National Aeronautics and Space Administration

Investigating Surveillance Performance for UAS Detect-and-Avoid Systems

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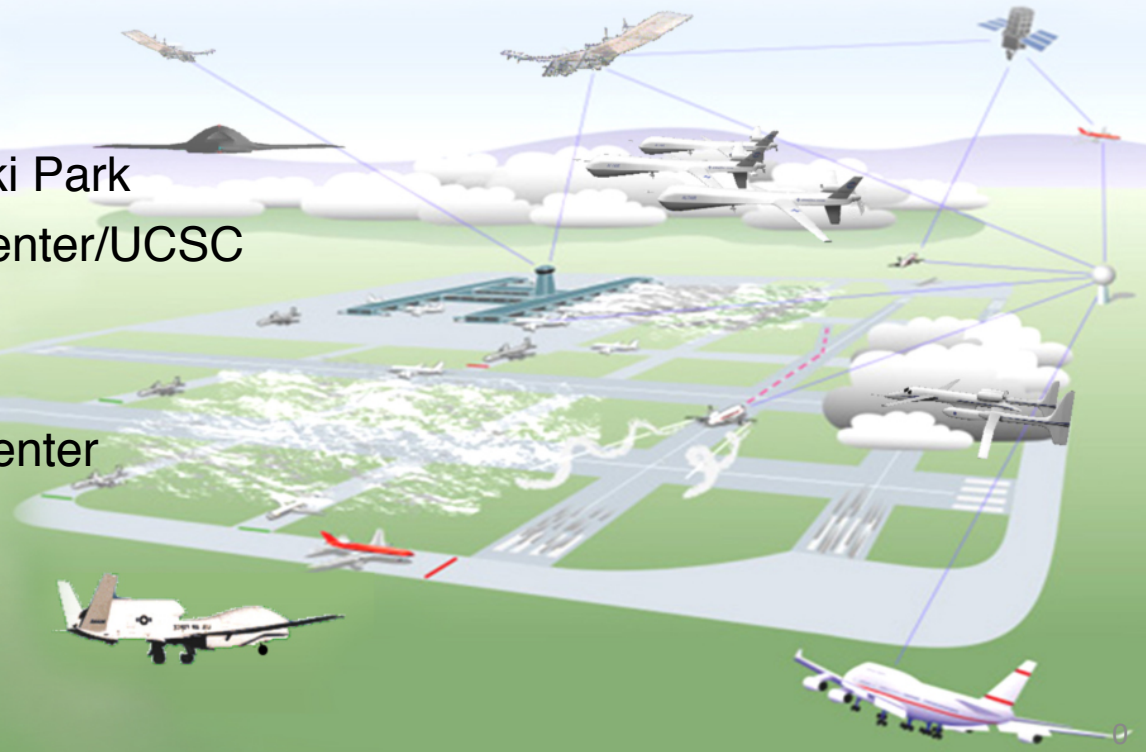


Background and Motivation

- A Detect-And-Avoid (DAA) capability is required for UAS to meet the requirement in CFR 91.113 to “see and avoid” other aircraft and maintain “well clear”.
- RTCA Special Committee 228 is developing Minimum Operational Performance Standards (MOPS) for DAA systems.
- A surveillance system is a critical component of DAA system to detect and track intruder aircraft. Thus, the MOPS will include surveillance system requirements.
- Encounter characteristics of “well-clear” violations between UAS and manned aircraft have not been investigated.

Objectives

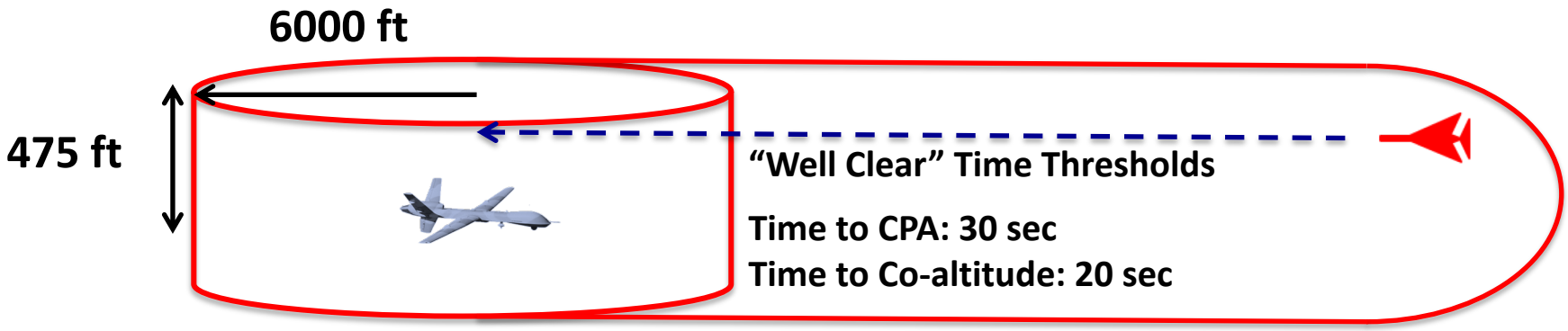
- Investigate unmitigated encounter characteristics of well-clear violations between UAS and cooperative VFR aircraft in Class E airspace

- Investigate the relationship between encounters to surveillance system characteristics in terms of detection range and fields of regard (FOR)
  - the effect of surveillance volumes on the ratio of undetected well-clear violations (WCV)
  - the time to WCV of intruders with different surveillance volumes

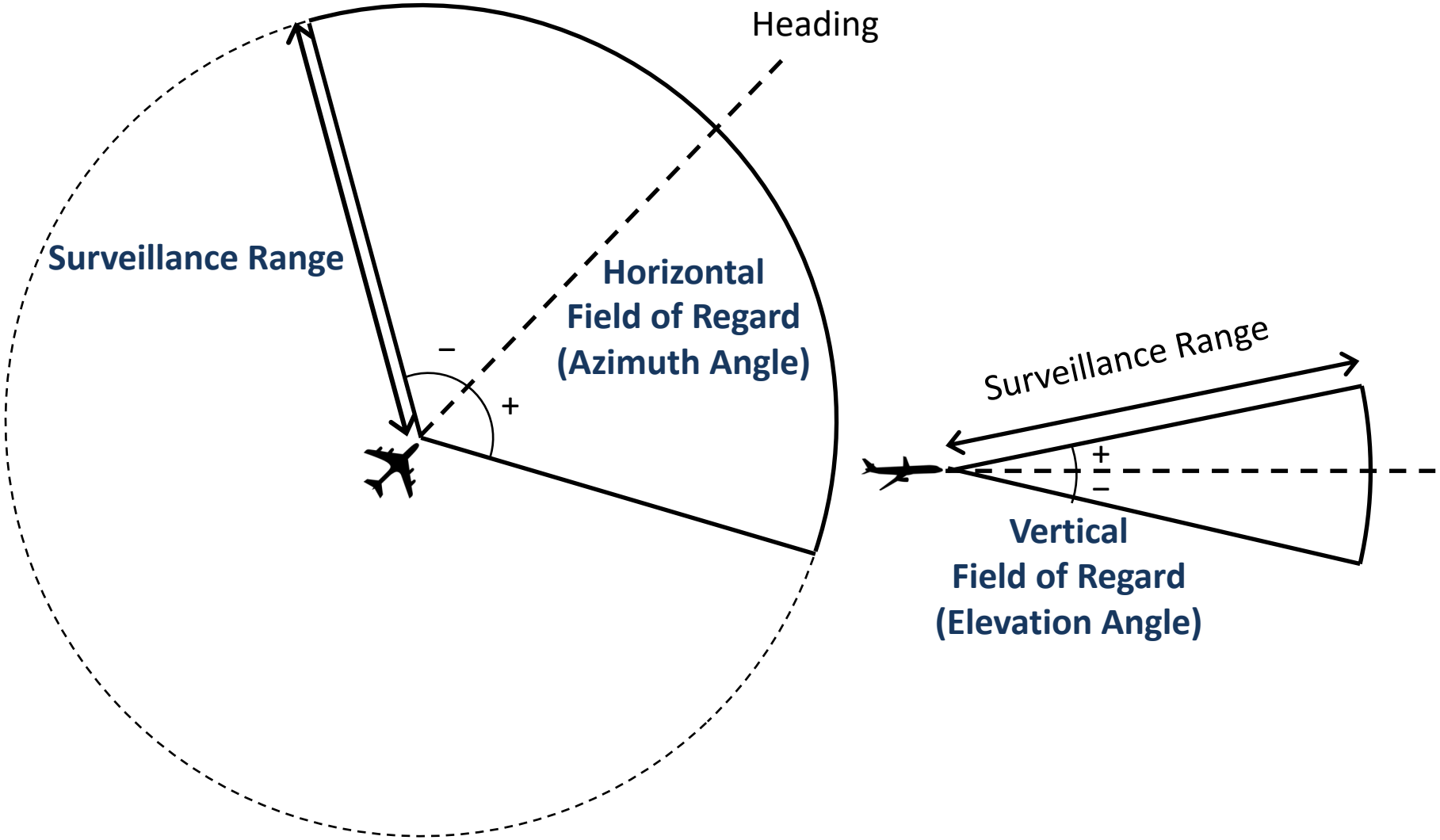
Concept of Well Clear Violation

- Airborne separation standard
- Time and distance-based definition of “Well-Clear Violation”
  - When two aircraft are within distance thresholds
  - When the projected closest point of approach (CPA) of two aircraft is within a distance-based volume in particular time thresholds
- Similar to Traffic Collision Avoidance System (TCAS) II alerting logic and criteria

“Well Clear” Distance Thresholds

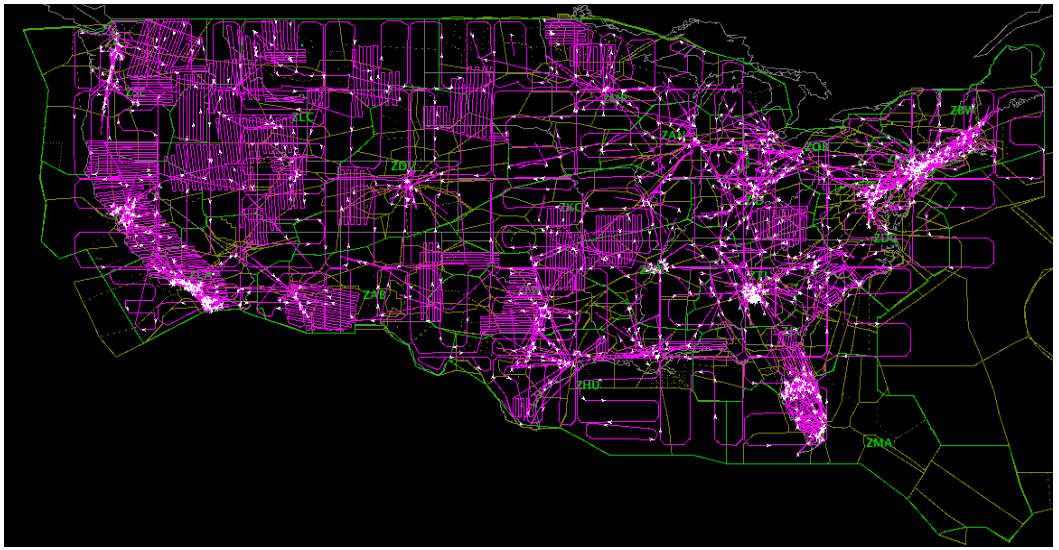


Generic Surveillance Model



NAS-Wide Air Traffic Simulation

- Airspace Concept Evaluation System (ACES)
  - Simulate NAS-wide air traffic operations and encounters between UAS and VFR traffic



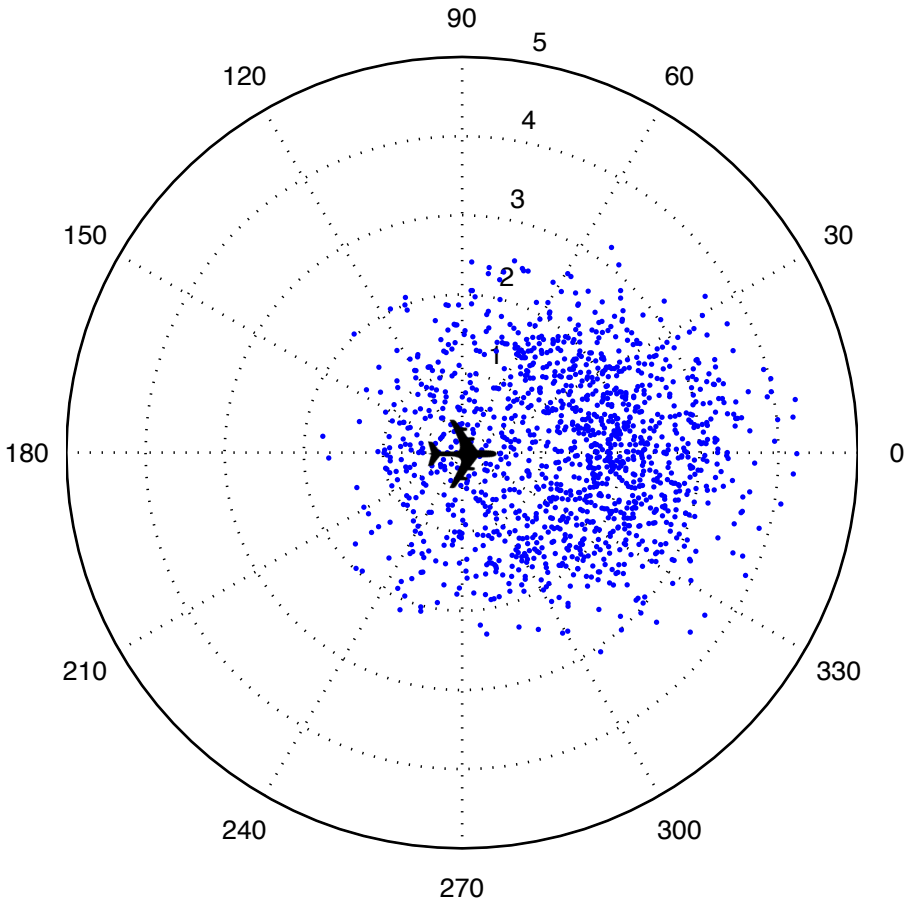
- Traffic scenario for a single day

  - Historical cooperative VFR traffic
    - Air Defense radar data on July 25, 2012
    - Total 26,770 flights, 24,838 flight hours

  - Proposed UAS flights
    - Various types of UAS missions generated by Intelligent Automation Inc.
    - Total 18,262 flights, 18,900 flight hours

Simulation Results and Analysis

Relative Position of Threats

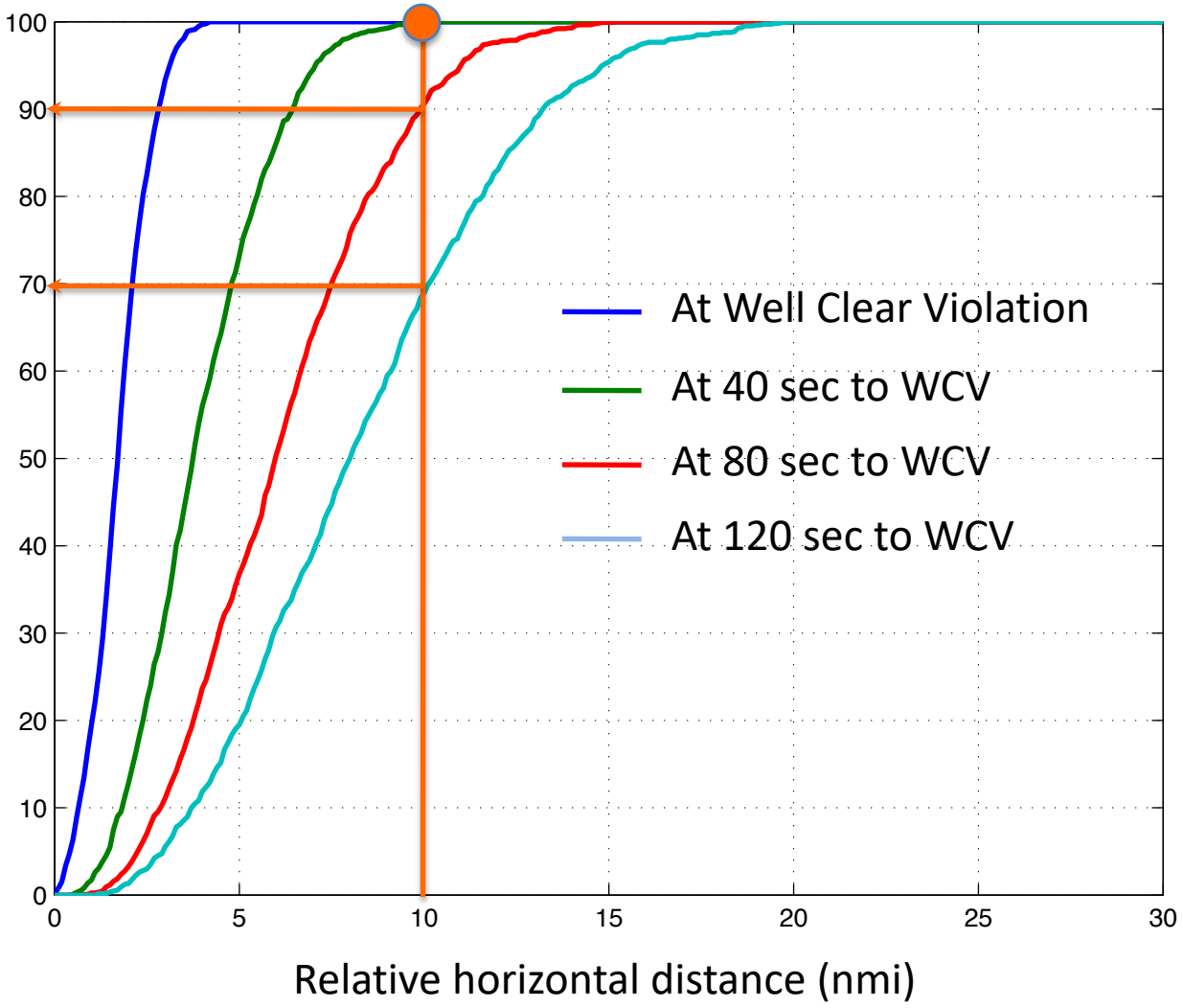


Head-On

Relative Position of Threats at the WCV

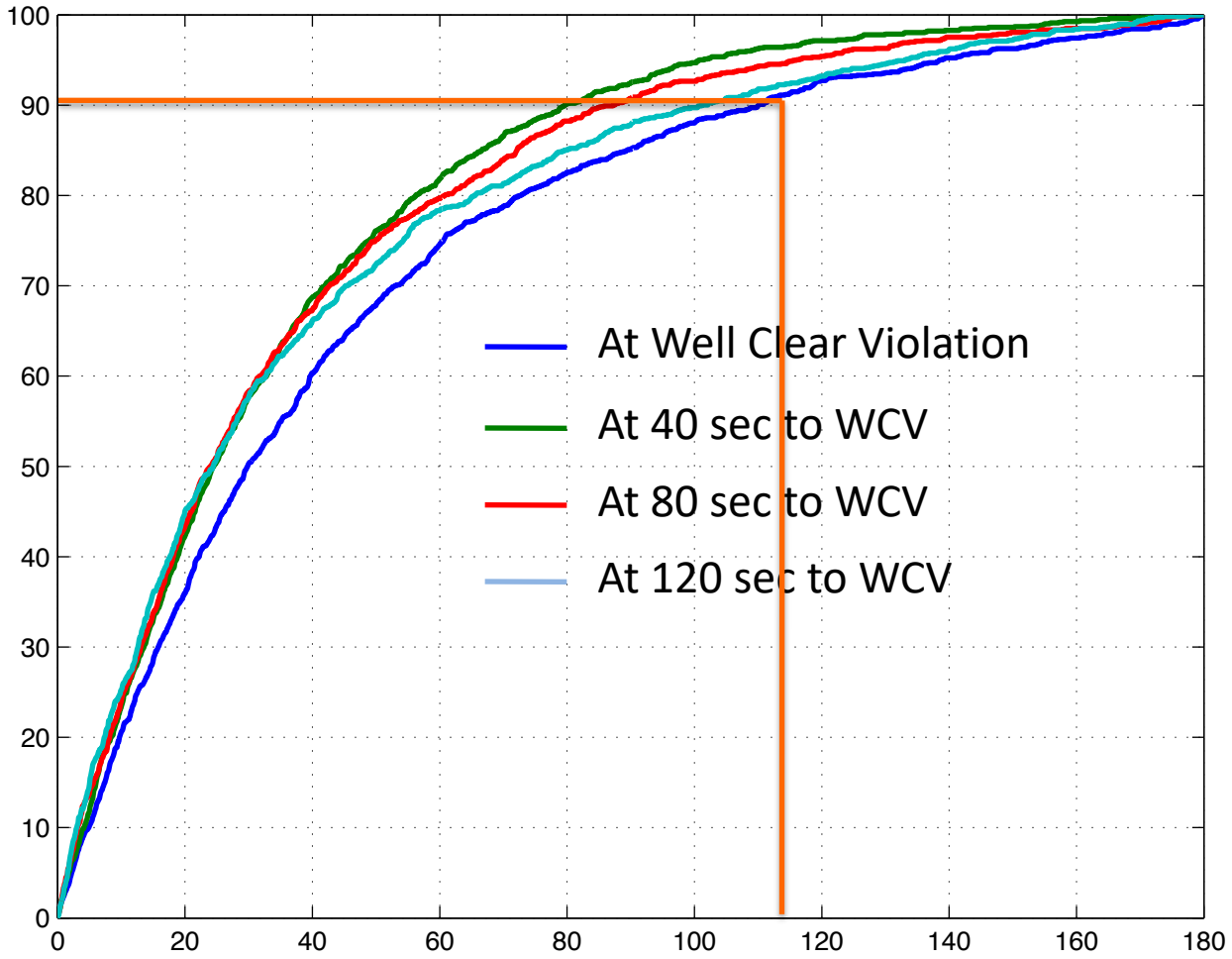
Relative Horizontal Distance of Threats

Percentage of Intruders within a given range (%)



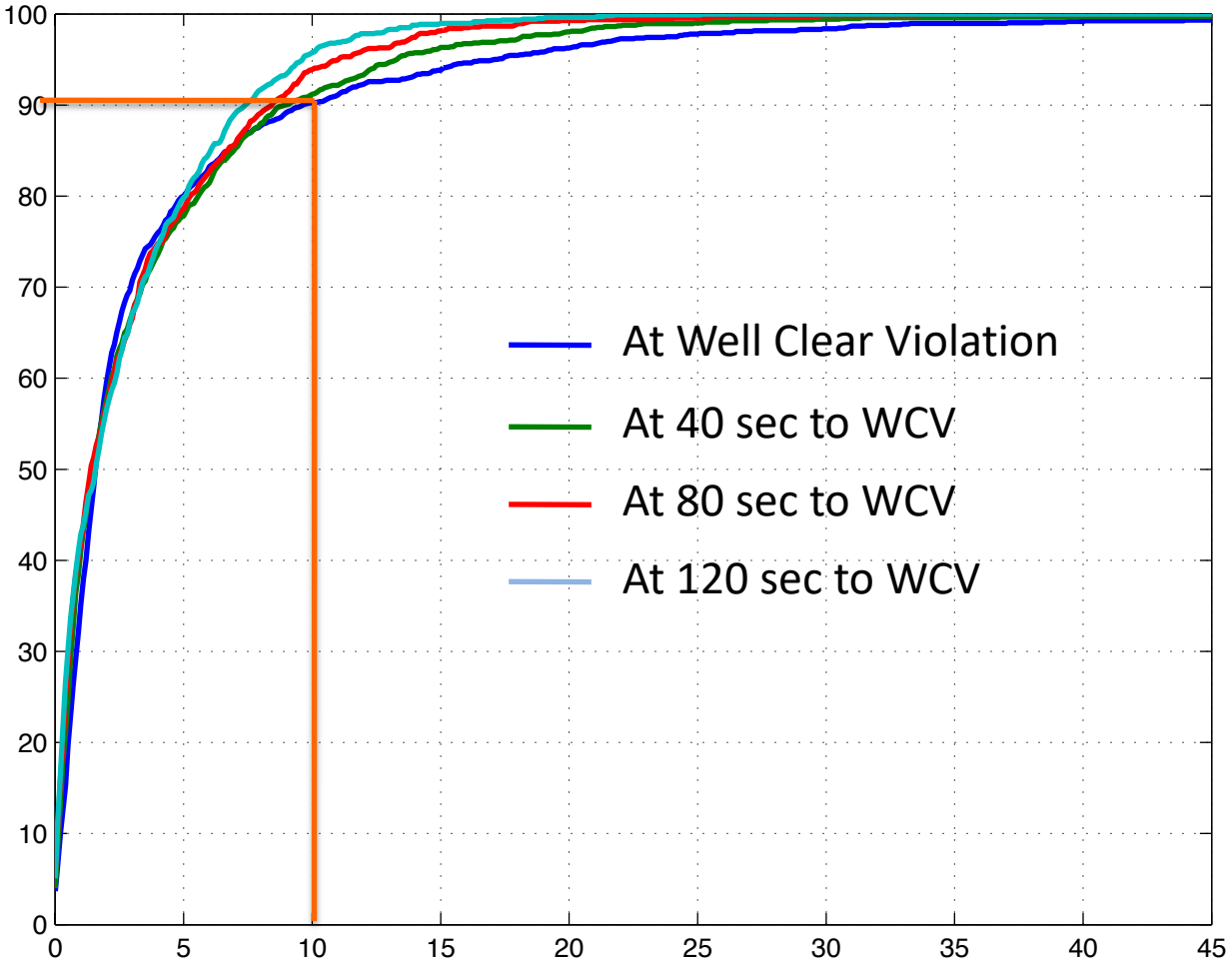
Relative Heading Angle of Threats

Percentage of Intruders within a given horizontal FOR (%)



Relative Vertical Angle of Threats

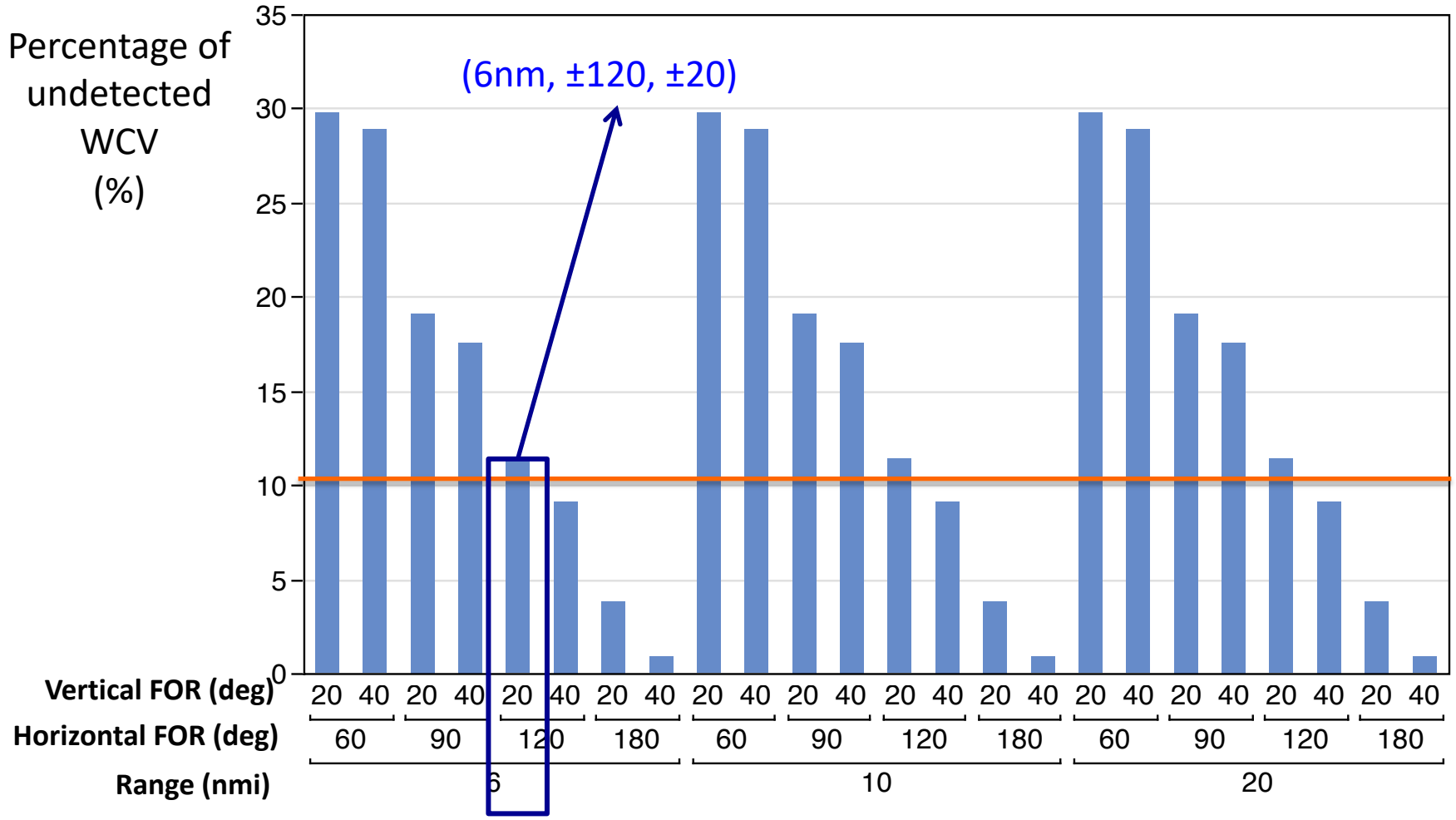
Percentage of Intruders within a given vertical FOR (%)



Effects of Surveillance Parameters

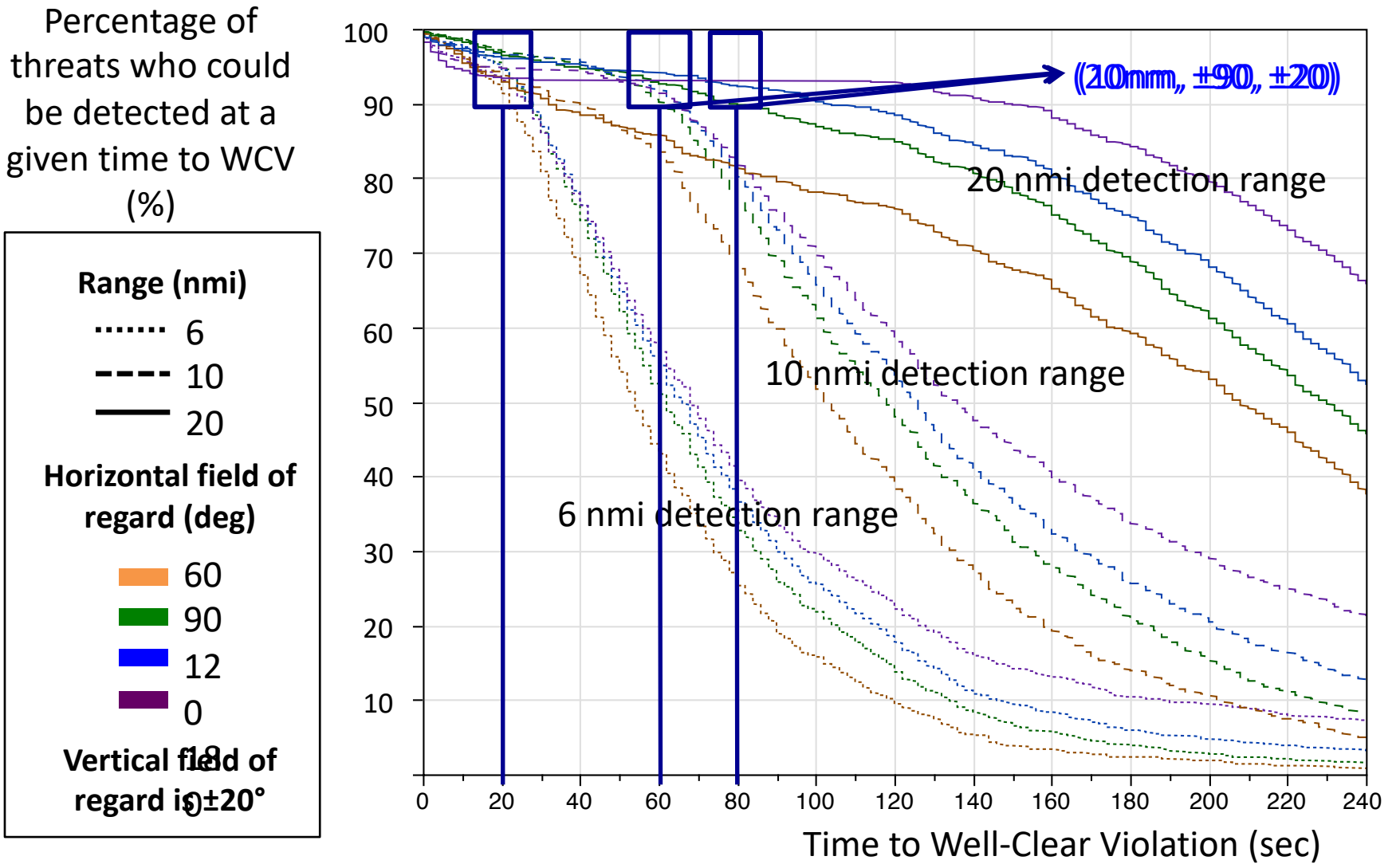
- Selected sets of surveillance parameters
  - Surveillance Range: 6, 10, 20 nmi
  - Horizontal Field of Regard: (±) 60, 90, 120, 180 deg
  - Vertical Field of Regard: (±) 20, 40 deg
  - Total 24 sets of surveillance parameters (3*4*2)
- Analysis for undetected WCV
  - Metric: Ratio of the number of undetected WCV to the total number of WCV for a given set of surveillance parameters
- Analysis for Detected WCV
  - Metric: Time to WCV of threats at first detection with a given set of surveillance parameters

Ratio of Undetected WCV



* Percentage of undetected WCVs is closely related to horizontal field of regard!

Analysis of the Time to WCV



Concluding Remarks

- Analyzed and built a database for well-clear violations between UAS and VFR traffic
  - Allow system designers to conduct trade space analysis
- The ratio of undetected WCV was substantially affected by horizontal field of regard
  - 90% of WCV could be detected with a surveillance volume **(6nmi, ±120°, ±20°)**
- The time to WCV was most sensitive to surveillance detection range
  - 90% of threats could be detected at least 60 sec before the violation with a surveillance volume **(10nmi, ±90°, ±20°)**

Future Works

- Perform sensitivity analysis with multiple days of traffic
  - Effects of different traffic density of VFR and UAS traffic
  - Effects of different UAS missions and flight characteristics
- Conduct mitigated surveillance study with a DAA system
  - Effects of threat prediction and avoidance algorithms
- Use high-fidelity sensor models to detect intruder aircraft under uncertainty
- Investigate the effects of various definitions of well-clear separation standard

Questions?

- Paper to be published in AIAA Aviation, Technology, Integration, Operation (ATIO) 2014 conference

Chunki Park, Seung Man Lee, and Eric Mueller

"Investigating Detect-and-Avoid Surveillance Performance for Unmanned Aircraft Systems"

Contact Information

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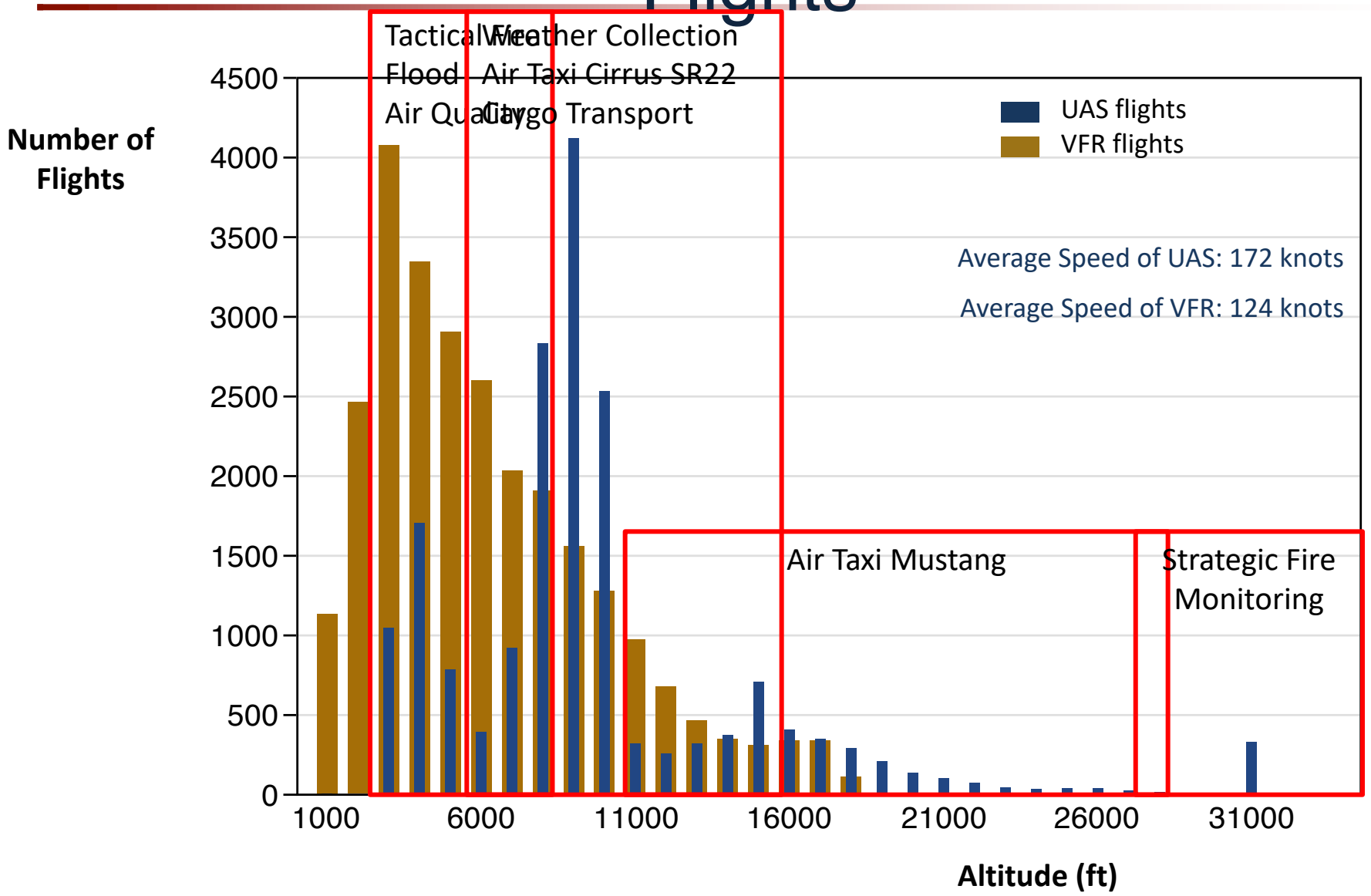
BACKUP SLIDES

Characteristics of UAS and VFR Flights



Definition of Well Clear Violation

$$R_{xy} \le DMOD \; or \; (P_{cpa} \le HMD \; and \; 0 \le Tau_{Mod} \le TTHR)$$

and

$$R_z \le ZTHR \; or \; (0 \le T_{COA} \le TCOA)$$

Where

R_{xy} : *Horizontal Range*

P_{CPA} : Predicted horizontal range at time of closest point of approach

Tau_{Mod} : Modified Tau

R_z : Relative Altitude

T_{COA} : Time to Co - Altitude

$DMOD = 6000\,ft$ $\quad HMD = 6000\,ft$ $\quad ZTHR = 475\,ft$

$TTHR = 30\,\text{sec}$ $\quad TCOA = 20\,\text{sec}$