



# Detect-and-Avoid Well Clear and Low SWaP Operations



Gilbert Wu



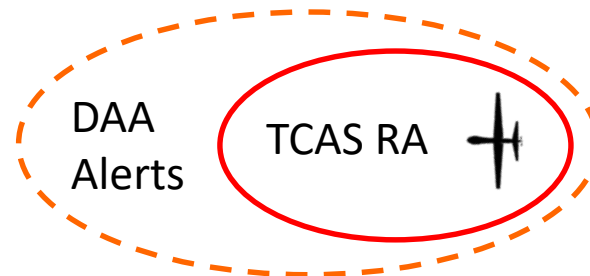
# Detect-and-Avoid (DAA) Well Clear

- DAA well clear (DWC) developed in SC-228 Phase 1 MOPS was largely driven by TCAS interoperability considerations
  - TCAS is not a factor for non-cooperative aircraft, i.e., aircraft without a functioning transponder
  - DWC is unnecessarily large for safety
- Phase 2 work seeks an alternative, smaller DWC for non-cooperative aircraft

non-cooperative aircraft



cooperative aircraft





# Low Size, Weight, and Power (SWaP) Sensor

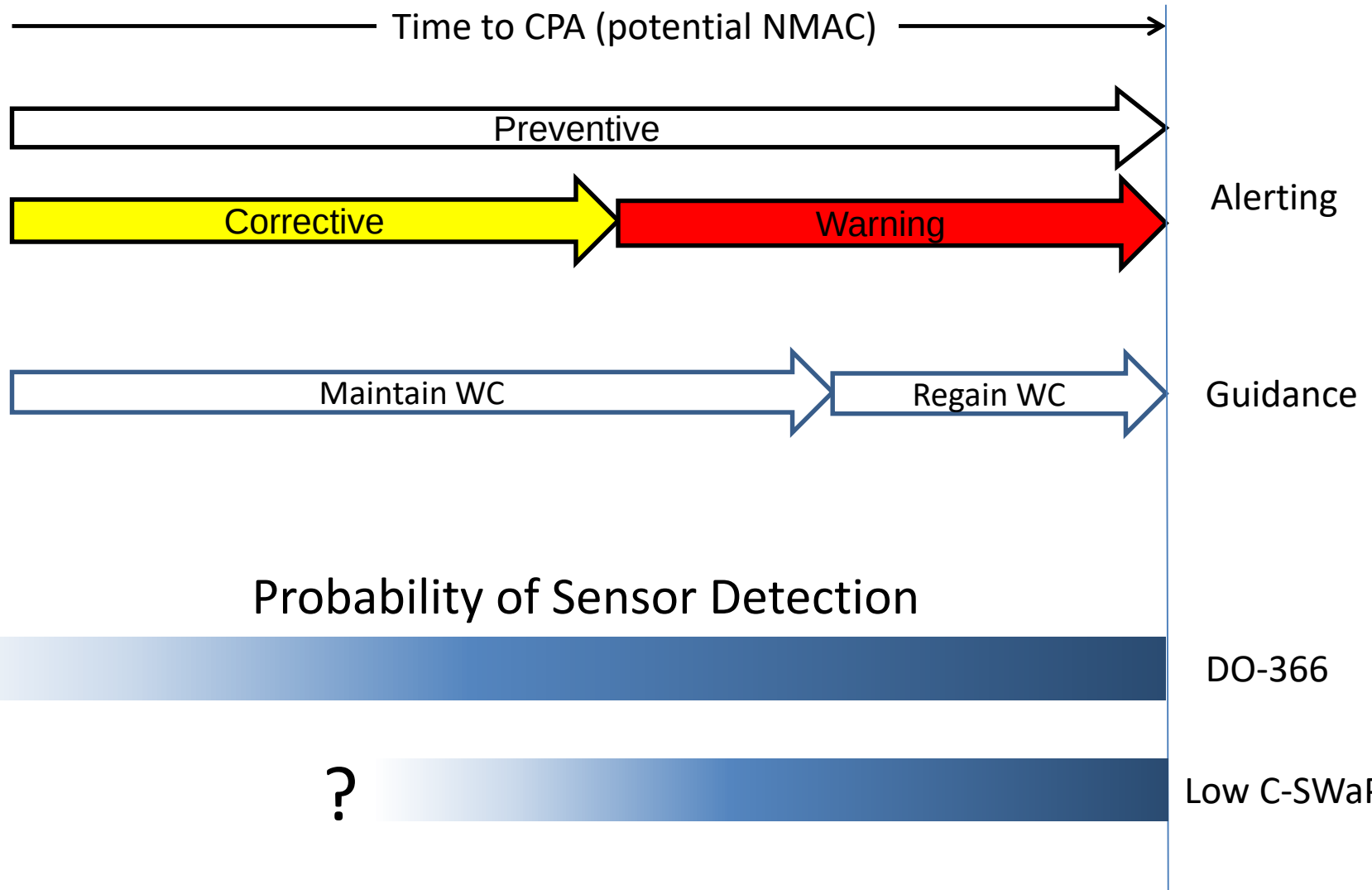
- Phase 1 air-to-air radar is high-power and high payload, not suitable for many UAS operations that have lower mission speeds and utilize smaller UAs
- Low SWaP sensor requirements developed at SC-228:
  - Air-to-air radar
  - Electro-Optical / Infrared (EO/IR)
- DAA performance considerations
  - Operational suitability metrics
  - Safety metrics
- Alternative DWC contributes to reducing the barrier for low SWaP sensors



- The DAA Subproject sought a partner to a cooperative agreement to
  - develop requirements for airborne low SWaP sensors
  - verify the interoperability with existing DAA requirements
  - verify pilot performance in human-in-the-loop simulations
  - validate/demonstrate the new technology with flight tests
- Request for Information in 2016, followed by Cooperative Agreement Notice
- **Honeywell International** was selected as partner
  - Honeywell provides low SWaP radar and aircraft integration support
  - NASA conducts flight tests to demonstrate integration of technology and inform the MOPS development
- HW POC: Jamal Hague
- NASA POC: Gilbert Wu



# DAA Alerting and Guidance



NMAC: near mid-air collision

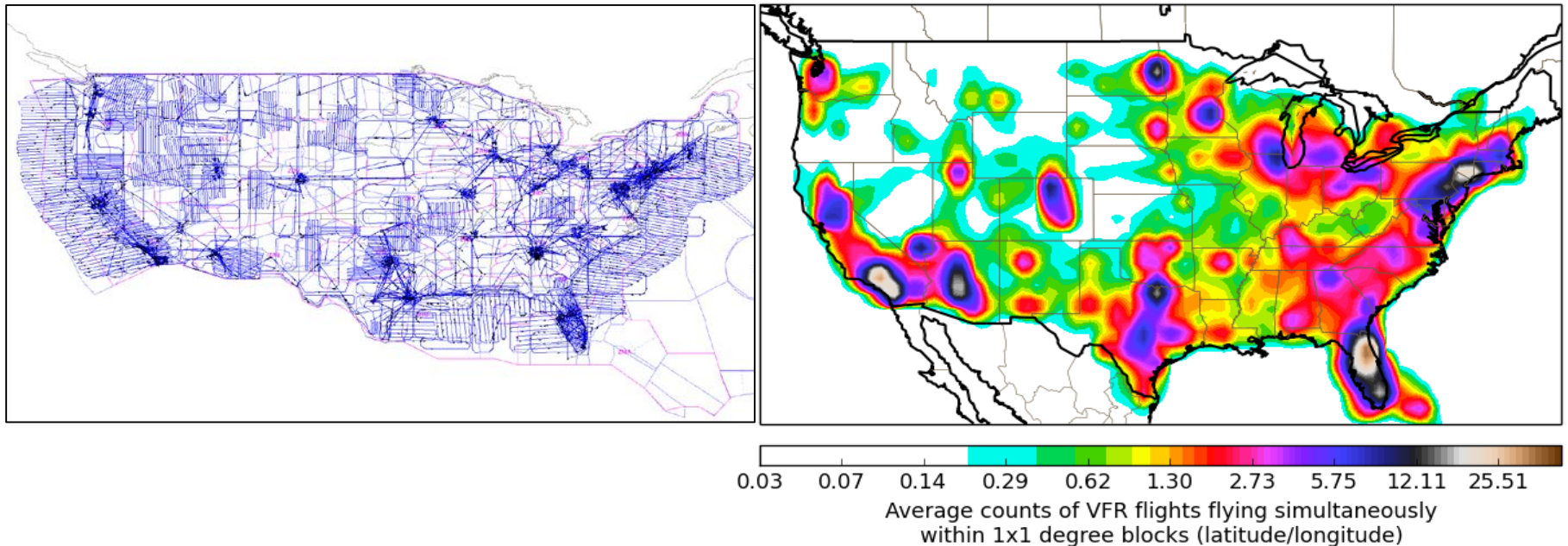


# Low SWaP Modeling and Simulation Work

- Fast-time simulations I, II, and III (NASA Modeling and Simulation team)
- Maneuver initiation range and DAIDALUS support (NASA Guidance and Control Team)
- Low SWaP human-in-the-loop simulations I and II (NASA HSI Team and )
- Fast-time closed-loop simulation (MIT Lincoln Lab)
- Sensor field of regard alerting timeline (CAL Analytics)

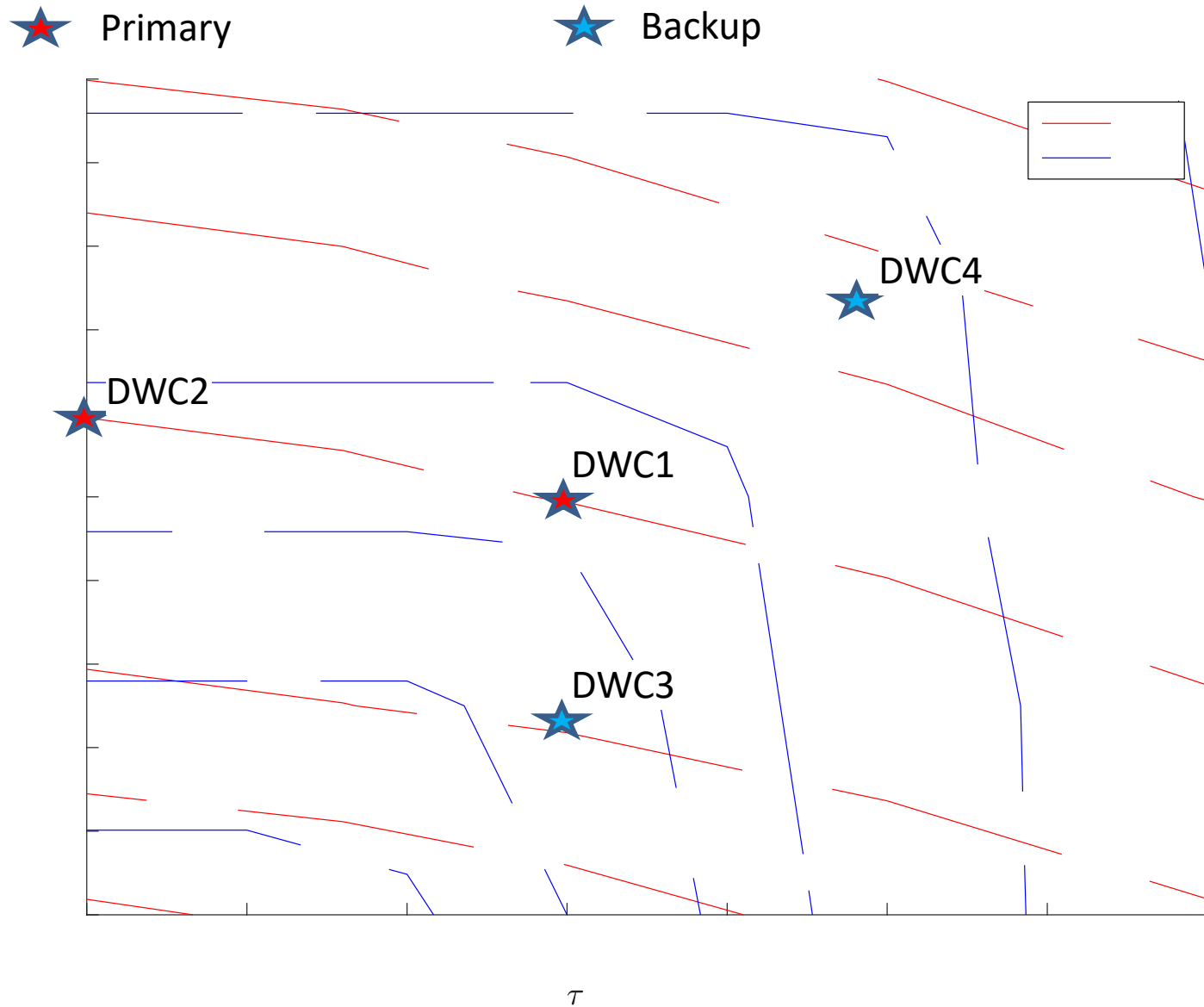
# Encounter Set

- 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





# Candidate Non-Cooperative DWCs





## SC-228 Selection

- On March 6<sup>th</sup> 2019, 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
  - DWC2 reduces the surveillance requirements the most

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



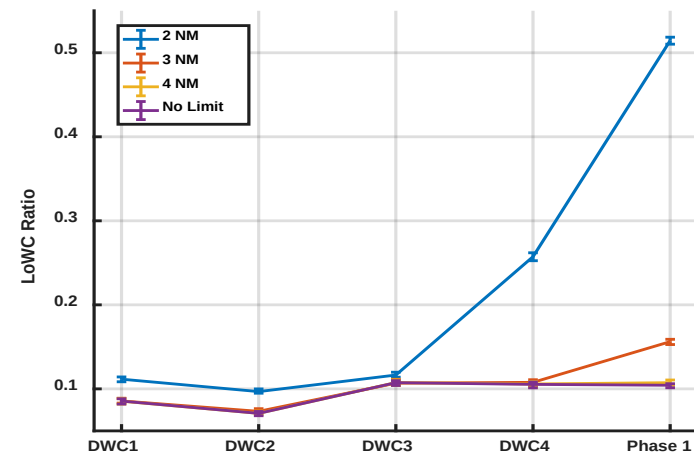
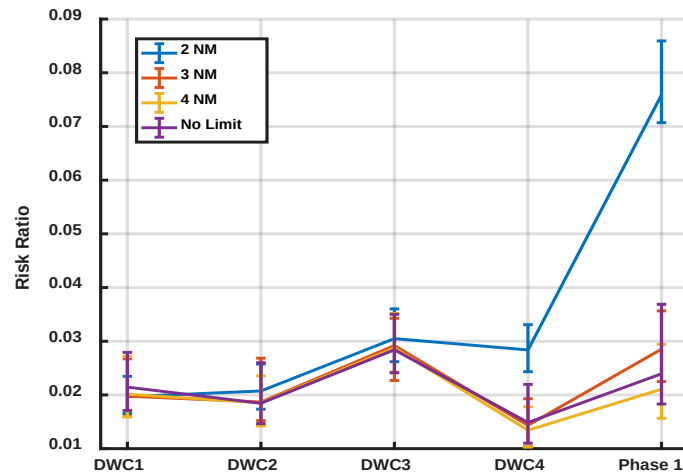
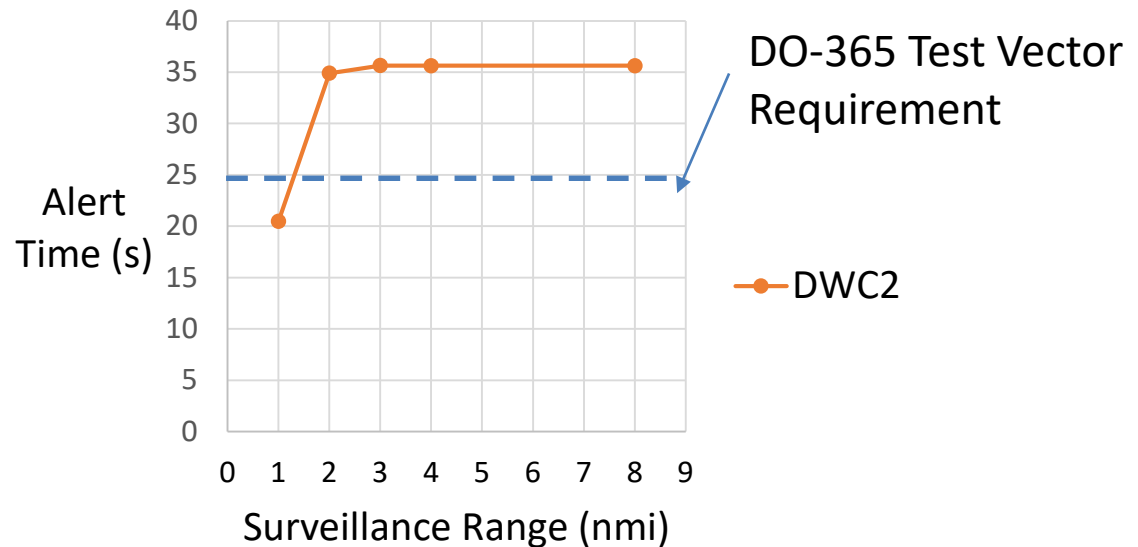
# Surveillance Range Considerations

## Operational Suitability

- Alerting performance
- Pilot performance and acceptance

## Safety Metrics

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





## Future Events

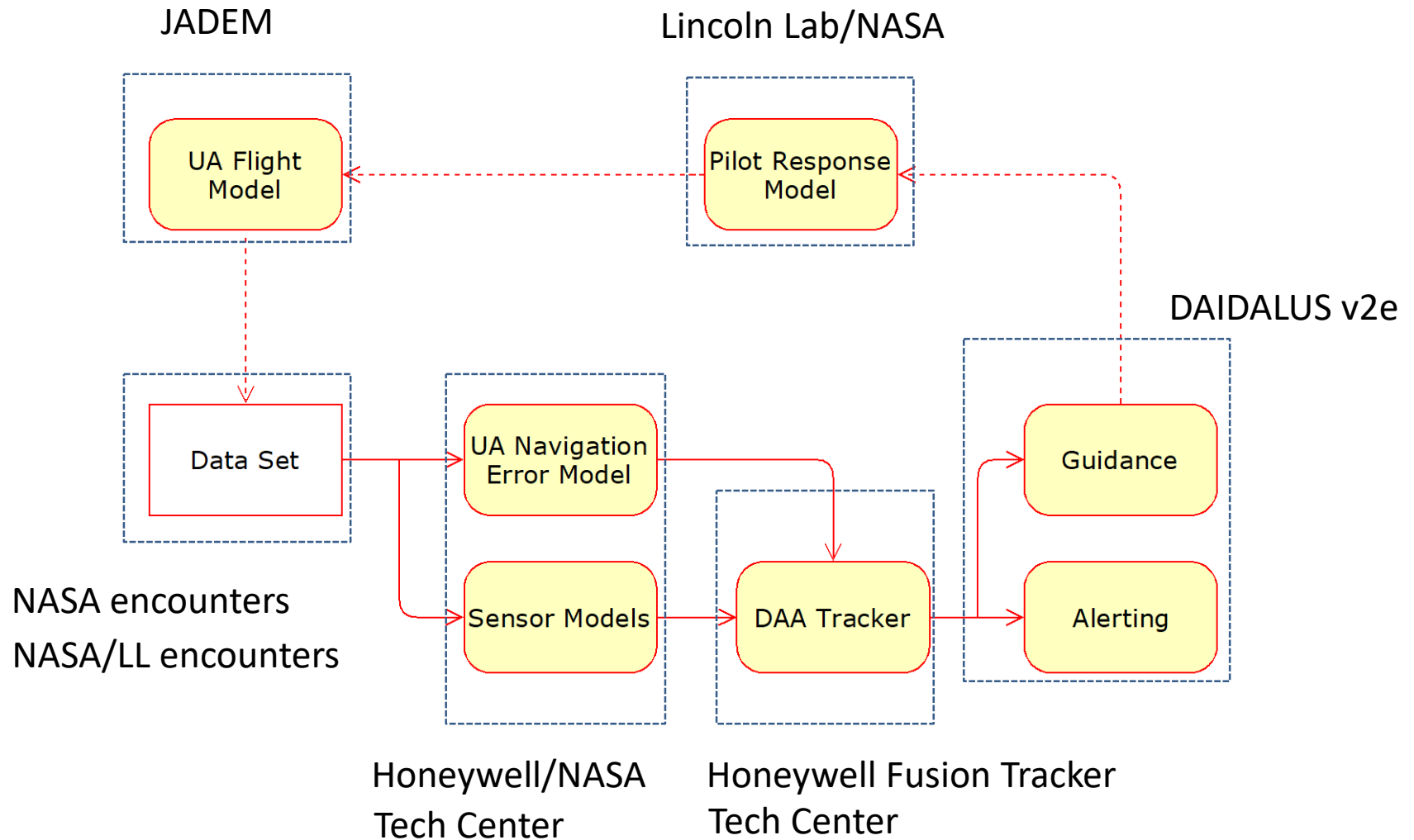
- Flight Test 6 complete December 9, 2019
- Flight Test 6 joint briefing to SC-228 in January 2020
- DAA MOPS revision A exit FRAC2 January 2020
- ATAR MOPS scheduled in June 2020
- DAA MOPS revision B scheduled in October 2020
- EO/IR MOPS scheduled in January 2021



# Backup Slides



# Simulation Architecture





# 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 Quality 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 and Altitude of UAS and VFR Traffic

