Distribution of the First Alert Range for Low UA Speed Encounters

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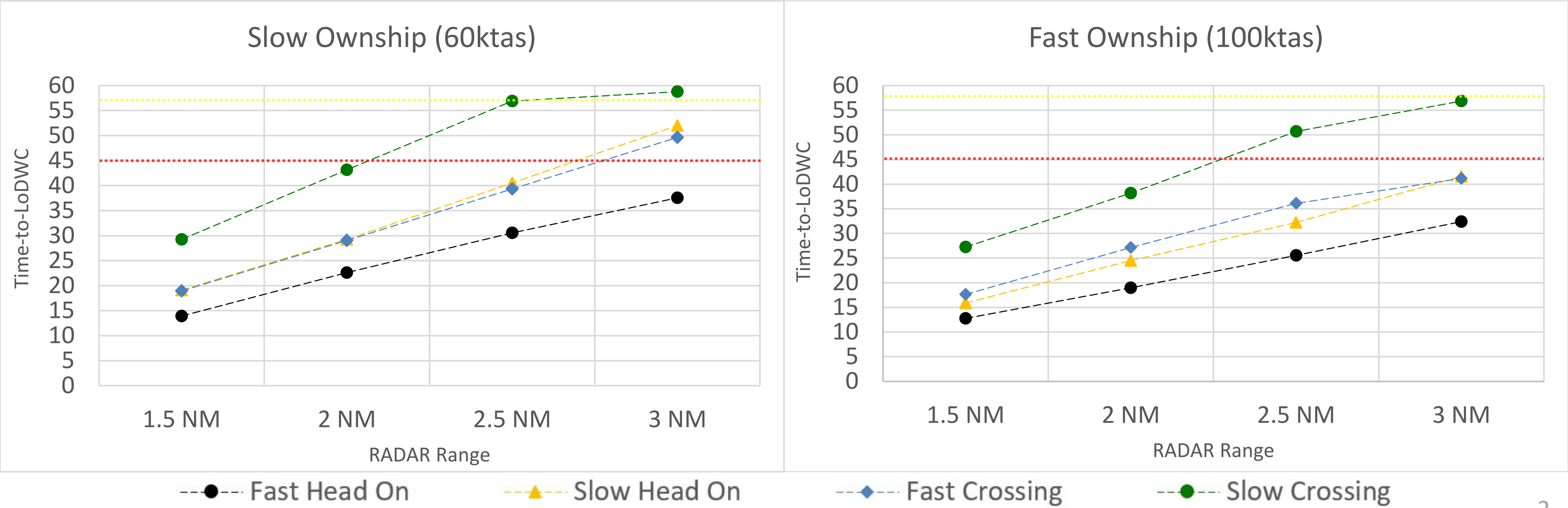
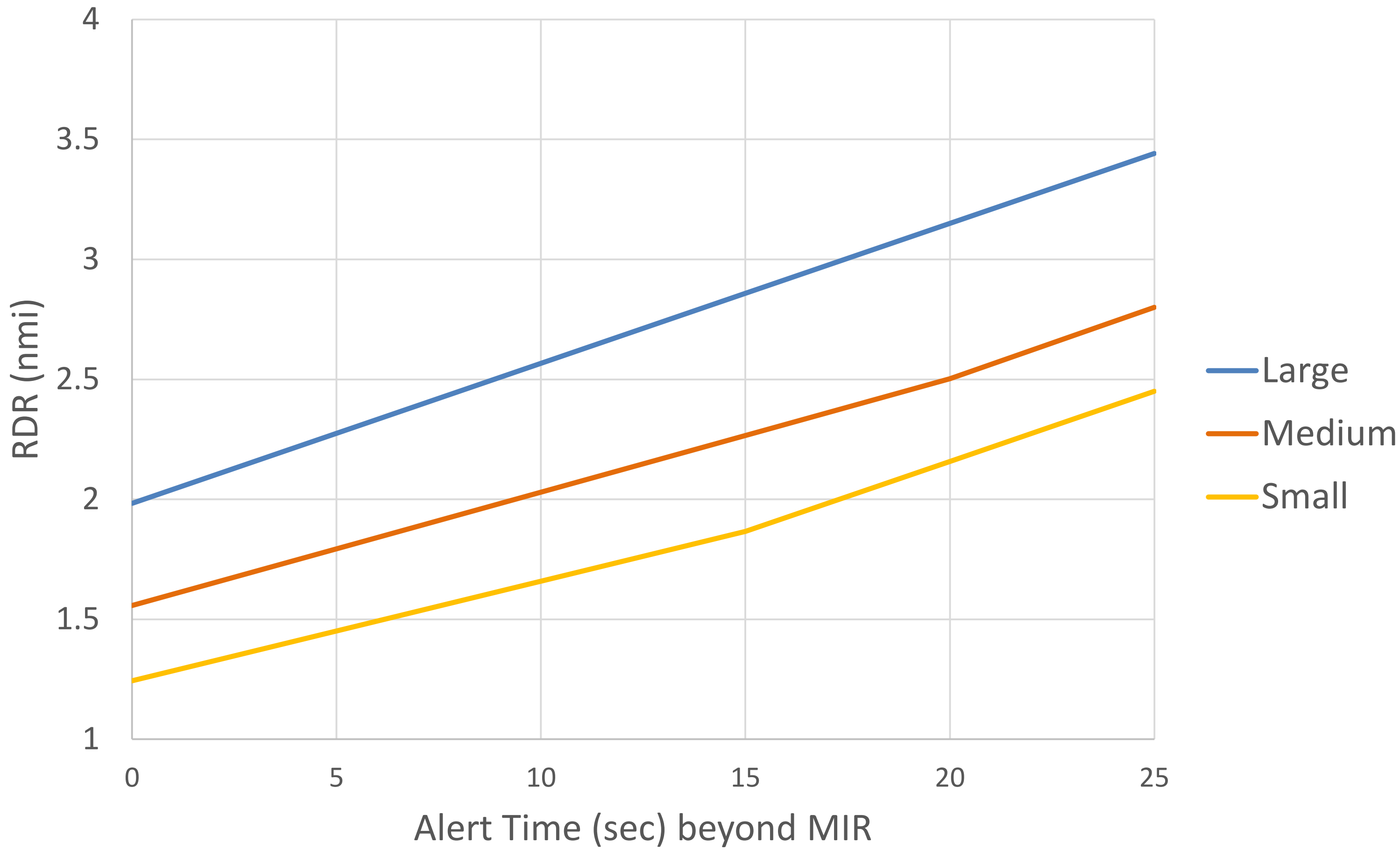
Background

- NASA's low SWaP HITL2 results indicate a surveillance range of 2.5 nmi allows pilots to perform well in maintaining DWC
- However, with 2.5 nmi, only the 25% of the encounters (specifically, slow crossing) have Corrective alerts > 14 seconds
- Simulation of an encounter set can show the percentage of sufficient corrective alert durations as a function of surveillance range



RDR Variation with Required Alert Time



Results are derived from AAG's 2PAIRS. RDR is based on head-on encounters.

Alerting Timeline Results to be Presented

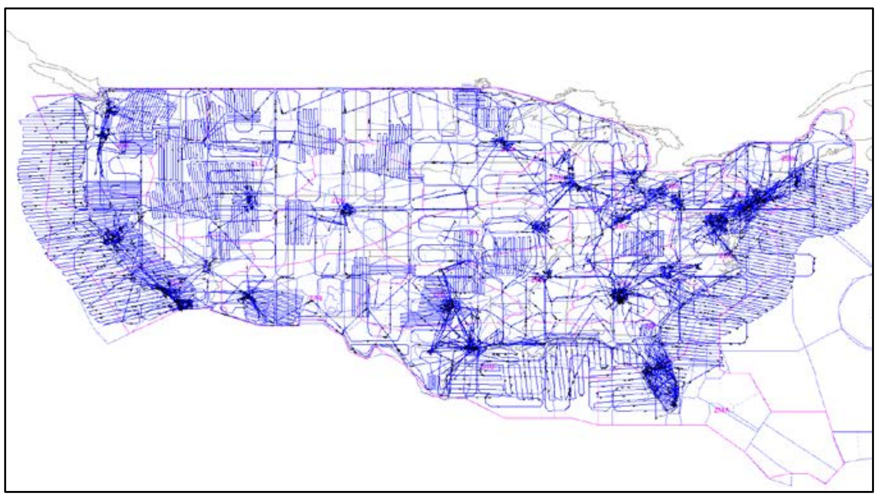
The following plots are created from previous simulation results:

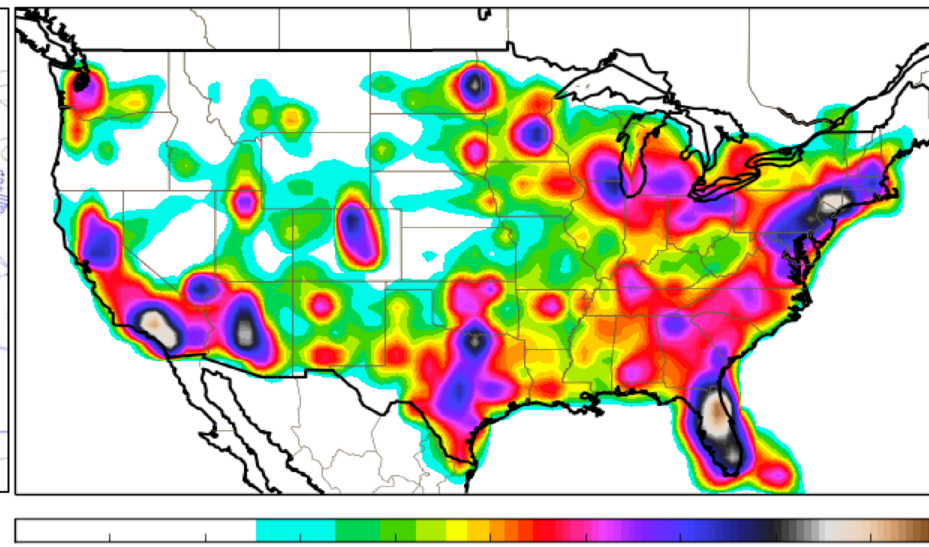
1. NASA simulation
   - Encounters : NASA UAS trajectories overlay with RADES radar tracks
   - Field of Regard: 8 nmi spherical range with full bearing and elevation
   - Alerting times: based on times to the buffered non-cooperative DAA well clear, (2200 ft HMD*, 0 sec τ_{mod}*, 450 ft h*)

2. CAL Analytics simulation
   - Encounters: Hybrid
     - ownship sampled from NASA UAS trajectories
     - intruders created from the Lincoln Lab uncorrelated encounter model
   - Field of regard: ±110° bearing, ±15° elevation, and RDR = MIR + 25, 15, and 10 seconds
   - Alerting times: based on times to the non-cooperative DAA well clear

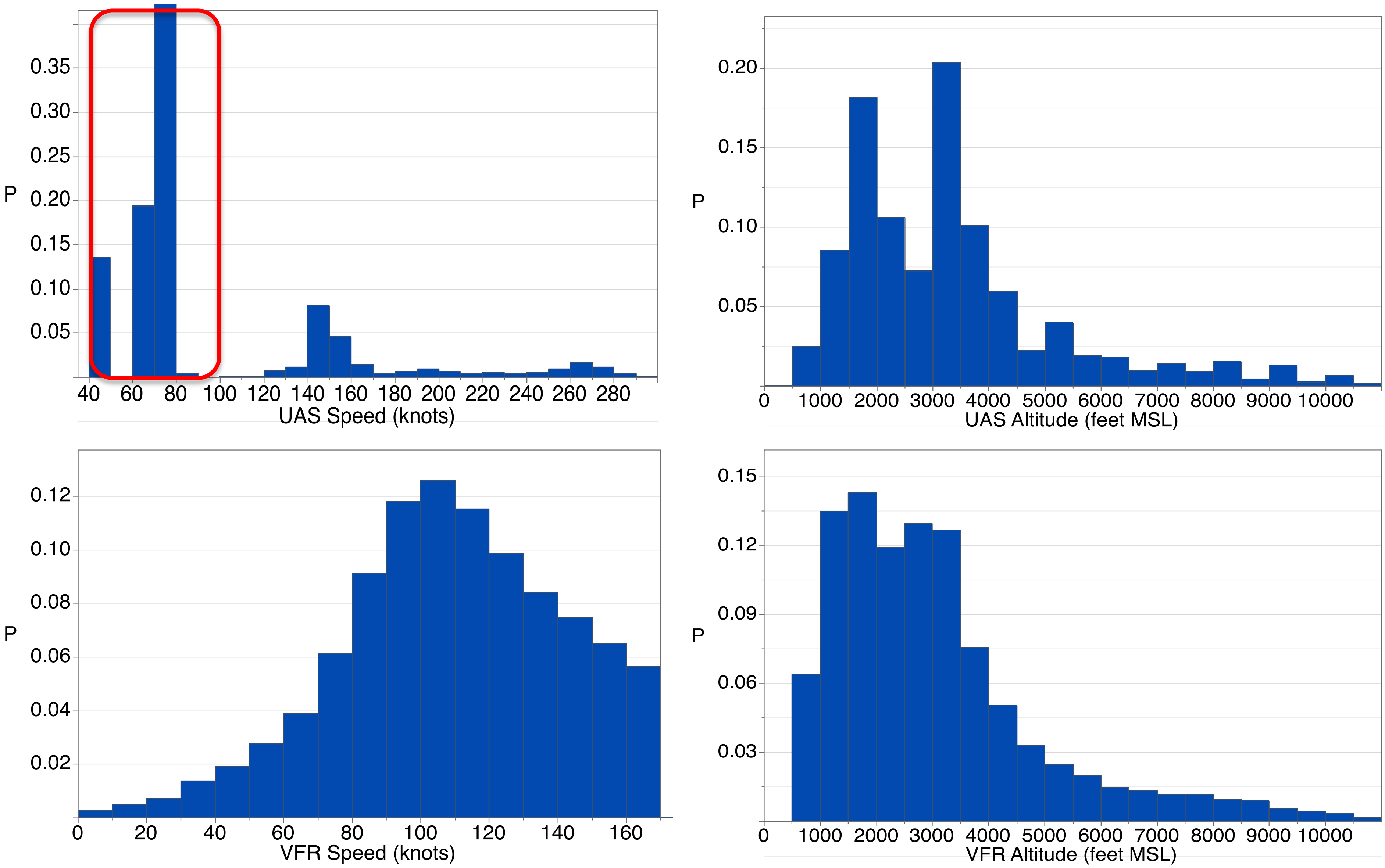
NASA Encounter Set

- 17,100 hours of projected UAS mission trajectories in one day overlaid with each of 21 days’ radar recorded visual flight rules (VFR) traffic
- Only encounters between 500 ft AGL and 10,999 ft MSL are analyzed





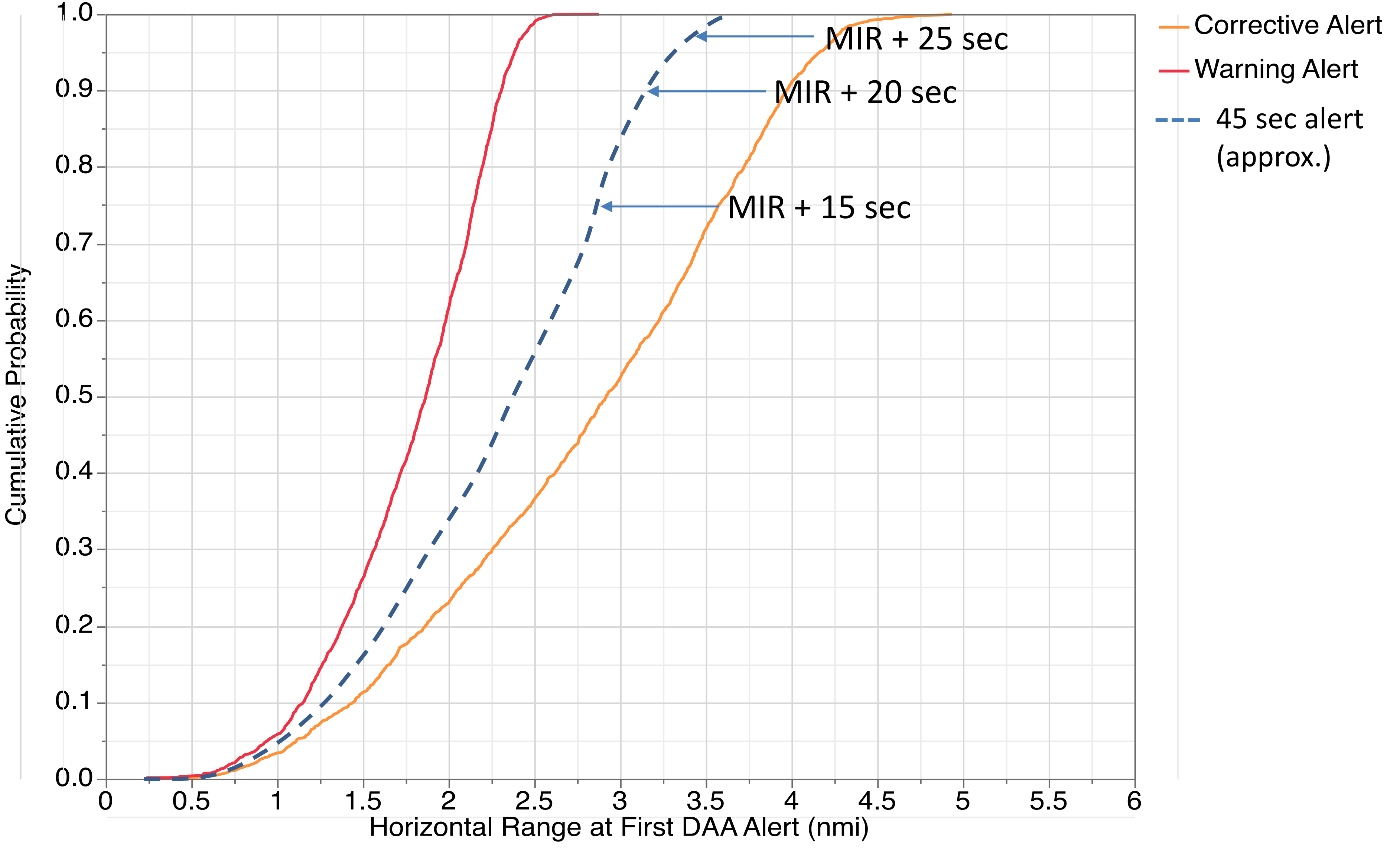
Speed and Altitude of UAS and VFR Traffic



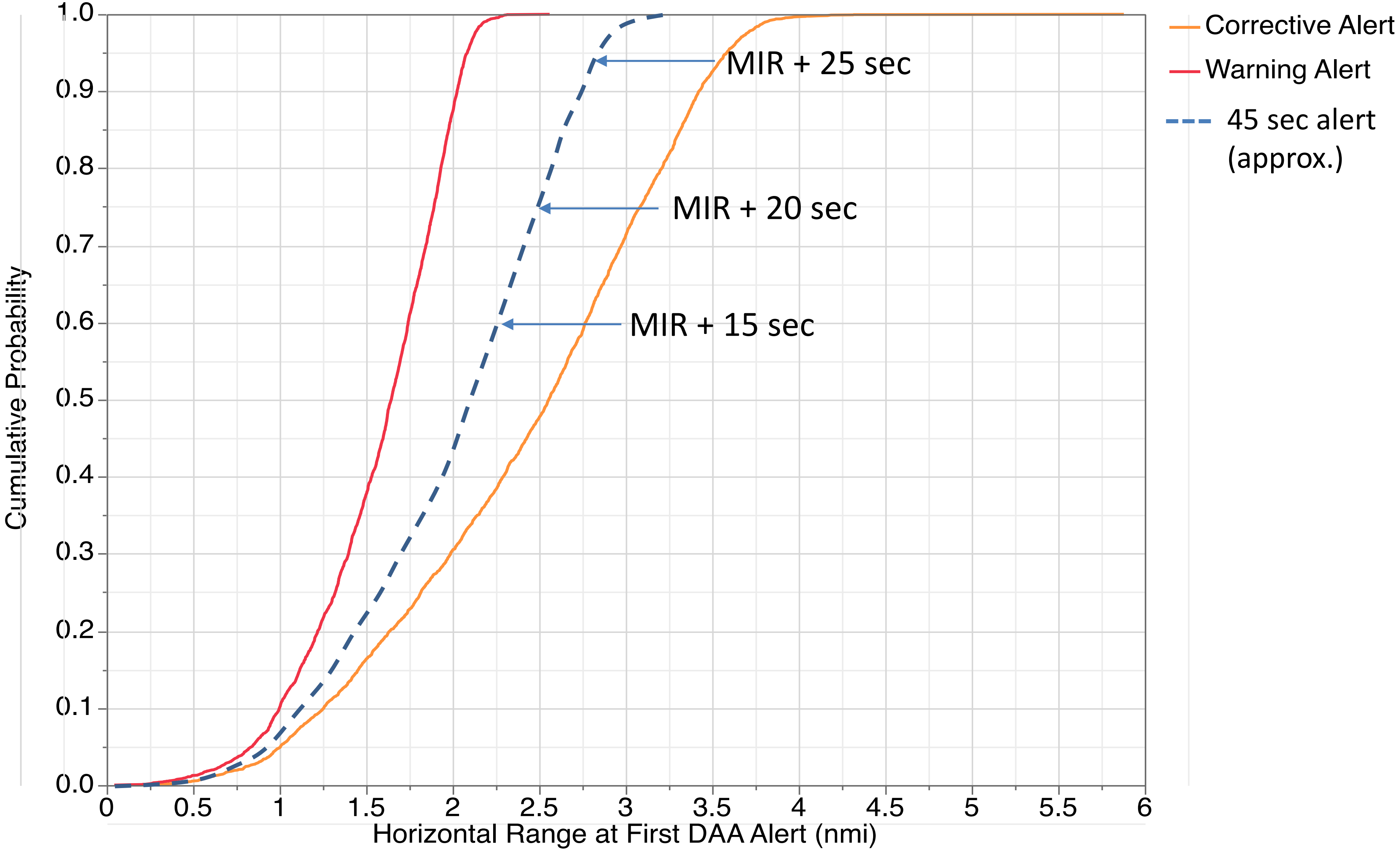
Simulation Setup

- Unmitigated
- 8 nmi spherical field of regard (FoR) with full bearing and elevation
- About 8,200 encounters result in LoDWC
- Alerts are computed by DAIDALUS based on
  - The buffered DWC has HMD* = 3342 ft (1.519 x 2,200 ft)
  - 60 and 30 seconds before a predicted loss of buffered DWC for corrective and warning alerts, respectively
- Distributions of the horizontal distance of the aircraft (range) at the first corrective and warning alerts are computed for
  - Large intruders (130 to 170 kts)
  - Medium intruders (100 to 130 kts)
  - Small intruders (< 100 kts)
- Distribution of a 15-second corrective alert (45 second alert in total) estimated by interpolation

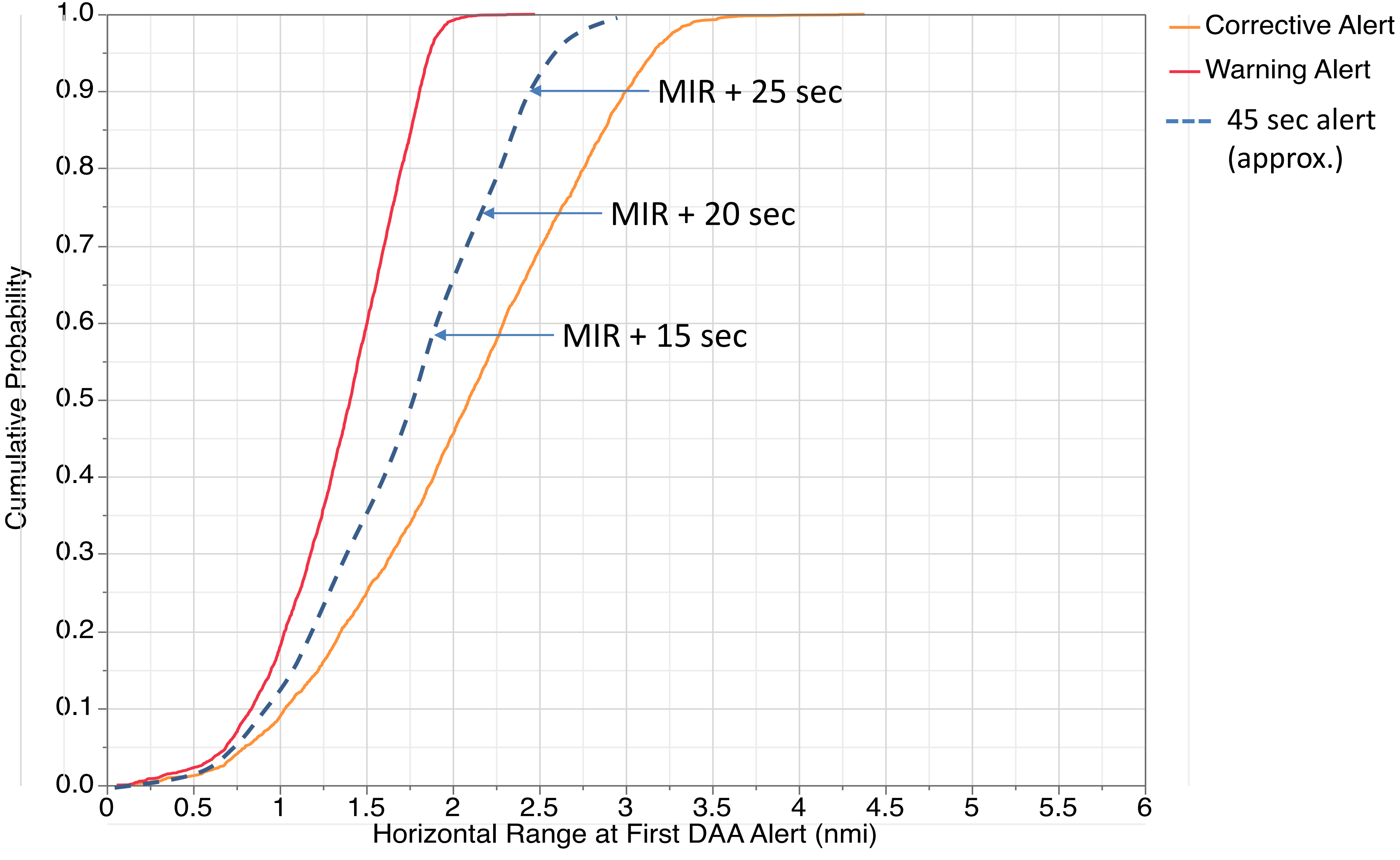
First Alert for Large Intruders (Between 130 and 170 KTAS)



First Alert for Medium Intruder (Between 100 and 130 KTAS)



First Alert for Small Intruder (<=100 KTAS)

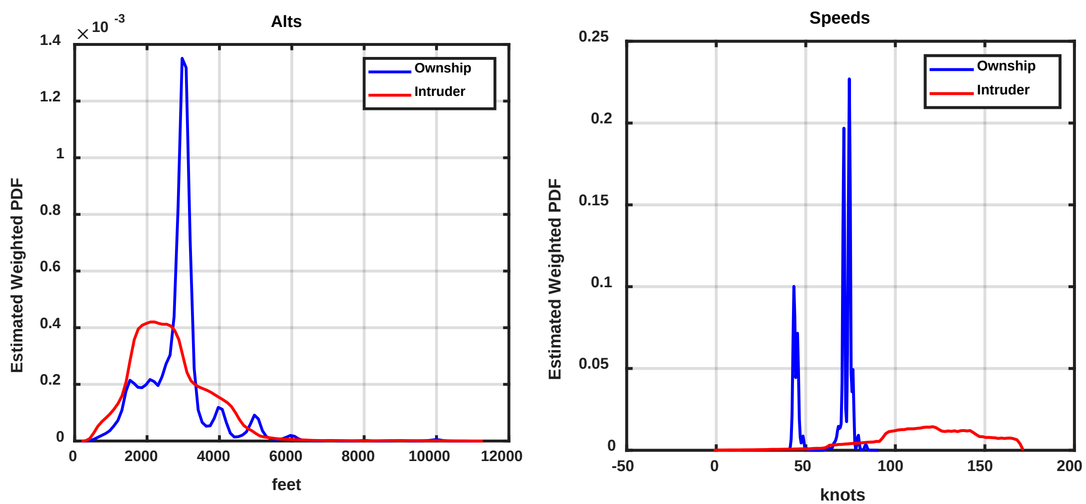


Discussions

- The percentage is considered optimistic since the simulated FoR covers all bearings and elevations
- When setting RDR to be MIR + 25 seconds (current ATAR MOPS adopts this), >= 90% of encounters achieve 45 seconds alerts (15 corrective + 30 warning) in all 3 intruder categories
- With RDR set to MIR + 20 seconds, > 74% of encounters achieve 45 seconds alerts
- With RDR set to MIR + 15 seconds, the 45 second alert percentage varies between 58% and 75% across categories

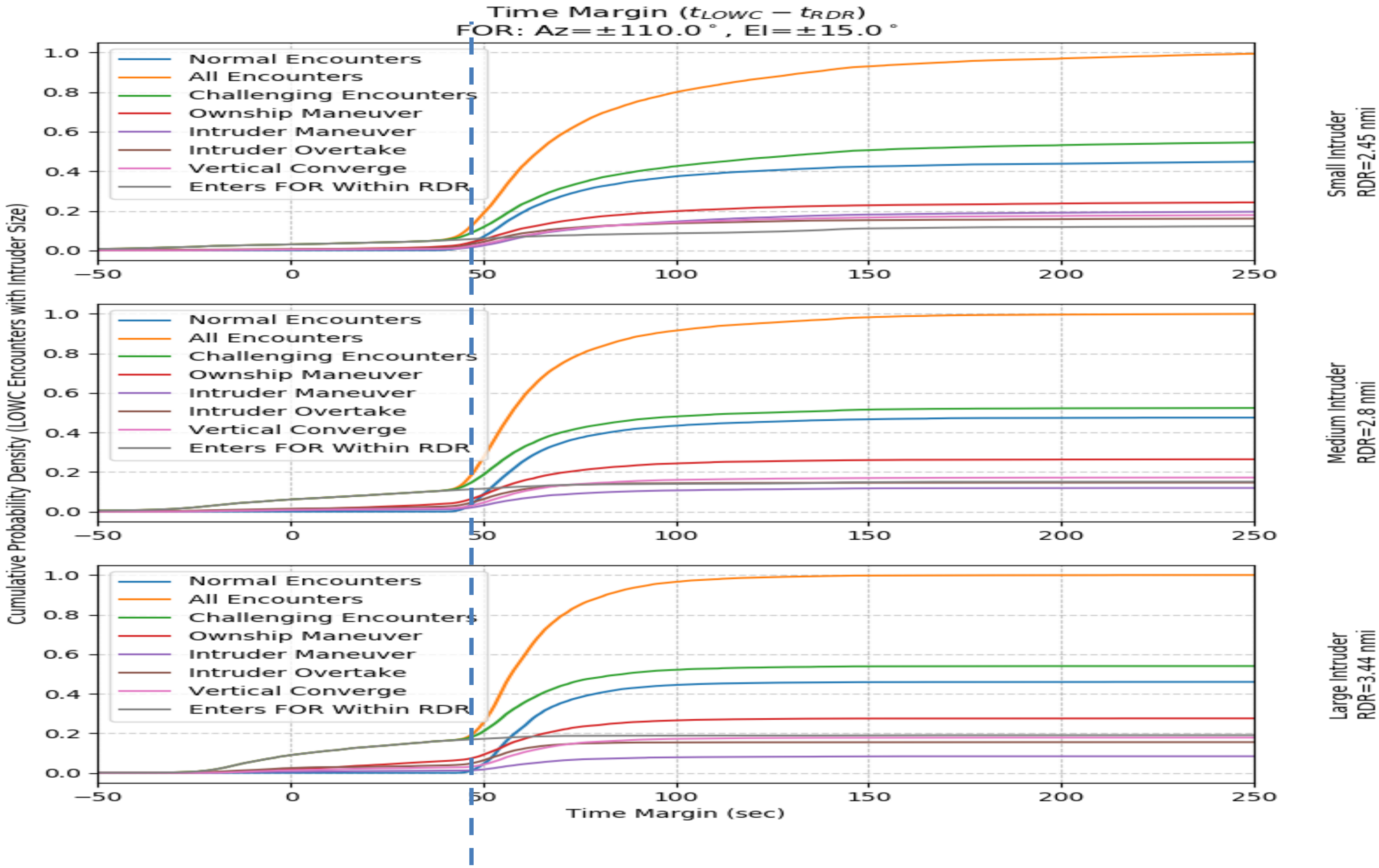
CAL's Alerting Time with a Finite FoR

- CAL Analytics performed alerting time analysis using a hybrid encounter set that sampled ownship from NASA UAS trajectories and intruder from Lincoln Lab's uncorrelated model
- The following plots show the first alert time distribution for a given FoR with ±110° bearing and ±15° elevation



Alerting Time with a Finite FoR

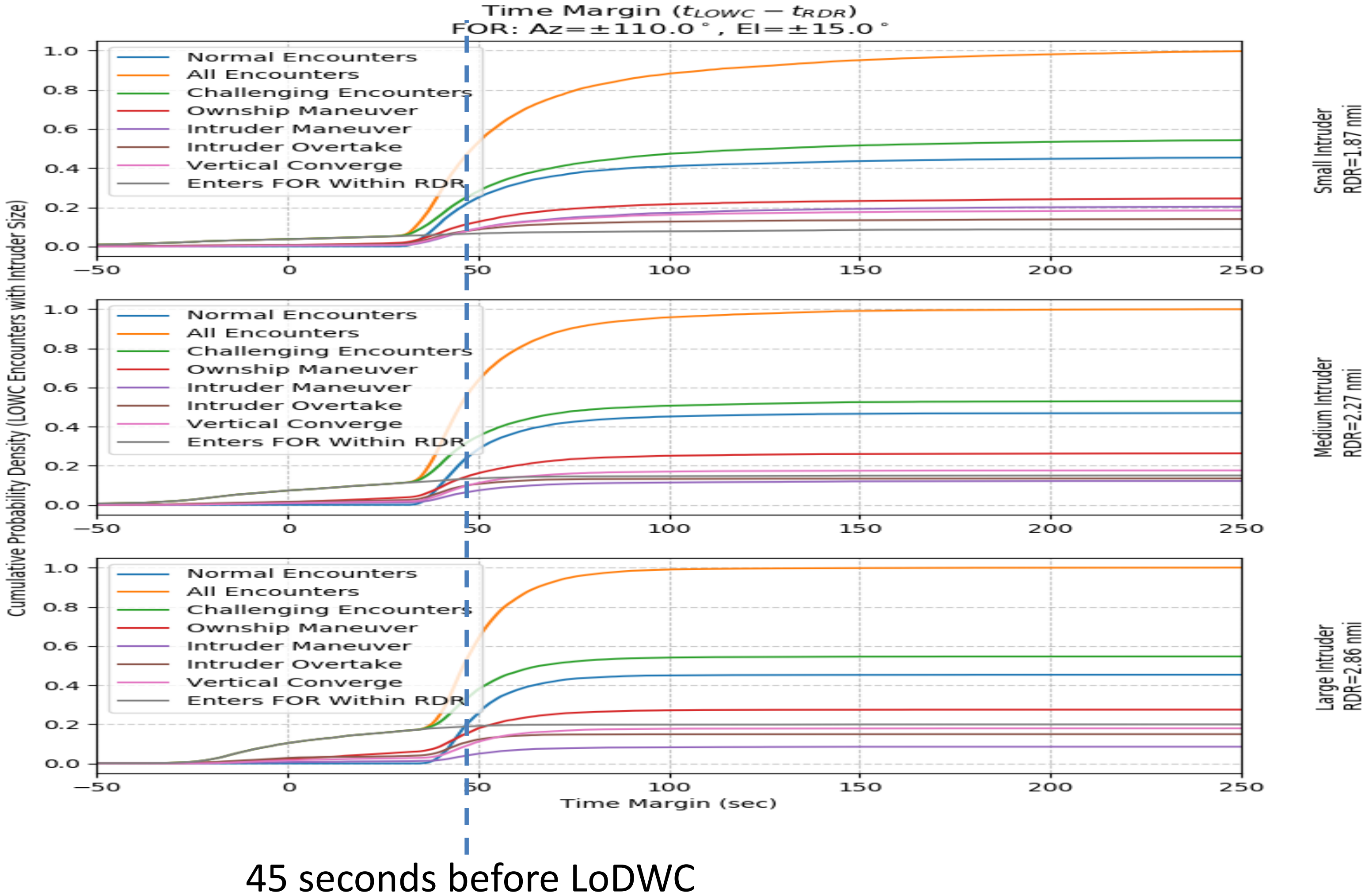
$$t_{RDR} = t_{MIR} + 25 \text{ sec} *$$



45 seconds before LoDWC

Alerting Time with a Finite FoR

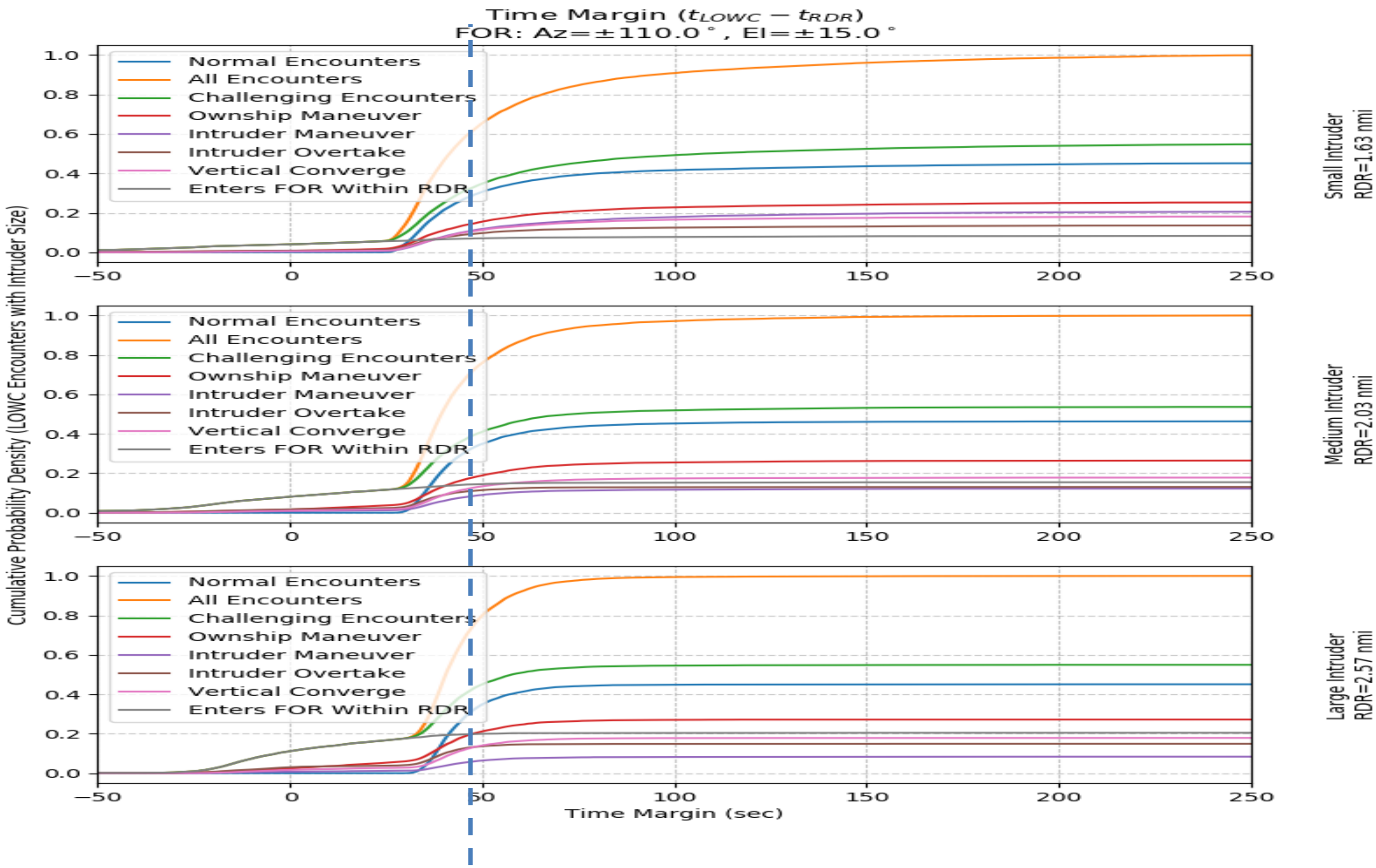
$$t_{RDR} = t_{MIR} + 15\text{ sec} *$$



*** RDR is based on additional time allotted before MIR for Pilot Response / ATC Coordination.**

Alerting Time with a Finite FoR

$$t_{RDR} = t_{MIR} + 10 \text{ sec} *$$



45 seconds before LoDWC

*** RDR is based on additional time allotted before MIR for Pilot Response / ATC Coordination.**

Discussions

- MIR + 25 seconds allows 45 seconds alert for almost all encounters except for those overtaking intruders that come from outside the FoR
- MIR + 15 seconds allows 45 seconds alert for only about half of the non-overtaking intruders encounters

Open Questions

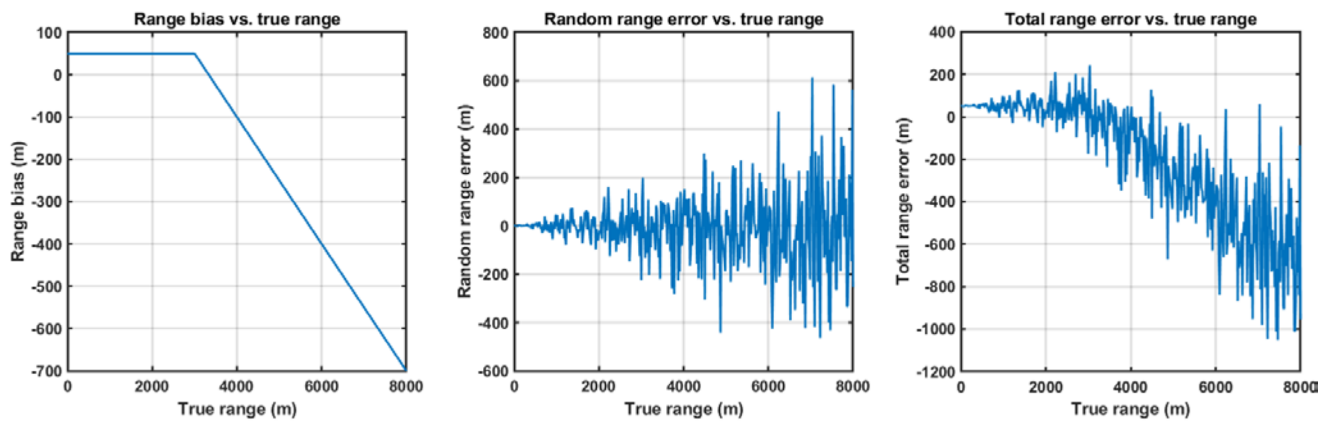
- Additional data or plots?
  - For MIR + 22 seconds
  - For high-speed encounters
- Do we want to trade some corrective alert times for reduction of the required surveillance range?
  - EO/IR's range and range rate estimation becomes problematic beyond 3 nmi
- If the EO/IR sensor can cover more than ±110° bearing (Julien is looking into it), what would be a good criteria for evaluating the trade space (same % of 45 sec corrective alert?)

Backup Slides

EO/IR Parametric Model

- Range estimation error[1]:
  - $\varepsilon(R) = \mu(R) + \sigma(R) * randn(1)$
    - R = range (meters)
    - $\mu(R) = 50 - 0.15 * MAX(0; R - 3000)$ (error bias at range R)
    - $\sigma(R) = 0.03 * R$ (error standard deviation at range R)
    - Randn: Matlab Normally distributed random numbers
  - Time correlation is 5 s

- Range rate estimation error[1]:
  - σ is 5% of true range rate (e.g., if range rate is 200 kts, std. dev. is 10 kt)
  - Delay is 5 s (time needed to provide information from first detection)
  - Time correlation is 2 s (TBC)



1. Farjon J., "White paper EO/IR sensor model", SAFRAN ED, 2019

Alert Times with the Phase 1 FoR

- Figure D-5 in DO-366 shows the alerting time distribution with the Phase 1 radar FoR imposed
  - o It appears that a considerable amount of encounters have less than 45 seconds alerts before LoDWC
- o MITRE's Study 5 shows that 45% of encounters do not have sufficient corrective alert times (14 seconds)
  - o HALE, MALE, and LEPR combined

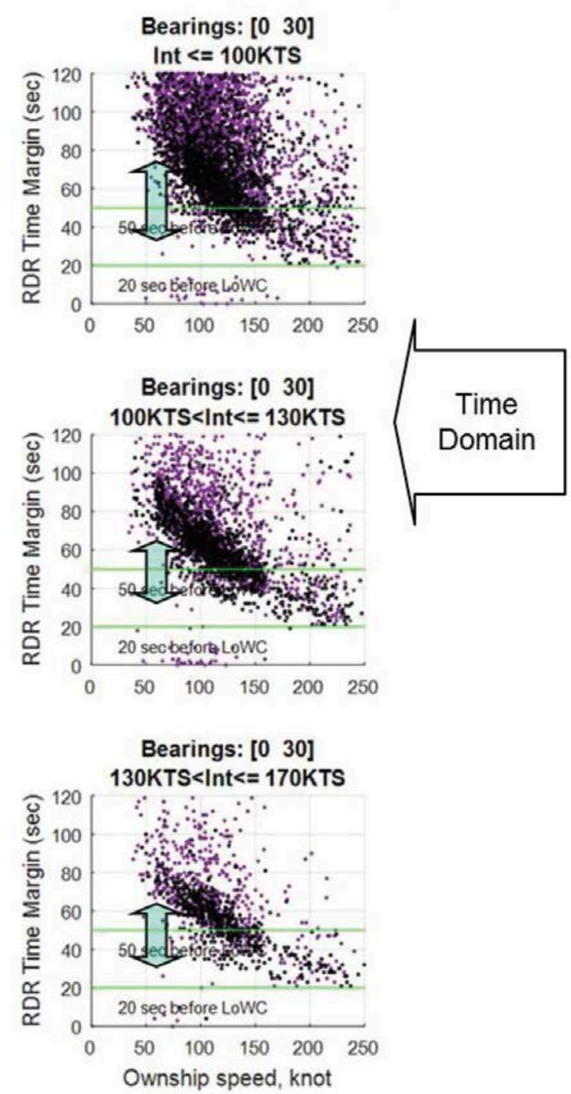
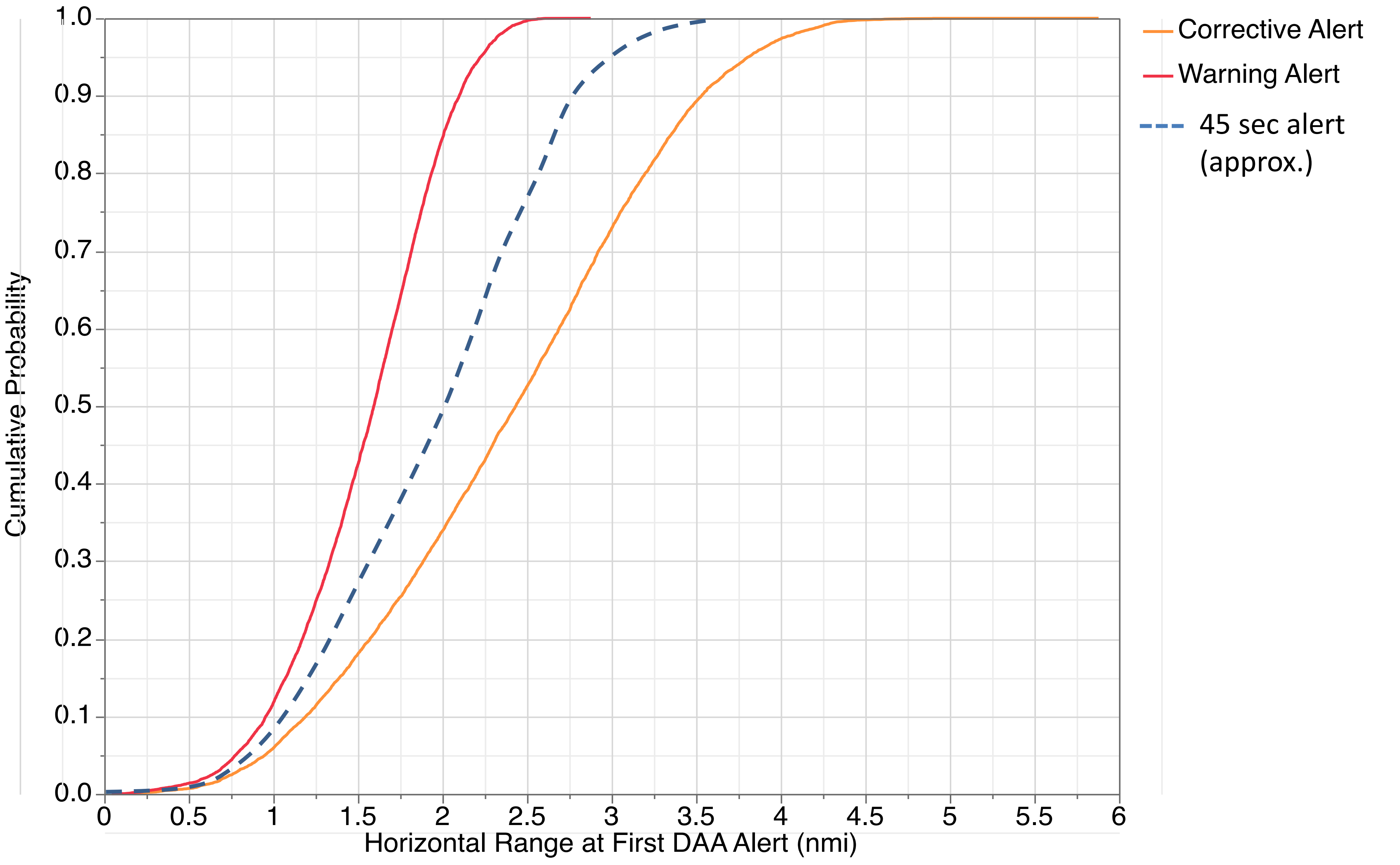
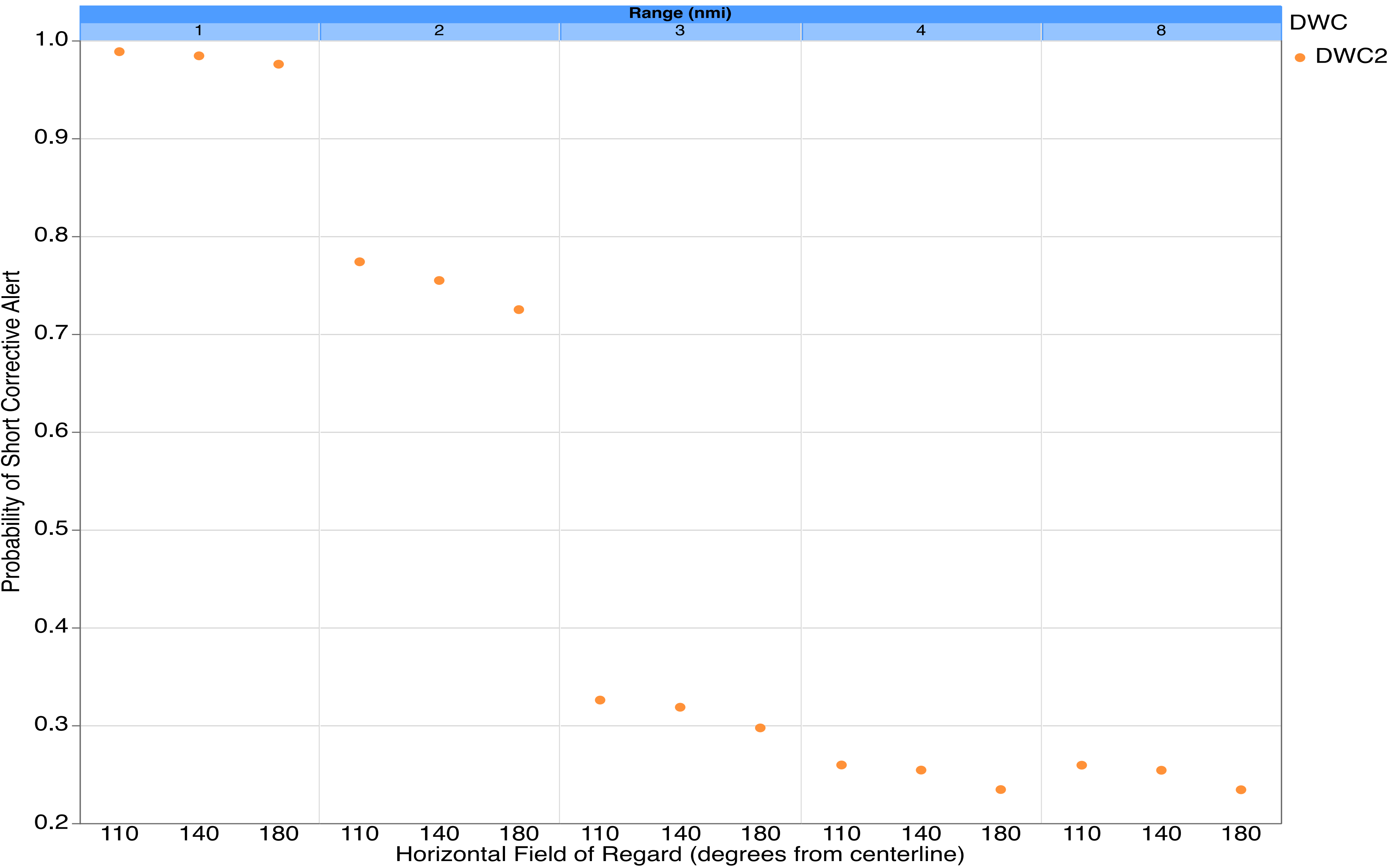


Figure D-5 Ex

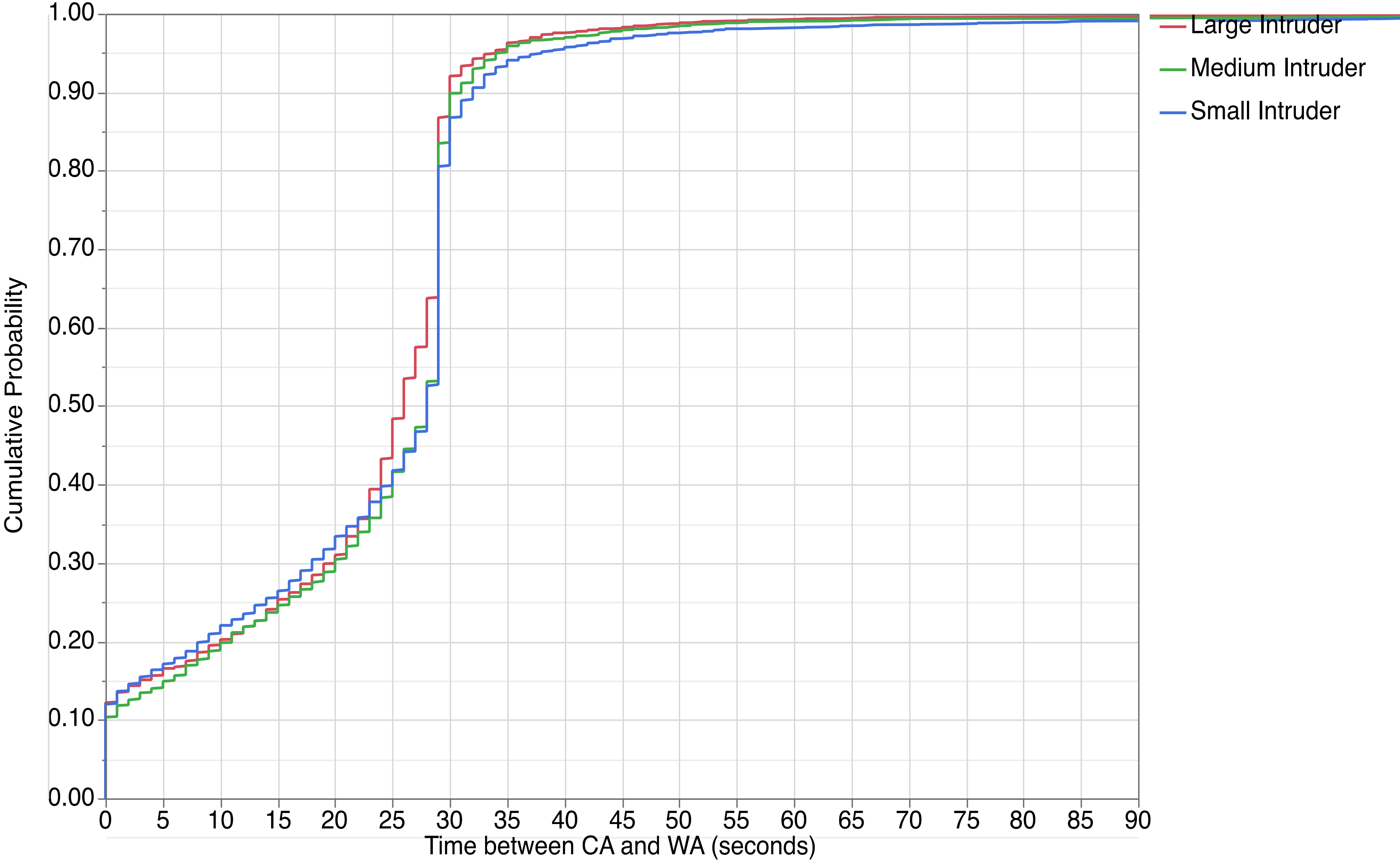
CDF of Range at First DAA Alerts for All Intruder



Probability of Short Corrective Alerts (Time between CA and WA <= 14 seconds)



CDF of Time between CA and WA for Low Speed UAS (When sensor range is 4nmi with Full FoR)



CDF of Time between CA and WA for Phase 1 UAS (to 200 KTAS) (When sensor range is 4nmi with Full FoR)