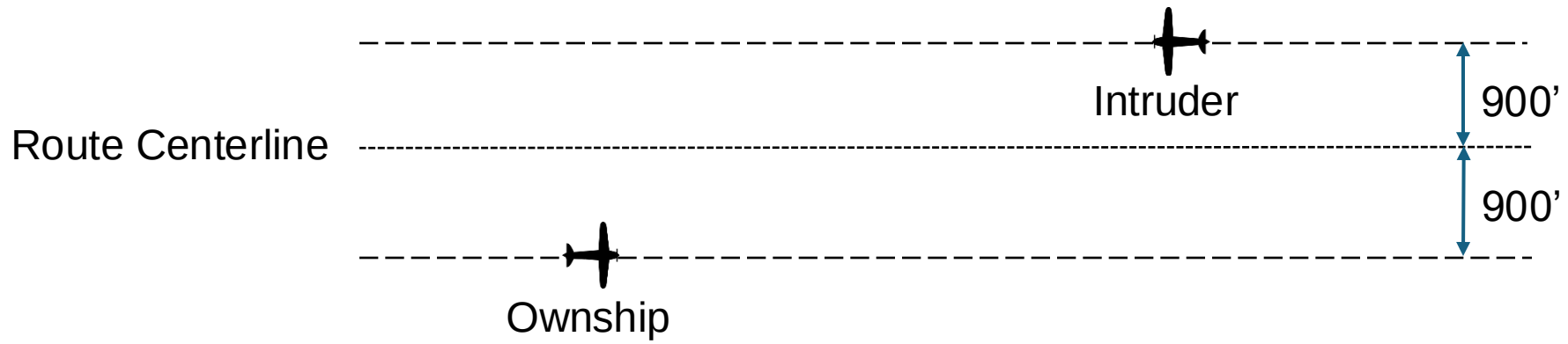
Encounter: Bidirectional Route, Lateral Offset

High UAM traffic density will likely require bidirectional routes with offsets:

- Vertical offset opportunities are limited – terrain below, overflying traffic above.
- Laterally-offset helicopter routes already exist where continuous ground references are available, e.g., shorelines, highways.
- Avionics-defined route offsets are more challenging for traffic avoidance; ADAA may help.

Example: 900’ route offset (1800’ eVTOL separation) with 1500’ WCV width

- Leaves 300’ for lateral navigation accuracy and/or flight technical error



ADAA Guidance: Bidirectional Route, Lateral Offset

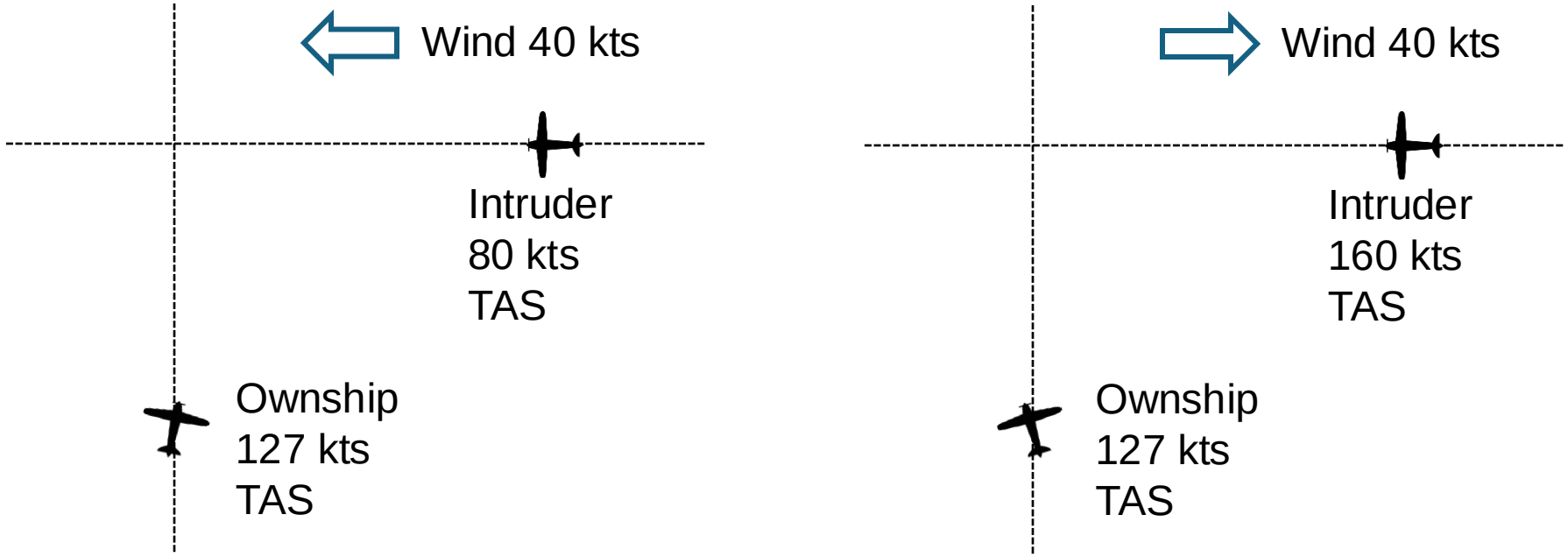
ADAA Guidance: Overtake Encounter, No Offset

ADAA Guidance: Crossing Encounter (No Wind)

ADAA Guidance: Importance of Wind Info

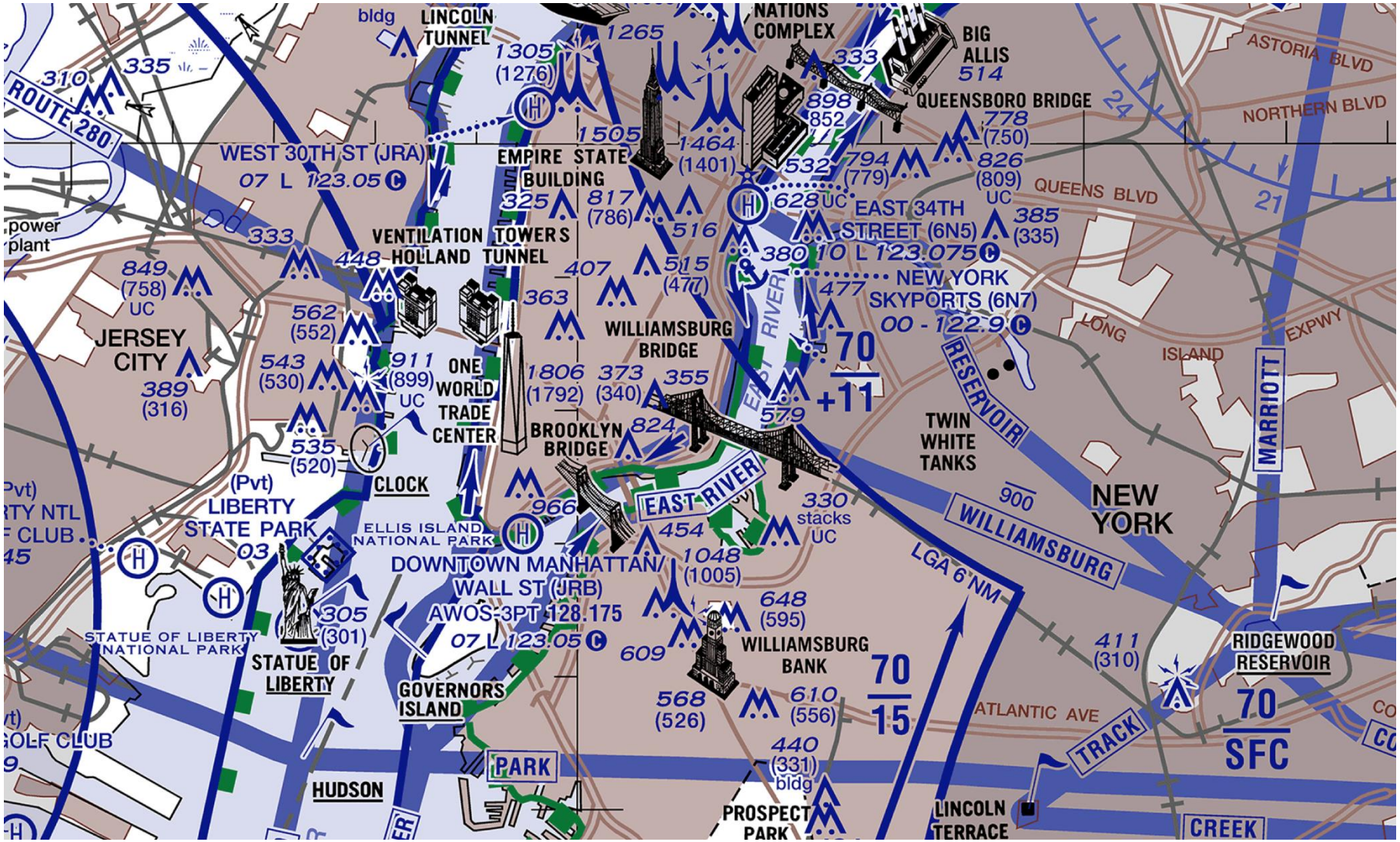
Consider two crossing encounters (below), each aircraft 1 NM & 30 seconds to collision point, all aircraft 120 kts *groundspeed*

- Left side: Intruder at 80 kts *airspeed* in a 40 kt tailwind (left turn okay for ownship)
- Right side: Intruder at 160 kts *airspeed* in a 40 kt headwind (left turn ***not*** okay)



ADAA Guidance: Crossing Encounter (Wind 270 degrees at 40 kts)

ADAA Challenges: Turns, Tight Spacing, Intersections



Source image credit: FAA Product ID HELNY, New York Helicopter Route Chart, 11 Jul 2024
https://aeronav.faa.gov/visual/07-11-2024/PDFs/New_York_Heli.pdf

Rotorcraft Challenges for ADAA

ADAA guidance for rotorcraft:

- A DAA-with-bands-guidance assumption: the vehicle heading and vehicle air velocity vector point in the same direction
- Almost always true for fixed-wing, and rotorcraft at speed; not so for rotorcraft at/near hover.
- Another bands-guidance assumption: guidance is given for simple (not compound) maneuvers: turn ***or*** change airspeed ***or*** change vertical speed.
- Bottom line: bands-guidance paradigm, as is, starts to falter at/near hover.

Workaround (solution?) for now:

- Take a hint from TCAS and suppress guidance/warnings below a critical altitude (1000' AGL for TCAS; 400' now for DANTi ADAA), and airspeed (presently 40 kts).
- This also circumvents the problem of extremely close spacing near vertiport pads.

Some Initial Lessons Learned to Date

ADAA is promising for UAM operations, with some open research areas:

- Clearly improved traffic awareness and conflict avoidance in congested UAM traffic conditions.
- Direct applicability of guidance for overtake encounters, bidirectional lateral offset routes, and crossing encounters.
- Lack of intent knowledge at intersections may prove challenging; an open research area.
- Wind knowledge (i.e., access to both ground and air velocities) may be essential for accurate ADAA crossing encounter guidance.
- Turns and tight spacing can cause false alerts, even with small WCV; incorporating knowledge of airspace structure and aircraft intent may improve performance.
- The DAA/ADAA design guidance for rotorcraft at very low speeds is an open research area.
- Aircraft spacing near multi-pad vertiports is extremely tight; has implications for guidance.

Work in progress, ADAA for UAM is a target-rich research area!

Thank You!
Questions?

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