



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

Low Size, Weight and Power (SWaP) HITL
Outbrief to SC-228 WG1





Background

- Fast time simulations have narrowed down potential low SWaP DWC definitions & examined the effect of detection range
 - Reduced DWC definitions for non-cooperatives
 - Below 3.5nm detection range, Corrective and Warning alert durations begin to drop below Phase 1 requirements

- Objective: Apply Phase 1 DAA alerting to non-cooperatives with Low SWaP detection range and DWC definitions
 - Characterize pilot performance when provided with similar alerting time to Phase 1 but detection range of 3.5nm
 - Compare DWC candidates 1 & 2 from fast time study
 - Include wide range of closure rates
 - Determine if changes to existing requirements are necessary



Experimental Design

- Independent Variables
 - DWC definition (within-subjects)
 - DWC1 (“tau”) = 2000ft HMD, 450ft ZTHR, 15s modTau
 - DWC2 (“disc”) = 2200ft HorzDist, 450ft ZTHR, no modTau
 - Ownship speed (between-subjects)
 - Slow (60kts)
 - Fast (100kts)
- Embedded Variable (within-trial)
 - Conflict type
 - Closure rate (fast vs. slow)
 - Intruder speed
 - Approach angle
 - Single vs Multi-threat encounter



Test Setup

- Participants
 - 12 active-duty UAS pilots
 - Average age: 36.67 years
 - Unmanned flight experience: 1,336 hours avg.
 - Manned flight experience: 1,731 hours avg.
- Four experimental trials (45 minutes each)
 - Two pre-filed mission routes
 - Fire Line (PT6) and Long Racetrack (FT6 Full Mission)
 - Oakland Center (Class E)
- Ownship: Generic RQ-7 Shadow model
 - Mission altitude: 8,000ft MSL
 - Maneuverability
 - Cruise spd: 60 or 100 KTAS
 - Turn rate: 7deg/sec
 - Climb/descent rate: 500 ft/min
 - Surveillance
 - ADS-B In (cooperative)
 - Detection range: 20nm
 - Low SWaP RADAR (non-coop)
 - Limited detection range: 3.5nm
 - +/- 110deg azimuth
 - +/- 15deg elevation





Scenario Design

- Primary Pilot Task

- Remain DAA well clear from other aircraft
 - 6 scripted DAA conflicts per trial
 - 5 single-threat non-coop intruders
 - » Varying speeds & approach angles
 - » Includes 1 “Blunder” (Warning at First Alert)
 - 1 cooperative intruder (Phase 1 criteria)
 - » Racetrack: Single-threat, Crossing
 - » Fire Line: Multi-threat with secondary non-coop intruder






25s-to-LoDWC -->

Encounter Label	Intruder Speed	Approach Angle	Proportion
Fast Head on	170kts	0	17%
Slow Head on	100kts	0	17%
Fast Crossing	170kts	+/- 90	17%
Slow Crossing	100kts	+/- 90	17%
BLUNDER	100kts	0-90	17%
Cooperative	200kts	+/- 45	8%
Multi-threat (Fire Line only)	200kts (Coop)	+/- 45	8%
	100kts (non-coop)	0	

*Secondary tasks – scripted SA queries + electronic failure checklists



Alerting Logic

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



Hypotheses

- Research Question
 - Is pilot performance with a low SWaP sensor comparable to performance with the Phase 1 RADAR?
 - Are changes to the Phase 1 DAA alerting and guidance requirements necessary to accommodate low SWaP sensors?
- Expected Outcome
 - Empirical data to help verify low SWaP sensor requirements and their interactions with DAA alerting, guidance, and display requirements
 - Both DWC candidates expected to produce pilot response times and LoDWC rates similar to Phase 1
 - Reduced hazard zones may preserve enough alerting time to maneuver safely
 - DWC1 (“tau”) should yield greater horizontal separation overall
 - DWC2 (“disc”) should allow for more time to maneuver before LoDWC

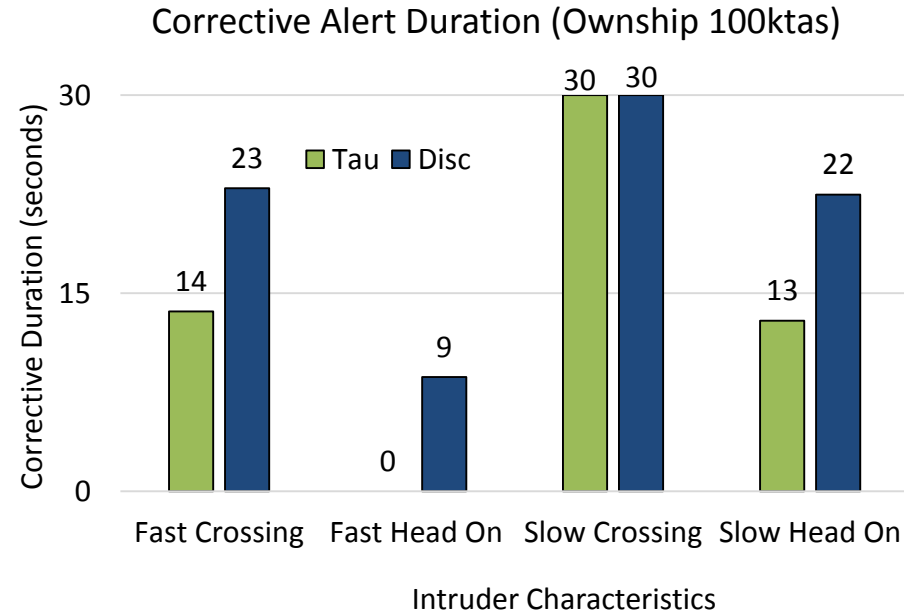
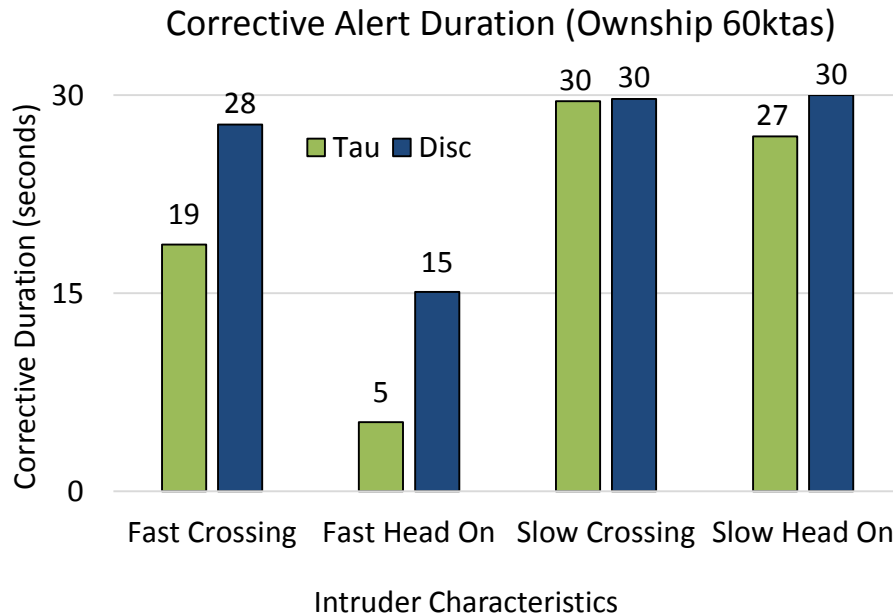


ANALYSIS & RESULTS



Alerting Performance - Unmitigated

- Tau candidate
 - More susceptible to short Corrective alert durations
 - Especially with Fast Ownship
 - Fast Head On: **Warning at First Alert (28s)**
 - Avg. corrective duration overall: 17s
- Disc candidate
 - Over 15 seconds of Corrective alerting time for most encounters
 - Exception: Fast Head On
 - Avg. corrective duration overall: 23s

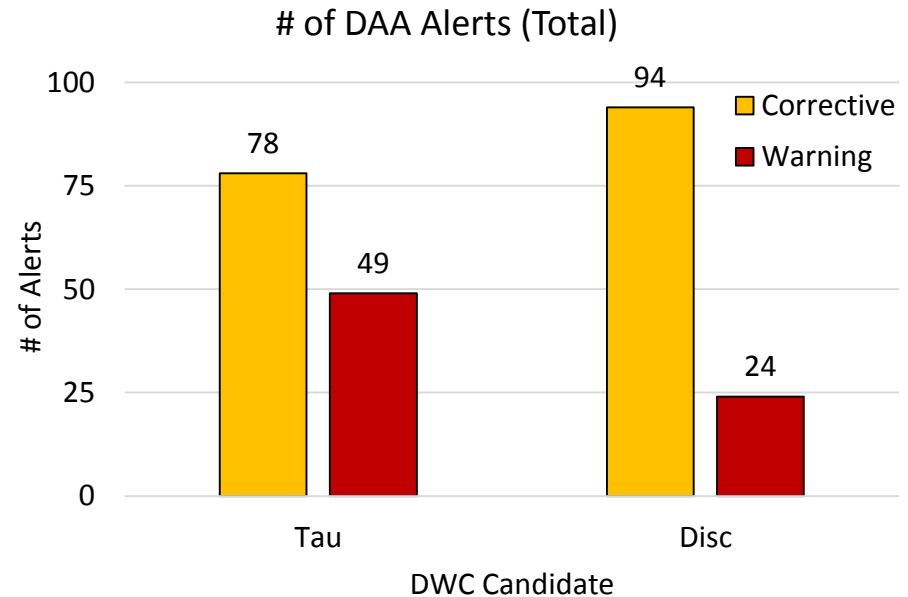
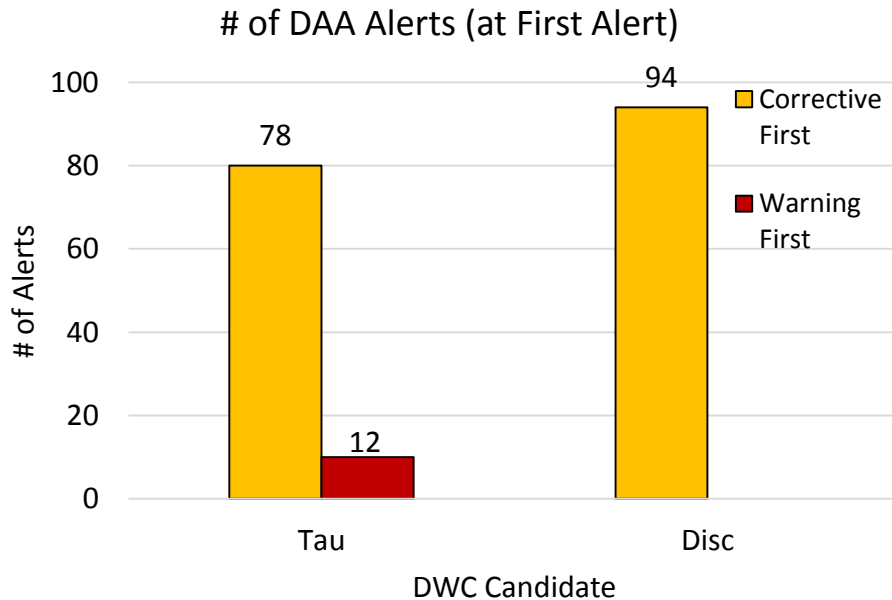


*Non-coop, non-blunder



Alerting Performance - Mitigated

- Tau candidate - twice as many Warnings overall relative to Disc
 - First appeared as Warning in fastest closure rate encounter
 - Correctives also progressed to Warning much more often
 - 47% vs. 26%



*Filter Criteria: 184 single-threat, non-blunder, non-coop encounters



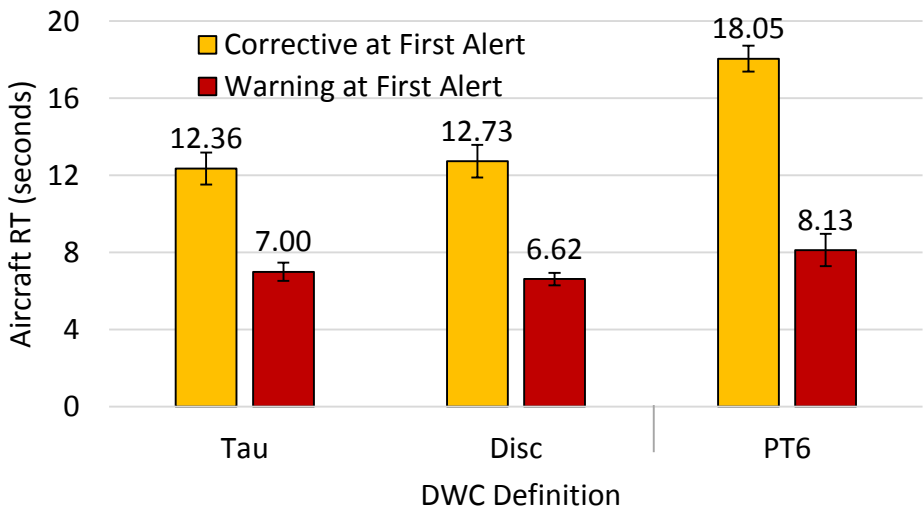
MEASURED RESPONSE & ATC COORDINATION



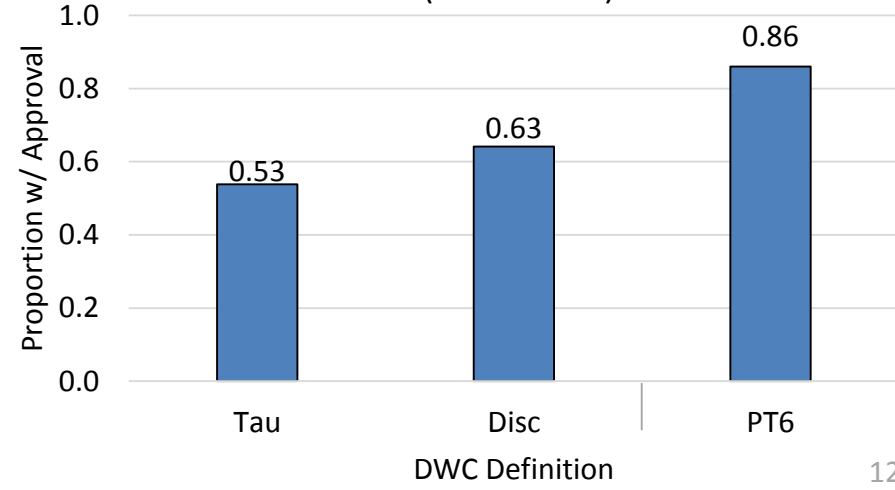
DWC Candidate

- No differential effect of DWC candidate on Aircraft RTs overall
 - Nearly identical responses to Correctives & Warnings
- Aircraft RTs were faster compared to Phase 1 findings
 - Uploaded resolutions with a higher sense of urgency
 - Initiated edits **3 sec** sooner; did not always wait for ATC response
 - For all maneuvers against caution-level threats,
 - **86%** - Notified ATC before upload
 - **60%** - Waited for ATC approval
 - Slightly more often with Disc candidate ↘

Aircraft RT (single-threat)



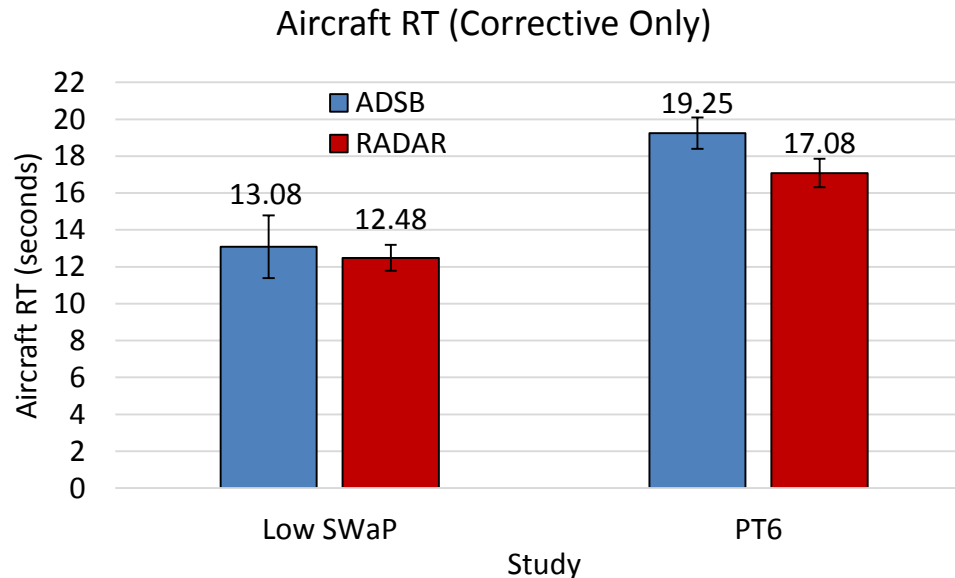
Proportion of Maneuvers with ATC Approval (Correctives)





Intruder Equipage

- Pilots responded equally to threats of both equipage types
 - Treated cooperative targets with same urgency as non-coops
 - 85% of intruders were non-cooperative
 - Developed consistent avoidance strategy, applied to all encounter types
 - Limited almost exclusively to lateral maneuvers
 - ATC Notification times comparable to findings w/ Phase 1 RADAR (8nm)
 - PT6: more even distribution of coop (62%) vs. non-coop traffic (38%)



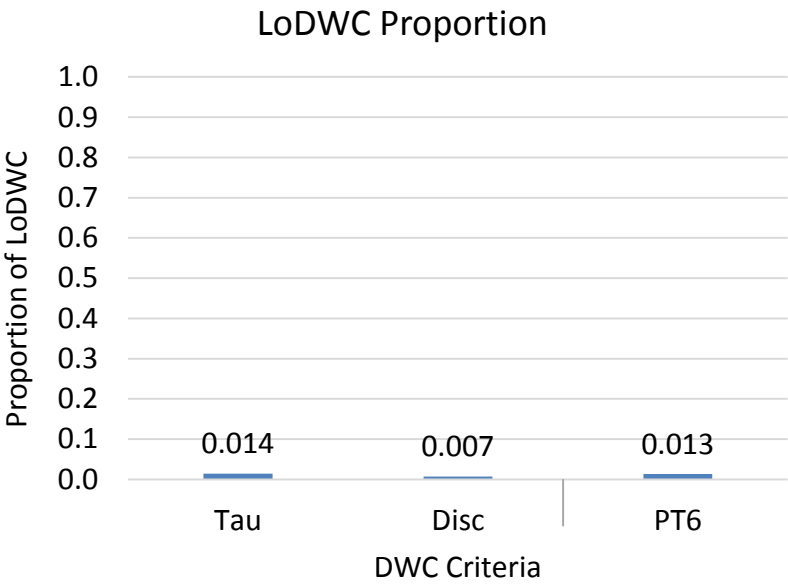


SEPARATION DATA



Losses of DAA Well Clear

- 3 total LoDWC out of 289 encounters = **1%**
 - Zero NMACs, nearly identical to Phase 1 performance
 - All from **1 pilot**, all short-duration Corrective alerts
 - Corrective alert duration: 9-14s
 - 2 due to ineffective altitude maneuvers



LoDWC Instances

DWC	sLoWC%	Duration	Cause	Encounter
Tau	1.47	6s	Early Return to Course (361ft. vertSep)	Slow Head On (secondary threat)
	11.27	16s	Ineffective maneuver (altitude only)	Fast Crossing
Disc	30.63	9s	Ineffective maneuver (altitude only)	Fast Head On

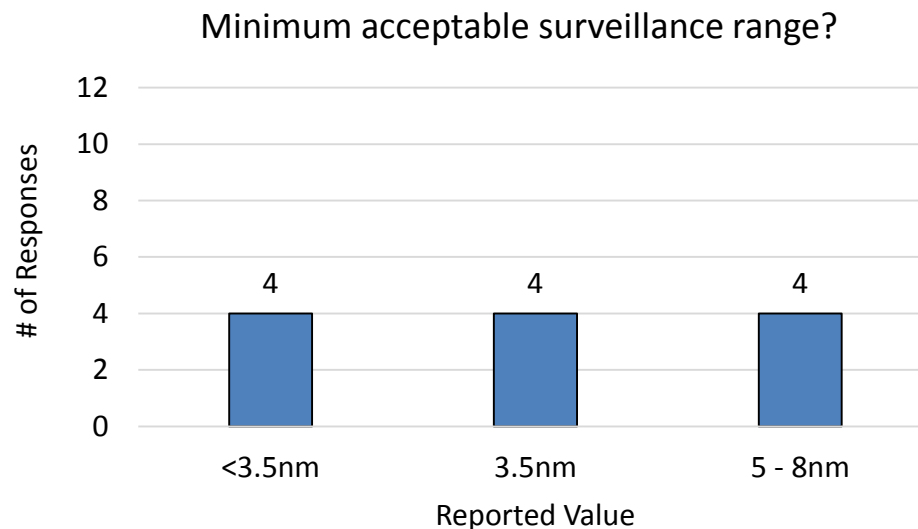


SUBJECTIVE FEEDBACK



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
 - Contingent factors:
 - Higher mission task workload
 - Secondary tasks were minimal distraction; stayed ready
 - Emergencies – turning off course may not be feasible (low fuel, need to land)
 - Vigilance decrements during long duty cycles
 - Congested communication frequency
 - Latency
 - “Expect faster response with GCS input controls”





CONCLUSIONS & PATH FORWARD



Implications

- Objective metrics clearly indicate that pilots can maintain DWC with either DWC candidate at 3.5NM detection range
 - Tau → less Corrective alert time + more Warning alerts
 - Full ATC coordination not always viable
 - Disc → longer Corrective times (~6sec) + earlier onset of Recovery bands
 - Quick response times limited LoDWC occurrences to 1 pilot
- Pilot response times against Corrective alerts ~5sec faster than observed in Phase 1; no difference observed for Warning alerts
 - Closer proximity at first alert
 - **60%** were active DAA alerts at first appearance
 - Frequent short-duration Corrective alerts
 - Pilots adopted a global strategy of initiating edits immediately in response to all Correctives (including against cooperative intruders)
 - Aircraft performance (faster turn, slower climb) limited maneuver options
- Potential challenges to reducing detection ranges below 3.5nm
 - Pilot acceptability
 - May not be able to retain Corrective alerting (especially w/ Tau)



Questions?

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