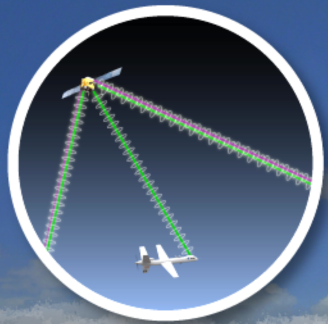


# Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project

Low Size, Weight, and Power (SWaP)

Experiments 1 & 2

*Flight Test Series 6 VIP Day*


Presented by:
Conrad Rorie
Human Systems Integration


November 13, 2019

# Overview

- Background
- Scenario Design
- Low SWaP Experiment 1
  - Experimental Design
  - Results
  - Conclusions
- Low SWaP Experiment 2
  - Experimental Design
  - Results
  - Conclusions
- FT6 Full Mission Implications

# Background

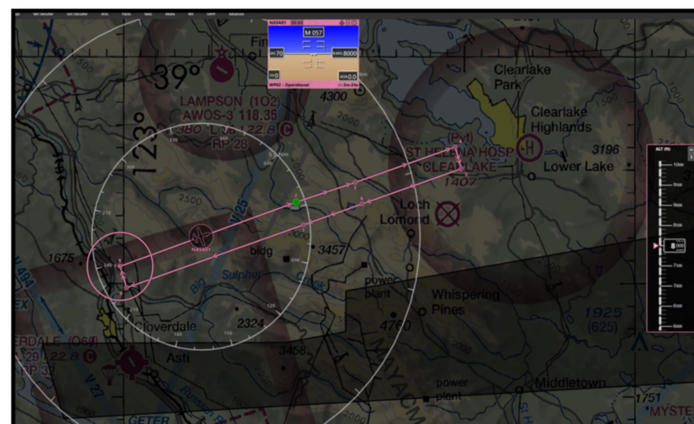
- HSI performed two human-in-the-loop (HITL) simulations investigating the effects of shorter RADAR surveillance ranges on DAA system performance in support of Phase 2
  - The studies were designed to:
    - Serve as a validation of the fast-time simulation work performed by the Modeling and Sim team
    - Identify whether any new DAA display, alerting and guidance requirements are needed for UAS equipping with low SWaP sensors
    - Establish a baseline for the Flight Test 6 Full Mission configuration flights
      - The scenario design & encounters used in these HITLs were replicated in FT6

- Low SWaP 1 (Nov 2018) examined system performance with two candidate non-cooperative DAA well clear (DWC) definitions as selected by M&S

- Low SWaP 2 (Sept 2019) assessed DAA system performance with four different RADAR declaration ranges

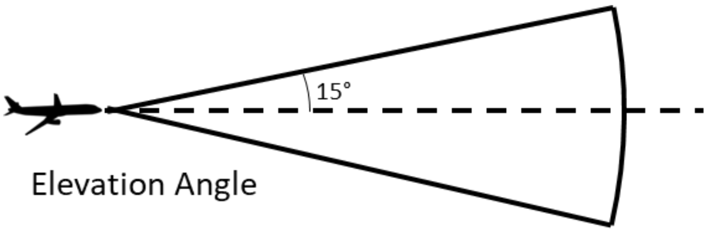
# Scenario Design

- Low SWaP HITLs 1 & 2 used a similar scenario design, which was leveraged for FT6 Full Mission
- Oakland Center airspace was modeled and staffed with confederate ATC and “pseudo” pilots
  - UAS route remained within Class E airspace
  - Mission altitude = 8000ft MSL
- Pilots flew 4 experimental trials different mission routes
  - Used Vigilant Spirit Control Station (VSCS) to control the vehicle
  - The scenarios included a ‘Racetrack’ route and an active TFR to mimic what would be flown in FT6
  - 6 scripted DAA encounters per trial
    - 4 non-cooperative & 2 cooperative

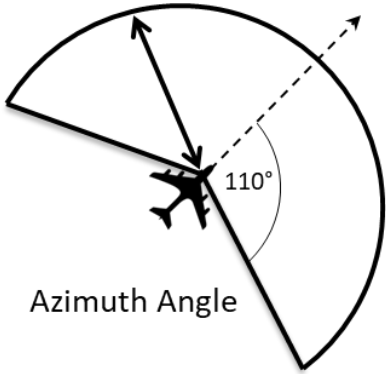


# Scenario Design

- Vehicle Model: Generic RQ-7 Shadow
  - Smaller than the Tiger Shark but modeled similar performance:
    - Cruise Speed: 60 kts
    - Turn Rate: 7°/sec
    - Climb/Descent Rate: ± 500 ft/min
  - Surveillance:
    - Cooperative Sensor: ADS-B In
      - Detection Range: 20nm
      - Vertical Range: ± 5000ft
      - Lateral Range: 360°
    - Non-Cooperative Sensor: Low SWaP RADAR
      - Detection Range: 1.5-3.5nm (varied by study)
      - ± 110° azimuth
      - ± 15° elevation



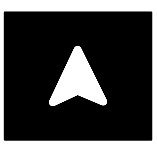
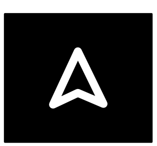

Elevation Angle




Azimuth Angle

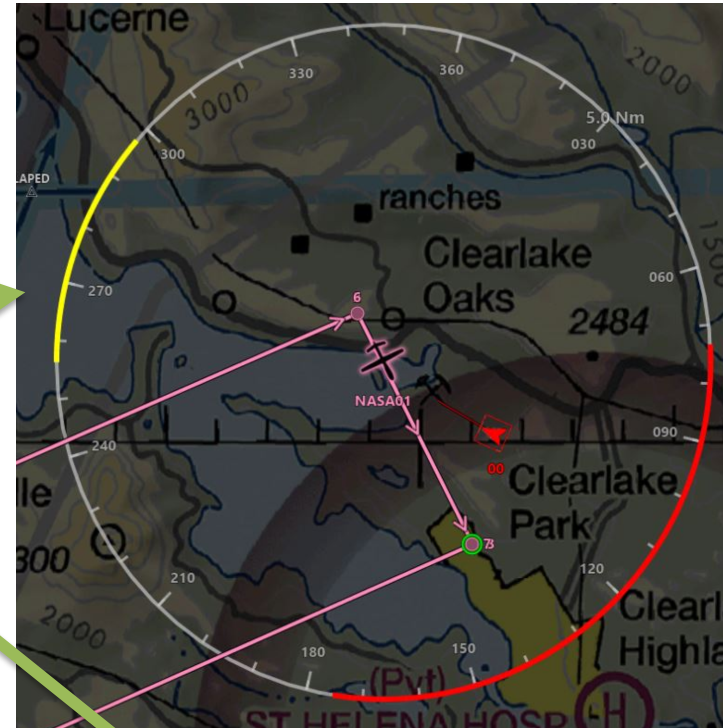
# Scenario Design

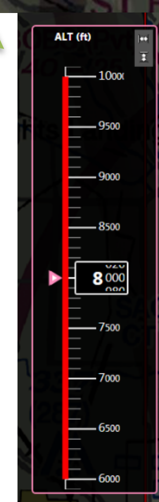
- DAA Alerting Structure

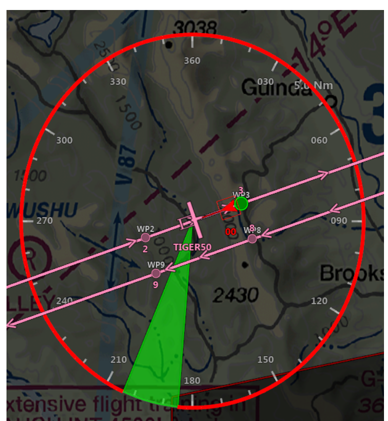
| Icon | Alert Level | Expected Pilot Response | Time to Loss of DAA Well Clear | Aural Alert Verbiage |
|---|---|---|---|---|
|  | DAA Warning Alert | Maneuver immediately | 30 sec | "Traffic, Maneuver Now" x2 |
|  | Corrective DAA Alert | Maneuver following ATC approval | 60 sec | "Traffic, Avoid" |
|  | Preventive DAA Alert | Monitor traffic; maneuver not currently required | N/A | "Traffic, Monitor" |
|  | Guidance Traffic Alert | No maneuver required | N/A | N/A |
|  | Remaining Traffic | No maneuver required | N/A | N/A |

# Scenario Design

- DAA Maneuver Guidance
  - Shown as ‘banding’ to help pilots determine which trajectories are predicted to lead to loss of DWC
    - Yellow bands = predicted to lead to Corrective alert
    - Red bands = predicted to lead to Warning alert
  - Altitude bands were saturated to show no vertical maneuvers would maintain DWC
  - Guidance to *regain* DWC would appear at the point that a loss of DWC was unavoidable



# Scenario Design

- Primary Metrics
  - Alerting Performance
    - How did the IV impact the type/frequency of DAA alerts?
  - Response Times
    - How long did it take pilots to notice a DAA alert and upload an avoidance maneuver?
  - Losses of DAA Well Clear (LoDWC)
    - How often did pilots lose well clear against the scripted conflicts?
  - Subjective Feedback
    - How acceptable did pilots find the various experimental conditions?

# LOW SWAP EXPERIMENT 1

# Experimental Design

- Independent Variables:
  - DWC Definition (*within-subjects*) – **Primary Variable**
    - "Tau" (DWC1) = **2000ft HMD**, 450ft ZTHR, **15s modTau**
    - "Disc" (DWC2) = **2200ft HorzDist**, 450ft ZTHR, **no modTau**
  - Ownship Speed (*between-subjects*)
    - Slow (60kts)
    - Fast (100kts)
  - Intruder Speed (*within-trial*)
    - Slow (100kts)
    - Fast (170kts)
  - Intruder Approach Angle (*within-trial*)
    - Head-on (0°)
    - Crossing (45-90°)

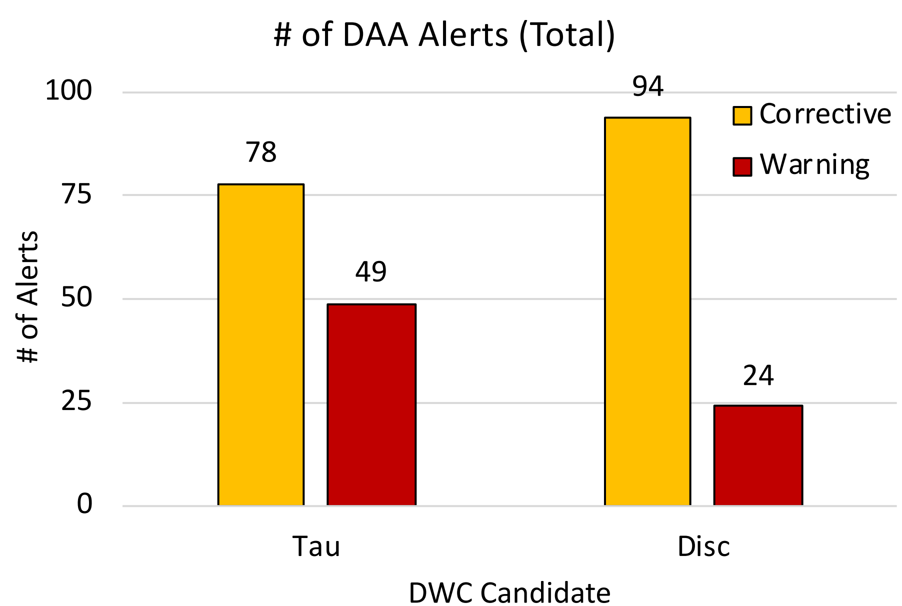
*These variables were included to capture as many different closure rates as possible*

- Participants:
  - 12 active-duty UAS pilots; confederate ATC & pseudo-pilots

- Low SWaP RADAR Characteristics:
  - RADAR Declaration Range = 3.5nm (held constant)
  - Sensor noise was **not** modeled

# Alerting Performance

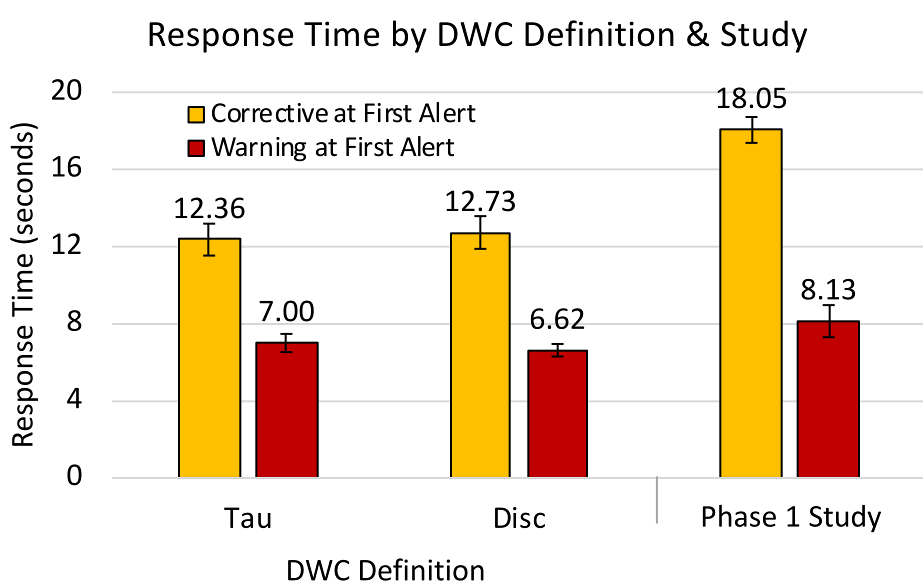
- Tau candidate nominally provided pilots with *less time* to resolve a threat & coordinate with ATC
  - <u>Tau candidate</u>: **4 of 8** encounter types had Corrective alert duration *greater than* 15 sec
  - <u>Disc candidate</u>: **6 of 8** encounter types had Corrective alert duration *greater than* 15 sec
- As a result, intruders progressed to a DAA Warning alert twice as often in the Tau condition than the Disc condition



# Response Times

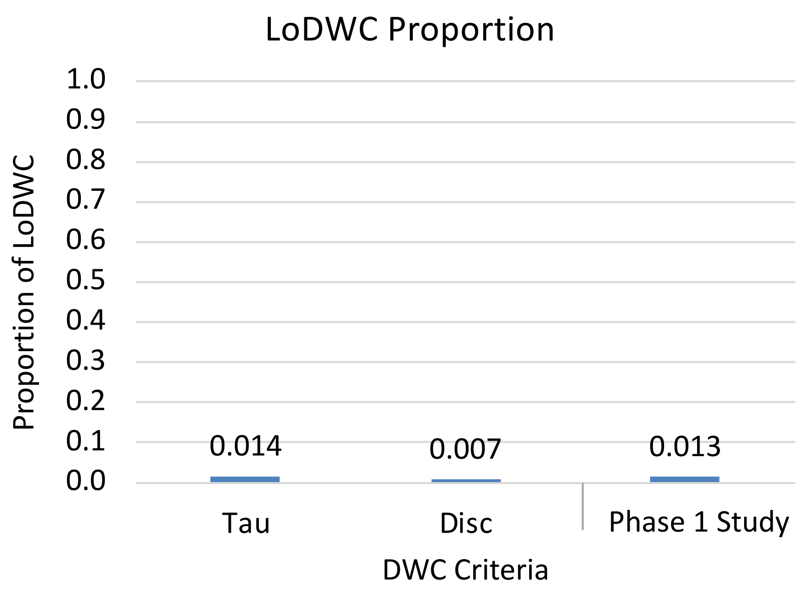
- No effect of DWC candidate on response times
  - Nearly identical responses to Correctives & Warnings

- Responses were faster in Low SWaP HITL 1 than they were in previous Phase 1 work
  - Pilots appeared to respond with more urgency
    - Likely the result of frequent short-duration Corrective alerts



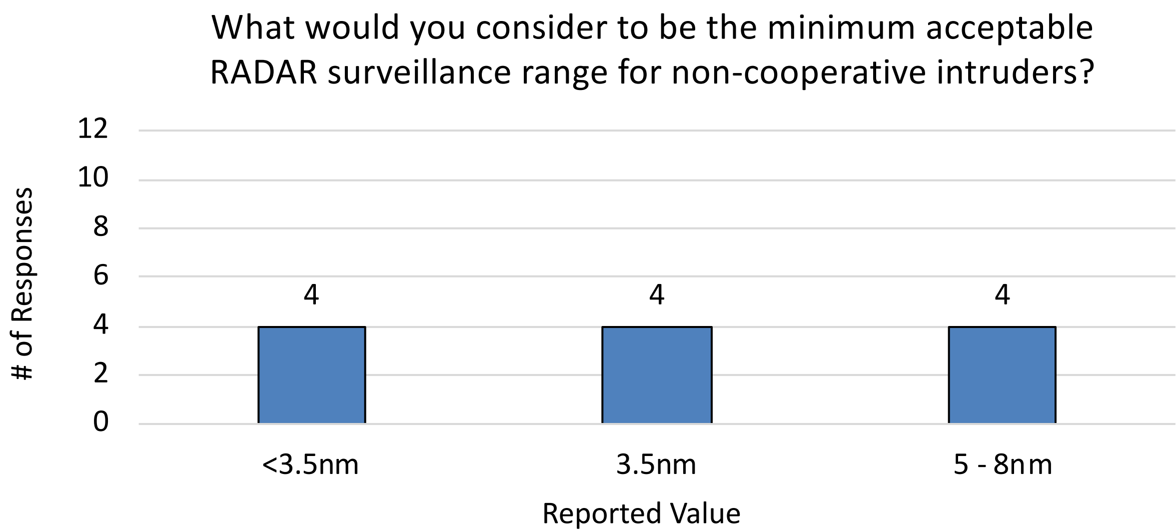
# Losses of DAA Well Clear

- There were 3 LoDWC across *all conditions* (3/289 = 1%)
  - Zero NMACs recorded
  - Nearly identical to Phase 1 results



# Subjective Feedback

- Two-thirds of pilots indicated that 3.5nm – or more – would be their minimum acceptable surveillance range
  - One third would find 2.5-3nm acceptable



# Conclusions

- The “Disc” (DWC2) DWC candidate provided pilots with the most time to coordinate with ATC
- Both candidates resulted in an extremely low number of losses of DAA well clear
- DWC2 was selected as the new non-cooperative DWC definition at the March SC-228 F2F meeting
- It was determined that a study was needed to look at smaller surveillance ranges with DWC2

# LOW SWAP HITL 2

# Experimental Design

- Independent Variables
  - RADAR Declaration Range (**within-subjects**) – **Primary Variable**
    - 3.0nm
    - 2.5nm
    - 2.0nm ← identified by the fast-time work as the 'breaking point'
    - 1.5nm
  - Ownship Speed (**between-subjects**)
    - Slow (60kts)
    - Fast (100kts)
  - Intruder Speed (**within-trial**)
    - Slow (100kts)
    - Fast (170 kts)
  - Intruder Approach Angle (**within-trial**)
    - Head-on (0°)
    - Crossing (45-90°)

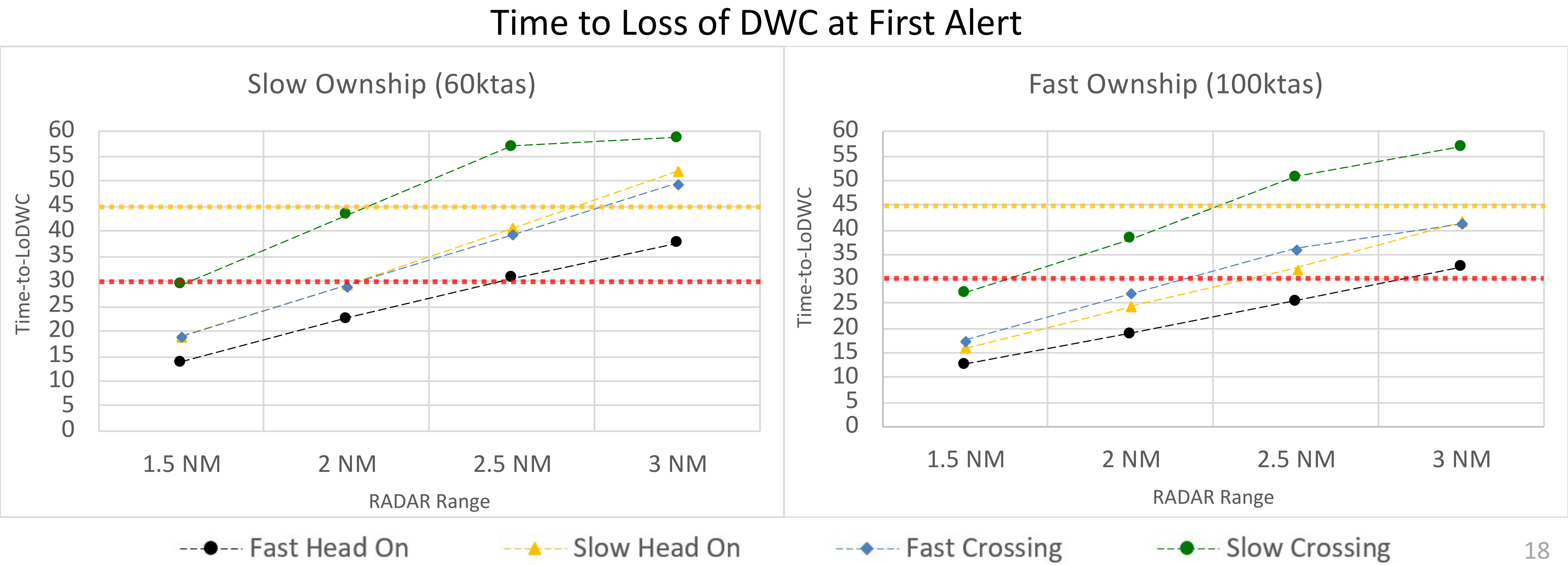
*Same closure rate variables as Experiment 1*

- Participants
  - 9 active-duty UAS pilots; researcher acted as ATC, no pseudo-pilots
- Low SWaP RADAR Characteristics:
  - Honeywell Sensor Model provided representative cooperative (ADS-B) and non-cooperative (ATAR) sensor performance

# Alerting Performance

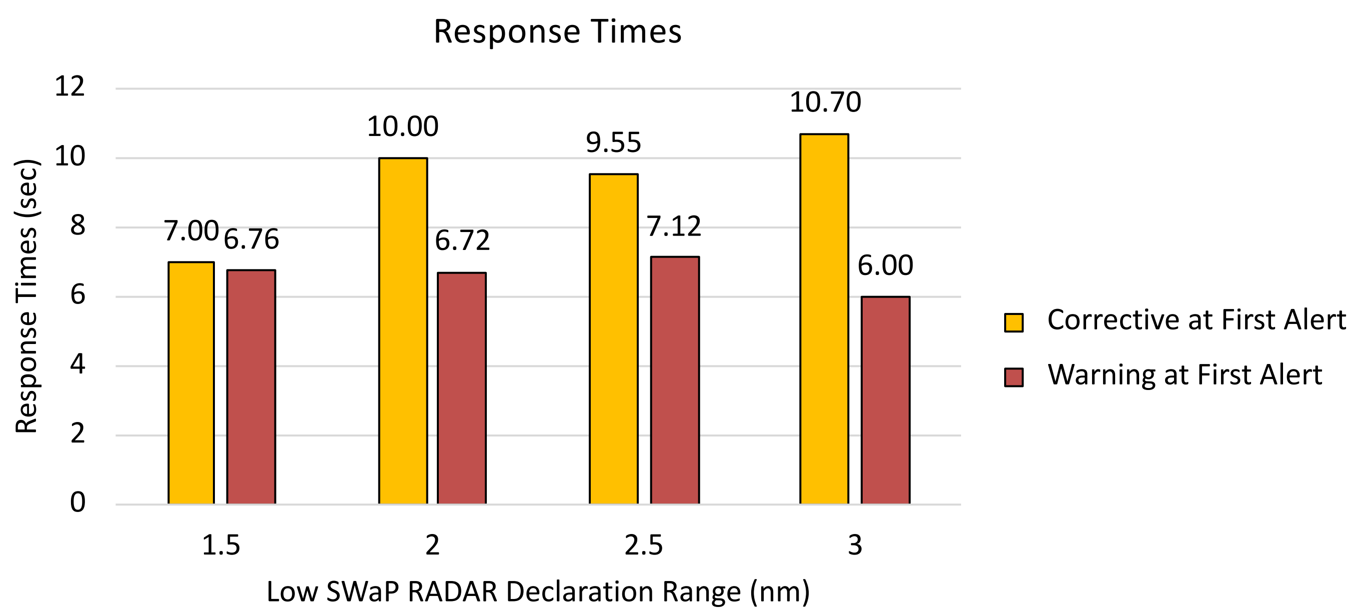
- 1.5nm & 2nm declaration ranges rarely allow for Corrective alerts and *never* provide > 15sec Corrective alert duration
  - They both typically provide less than the full Warning alert time

- 2.5nm & 3nm declaration ranges nearly always provide for the full Warning alert
  - Short-duration Corrective alerts are still common at these ranges



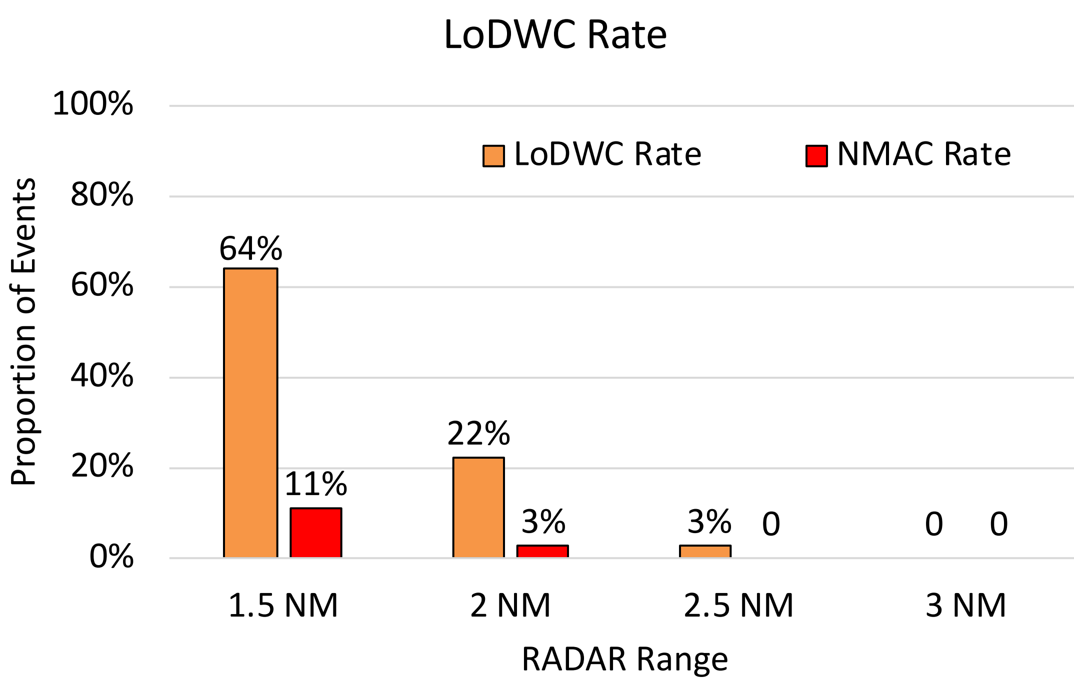
# Response Times

- Response times decreased with surveillance range
  - Greater proportion of Warning alerts at smaller ranges meant faster response times due to lack of ATC coordination



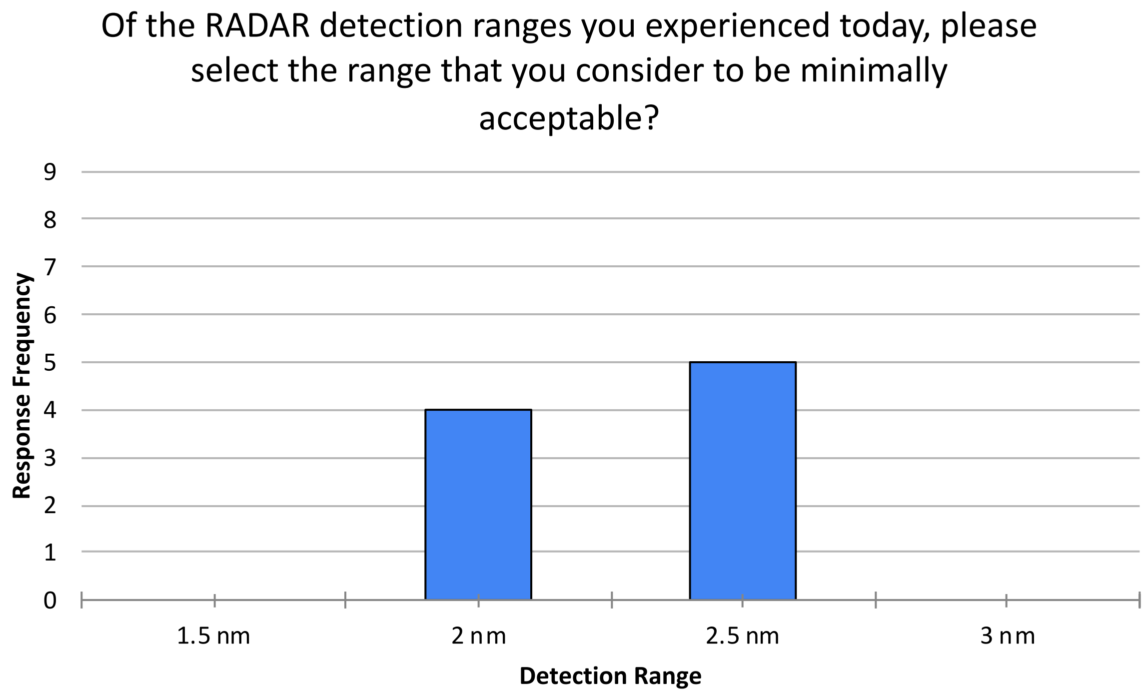
# Losses of DAA Well Clear

- Shortened alerting time associated with 1.5nm & 2nm ranges led to substantial increases in instances of LoDWC *and* NMACs
  - Pilots could not react in time to avoid frequent separation violations
  - Particularly a problem with faster ownship speeds (100kts)



# Subjective Feedback

- The minimally acceptable range was driven by which ownship speed condition participants had been exposed to
  - Those with the slow ownship speed (60kts) selected 2nm (with exception of 1 pilot that selected 2.5nm)
  - All of those in fast ownship speed condition (100kts) selected 2.5nm



# Conclusions

- A 2.5nm declaration range is necessary to provide pilots with sufficient time to reliably maintain DAA well clear
  - At this range, however, ATC coordination is typically **not** viable
  - A larger range may ultimately be required by SC-228 if ATC coordination is deemed necessary for these encounter types
- FT6 Full Mission Implications
  - These results – paired with the fast-time work – established our low SWaP RADAR declaration range requirement of 2.5nm for the Full Mission flights
  - FT6 Full Mission leveraged the scenario design of the HITLs to maximize comparability
    - Vehicle performance, mission route, airspace, ATC interactions, and encounter geometries were kept as similar as possible
    - Will allow us to compare alerting performance, response times, proportion of losses of DAA well clear, and pilot acceptability across the studies

- Questions?