DANTi
Assistive Detect and Avoid

AMP Project – Flight Operations Sub-Project

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Outline

- DANTi: Understanding Assistive Detect and Avoid
  - See and Avoid
  - Detect and Avoid
  - DANTi Architecture and Prior Research
- DANTi Research in UAM.
  - Well Clear and Tactical Conflict Management
  - TCM-SCM Interoperability

Understanding Assistive Detect and Avoid

DANTi

See and Avoid

The Code of Federal Regulations requires

- That vigilance is maintained by each person operating an aircraft to **see and avoid** other aircraft, **maintaining well clear** regardless of the type of operation

- **See and avoid** is required by many Visual Flight Rules (VFR) operations as the only means of remaining well clear of traffic aircraft

- See and avoid safety records show that mid-air collisions continue to occur in the U.S. at a rate of about 10 collisions per year

From See and Avoid to Detect and Avoid

When the pilot in command is remote.

- Unmanned Aircraft Systems (UAS) are flown by remote pilots that are unable to comply with see and avoid rules
- Detect and Avoid (DAA) systems are required as an **alternative means of compliance** with see and avoid rules for remote pilots of UAS

DAA Standards (*)

Developed for remotely piloted aircraft – IFR only

- Established a **quantified** definition of the well clear volume (WCV) that automated algorithms can use to compute actions to "Remain" or "Regain" Well Clear.
- Established pilot procedures, airspace constraints, and flight rules applicable to DAA
- Developed minimum requirements for alerting and guidance

(*) RTCA DO 365, 365 A, and 365 B

Assistive DAA (ADAA)

When the pilot in command is in the cockpit.

- Detect and Avoid (DAA) technology for crewed operations under VFR in VMC in an advisory role, for enhanced safety.
- Provide pilots with traffic awareness and maneuver guidance support with see and avoid regulations
- See and avoid still primary collision mitigation. Pilots visually clear in direction of guidance, before maneuver.
- ADAA alerting and guidance, analogous to ATC advisories

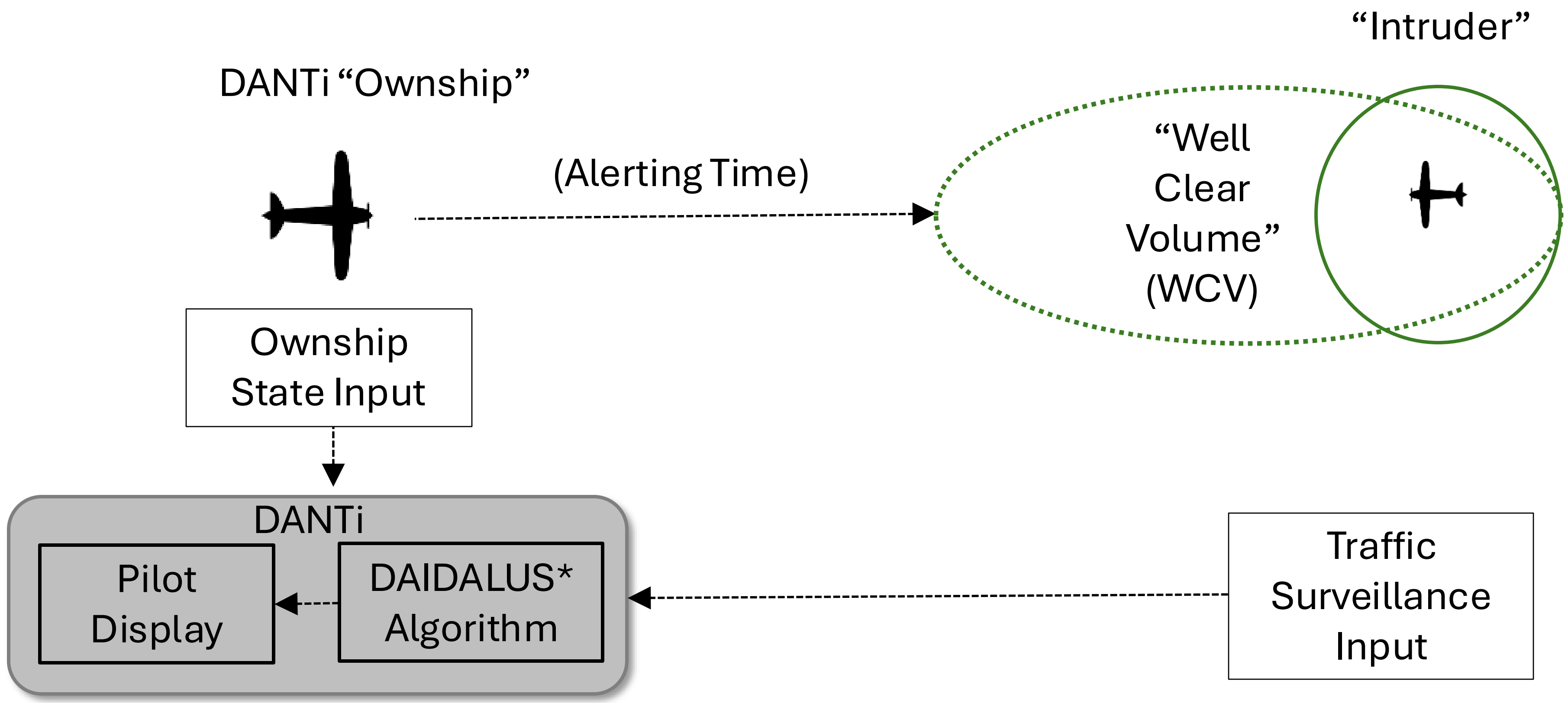
What is DANTi?

- DANTi is a NASA-developed prototype software application for DAA research (*)

- DANTi's fully configurable DAA alerting and well-clear volume (WCV) parameters enable the study of different operational concepts.

(*) https://shemesh.larc.nasa.gov/fm/DANTi/

DANTi Architecture



DAIDALUS

(*) DAIDALUS: NASA-Developed DAA Algorithm (Detect and Avoid Alerting Logic for Unmanned Systems), reference implementation for DO 365 DAA MOPS. https://shemesh.larc.nasa.gov/fm/DAIDALUS/

See and Avoid (SAA) and Collision Risk

On the Viability of See-and-Avoid in UAM Operations, R. Mogford and W. Johnson (*):

- Collision risk remains high for visual operations relying only on see and avoid
- A total of 156 midair collisions in the U.S.,1991-2000 for an average of 15.6 collisions per year with failure of SAA accounting for 94% of the incidents (*).
- Collision risk (or the probability of a collision if no action is taken) increases in proportion to the number of proximate aircraft pairs and approximately as the square of the number of aircraft (*)
- The use of SAA for UAM operations is risky.
- The performance of SAA can be improved by using airspace structure and supportive flight deck technologies.

https://ntrs.nasa.gov/api/citations/20230006849/downloads/SAA%20Mogford%20and%20Johnson.pdf

DAA and NMACs

Analysis of DAA Alerting and Guidance using reconstructed trajectories that resulted in (N)MACs . E. Theunissen et al. (*)

Could DAA alerting and guidance provided by a DAA system meeting the minimum operational performance requirements in RTCA DO-365, have contributed to the prevention of 8 (N)MACs that occurred between 1972 and 2015?

Table 2. (N)MACs analyzed for the study described in this paper

Location / type	Date	Aircraft involved	Sources
San Diego / Midair	August 16, 2015	Sabreliner, Cessna 172M	NTSB Investigator-in-Charge presentation [6]
Moncks Corner / Midair	July 7, 2015	F-16CM, Cessna 150M (VFR)	NTSB Investigator-in-Charge presentation [7]
Lelystad / near midair	August 1, 2015	DO-228-100 (VFR), Tecnam P92 Echo Super (VFR)	Dutch Safety Board [8]
Hudson River / Midair	August 8, 2009	Piper PA-32 (VFR), Eurocopter AS350 (VFR)	NTSB/AAR-10/05 [9]
Front Royal / near midair	April 26, 1972	Boeing 720B, Convair 240 (VFR	
Memphis / Midair	May 18, 1978	Falcon Jet (IFR), Cessna 150 (VFR)	
Greenwood / Midair	Sept. 11, 1992	Piper PA-32 (VFR), Mitsubis MU-2B (VFR)	
Etten-Leur / Midair	December 22, 1999	F-16, Piper PA28	

Figure 8. DAA display for F-16, Moncks Corner, TCPA 40

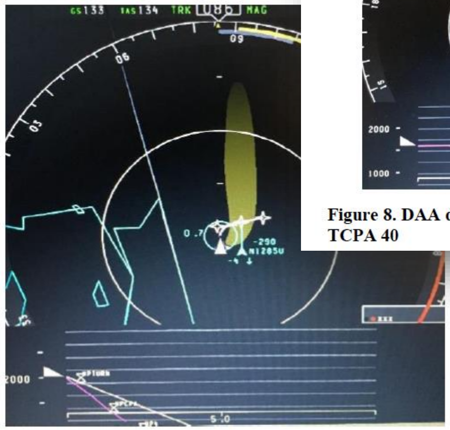


Figure 13. ND showing that a turn to the right will result in an alert

Contributing to the accident were the inherent limitations of the see-and-avoid concept, resulting in the inability of the pilots involved to take evasive action in time to avert the collision.” (**)

Preventive guidance would have significantly reduced the likelihood of a pilot turning into the direction that caused the (N)MAC. (*)

Corrective alert would likely have caused the pilots to assess the cause of the alert and take appropriate action. (*)

(*) **Analysis of DAA Alerting and Guidance using reconstructed trajectories that resulted in (N)MACs . E. Theunissen et al, Netherlands Defence Academy.** e.theunissen@mindef.nl

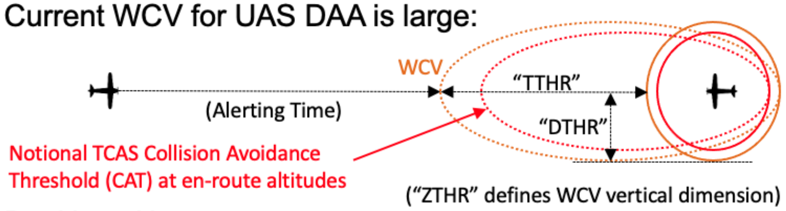
(**) San Diego Mid Air Accident Report . https://asn.flightsafety.org/asndb/320244

DANTi Flight Research for GAs

J. Chamberlain et al. DANTi: Detect and Avoid in the Cockpit Flight Test (*)

DANTi Initial Flight Tests

- Objectives:
  - Demonstrate proof of concept and make initial observations
  - First look at best WCV size for airport traffic pattern operations
- Current WCV for UAS DAA is large:



- But Near Airports:
  - Aircraft spacing is tighter and TCAS CAT is smaller
  - Smaller WCV may be operationally better with fewer false alerts

WCV Parameter Threshold Sets

- Four WCV Parameter Threshold Sets Were Flight-Tested:
  - Set 1 is WCV specified in current draft UAS DAA standard
  - Set 2 is smaller WCV compatible with low-altitude TCAS CAT
  - Set 3 is a cylindrical "hockey puck" WCV
  - Set 4 is same WCV as Set 3 but with half the Alerting Time

	Threshold Set			
WCV Parameter	**1**	**2**	**3**	**4**
DTHR (feet)	4000	1200	1200	1200
ZTHR (feet)*	(450)	(300)	(300)	(300)
TTHR (seconds)	35	15	0	0
Alerting Time (seconds)	40	40	40	20

* ZTHR was set to 1000 feet for collision-geometry flight encounters

Summary and Conclusions

- DAA Can Mitigate Collision Risk for Manned Aircraft
- Proof-of-Concept Demonstrated With DANTi Prototype
- Heading-Up Display Useful for Visual Traffic Acquisition
- WCV in UAS DAA Standard Too Large for Traffic Pattern
  - Smaller WCV based on low-altitude TCAS CAT (Set 2) is better
- Necessary Future Work Includes:
  - More encounter types, WCV Sets, pilot assessments
  - Multi-sensor implementations
  - Safety case
  - Human factors assessments of displays, alerts, guidance
  - Standards development and/or revision

(*) https://ntrs.nasa.gov/api/citations/20170005874/downloads/20170005874.pdf

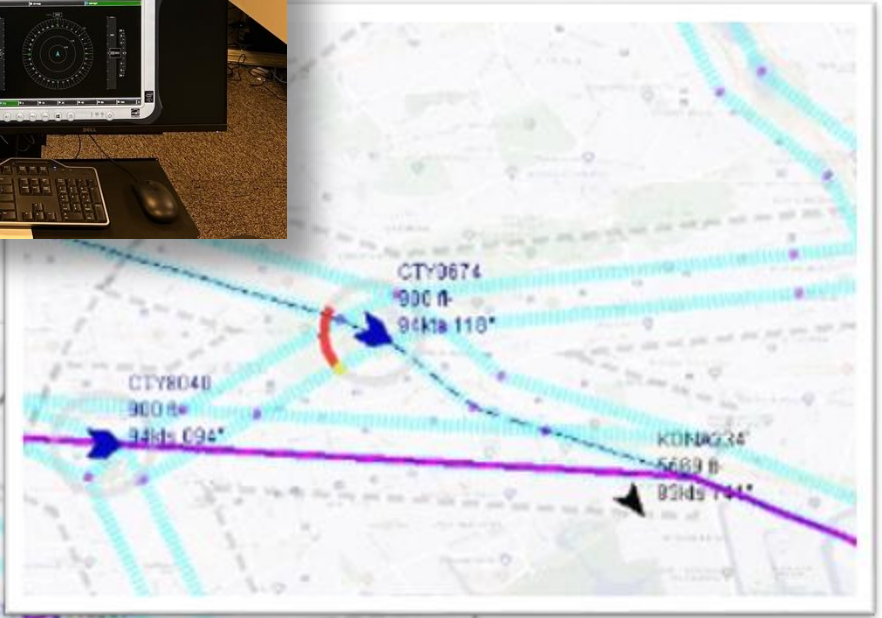
DANTi Research in UAM

DANTi Integrated in NFLITE-LVC Simulation

Air Mobility Pathfinders Project

- DANTi is integrated in the NFLITE (**) simulation for Strategic and Tactical Conflict Management interoperability research
  - UAM piloted flight simulators
  - Virtual traffic equipped with DAA

DANTi-Equipped Piloted UAM Flight Simulator



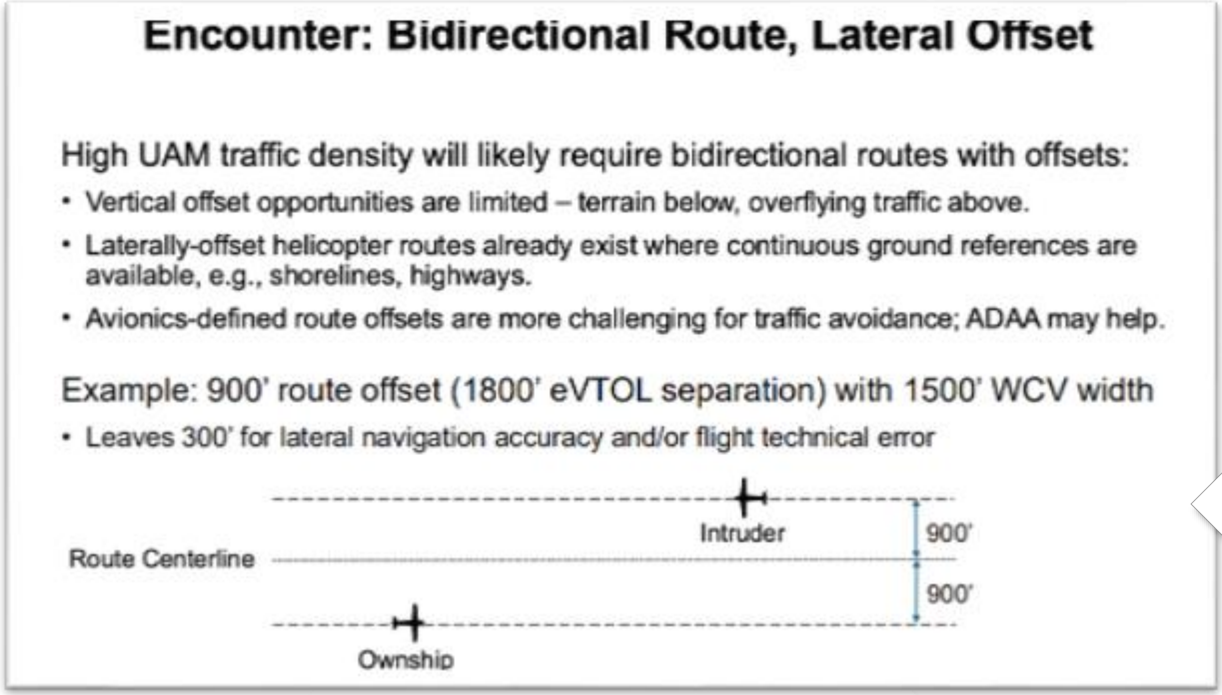
DAA-Equipped Virtual UAM Traffic Simulator

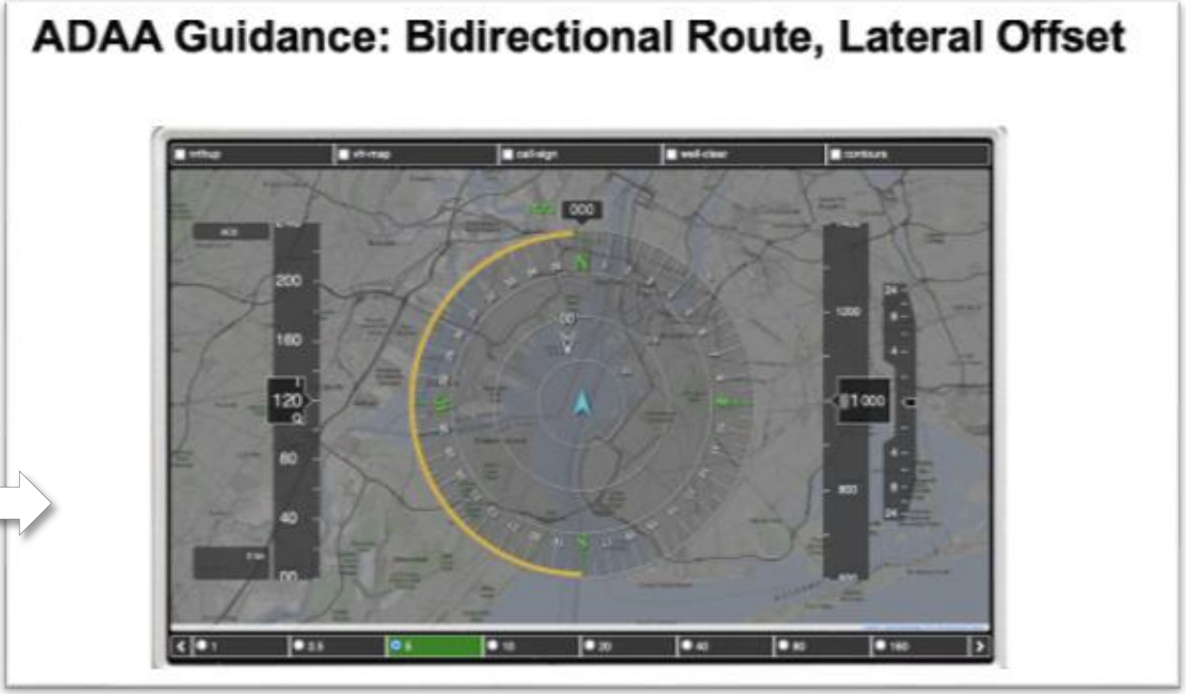
(*) FAA Policy No: PS-AIR-21.8- 1602 for Approval of Non-Required Safety Enhancing Equipment (NORSEE) Date: 03/31/16

(**) NASA FAA Laboratory Integrated Test Environment

Initial observations of ADAA use in the UAM NFLITE Simulation Environment

J. Chamberlain et al. “Assistive Detect and Avoid Technology in Urban Air Mobility Environments” (*)





(*) https://ntrs.nasa.gov/api/citations/20240008222/downloads/ADAAV1b.pdf

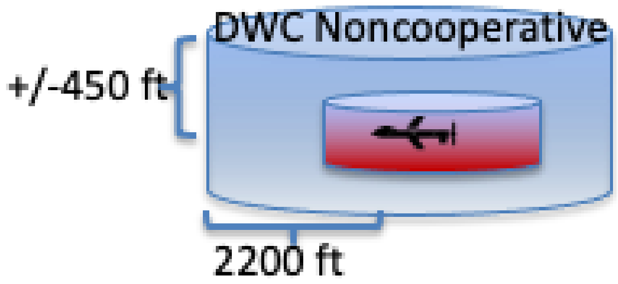
Initial observations of ADAA use in the UAM NFLITE Simulation Environment (Cont.)

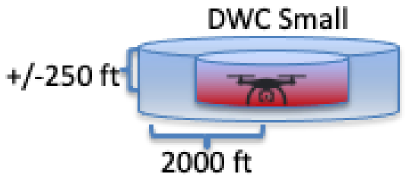
J. Chamberlain et al. “Assistive Detect and Avoid Technology in Urban Air Mobility Environments” (*)

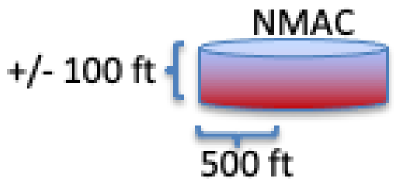
ADAA Guidance: Overtake Encounter – No Offset

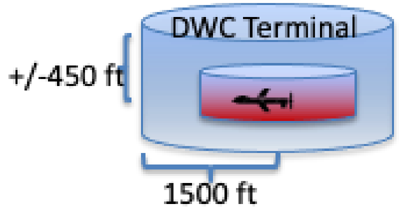
ADAA Guidance: Crossing Encounter - No Wind

(*) https://ntrs.nasa.gov/api/citations/20240008222/downloads/ADAAV1b.pdf

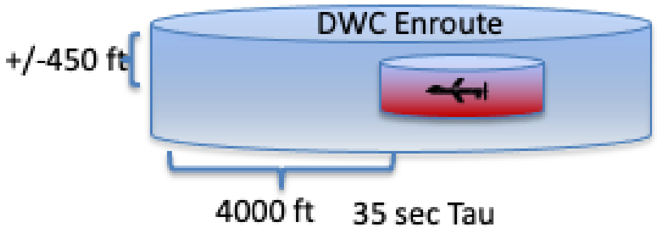






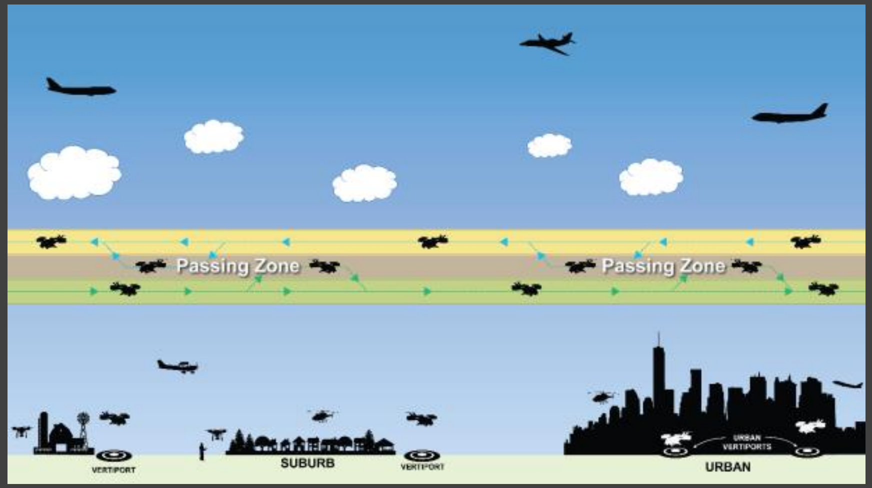


Well Clear Type	Tau Mod	Vertical	Horizontal
Enroute	35 Sec	+/- 450 ft	4000 ft
Non-cooperative	0	+/- 450 ft	2200 ft
Terminal	0	+/- 450 ft	1500 ft
Small UAS-GA	0	+/- 250 ft	2200 ft
Collision Avoidance	0	+/- 100 ft	500 ft
UAM	?	?	?



How large is “Well Clear”?

DAA Well Clear (DWC) size depends on the airspace, aircraft, surveillance sensors, and other factors.



Cooperative Airspace: FAA UAM ConOps 2.0 (*)

Evaluating “Well Clear” for UAM in Cooperative Airspace

(*) https://www.faa.gov/sites/faa.gov/files/Urban%20Air%20Mobility%20%28UAM%29%20Concept%20of%20Operations%202.0_1.pdf

Initial observations of ADAA use in the UAM NFLITE Simulation Environment

J. Chamberlain et al. “Assistive Detect and Avoid Technology in Urban Air Mobility Environments” (*)

- Improved traffic awareness and conflict avoidance.
- Lack of intent knowledge at intersections is challenging
- Turns and tight spacing can cause false alerts
- Maneuver guidance for rotorcraft at very low speeds is a challenge
- Guidance near multi-pad vertiports is a challenge

(*) https://ntrs.nasa.gov/api/citations/20240008222/downloads/ADAAV1b.pdf

Key References

DANTi

- https://shemesh.larc.nasa.gov/fm/DANTi/
- DANTi is available under NASA's Open Source Agreement from GitHub
- A desktop version of DANTi is also available for download with DAA-Displays , NASA-developed open-source toolkit designed to support research on DAA technologies.

DAIDALUS

- https://shemesh.larc.nasa.gov/fm/DAIDALUS/
- DAIDALUS algorithms have been formally specified and verified for functional correctness in PVS . The PVS formal development is part of the NASA PVS Library. Furthermore, implementations of DAIDALUS algorithms in Java and C++ are available under NASA's Open Source Agreement: DAIDALUSv2@GitHub
- Latest Release: v2.0.1 (August-4-2020).
- DAIDALUS is included in Appendix G of RTCA/FAA Minimum Operational Performance Standards (MOPS) DO365 for detect and avoid of unmanned aircraft systems (UAS) by RTCA Special Committee 228.

Questions

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