Fast Time Simulation 2 Experiment Plan

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Objectives

- Investigate the trade space between Detect-and-Avoid (DAA) alerting timeline and the surveillance volume of a low cost, size, weight, and power (Low C-SWaP) sensor
- Inform the SC-228 of recommendations to alerting and low C-SWaP sensor requirements

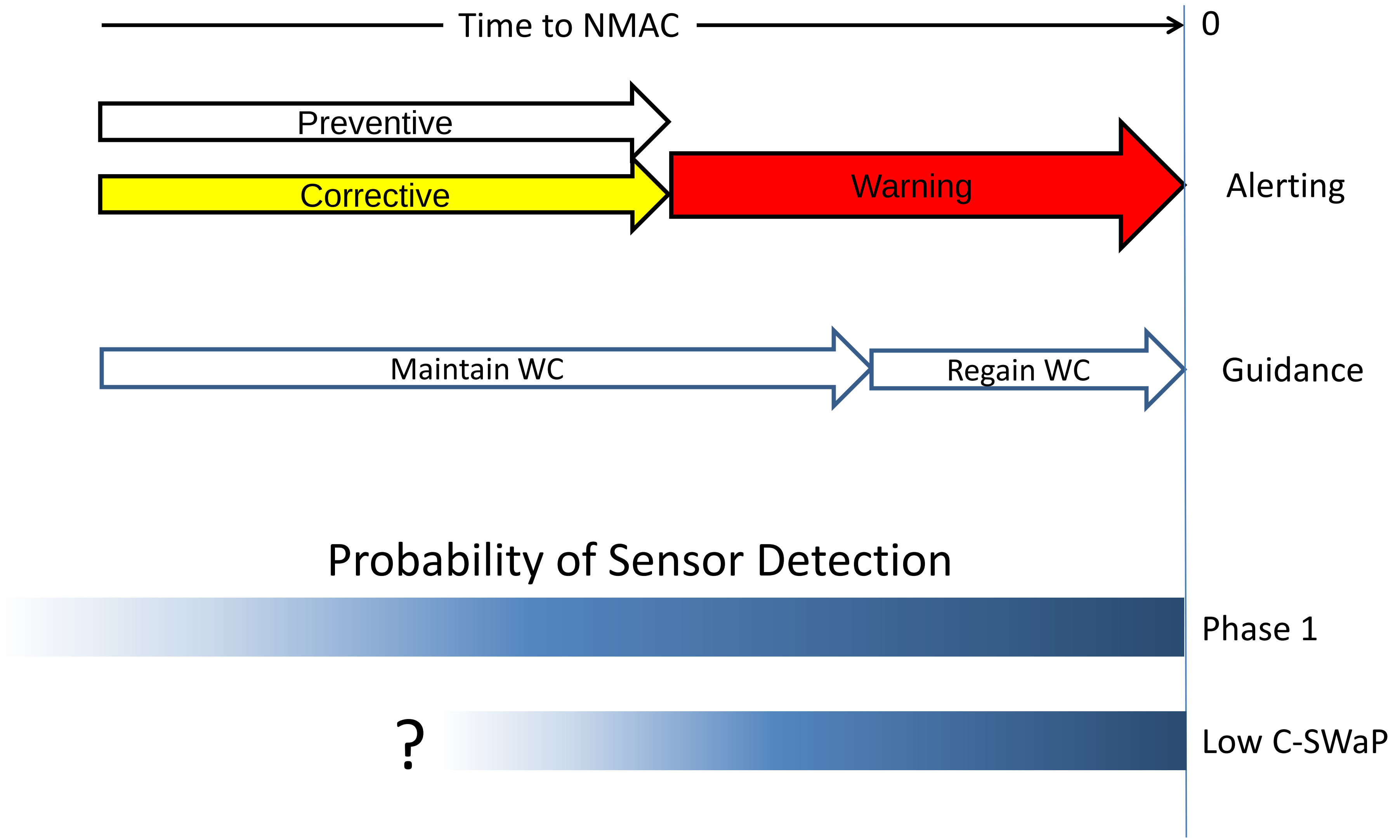
Schedule

- Dec. 2017 – Jan. 2018: Planning
- Jan. – Apr. 2018: software development
- May 2018: data collection
- Jun. – Sep. 2018: analysis
- Early August: Brief preliminary results to SC-228 for feedback
- Sep. 2018: Final briefing at the SC-228 WG1 face-to-face

Background

- Fast Time Sim 1 recommends candidate DAA Well Clear (DWC) definitions for UAS with low C-SWaP sensors and non-cooperative aircraft
- Assumed applicability in operations
  - Encounters above 500 ft AGL and below 10,000 ft MSL
  - During extended operations in airspace classes D, E (non-terminal), or G (non-terminal), or
  - During transit operations in classes B and C
  - For UAS within a certain speed range (assumed to be [40, 100] kts)
- Additional evaluation of candidate DWCs in terms of alerting and guidance performance is necessary
- Sensor requirements constrain alerting requirements

DAA Alerting and Guidance Timeline



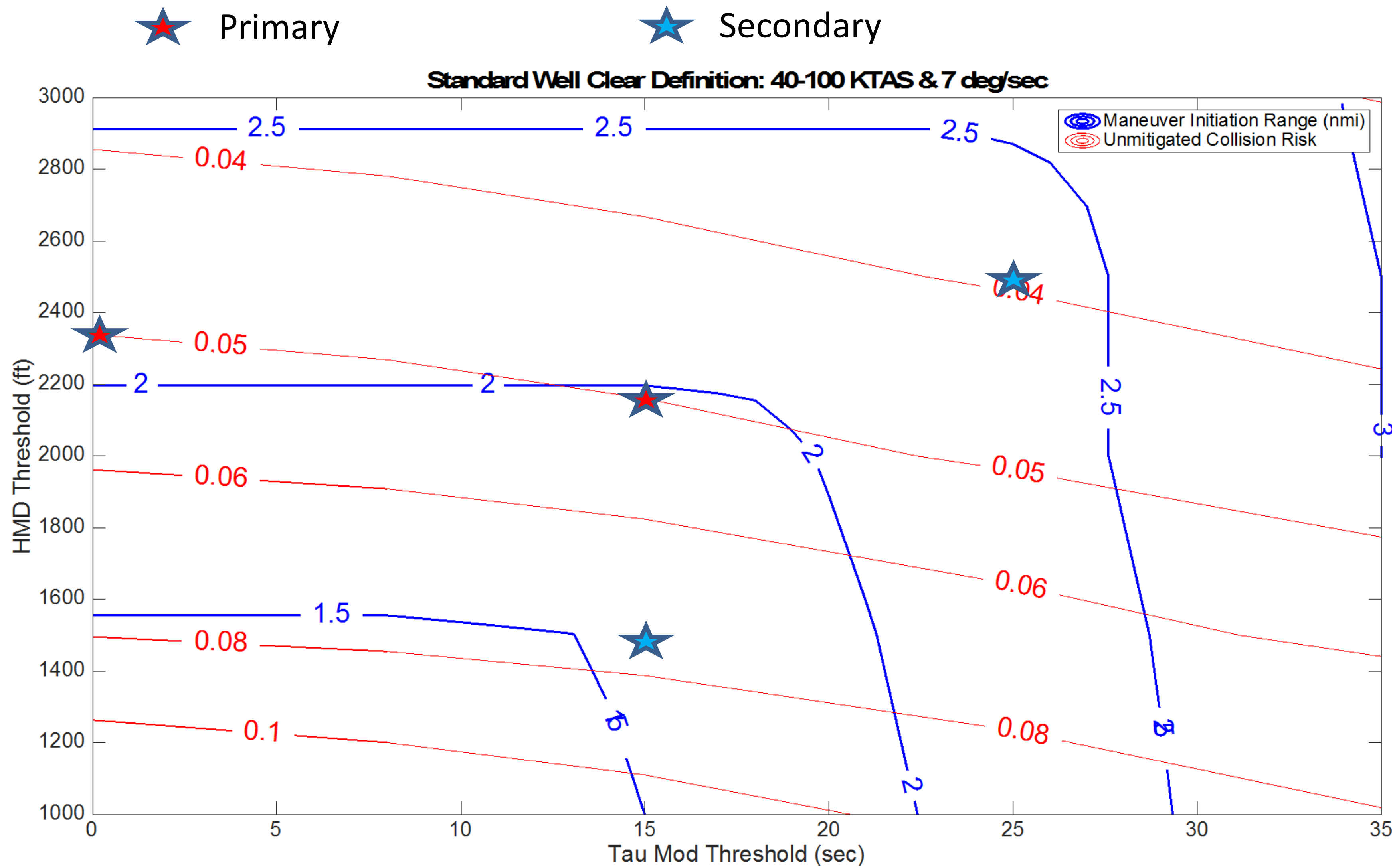
Approach

- Evaluate the alerting performance as a function of the surveillance volume
  - For each DWC
  - ACES-generated encounters
  - May inject sensor uncertainties
- Answer questions such as
  - What surveillance volume would allow enough alerting time for maintaining DWC?
  - How do results vary among candidate DWCs?
  - How do sensor uncertainties degrade alerting performance?

Independent Variables

- Four candidate DWCs (2 primary and 2 secondary)
  - Different horizontal parameters; same vertical (450 ft)
- Sensor surveillance volume
  - Range, bearing, and elevation
- Sensor uncertainties (on/off): a lower priority item
  - If on, co-altitude treatment (on/off)

Candidate DWCs

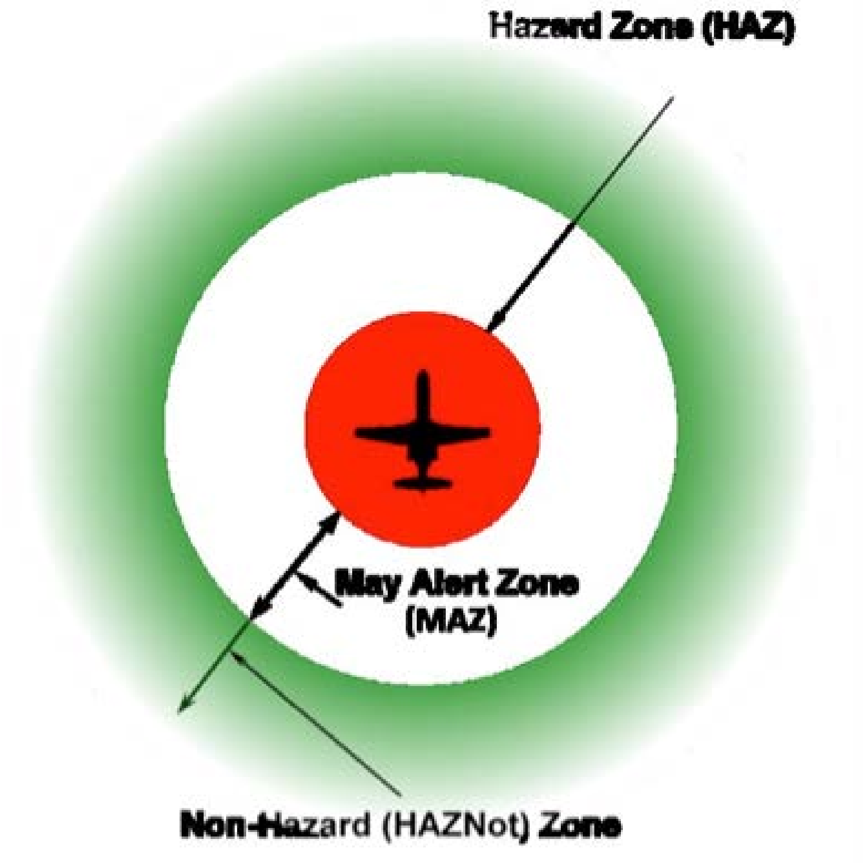


Performance Metrics

- Open-Loop Metrics for each alert type
  - Average time of alert
    - Up to LoDWC
    - Up to WC bands saturation
  - Probability of late alert
  - Probability of missed alert

Hazard Zone Definition

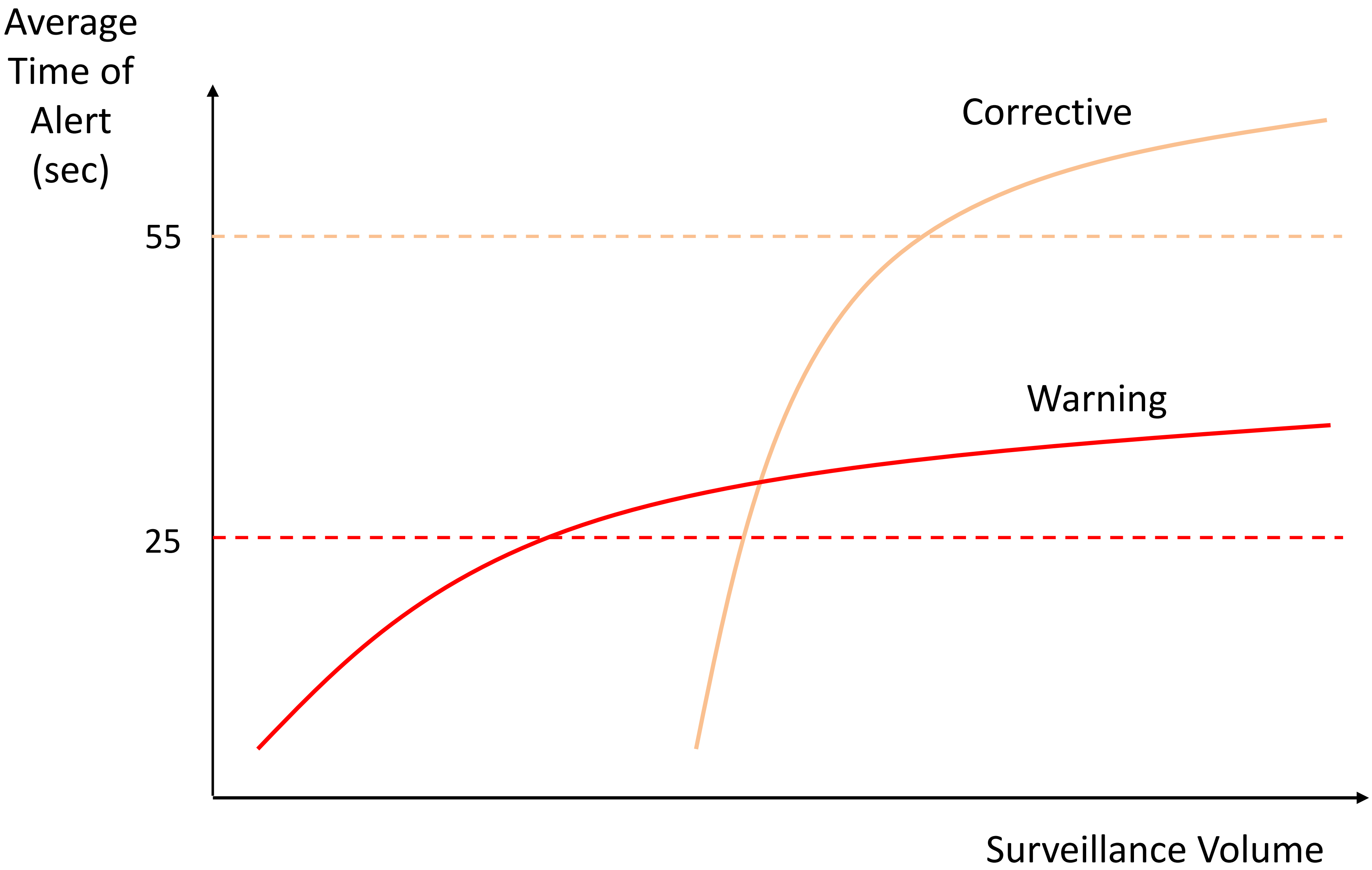
- Hazard Zone (HAZ) depends on the DWC
  - Set HAZ for Corrective and Warning alert types to the DWC itself
  - Set HAZ for Preventive alert type to the DWC but with 700 ft altitude separation
- Non-Hazard Zone (HAZNot) less relevant as sensor requirements drive the maximum alerting zone



Alerting Parameters

- Detect and AvoID Alerting Logic for Unmanned Systems (DAIDALUS) as reference DAA algorithm
- DAIDALUS allows buffers around the DWC for alerting to account for maneuvers and sensor uncertainties
- Set the buffers to be alert-type specific but independent of DWC definitions
  - For example, add 3000 ft horizontal buffer to each DWC

Hypothesis

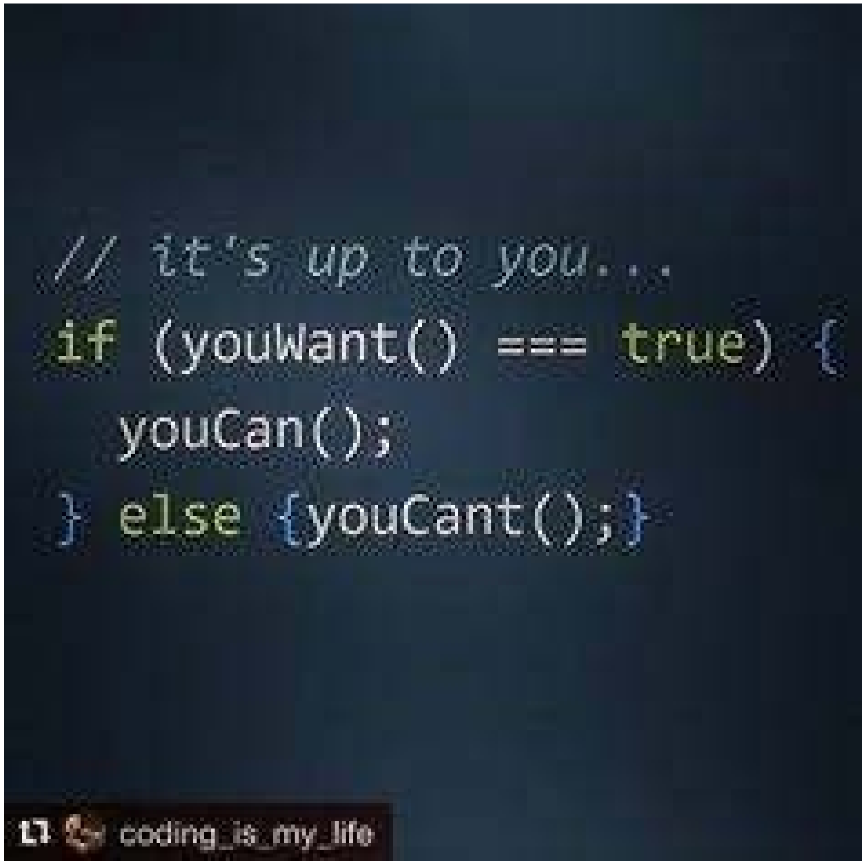


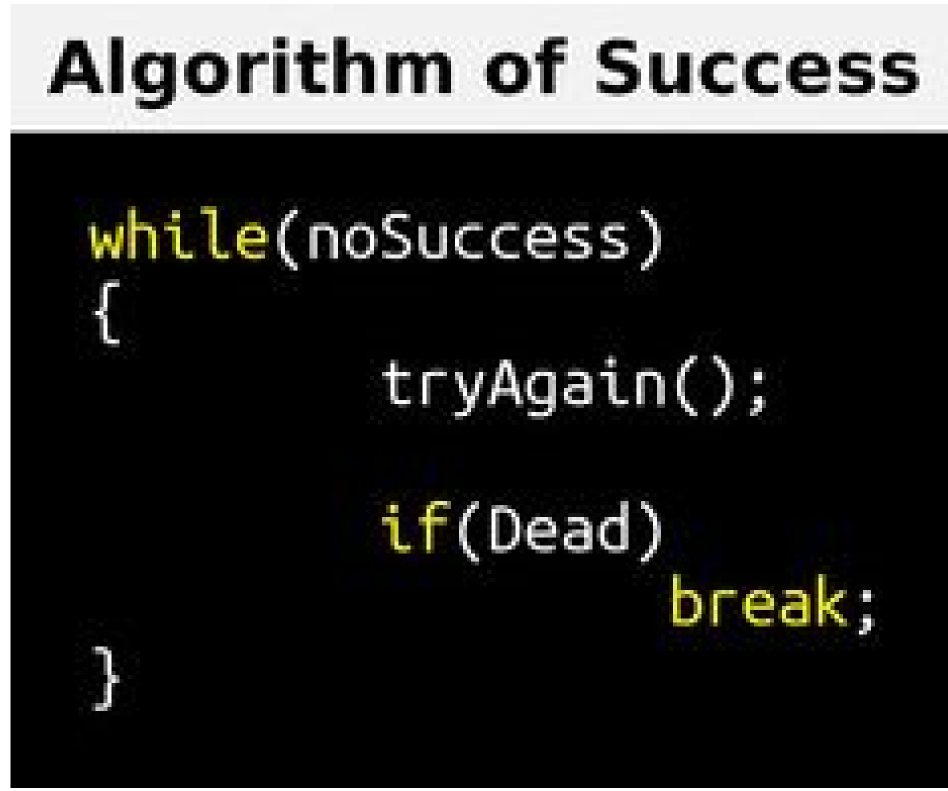
Average
Time of
Alert
(sec)
55
25
Corrective
Warning
Surveillance Volume

Related Research Tasks

- Closed-loop simulations using candidate DWCs for (1) low C-SWaP only; and (2) Phase 1 UAS (Aug. 2018)
  - Safety metrics such as mitigated P(NMAC|LoWC), risk ratio, etc.
  - Phase 1 alerting timeline
  - Simple pilot response model
  - Lincoln Lab on (1) and Cal Analytics on (2)
- HITL for low C-SWaP (Nov. 2018)
- Fast time simulation 3 (Jun. 2019)

We Will Get There!





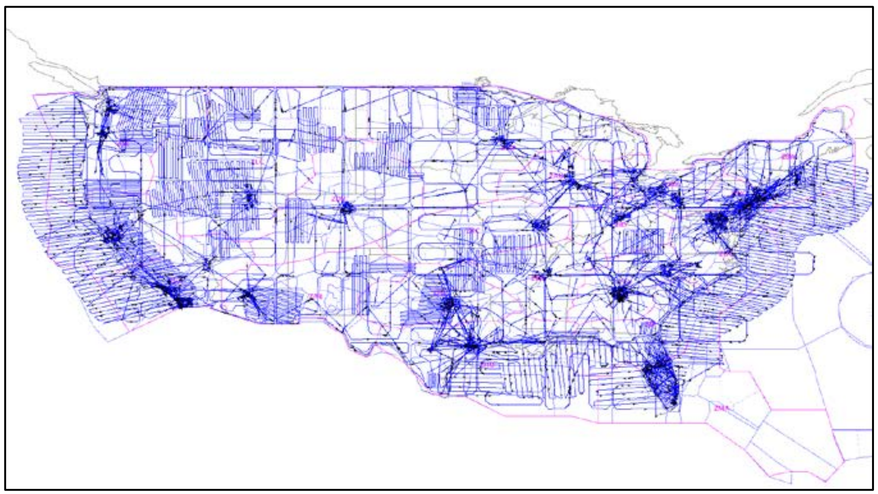
Backup Slides

Parameters for DAA Alerting Requirements

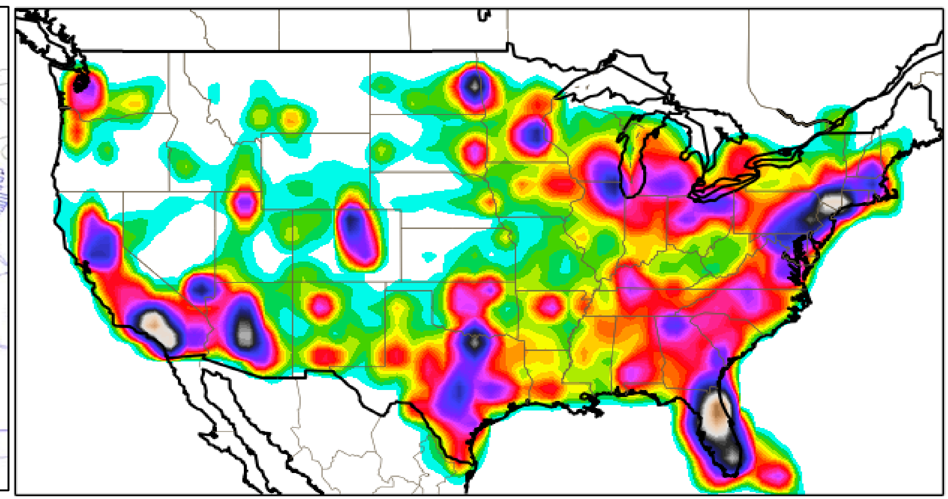
Alert Type →		Preventive Alert	Corrective Alert	Warning Alert
Alert Level →		Caution	Caution	Warning
Hazard Zone	τ^*_{mod} (Seconds)	35	35	35
	DMOD and HMD* (Feet)	4,000	4,000	4,000
	h^* (Feet)	700	450	450
Hazard Zone Alert Times	Minimum Average Time of Alert (Seconds)	55	55	25
	Late Threshold (THR_{Late}) (Seconds)	20	20	15
	Early Threshold (THR_{Early}) (Seconds)	75	75	55

ACES Encounters Considered

- 3.3 million encounters
  - between projected UAS trajectories and recorded VFR traffic from 21 days in year 2012
  - Cooperative aircraft regarded as surrogates of non-cooperative
- About 60% of the encounters are considered “low C-SWaP”
- 708 NMACs (for low C-SWaP)
- Number of LoWCs varies



UAS

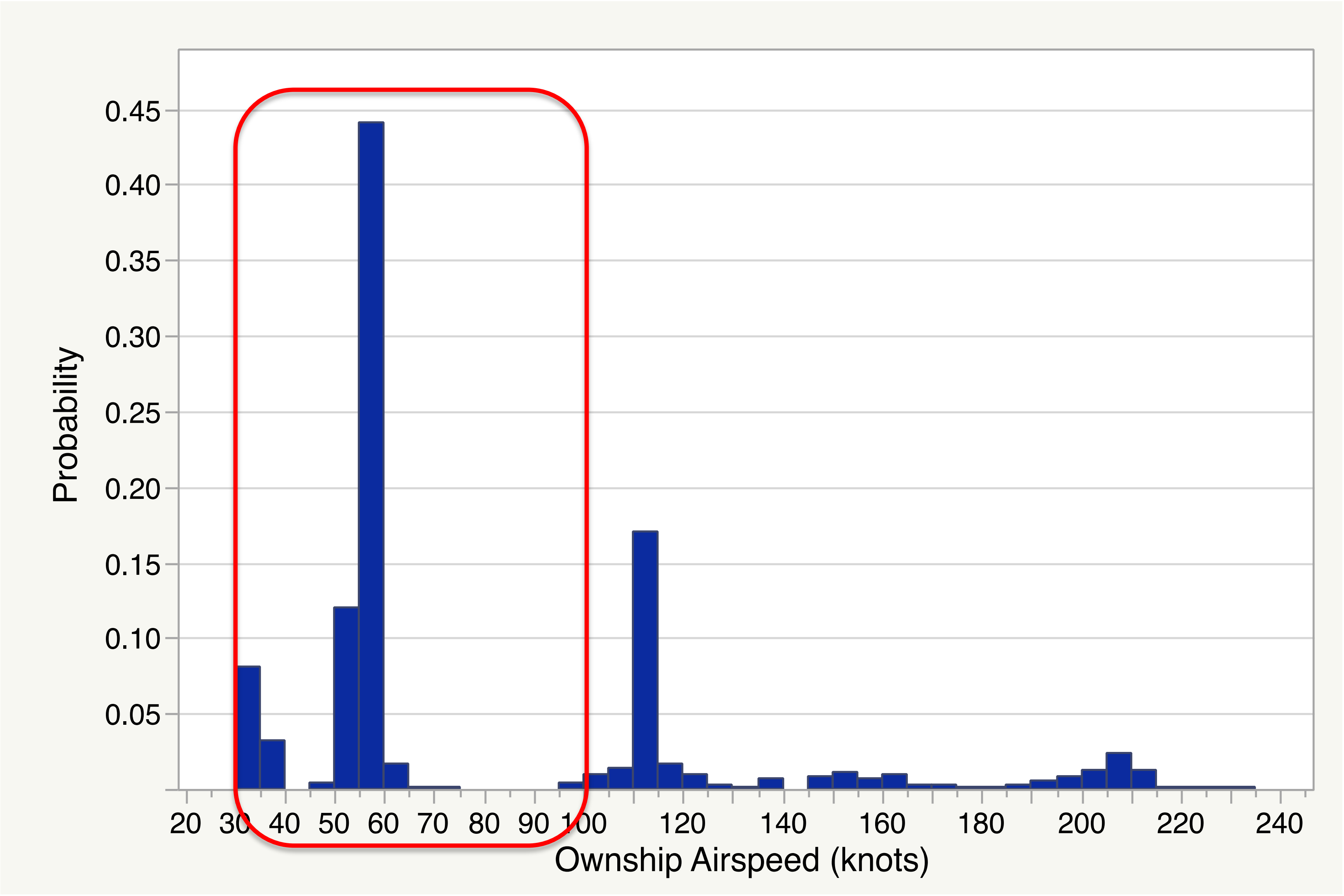


VFR

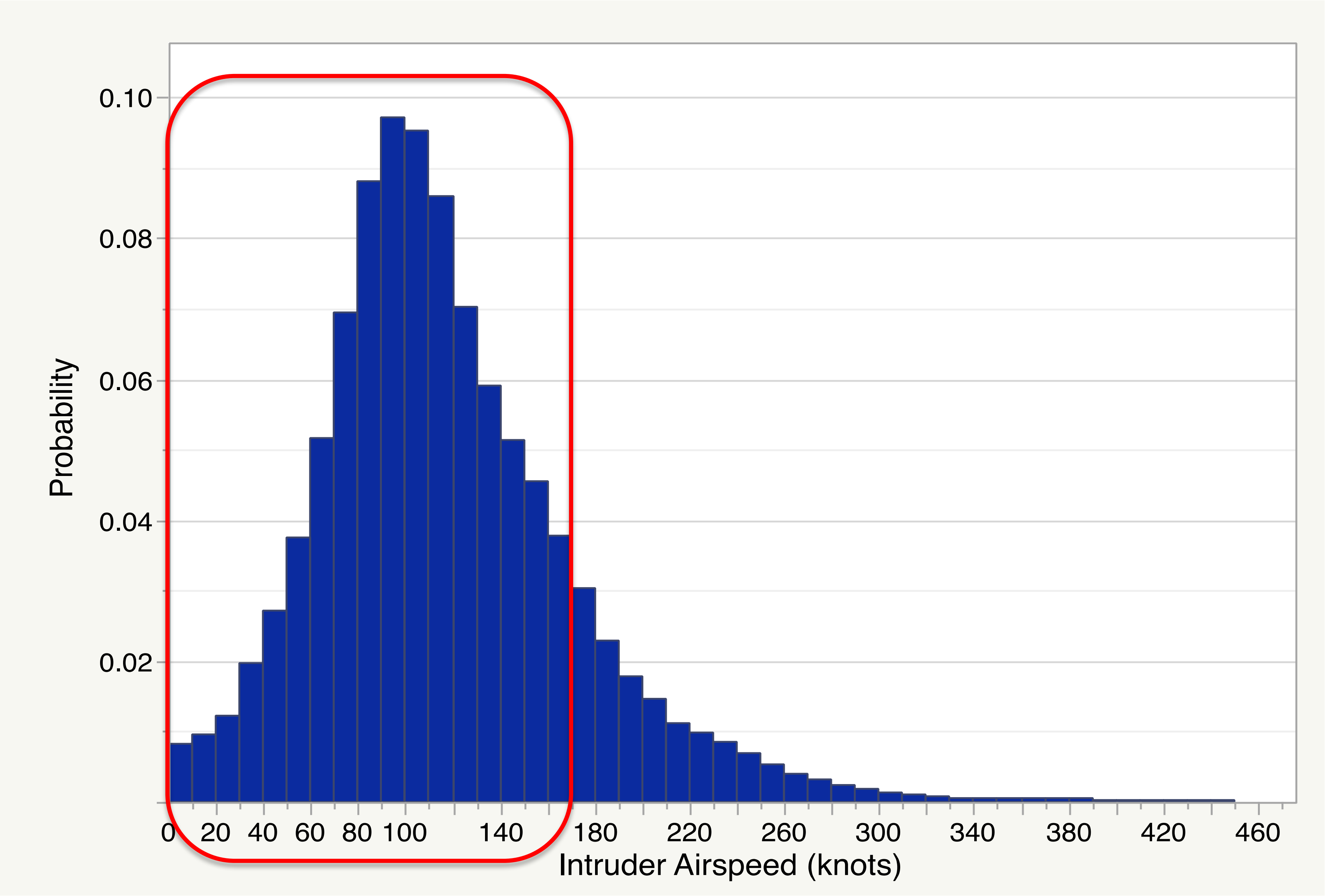
UAS Missions

Number	Mission Types	Airspace	UAS Group	Cruise Altitude	Cruise Speed (KTAS)	Flight Pattern
1	Aerial Imaging and Mapping	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, E, and G (including Mode C Veil) with Class B or C transition	Aerosonde Mk 4.7	3000 ft. AGL	44 to 51	Radiator-grid pattern or circular pattern
2	Air Qualtiy Monitoring	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, E, and G (including Mode C Veil) with Class B or C transition	Shadow-B (RQ7B)/NASA Sierra	4k, 5k, and 6k ft AGL	74 to 89	Radiator-grid pattern
3	Airborne Pathogen Tracking	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, E, and G (including Mode C Veil) with Class B or C transition	Shadow-B (RQ7B)/NASA Sierra	3,000 ft., 5,000 ft. and 10,000 ft. AGL	72 to 97	Radiator-grid pattern
4	Flood Inund. Mapping	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, Mode C Veil, E, and G	Aerosonde Mk 4.7	4,000 ft. AGL	46 to 51	Grid pattern
5	Flood Stream Flow	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, Mode C Veil, E, and G	Aerosonde Mk 4.7	4,000 ft. AGL	46 to 51	Grid pattern and/or along stream direction
6	Law Enforcement	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, E, and G (including Mode C Veil) with Class B or C transition	Aerosonde Mk 4.7	3,000 ft. AGL	44 to 51	Three types of pattern: 1) grid pattern, 2) random, 3) outward spiral
7	Point Source Emission	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, Mode C Veil, E, and G	Shadow-B	3,000 ft. AGL	72 to 80	Grid pattern and/or along stream direction
8	Spill Monitoring	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, Mode C Veil, E, and G	Shadow-B/Sierra	3,000 ft. to 13,000 ft. AGL	72 to 93	Up and down-wind flights in a radiator-grid pattern, Round-the-clock
9	Tactical Fire Monitoring	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, E, and G (including Mode C Veil) with Class B or C transition	ScanEagle/Shadow-B	3,000 ft. AGL	72 to 75	Circular flight path following the perimeter of a wildfire
10	Traffic Monitoring	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, E, and G (including Mode C Veil) with Class B or C transition	Shadow-B	1,500 ft. AGL	58 to 84	Geo-spatial monitoring flight path
11	Wildlife Monitoring	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, Mode C Veil, E, and G	Aerosonde Mk 4.7	3,000 ft. AGL	44 to 51	Radiator-grid pattern
12	News Gathering	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, E, and G (including Mode C Veil) with Class B or C transition	Aerosonde Mk 4.7	1,500 ft. to 3,000 ft. AGL	44 to 51	Random-path: e.g., police-chase; Circular orbit:

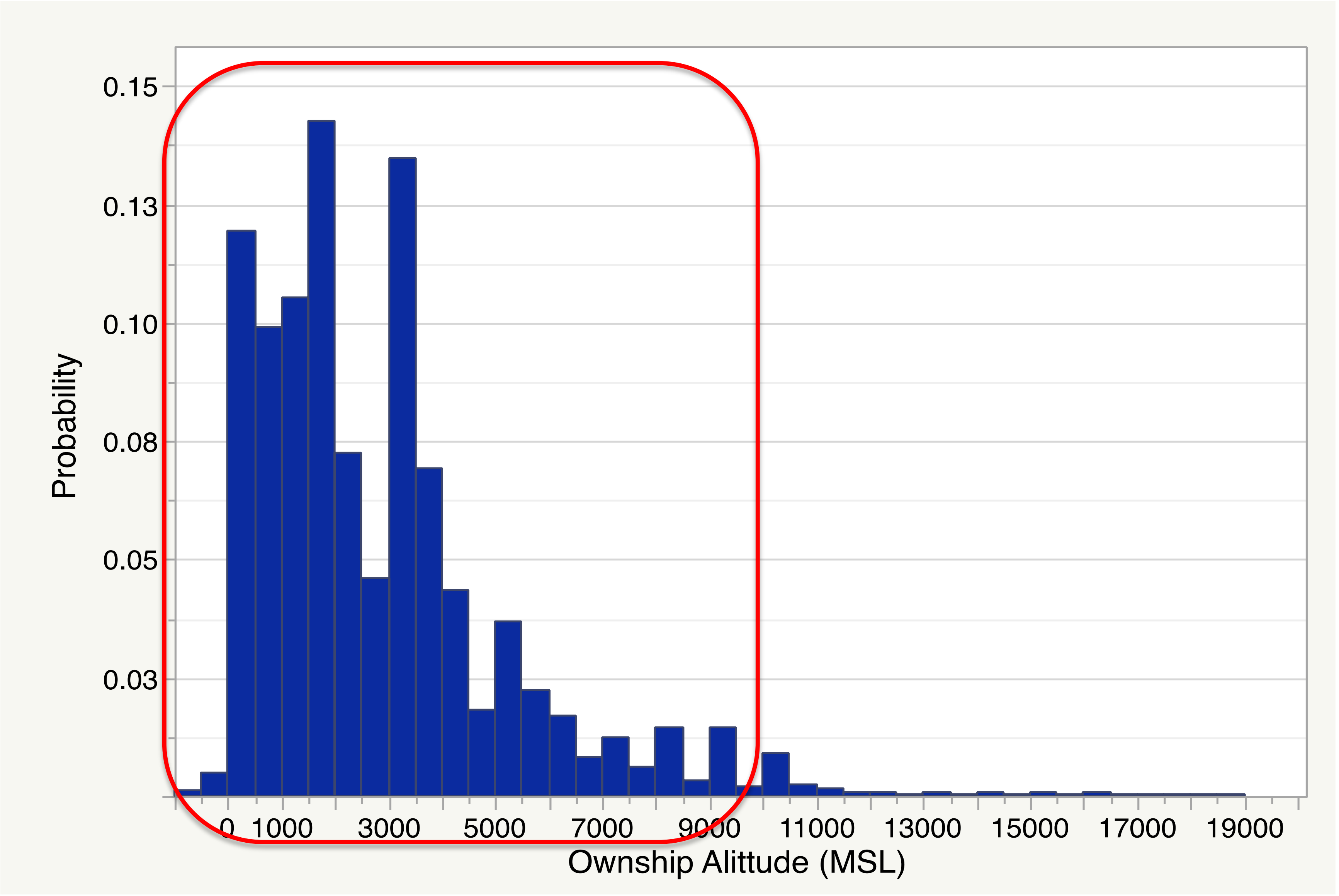
Speed Distribution of Ownship



Speed Distribution of Intruder



Altitude Distribution of Ownship



Altitude Distribution of Intruder VFR Aircraft