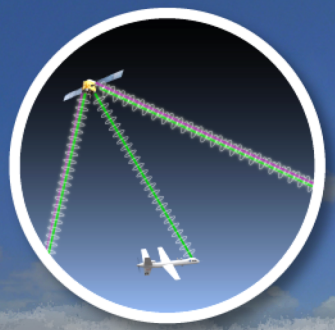

SC-228 Low SWAP DAA Requirements Development

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Low Size, Weight, and Power (SWaP) Sensors

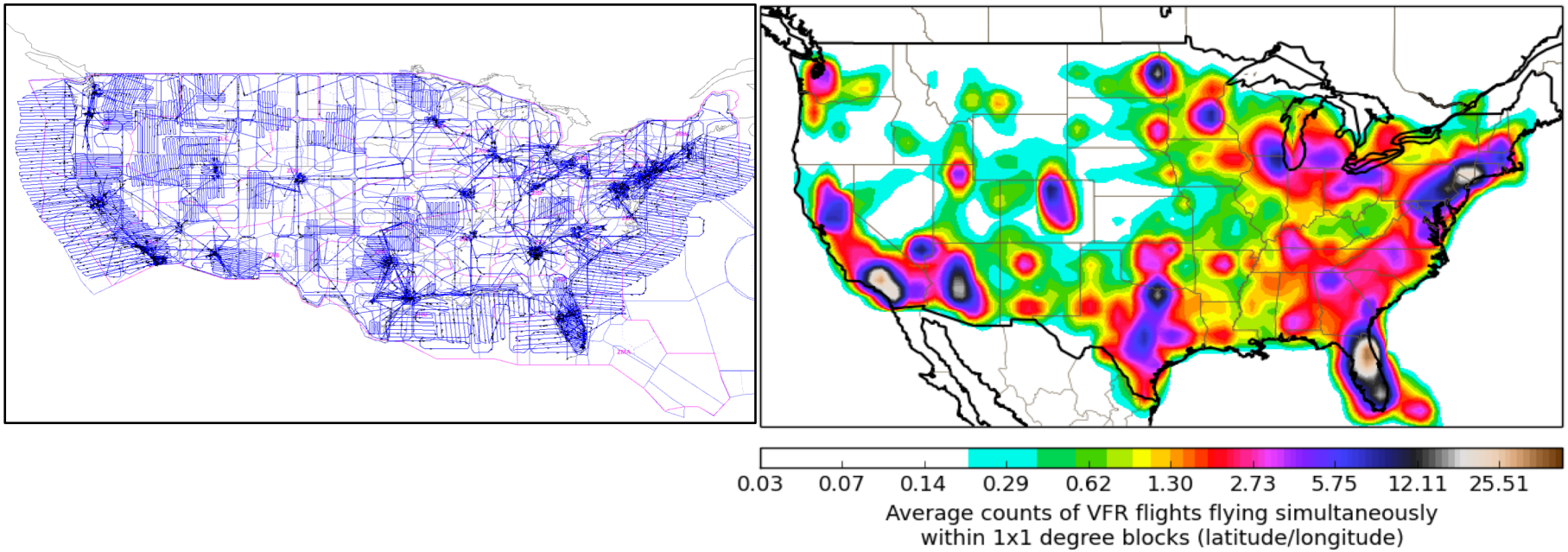
- Gap in SC-228 Phase 1 DAA MOPS (DO-365)
  - ADS-B and active surveillance are fairly low SWaP
  - Radar consumes much power (> 1000 W) and is heavy (>60 lbs), making it unsuitable for many UAS operations
- Low SWaP sensors considered in Phase 2 work
  - Radar
  - EO/IR
- Low SWaP work inherits most of the operational assumptions of DAA MOPS, such as
  - Extended operations in airspace classes D, E (non-terminal), or G (non-terminal), or
  - Transit operations in classes B and C
  - Above 500 ft AGL
- UA performance assumptions for low SWaP operations
  - Mission speed range 40 to 110 KTAS
  - Capability of turning at a rate 7 degrees/sec

Non-Cooperative DAA Well Clear (DWC)

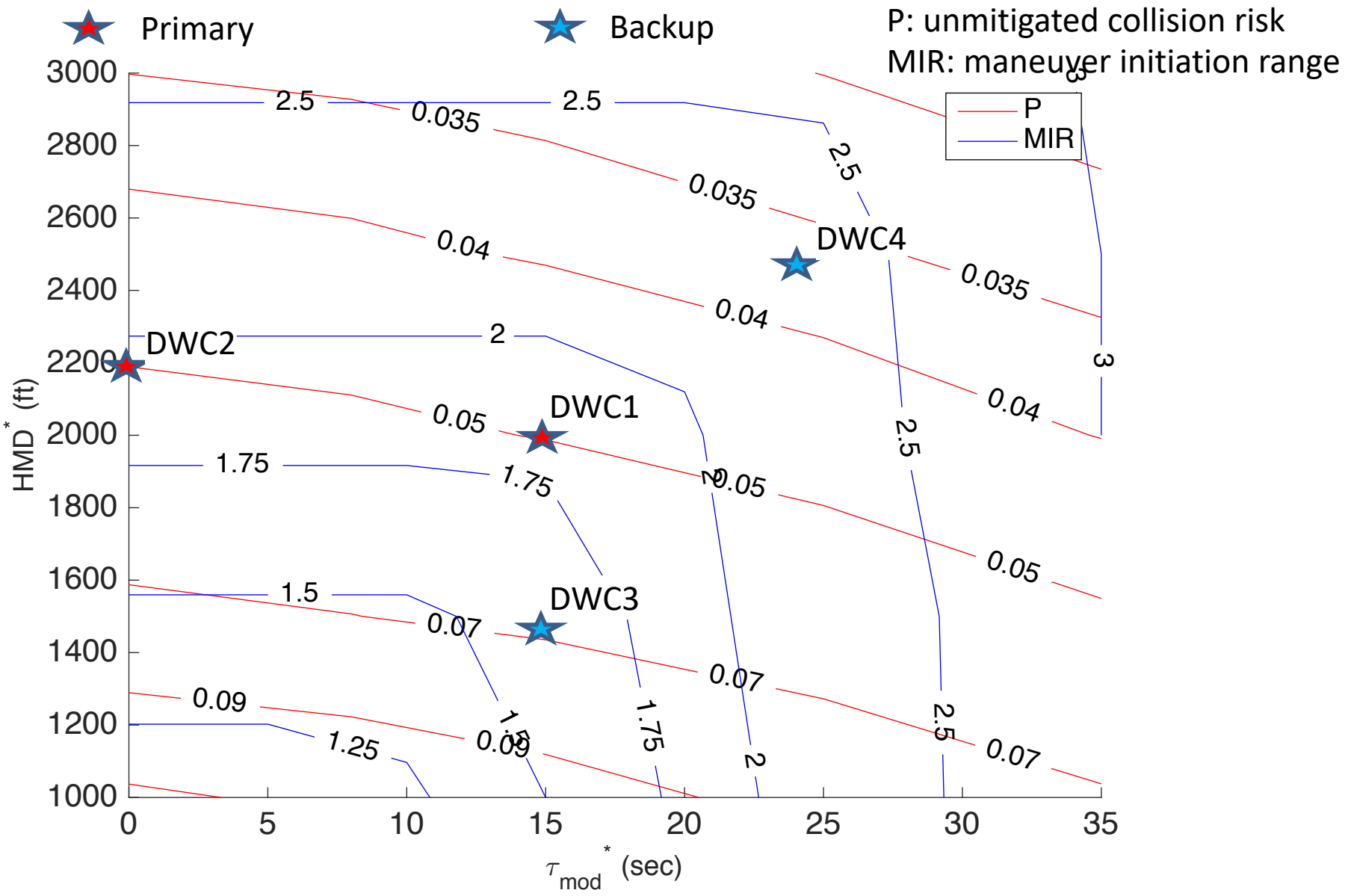
- Phase I DWC was largely driven by TCAS II interoperability considerations, which are not a factor for encounters with non-cooperative aircraft
- Phase 1 DWC is large and deemed very safe; however, the same level of safety might be achieved with a smaller DWC
- A smaller DWC may mitigate difficulty for UAS with Low SWaP sensors to remain well clear
- Non-cooperative aircraft
  - Assumed to fly at 170 KTAS (95 percentile according to MIT Lincoln Lab's study) or less
  - Predominantly in classes E and G below 10,000 ft MSL

NASA's Encounter Set

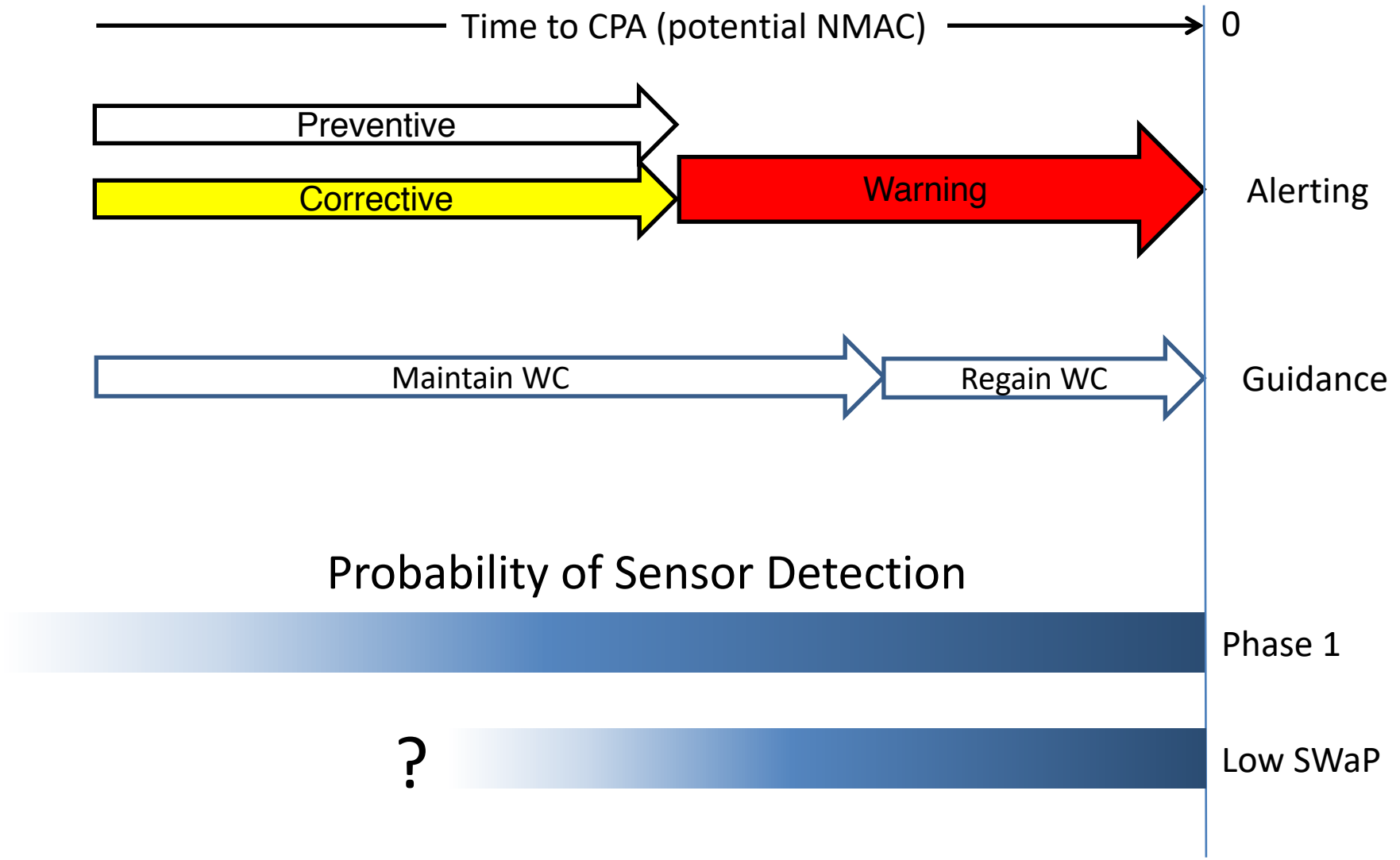
- 17,100 hours of projected UAS mission trajectories in one day overlaid with each of 21 days' radar recorded visual flight rules (VFR) traffic
- Low SWaP encounters are a subset



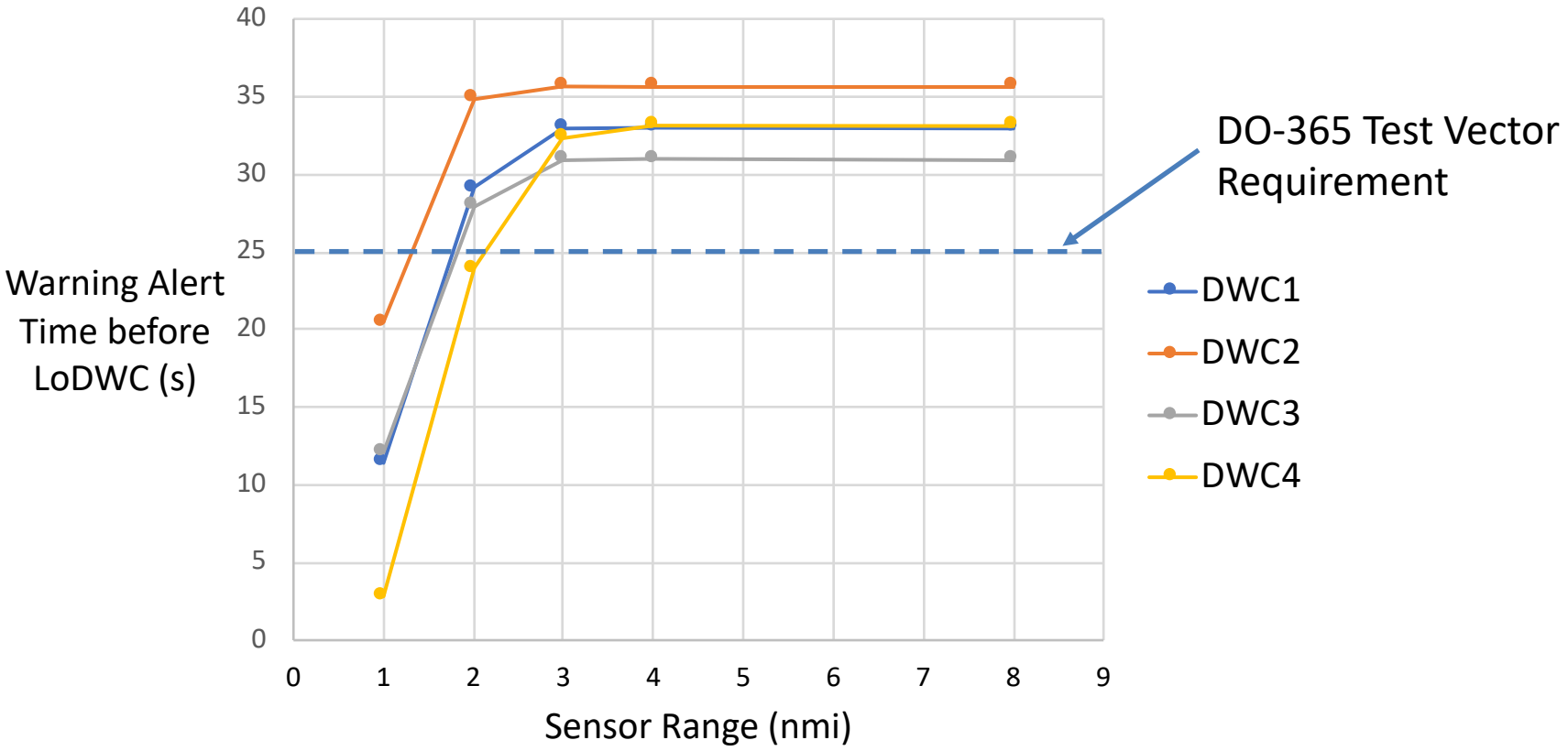
Candidate DWCs



Alerting and Guidance Timeline

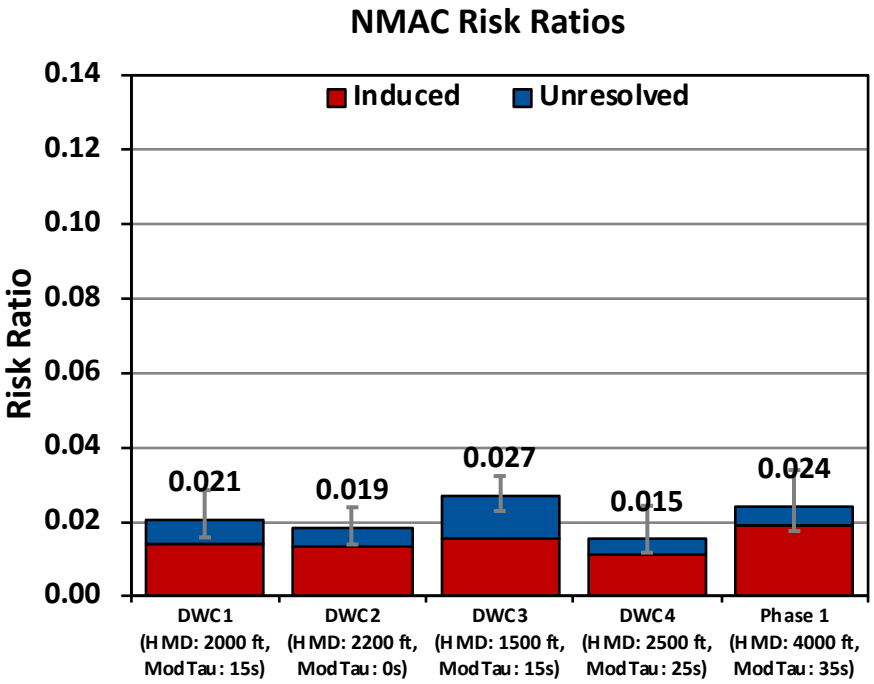


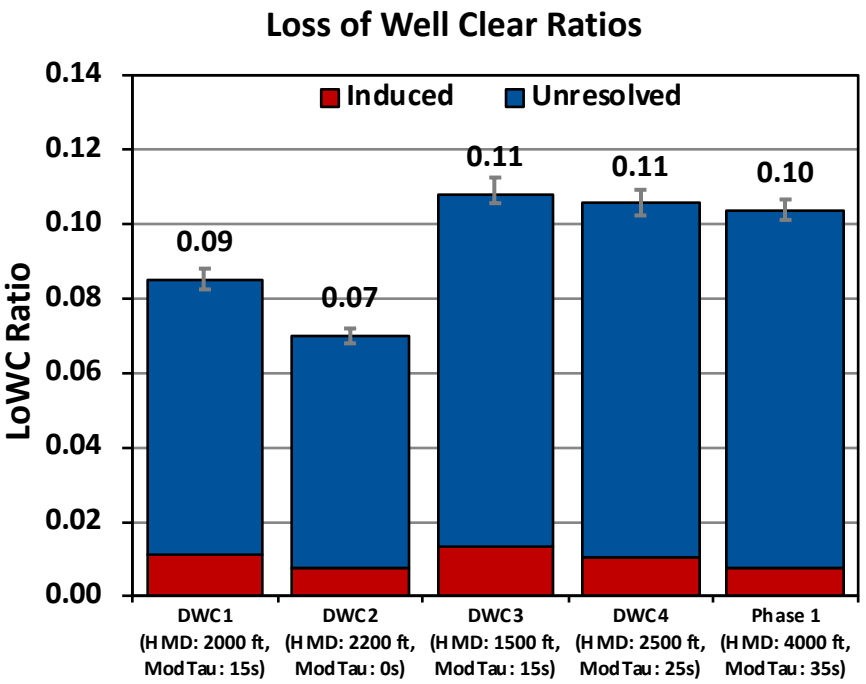
Average Warning Alert Time before LoDWC



	DWC1	DWC2	DWC3	DWC4
HMD*	2000 ft	2200 ft	1500 ft	2500 ft
τ_{mod}*	15 s	0 s	15 s	25 s

Safety Ratios





- Risk ratios are comparable among the DWC candidates
  - No statistically significant difference for risk ratios
- DWC1 and DWC2 have the lowest loss of well clear ratios

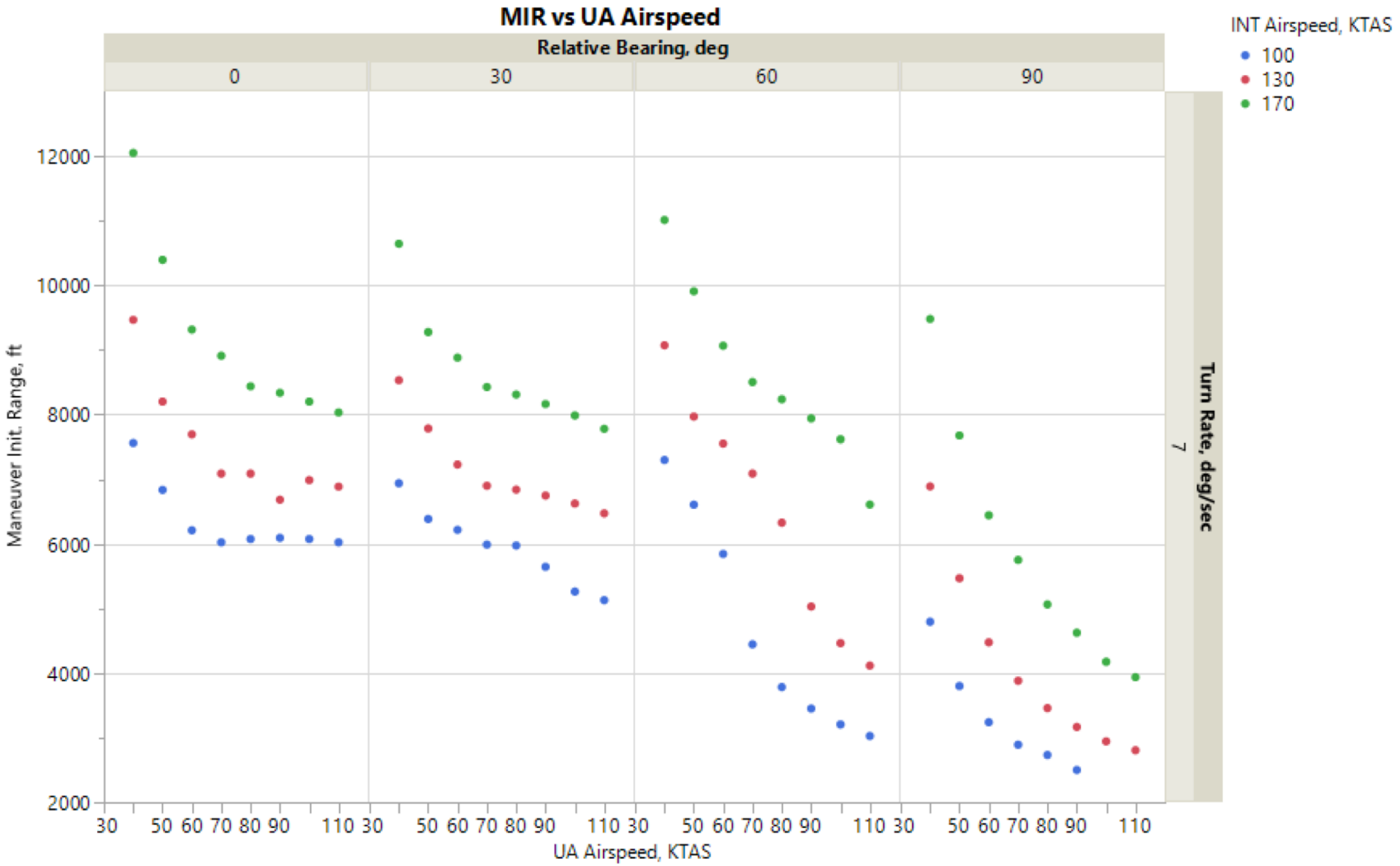
Risk ratios largely independent of DWC definition

Non-Cooperative DAA Well Clear (DWC)

- On March 6th, 2019, SC-228 selected a Detect-and-Avoid (DAA) Well Clear (DWC) (previously referred to as DWC2) for non-cooperative aircraft for additional studies
  - The non-coop DWC and Phase 1 DWC yield comparable safety metrics such as the NMAC risk ratio and loss of DWC ratio
  - Simulations were based on
    - Truth aircraft states
    - Phase 1 pilot response model in a deterministic mode
    - Version 1.0 of the DAIDALUS algorithm

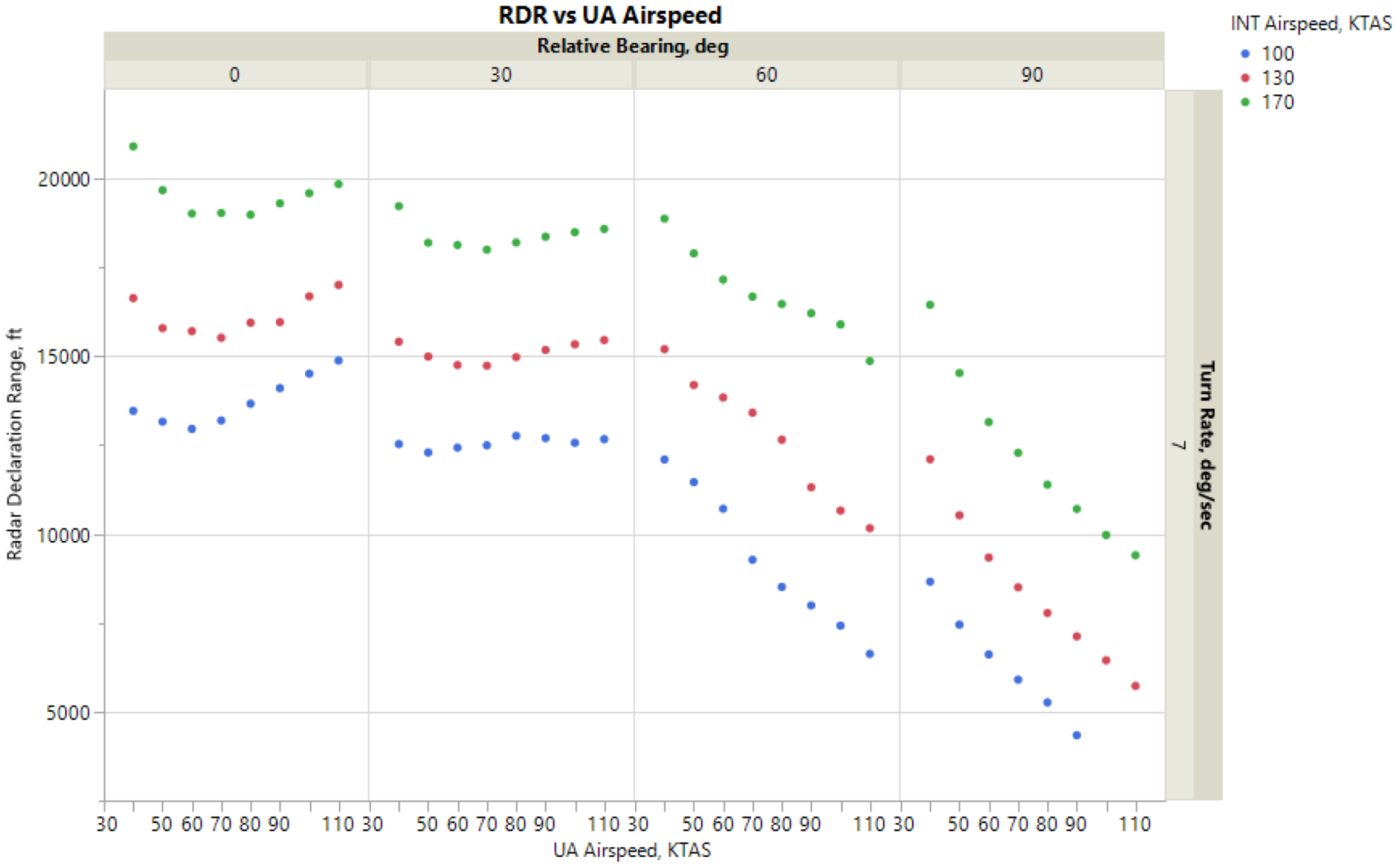
DWC	Γ_{mod} (sec)	HMD* (ft)	h* (ft)
Non-Coop	0 sec	2200 ft	450 ft
Phase 1	35 sec	4000 ft	450 ft

Maneuver Initiation Analysis



Radar Declaration Range

RDR = MIR + 25 seconds alerting time converted distance



Current Activities

- NASA/Honeywell Flight Test 6 (Aug. – Dec. 2019)
- NASA closed-loop fast time simulation with sensor uncertainties
- Low SWaP human-in-the-loop simulation (Sep. 2019)
- Low SWaP sensor surveillance volume analysis (Jul. to Dec. 2019)
- DAA closed-loop simulation with an EO/IR sensor Lincoln Lab., May to Dec. 2019)
- Active surveillance omnidirectional antenna analysis (MIT Lincoln Lab., May to Dec. 2019)

Backup Slides

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 spirial
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 and Altitude of UAS and VFR Traffic