National Aeronautics and Space Administration

Characteristics of a Well Clear Definition and Alerting Criteria for Encounters between UAS and Manned Aircraft in Class E Airspace

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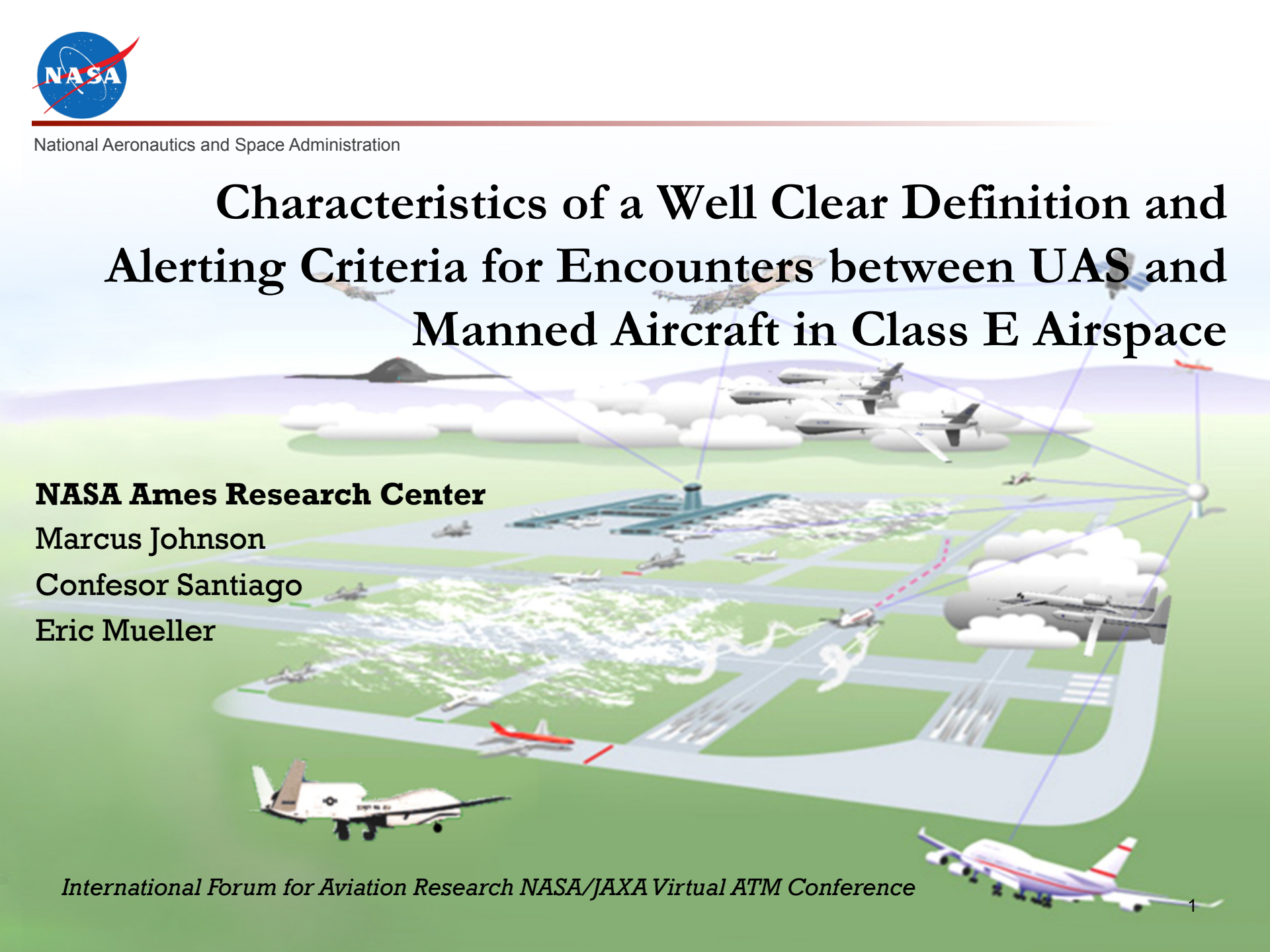


International Forum for Aviation Research NASA/JAXA Virtual ATM Conference

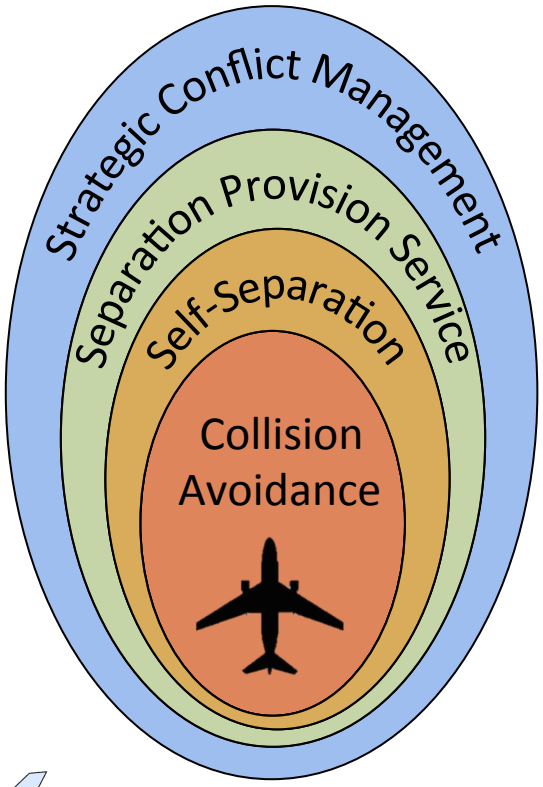
Outline

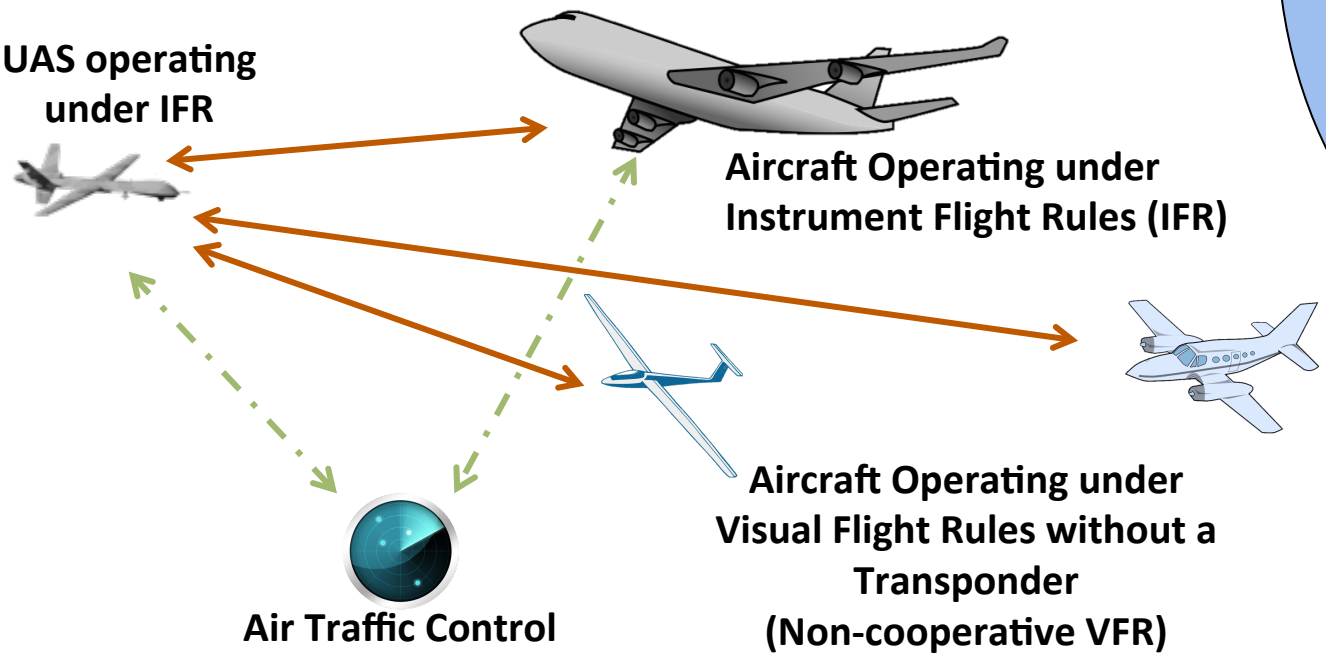
- Research and Motivation
- Analysis Overview and Definitions
- Simulation Setup
  - Traffic Scenarios
  - UAS Missions
- Fast-Time Simulation Study Results
  - **Analysis 1: Characterizing Encounters at Well Clear Boundary**
  - Analysis 2: Evaluating Alerting Criteria
- Conclusions

Background

14CFR Part 91, §**91.113**

…vigilance shall be maintained by each person operating an aircraft so as to **see and avoid** other aircraft…pilot shall give way to that aircraft and may not pass over, under, or ahead of it unless **well clear**.



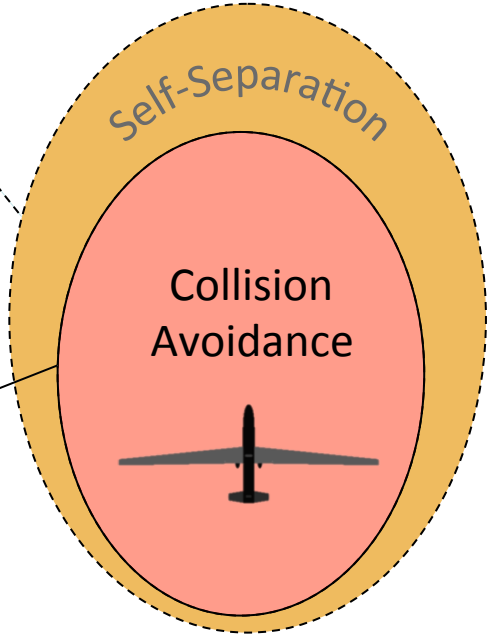


Background: Detect and Avoid

Manned Aviation

Analysis 2:
Alerting the UAS Operator

Analysis 1:
Loss of Well Clear



Unmanned Aviation

See and Avoid
Traffic Collision Avoidance System (TCAS)

Detect and Avoid
Collision Avoidance Function (TCAS/ACAS/etc.)

Analysis Overview

- **Analysis 1: Characterizing encounters at well clear boundaries**
  - Objective:
    - Investigate implications of using Well Clear Definitions proposed from the UAS community in terms of surveillance requirements and safety
  - Metrics:
    - Rate of Losses of Well Clear per UAS Flight Hour
    - Encounter Characteristics at the Loss of Well Clear (LoWC)

Unmitigated Encounter Rate Evaluation

Capabilities

UAS Models

UAS Mission Profiles

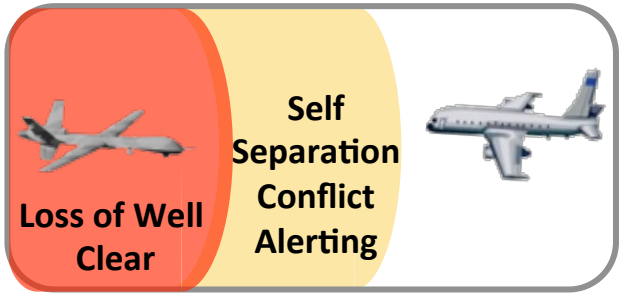
VFR Traffic from Air Defense Radar Data

US National Airspace System Simulation

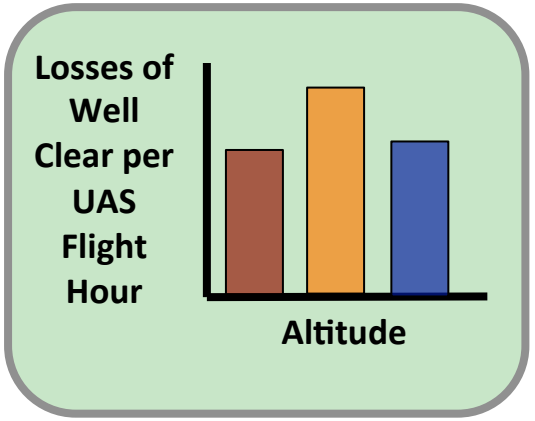
Airspace Concept Evaluation System (ACES)

Analysis

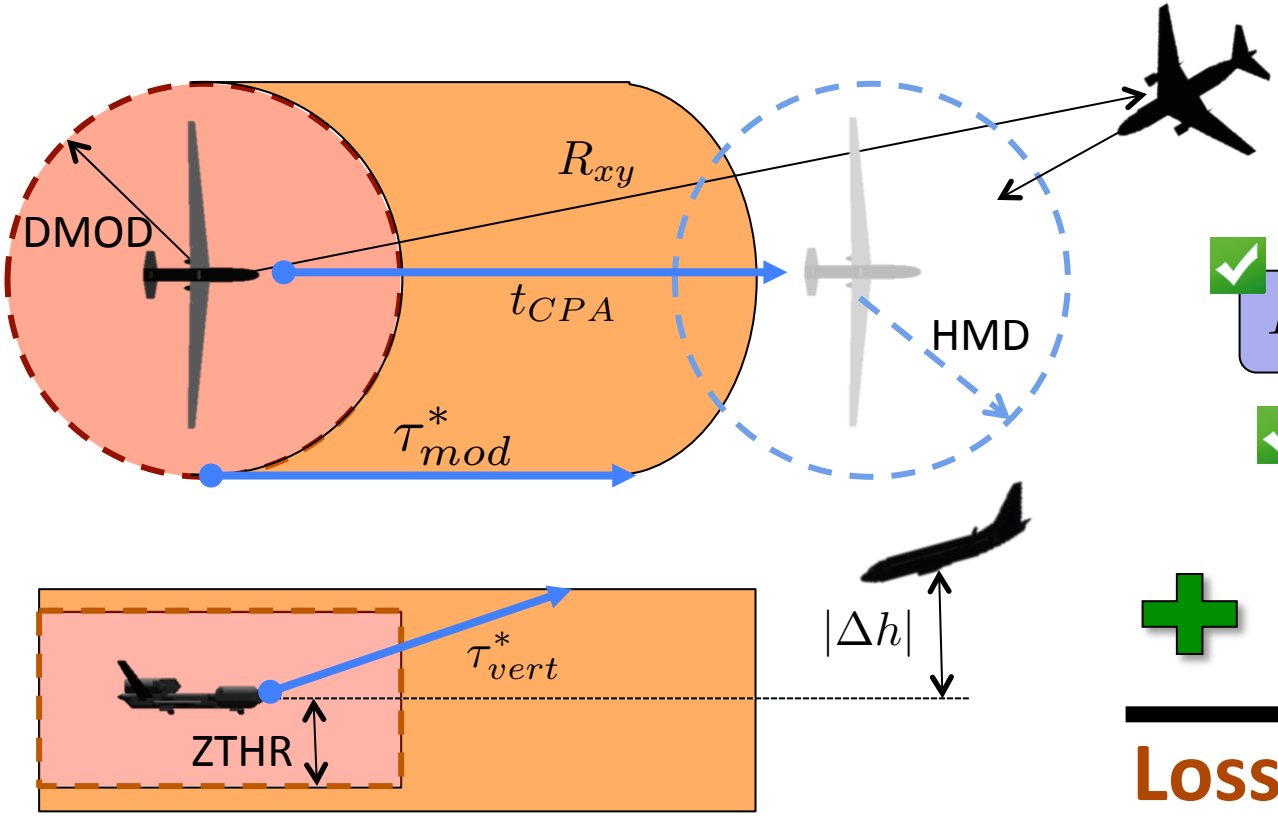
Metrics



Results



Loss of Well Clear



$$0 \leq \tau_{mod} \leq \tau^*_{mod}$$

$$R_{xy}(t_{CPA}) \leq HMD$$

$$0 \leq \tau_{vert} \leq \tau^*_{vert}$$

OR

$$|\Delta h| \leq ZTHR$$

Loss of Well Clear

Note: DMOD value = HMD value

$$\tau_{mod} = -\frac{R_{xy}^2 - DMOD^2}{\dot{R}_{xy} R_{xy}}$$

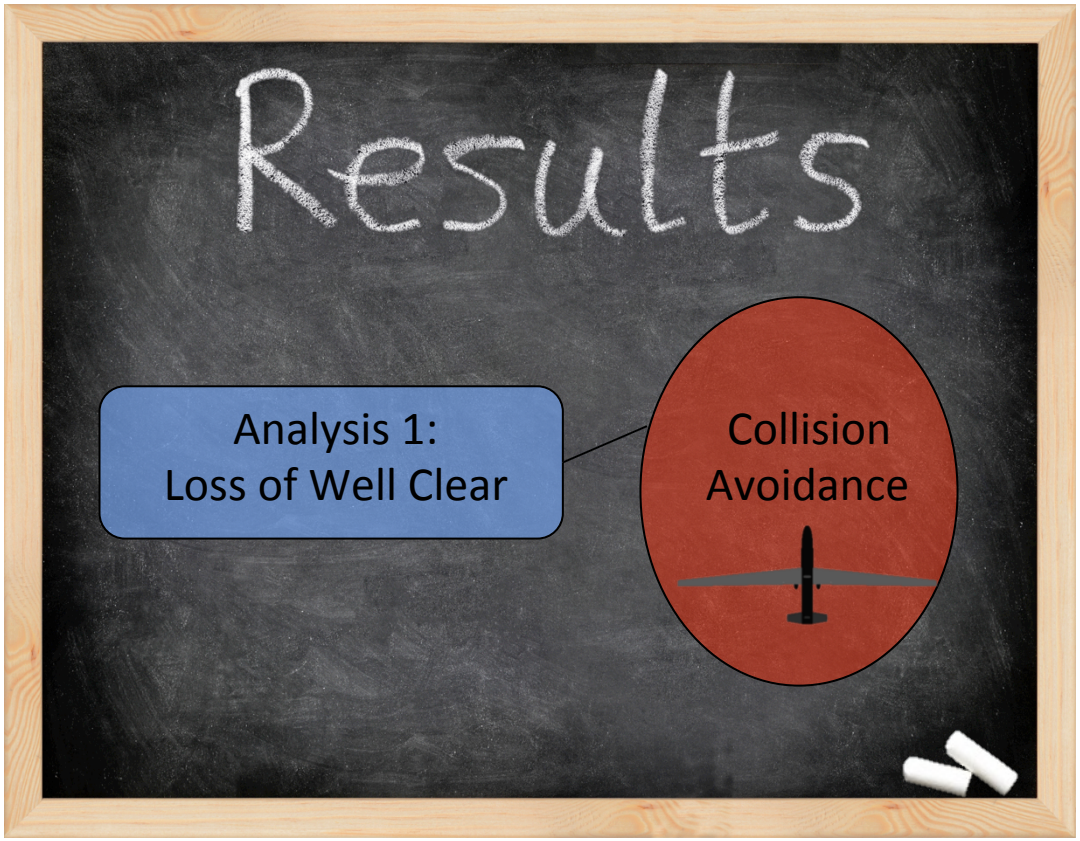
t_{CPA} Time at Closest Point of Approach

$$\tau_{vert} = -\frac{\Delta h}{\dot{\Delta h}}$$

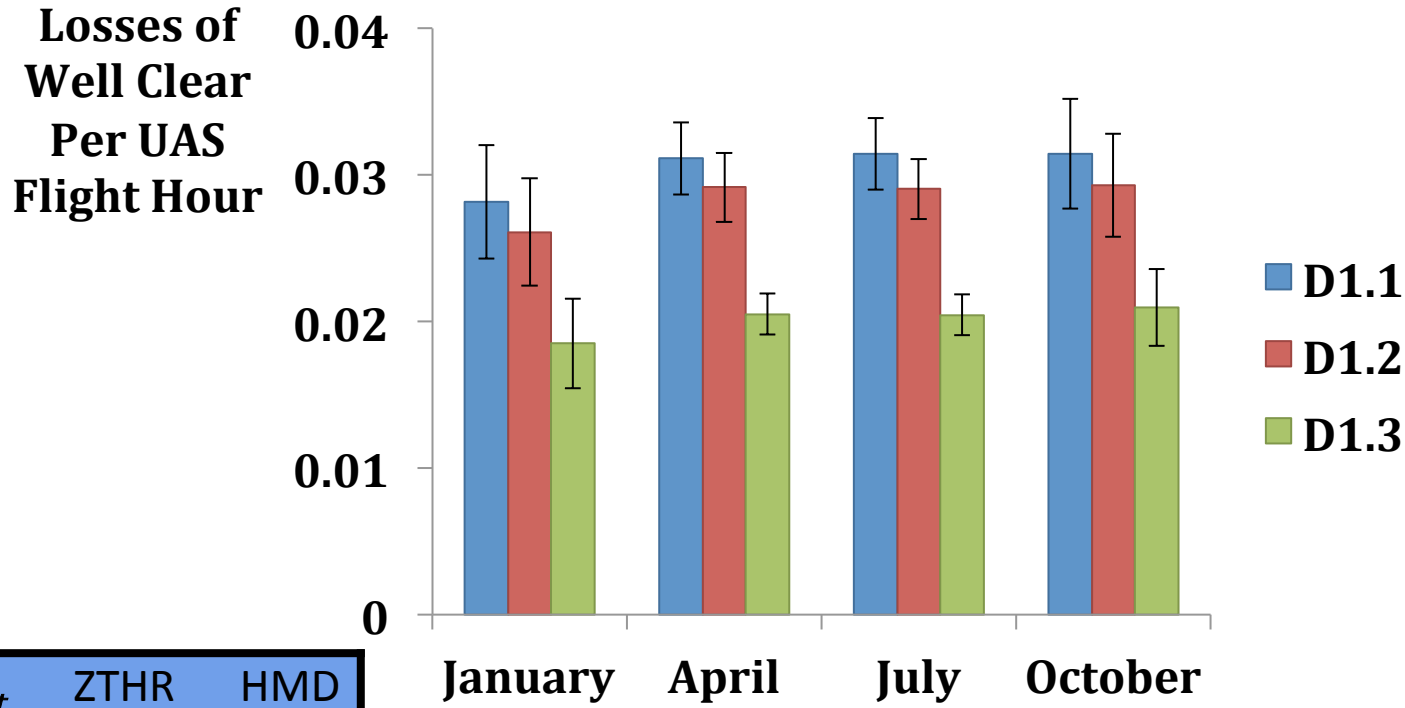
Simulation Configuration

- There are 24 different simulation runs
  - 1 simulation run is a single day in the US national airspace system (NAS)
- Each simulation had
  - UAS: 9 Different Proposed Missions
    - Total of 18,000 UAS flights in data set (~26,000 flight hours)
    - Variety of aircraft performance, mission profiles, geographic areas of operation
  - Traffic: Cooperative VFR Traffic (secondary radar returns)
    - Derived from 84th squadron air defense radar data
    - Varying volume of traffic (20-28k flights)
    - Days are spread over 4 seasons in 2012 (24 days total)
  - No Separation mitigation
    - Metrics only collected for UAS vs. VFR conflicts
    - No Detect and Avoid System was present

Analysis 1: Characterizing Encounters at Well Clear Boundaries



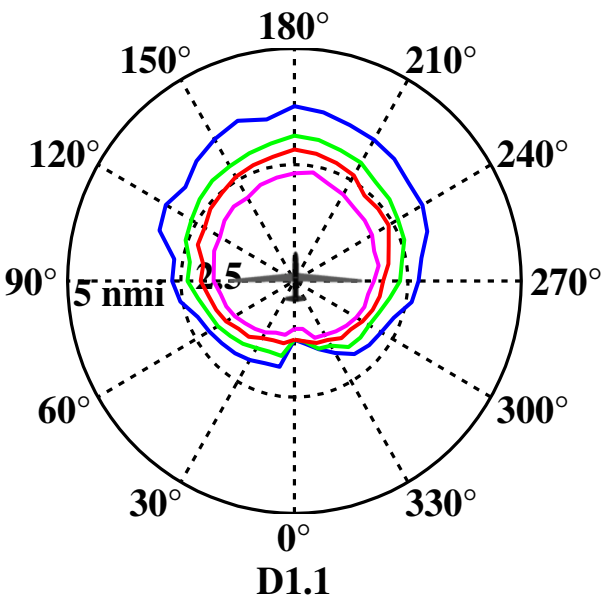
Rate of Losses of Well Clear by Definition

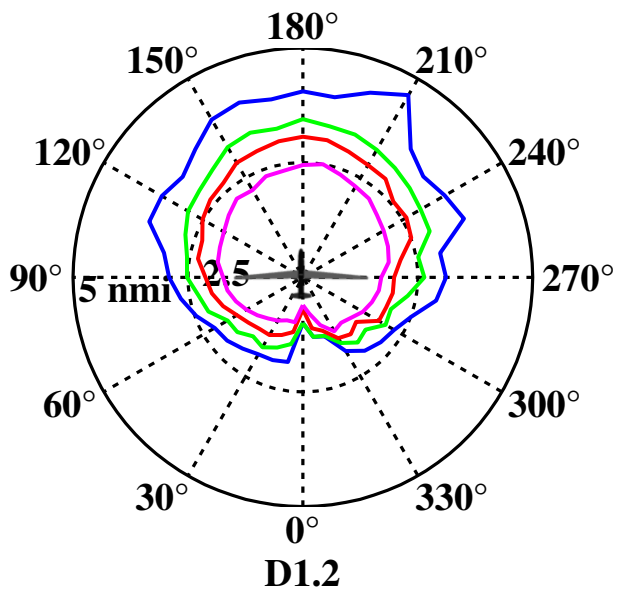


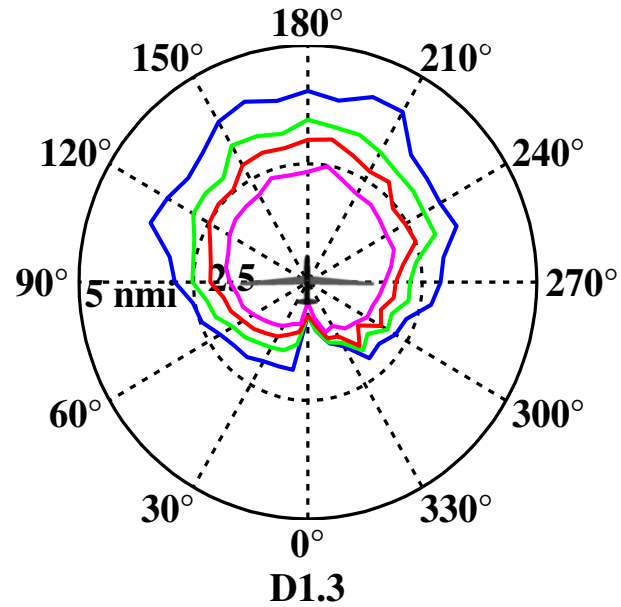
	τ^*_{mod} [s]	τ^*_{vert} [s]	ZTHR [ft]	HMD [ft]
D1.1	30	20	475	6000
D1.2	35	0	700	4000
D1.3	35	0	450	4000

UAS Community Proposed Definitions

Relative Heading and Distance at LoWC







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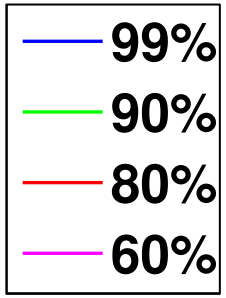
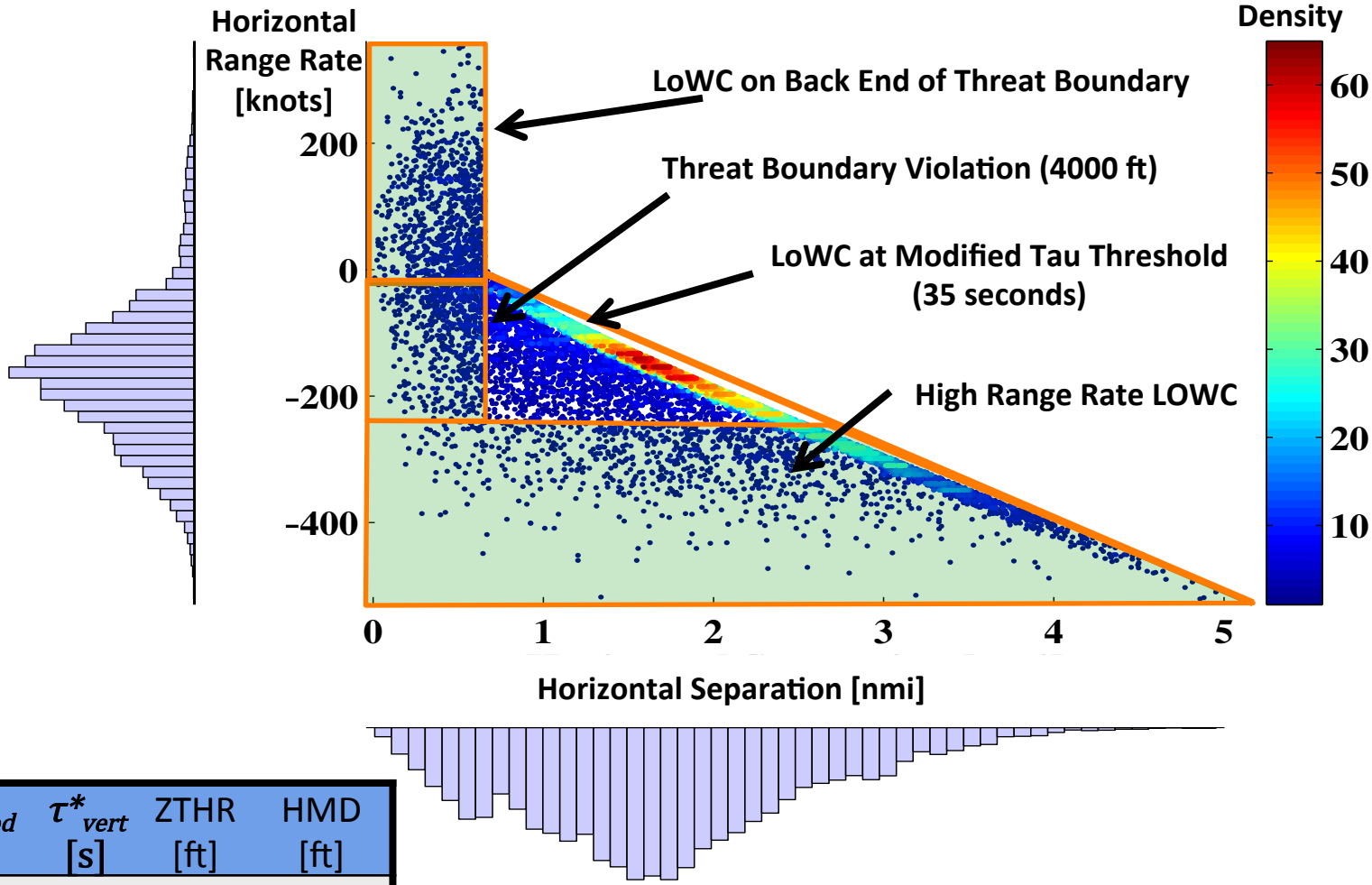


Range Rate vs. Separation at LoWC (Horizontal)



	τ^*_{mod} [s]	τ^*_{vert} [s]	ZTHR [ft]	HMD [ft]
D1.3	35	0	450	4000

Concluding Remarks

- Results indicate:
  - An unmitigated loss of well clear occurs approximately once every 40 flight hours.
  - Head-on encounters occur at further surveillance ranges then over-taking encounters
  - Most losses of well clear occur within 1-3 nautical miles and less than 200 knots closure rates

- Recommendations:
  - A time and distance-based well clear definition is motivated by:
    - maneuvering intruders
    - high closure rate intruders.
  - A minimum 4-5 nmi surveillance range is recommended to account for missed alerts.

Additional Remarks: Analysis 2

- Surveillance and Alerting Guidelines:
  - DAA system would want a surveillance range of 4-5 nmi
  - Using the proposed alerting criteria the surveillance range would nominally need to be 10 nmi to alert the UAS operator to take action
  - There is a trade-off between time to loss of well clear and percentage of nuisance alerts
    - The larger the alerting volume ➔ More time before loss of well clear and larger percentage of nuisance alerts.

- Recommendations:
  - Consider buffers for alerting criteria
  - Include ownship intent in alerting criteria
  - Consider multiple layers of alerting

Questions

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