Alternative Surveillance Fast Time Simulation with Sensor Uncertainties and Mitigation

Gilbert Wu

Background

- On March 6th, SC-228 selected a Detect-and-Avoid (DAA) Well Clear (DWC) for non-cooperative aircraft (previously called DWC2) 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

- Investigate the effect of limited surveillance volume and realistic radar noise on DAA performance
- Evaluate the ability of the sensor uncertainty mitigation (SUM) feature of the DAIDALUS algorithm to improve DAA alerting and guidance

Fast Time Simulation Schedule

Simulation Type		Low C-SWaP Operations	Phase 1 Operations
Unmitigated	Truth Tracks	NASA Briefing Mar. 2019	NASA Briefing May 2019
	Noisy Tracks	NASA TBD	
Mitigated	Truth Tracks with a Simple Phase 1 Pilot Model	Lincoln Lab (LL) Briefing Mar. 2019	Cal Analytics (CAL) Briefing Mar. 2019
	Noisy Tracks with a Revised Pilot Model	NASA Oct. 2019	

- Sensor volume and uncertainties

  – Surveillance volume of three radar classes

  – Truth tracks vs. noisy tracks

- DAIDALUS

  – with SUM

  – without SUM

- Pilot response model

  – NASA revised model for low SWaP
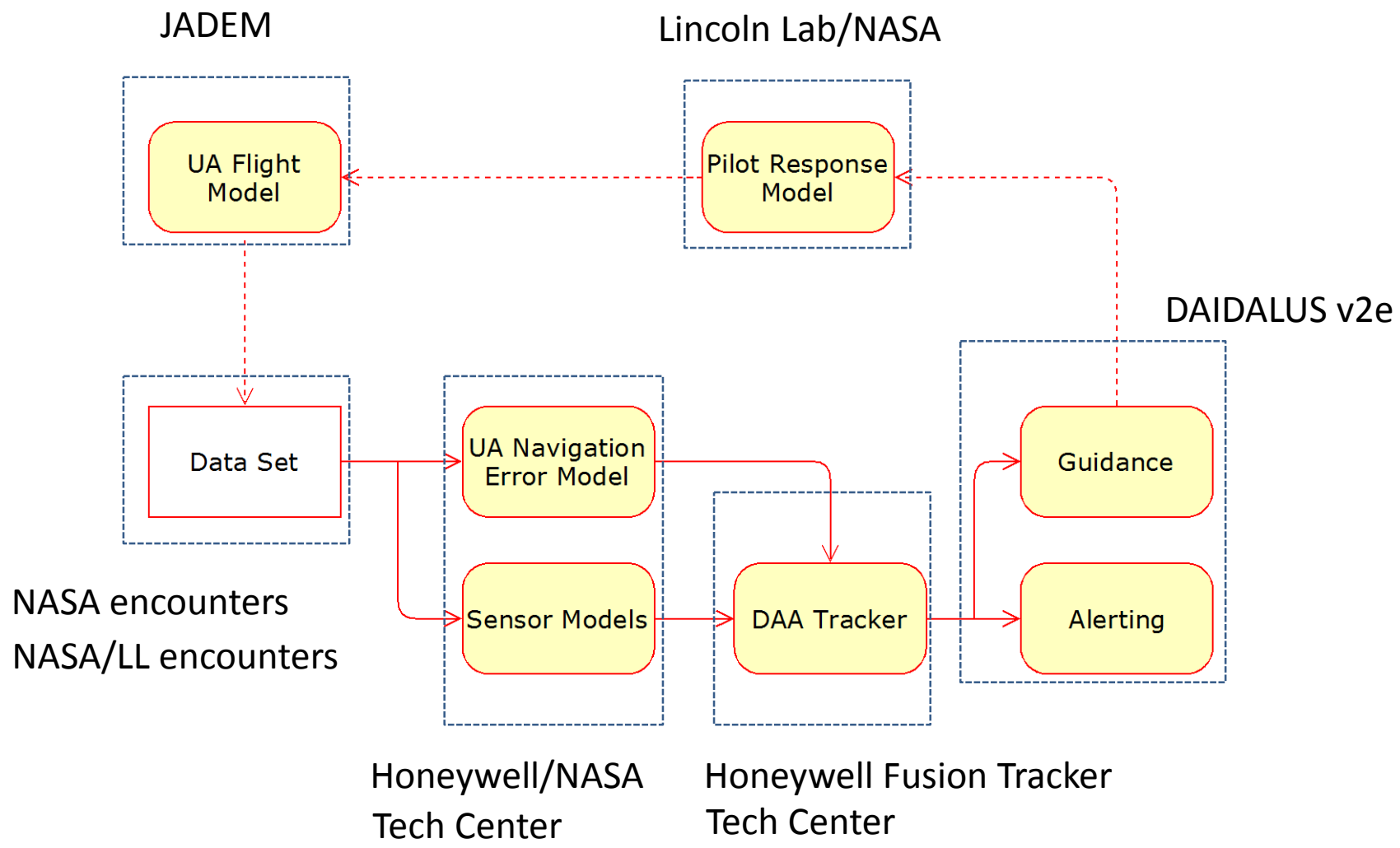
  – The Phase 1 Lincoln Lab model

- Safety Metrics

  - Near-mid-air-collision (NMAC) risk ratio

  - Loss of DWC (LoDWC) ratio

  - Severity of LoDWC

- Operational suitability metrics

  - Alert ratio

  - Maneuver duration time

  - Alert stability

  - …

Simulation Architecture

Challenges

- Low SWaP radar model parameters
  - NASA flight test 5 radar data were not enough for calibrating the model
  - NASA flight test 6 will not start data collection until late August
  - Mitigation: will use theoretical values obtained from Honeywell and rerun simulations later if necessary
- DAIDALUS SUM parameter tuning task delayed
  - NASA has just started looking into this due to other tasks taking precedence
  - A few issues in V2 were found and addressed just recently (March and April 2019)

Timeline

- June 2019:
  - Sensor model discussion with the M&S sub-working group
- July 2019
  - Pilot model discussion with the M&S sub-working group
  - Data collection
- October 2019
  - Results briefing
- December 2019
  - Additional results briefing

- NASA/Honeywell Flight Test 6 (Aug. – Dec. 2019)
- Low SWaP HITL (Sep. 2019)
- Low SWaP sensor surveillance volume analysis
  - Repeat Appendix B of DO-366 (AAG, Jul. – Oct. 2019): Maneuver initiation range analysis based on the non-cooperative DWC Repeat Appendices C and D of DO-366 (CAL, May -- Oct. 2019):
    - Probability of an Intruder Entering the Field of Regard within the Declaration Range
    - Validation of Radar Declaration Range (RDR) against DAA Alerting Requirements
- DAA closed-loop simulation with an EO/IR sensor (LL, May to Dec. 2019)
- Active surveillance omnidirectional antenna analysis (LL, May to Dec. 2019)
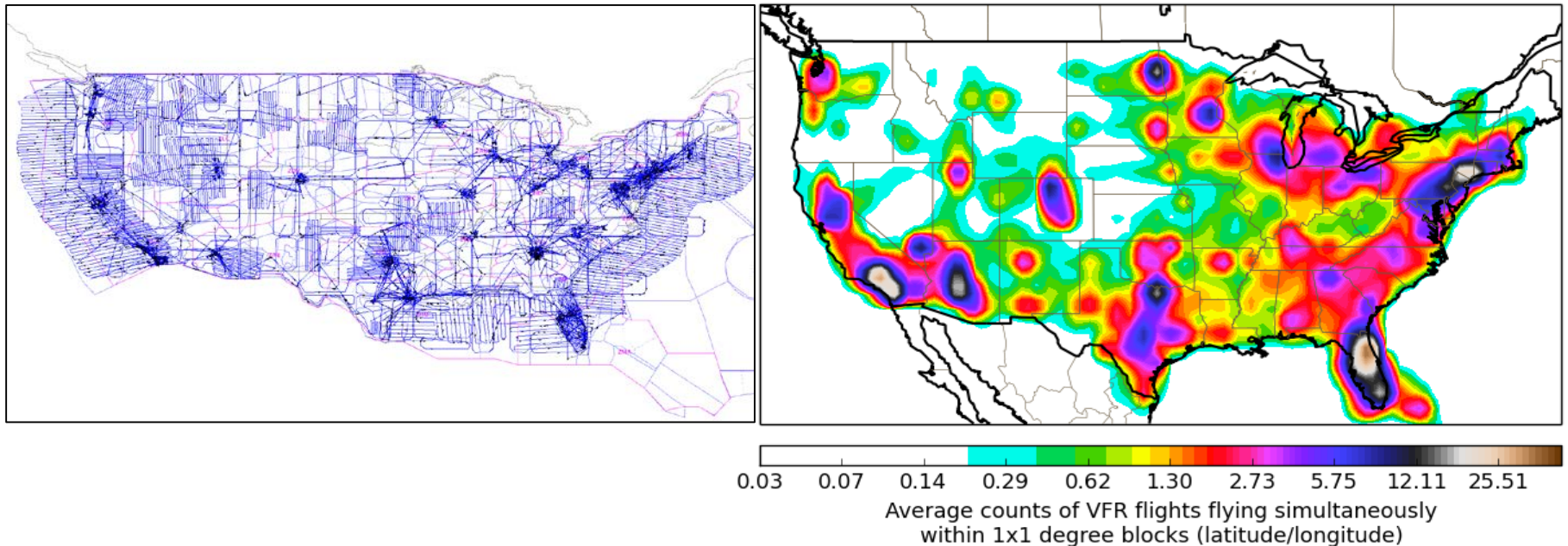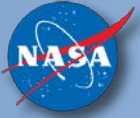
Backup Slides

- Alerting Performance Metrics

  - Average alert time

  - Late alert probability

  - Short alert

  - Missed alert probability

  - Correct required alert

  - Correct required non-alert

  - …

- 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

0.03   0.07   0.14   0.29   0.62   1.30   2.73   5.75   12.11   25.51

Average counts of VFR flights flying simultaneously
within 1x1 degree blocks (latitude/longitude)

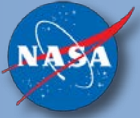| Number	Mission Types	Airspace	UAS Group	Cruise Altitude	Cruise Speed (KTAS)	Flight Pattern
1	Aerial Imaging and Mapping	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, E, and G (including Mode C Veil) with Class B or C transition	Aerosonde Mk 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:
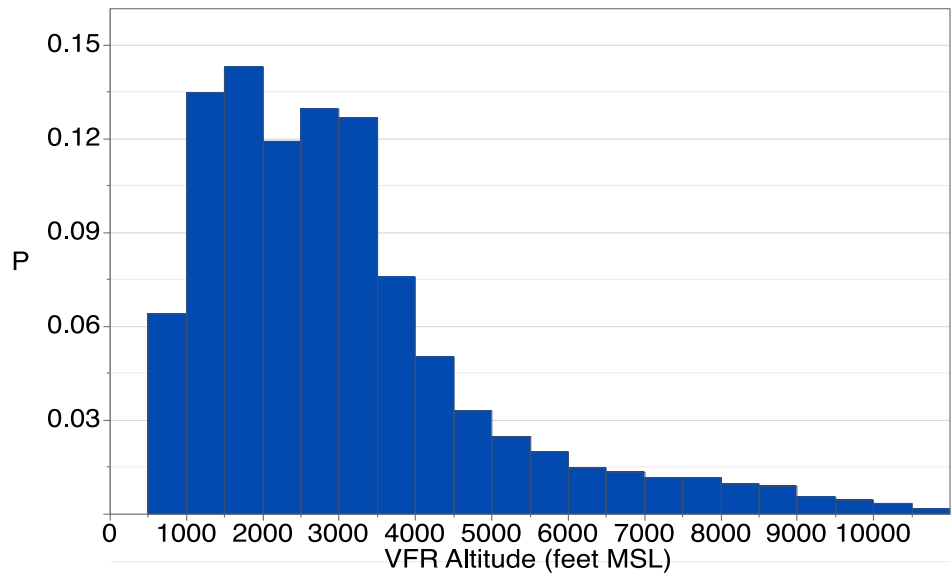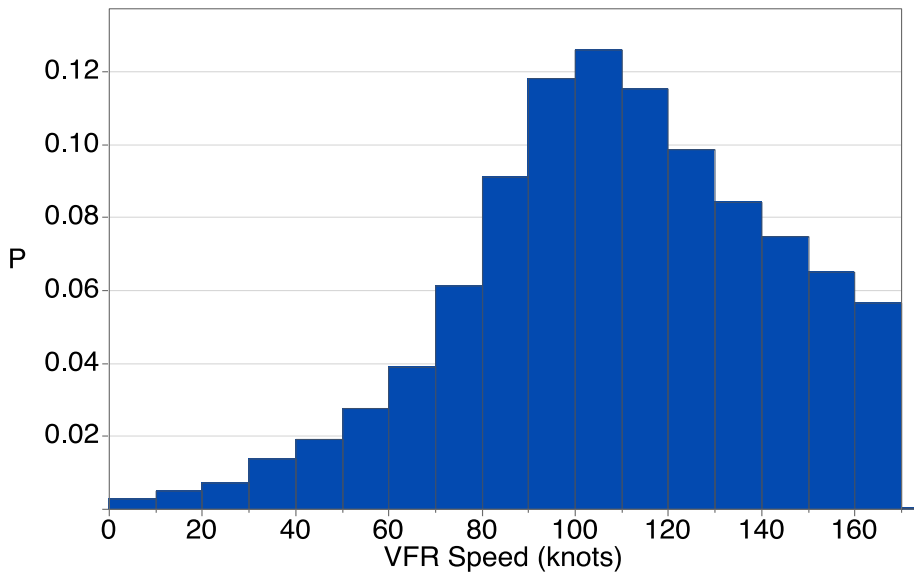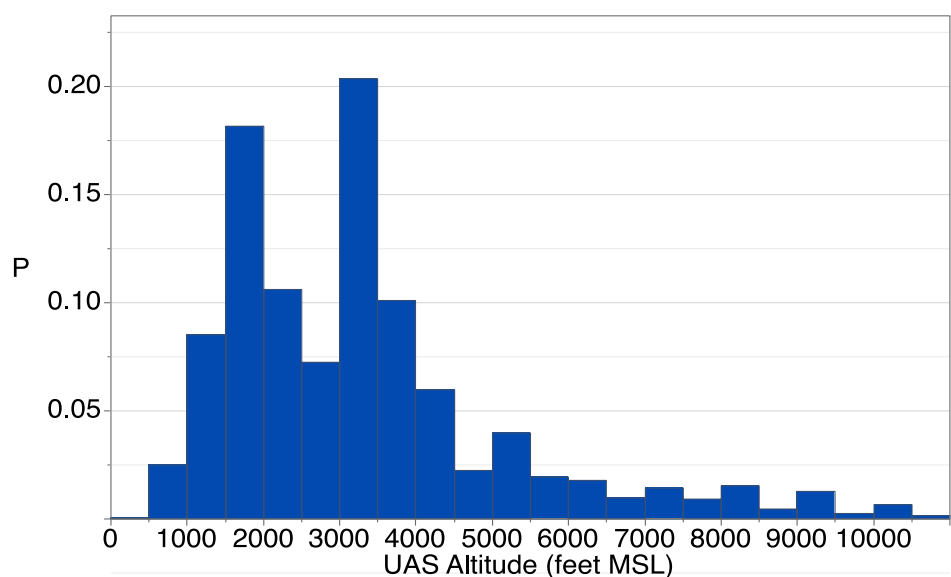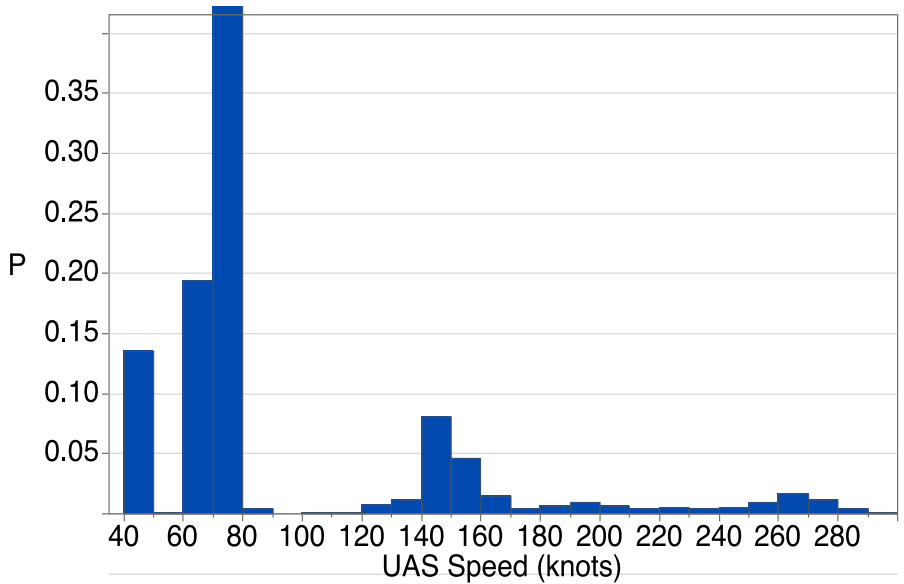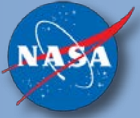
Encounter Statistics

- Total number of pairwise encounters with 21 days of traffic
  - 94,081

- Total number of NMAC: 505 Near Mid-Air Collisions

UA Speed Range (KTAS)	40 to 100 kts	100 to 150 kts	150 to 200 kts	200 to 291 kts
# Encounters	72667	9062	7040	5312

- Total number of LoDWCs
  - Non-coop DWC: 9958
  - Phase1 DWC: 24809

Number of LoDWC