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

Flight Test Series 6 Results

SC-228 WG1 Outbrief

Detect and Avoid Subproject

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Introduction

- Flight Test 6
  - Low Size, Weight, and Power (SWaP) UAS operations below 10,000 ft
  - Non-cooperative DWC and alerting
  - Non-cooperative sensor performance
  - 3 Phases
    - RADAR Characterization — Honeywell
    - Scripted Encounters — NASA
    - Full Mission — NASA
  - Conducted between July and November 2019
    - 23 Total flights including system checkouts and full mission rehearsal
    - 3 RADAR characterization flights
    - 130 DAA scripted encounters
    - 7 Full Mission Flights

Flight Test Objectives

1. Inform Phase 2 minimum operational performance standards (MOPS) development of requirements for Low SWaP airborne non-cooperative surveillance system
   - Approach: Characterize representative Low SWaP sensor in flight with **scripted encounters**
   - Data: Range/Azimuth/Elevation Limits, Positional Accuracy

2. Inform Phase 2 MOPS development of DAA Well-Clear alerting and guidance requirements
   - Approach: Characterize DAA system performance with **scripted DAA mitigated encounters**
   - Data: Alert Times, Alerting/Guidance Stability, Separation Data

3. Characterize pilot response data in a full-mission environment to validate previous HSI simulation work
   - Approach: Characterize performance of DAA system in a **simulated full mission environment** with live subject pilot response in the loop
   - Data: Pilot Response Time, Separation Data, Subjective Acceptability

NASC Tigershark

- Manufacturer: NASC
- UAS Type: DoD Group 3
- Wingspan: 22 ft.
- Endurance: 8-12 hour
- Max speed: 80 KTAS

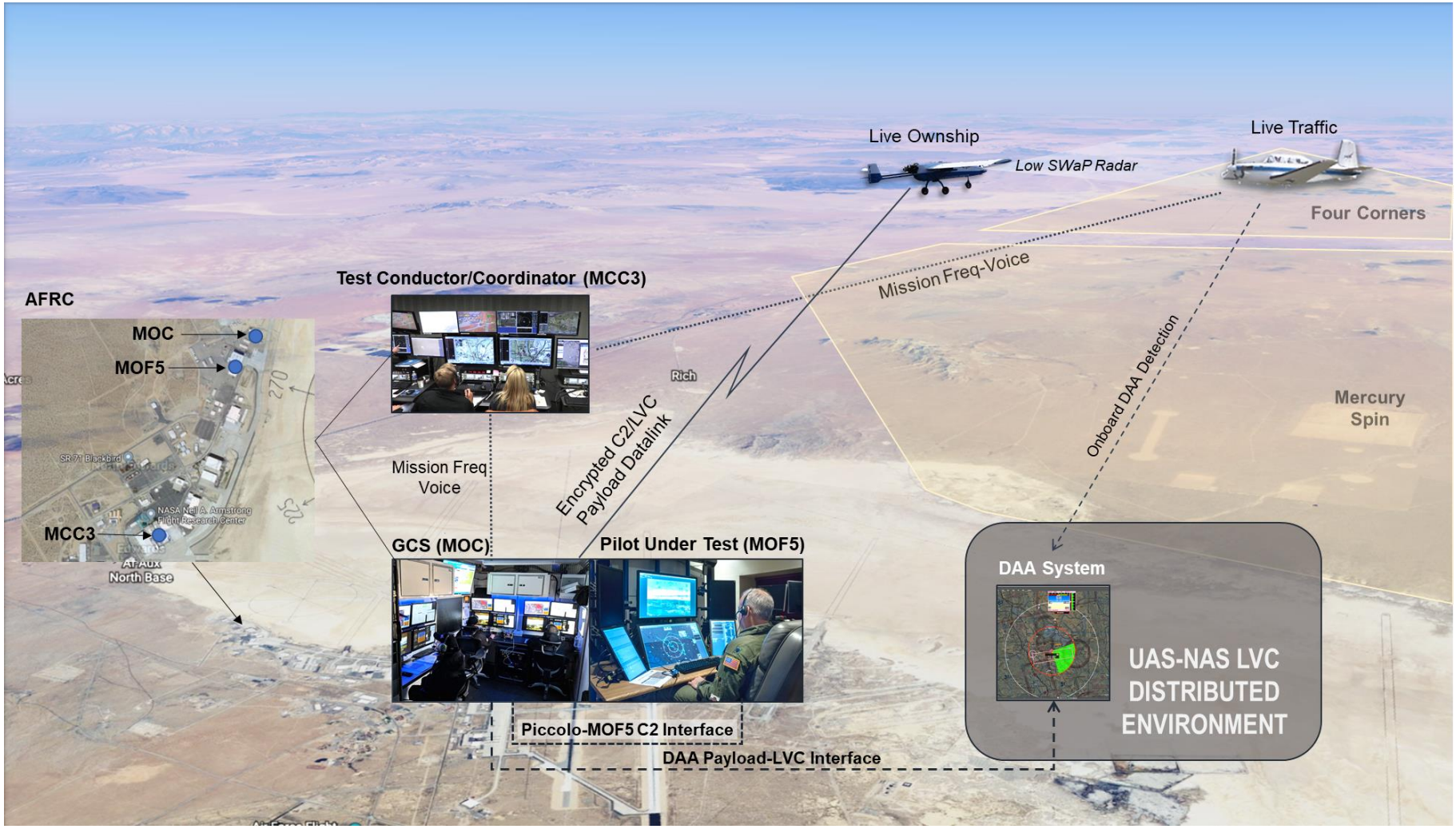
- Radome nose fabricated to house Low Size, Weight, and Power (SWaP) non-cooperative RADAR sensor – Honeywell “DAPA-Lite”
- Addition of exhaust injection smoke system for visual ID from manned aircraft
- Mobile Operations Center (MOC) houses internal pilot using Piccolo Control Center
- MOC linked to Research Ground Control Station (RGCS) where DAA system was housed

Non-Cooperative Sensor

- RADAR Characterization Flights
  - Honeywell DAPA-Lite RADAR integrated into NASC Tigershark
  - Flight cards designed to probe azimuth, elevation, and range limits of sensor
  - Flights completed in October
  - Results show range not sufficient for UAS detect-and-avoid operations

- RADAR Emulation
  - In order to continue investigating Low SWaP non-cooperative surveillance requirements, a software solution was developed to emulate a RADAR
  - ADS-B tracks outside of specified range, azimuth and elevation limits filtered out
    - Azimuth +/- 110°
    - Elevation +/- 15°
    - Range was variable in scripted encounter and set to 2.5 nmi in full mission
  - Non-cooperative flag manually triggered to invoke non-cooperative DWC and alerting
  - Sensor noise not simulated - ADS-B uncertainty used

Scripted Encounters CONOPS



- Pilot Under Test: NASA test pilot flying conditions on test card following DAA guidance

Scripted Encounters

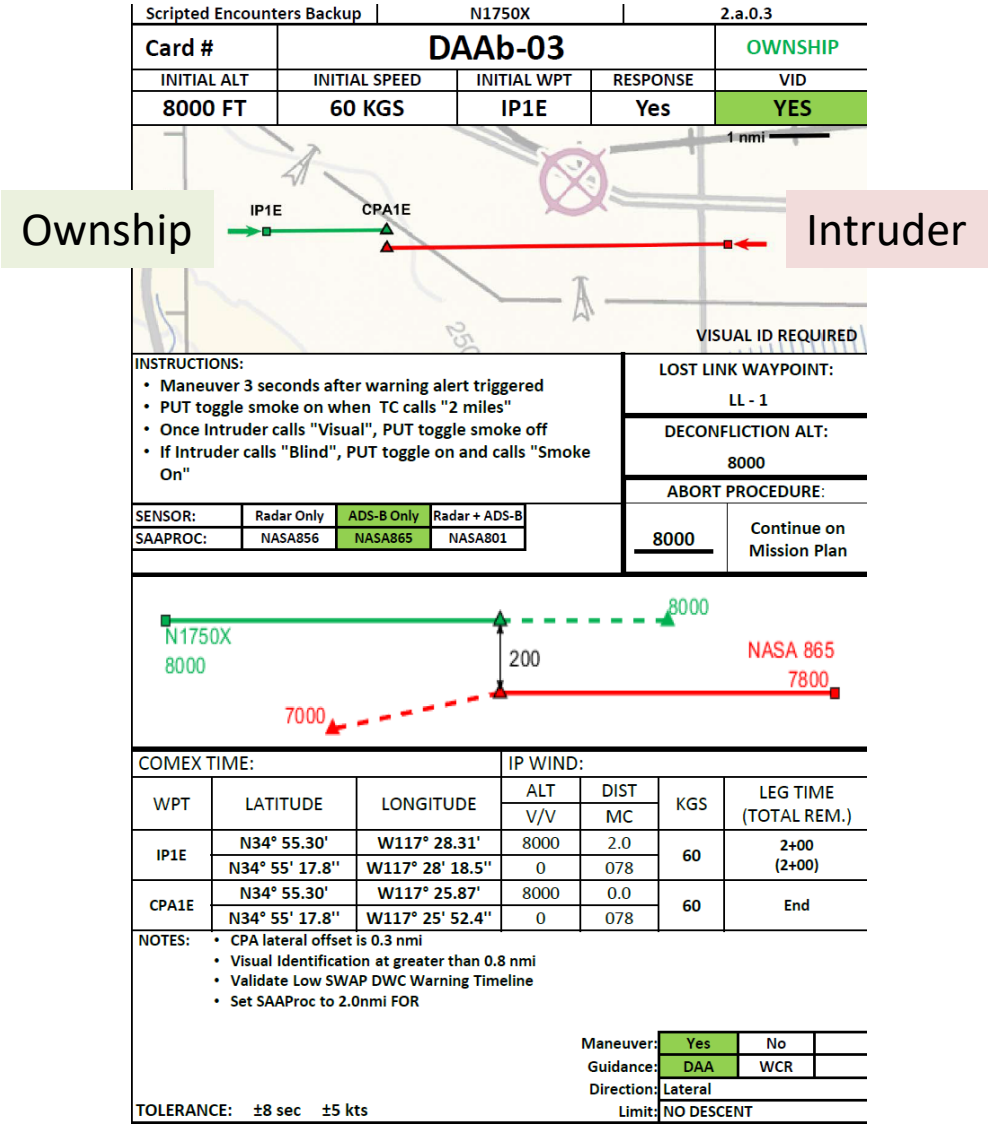
- Goal: Execute preplanned encounters between UAS and manned aircraft to collect **DAA alerting and guidance data**
  - Observe behavior of DAA alerting and guidance from different approach angles and horizontal/vertical offsets
  - Alerting and guidance performance with cooperative and non-cooperative sensors

- UAS Performance
  - 60 KTAS, (40-100 kts ground speed)
  - 7°/Second turn rate target

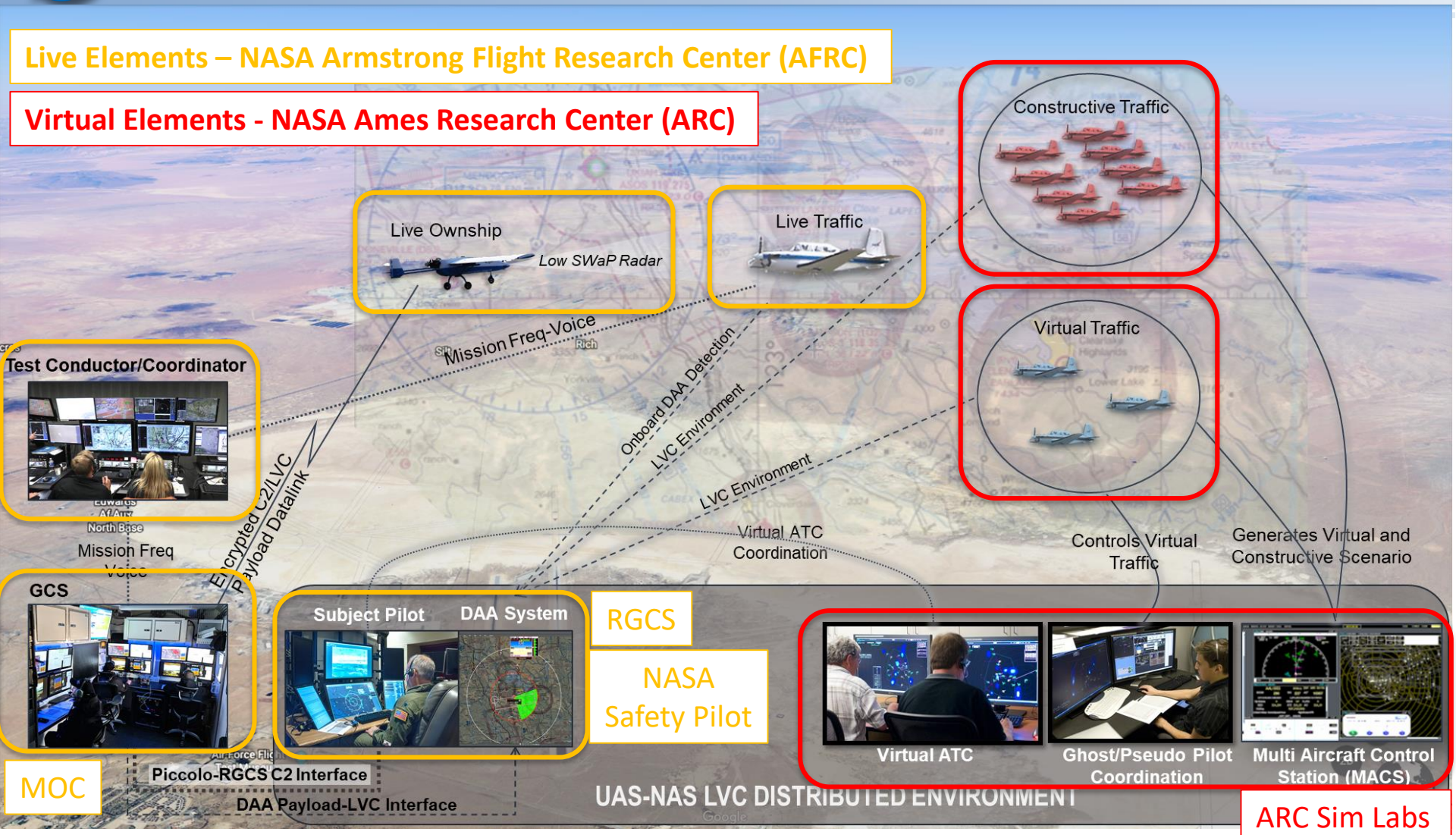
- Variables
  - Geometry: 0° (head-on), 40°, 50°, 60°, 80°, 90°, 120°, 160°, 180°
    - Intruder horizontal maneuver, Intruder climb/descend
  - Vertical Offset: 200, 400, 500, 700, 1000 ft
  - Intruder Speed: 60, 100, 170 kts ground speed
  - Maneuver Initiation: Warning vs corrective
    - Maneuver delay: 3 seconds for warning, 8 seconds for corrective
  - Sensor Selection: **ADS-B cooperative** vs **simulated "non-cooperative"** 2.0, 2.5, 3.5 nmi range
  - Mitigation: Unmitigated (fly-through) or mitigated

Scripted Encounters

- Procedure:
  - UAS and intruder begin at specified entry criteria
  - UAS pilot detects DAA alerting and guidance on Vigilant Spirit Control Station (VSCS)
  - UAS pilot holds for prescribed interval of time
  - UAS pilot initiates horizontal maneuver to within 15 degrees of edge of heading band following guidance bands' edge, increasing turn angle to keep up with the edge if necessary
  - UAS pilot returns to course if able



Full Mission Concept of Operations



- **Subject Pilot**: Non-NASA UAS pilot who is naïve to conditions of test encounters
- **Constructive Traffic**: Simulated traffic on scripted route, no human intervention
- **Virtual Traffic**: Simulated traffic controlled by pseudo pilots

Low SWaP HITL1 and HITL2 Recap

- Goal: characterize pilot response data in a full-mission environment to validate previous HSI simulation work
  - Low SWaP HITLs 1 and 2 will provided direct baselines for comparison

- Low SWaP HITL 1 Results
  - DWC1 vs DWC2 with a simulated Low SWaP RADAR declaration range of 3.5nmi
  - Pilots were found to maintain DWC at a rate consistent with Phase 1 work (e.g., Part Task 6)
  - DWC2 (2200 ft. horizontal, 450 ft. vertical) recommended

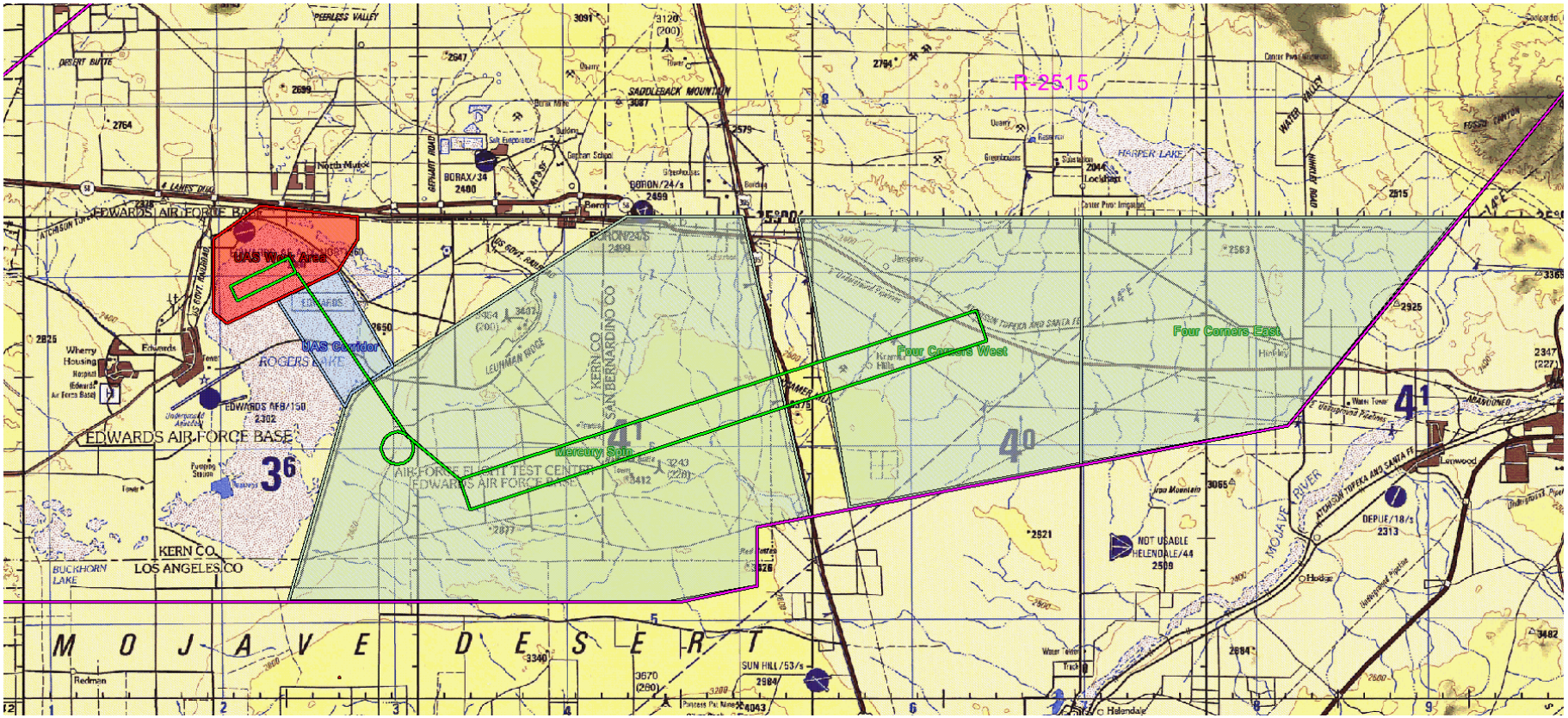
- Low SWaP HITL 2 Results
  - RADAR declaration ranges: 3.0, 2.5, 2.0, 1.5 nmi
  - Pilot performance influenced by warning alert duration
    - Most LoWC events had less than 25 seconds warning alert time
    - 2.5 nmi minimum to ensure 25 seconds of warning in tested cases
  - Subjective ratings favor 2.5 nmi as the minimum RADAR declaration range
  - 2.5 nmi recommended minimum RADAR detection range

- FT6 Full Mission used recommended 2.5 nmi declaration range

FT6 Full Mission

- Full Mission
  - FT6 Full Mission is an opportunity to investigate UAS pilot performance with a Low SWaP DAA system in flight
  - Pilots flew the same route and experienced the same encounters as the Low SWaP HITLs
- Each subject pilot encountered 6 live targets
  - 4 with Low SWaP non-cooperative sensor emulation
  - 2 with cooperative sensor (ADS-B)
  - Intruder speeds: 170kts or 100kts
  - Encounter geometry: Head-on, 90° crossing, 45° crossing
  - Encounter locations can shift
- 7 Subject pilots
  - Active military
  - UAV type certification
    - Fixed wing
    - Previous year experience
  - Current FAA medical or equivalent
    - Corrected to normal vision
  - Full color perception
  - Private Pilot Certificate
  - No previous UAS Integration in the NAS HITL activities
- Pilot participants used Vigilant Spirit Control Station (VSCS) to control the vehicle
  - Moving maps are translated to depict Oakland Center airspace to be consistent with past HITLs
  - ATC and pseudo-pilot confederates will be in the loop to mimic NAS operations

FT6 Full Mission Route



- Mission profile kept as similar to the Low SWaP HITL as possible
- Alternate missions designed in case airspace is unavailable

FT6 Full Mission – Oakland Airspace Translation

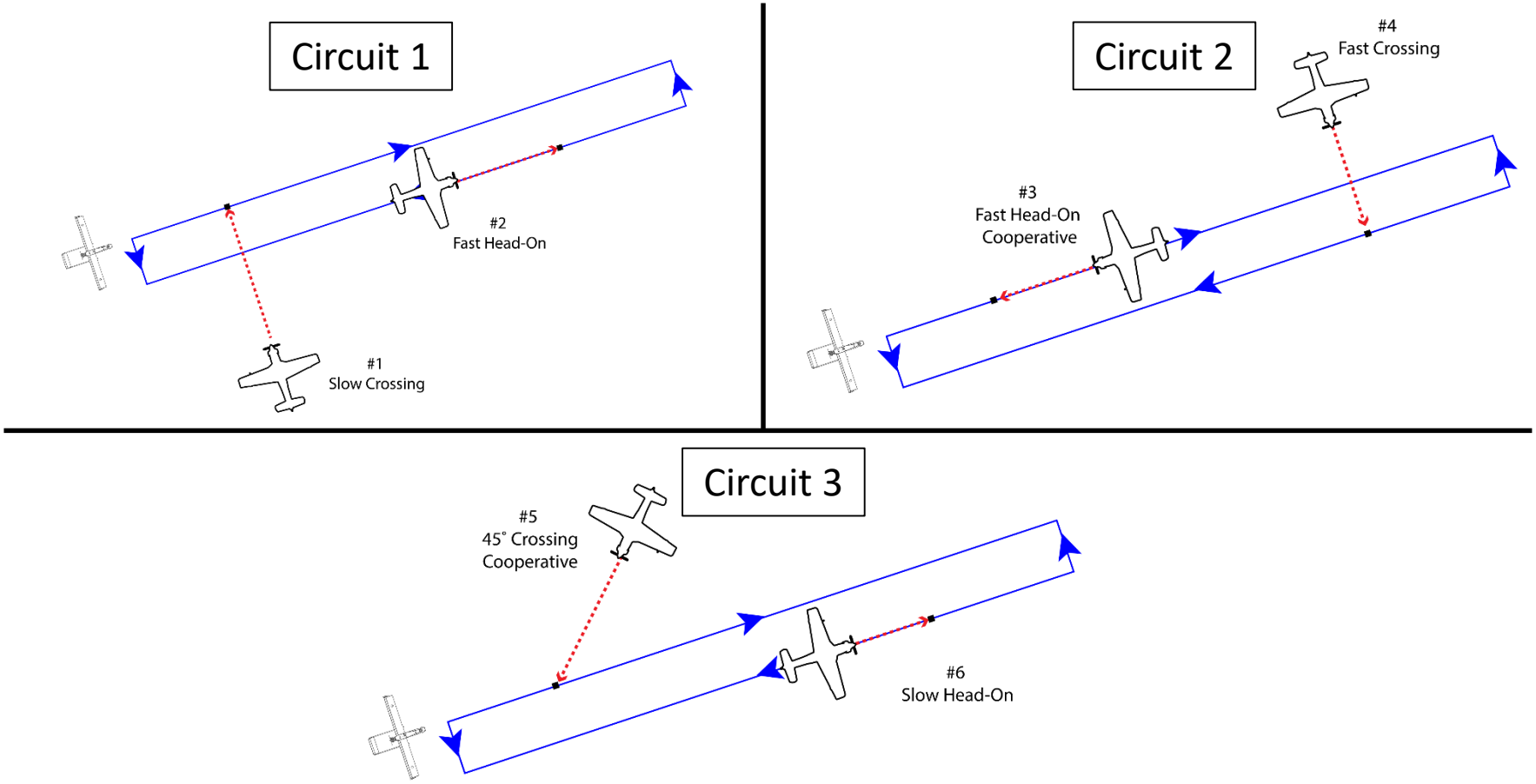
- Vigilant Spirit Control Station and MACS Oakland center map coordinates translated from Edwards AFB airspace
  - All ATC, UAS Operator, and Pseudo-pilot activity appeared to be occurring within Oakland center airspace
- Simulated TFR incorporated into MACS and VSCS maps to prevent pilot from exiting approved Edwards airspace

FT6 Full Mission Route - Oakland Center Airspace Translation

- Subject pilots:
  - Saw Oakland Center airspace on the VSCS Display
  - Spoke to and heard Oakland Center ATC
  - Saw and heard virtual and constructive traffic flying realistic airspace routes

FT6 Full Mission Route – Encounters by Circuit

- For flight test, 2 conflicts per circuit; 3 circuits per subject = 6 total encounters per subject pilot
  - Captures all encounters flown in Low SWaP HITL's Racetrack scenario
  - Precise CPA locations can shift
  - 4 non-cooperative intruders, 2 Cooperative intruder2



Training

- Training
  - Performed in SIL
  - Day before flight
    - Intro to FT6, responsibilities, vehicle overview
    - VSCS Interface: information display, sending commands, vehicle behavior
    - DAA System: alert meaning, guidance, surveillance system
    - Mission: airspace, ATC, secondary tasks
    - Simulation practice
  - Morning of flight
    - Refresher practice of simulated encounters

FT6 Flight Overview

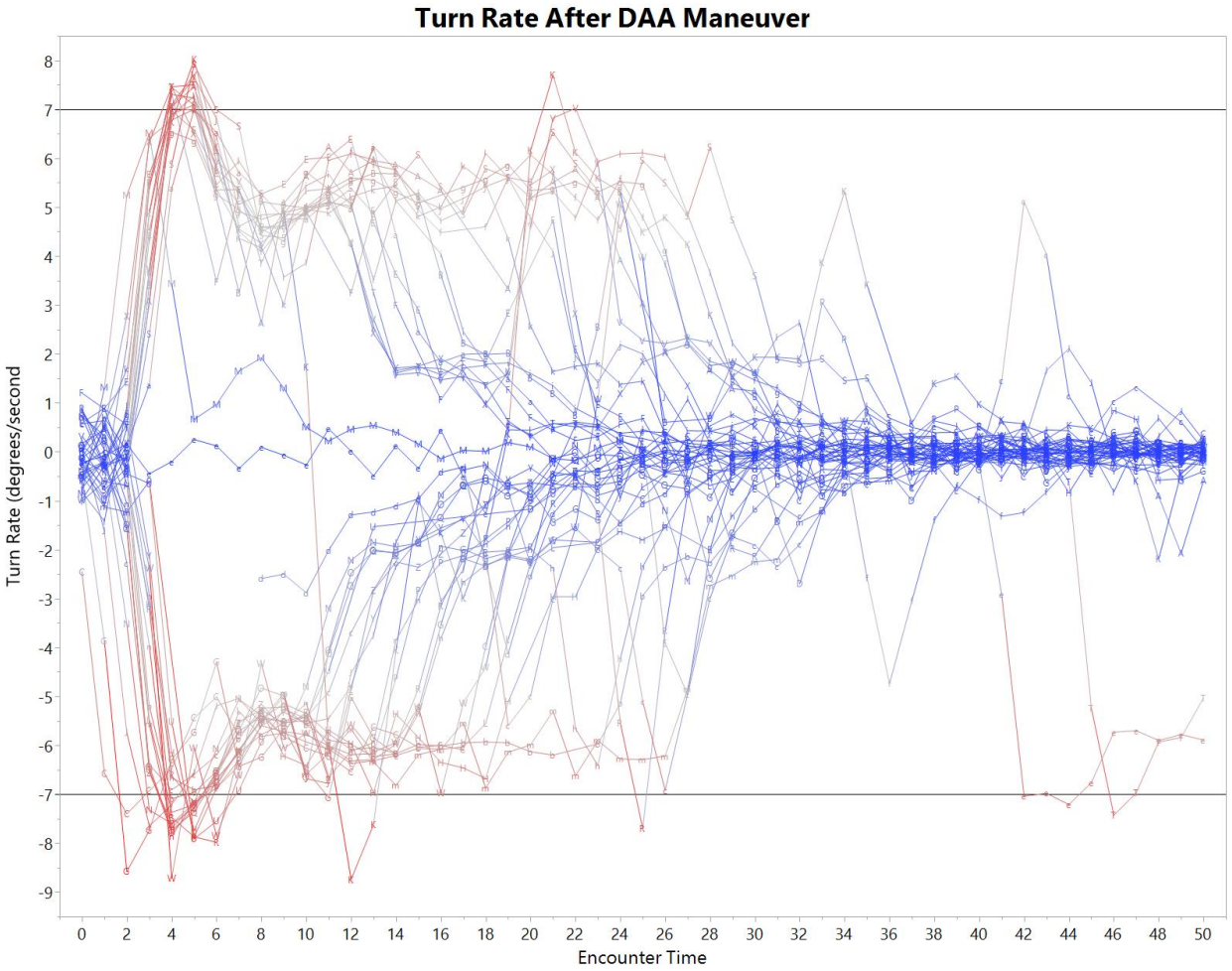
- 23 Total flights completed including system checkout flights
  - System checkout and RADAR characterization / scripted DAA encounters completed on same days when necessary
    - System checkout for full mission features on same flight as RADAR or scripted encounters
  - RADAR Characterization: 3 flights / 34 encounters
  - Scripted DAA Encounters: 9 flights / 96 encounters
  - Full Mission: 7 flights / 42 encounters

System Performance

- In order to investigate whether the UAS achieved performance consistent with research assumptions, turn rate and latency were measured
- Turn Rate
  - 7°/second were modeled in previous fast-time simulations
    - Did Tigershark XP achieve this during the test?
  - Previous human-in-the-loop simulations used an instantaneous turn rate
    - How did the Tigershark XP actually respond during the test?
- Latency
  - DO-365: 2 second max total latency

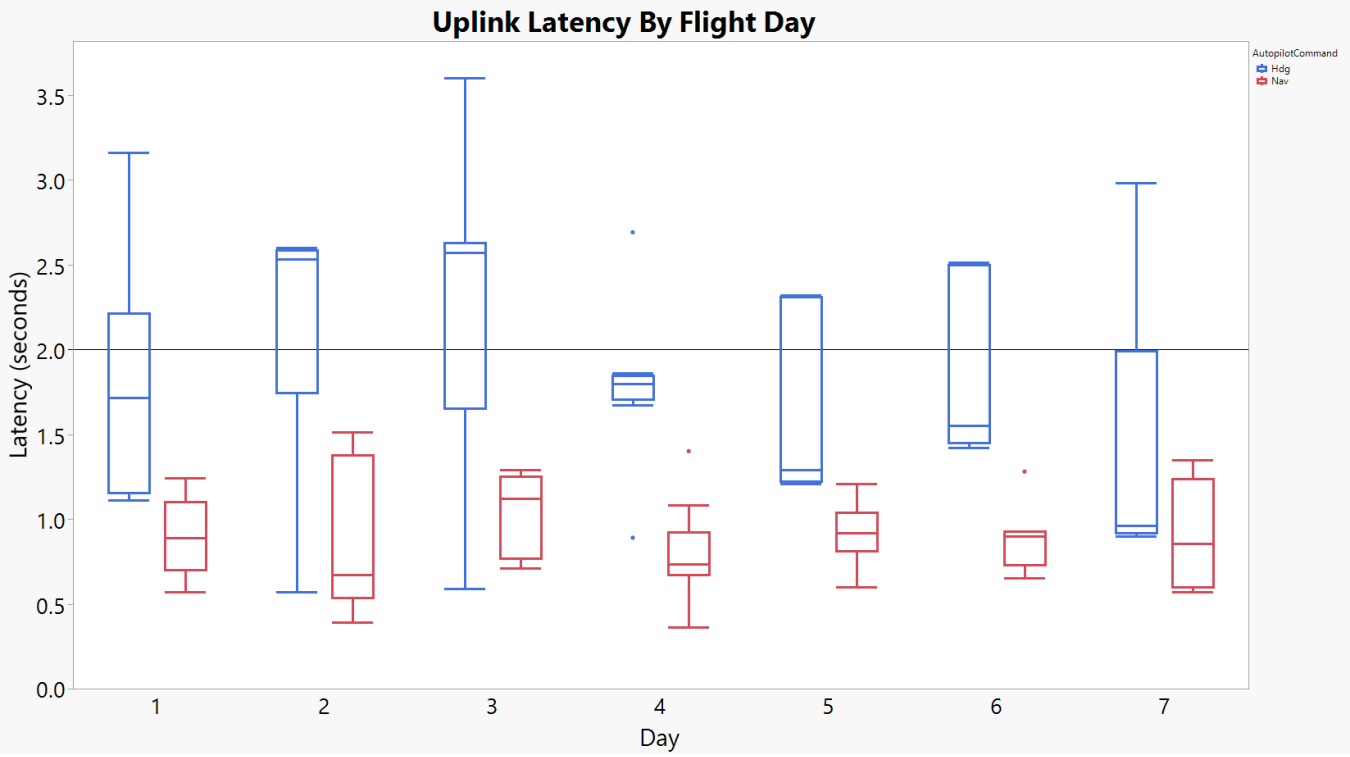
UAS Turn Rate

- It took generally 4-6 seconds for the UAS to reach its max turn rate
- 7°/second was not sustained
  - Turn rate hovered between 5 and 6 degrees per second after max turn rate
  - Mean turn rate (3°/second filter): 5.55°/second



Uplink Latency

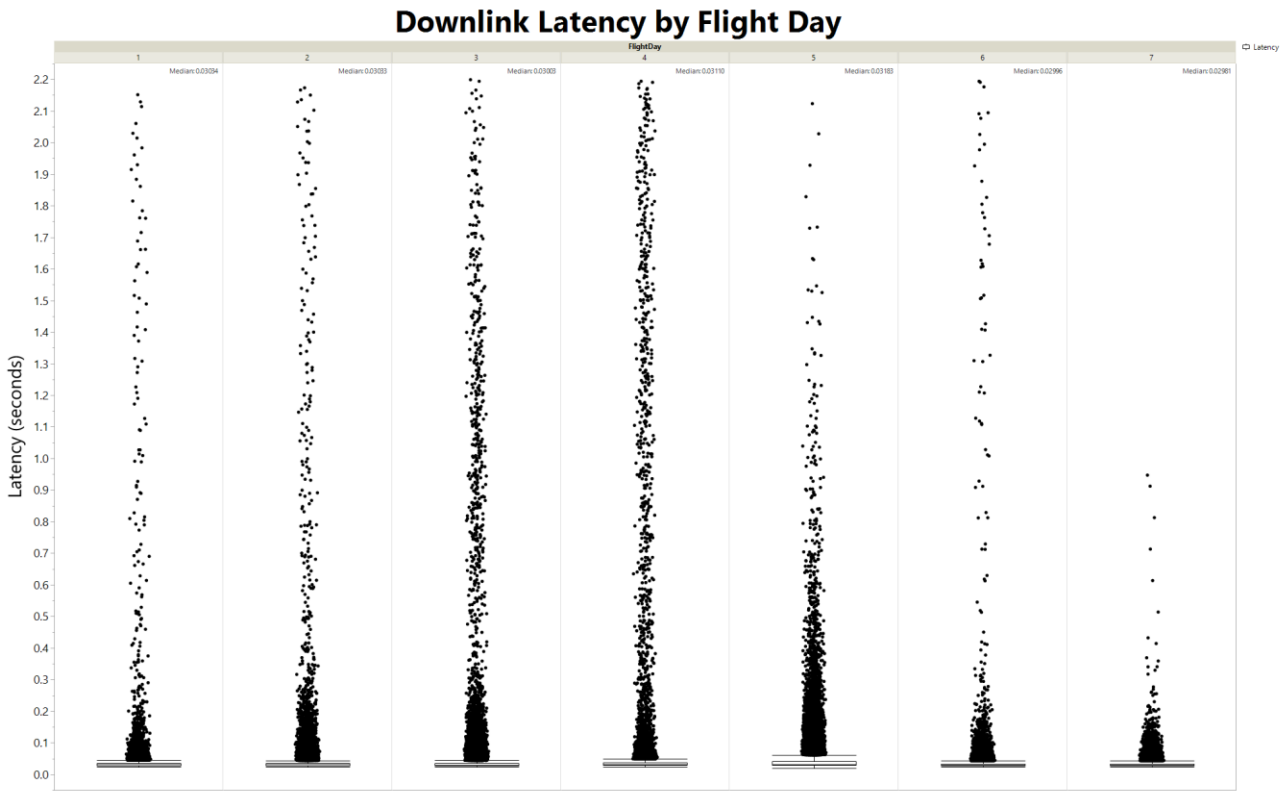
- Latency measured from time command sent in VSCS to time command received onboard vehicle
- Captured autopilot mode changes
  - NAV->HDG (first DAA maneuver)
  - HDG->NAV (return to course)
- Latency changed depending on command sent
  - NAV->HDG
    - M = 1.86
    - SD = 0.69
  - HDG->NAV
    - M = 0.89
    - SD = 0.28



Downlink Latency

- Measured time sent from vehicle to time received in LVC
- Several link “hit” events measured
  - Defined as downlink of greater than 2.2 seconds (99.5th percentile)
- Median downlink latency after link hits removed: 0.03 seconds

FlightDay	Median(Latency)
1	0.030
2	0.030
3	0.030
4	0.031
5	0.032
6	0.030
7	0.030



FT6 Lessons Learned

- High winds impacted flight operations with the Tigershark
  - Low ground speeds – difficult to set up encounters
  - Challenging launch and recovery
  - Survey multiple launch and recovery sites as best practice – cross winds
- Multiple flight plans provided flexibility
  - Allowed test to continue when part of airspace was unavailable
  - Allowed multiple encounter attempts during full mission
- Identification of backup data collection plans was helpful
  - RADAR range was identified as a project risk early-on
  - Allowed the development of the RADAR emulation in software
  - Provided plan for scripted encounters
- Rehearsal for full mission a necessity
  - Full mission procedures needed practice from the entire team to lock down
- Identification of display/interface requirements for human-in-the-loop flight testing
  - How operator, ATC expect vehicle to respond
  - VSCS – Piccolo interactions need to be known
  - Still would have been difficult to identify PTT issue in full mission
- Smoke system for visual identification was of limited utility
  - Visibility of smoke depended on weather – overcast skies and haze hampered visual ID

HONEYWELL SLIDES

RADAR CHARACTERIZATION

SCRIPTED ENCOUNTERS DATA ANALYSIS

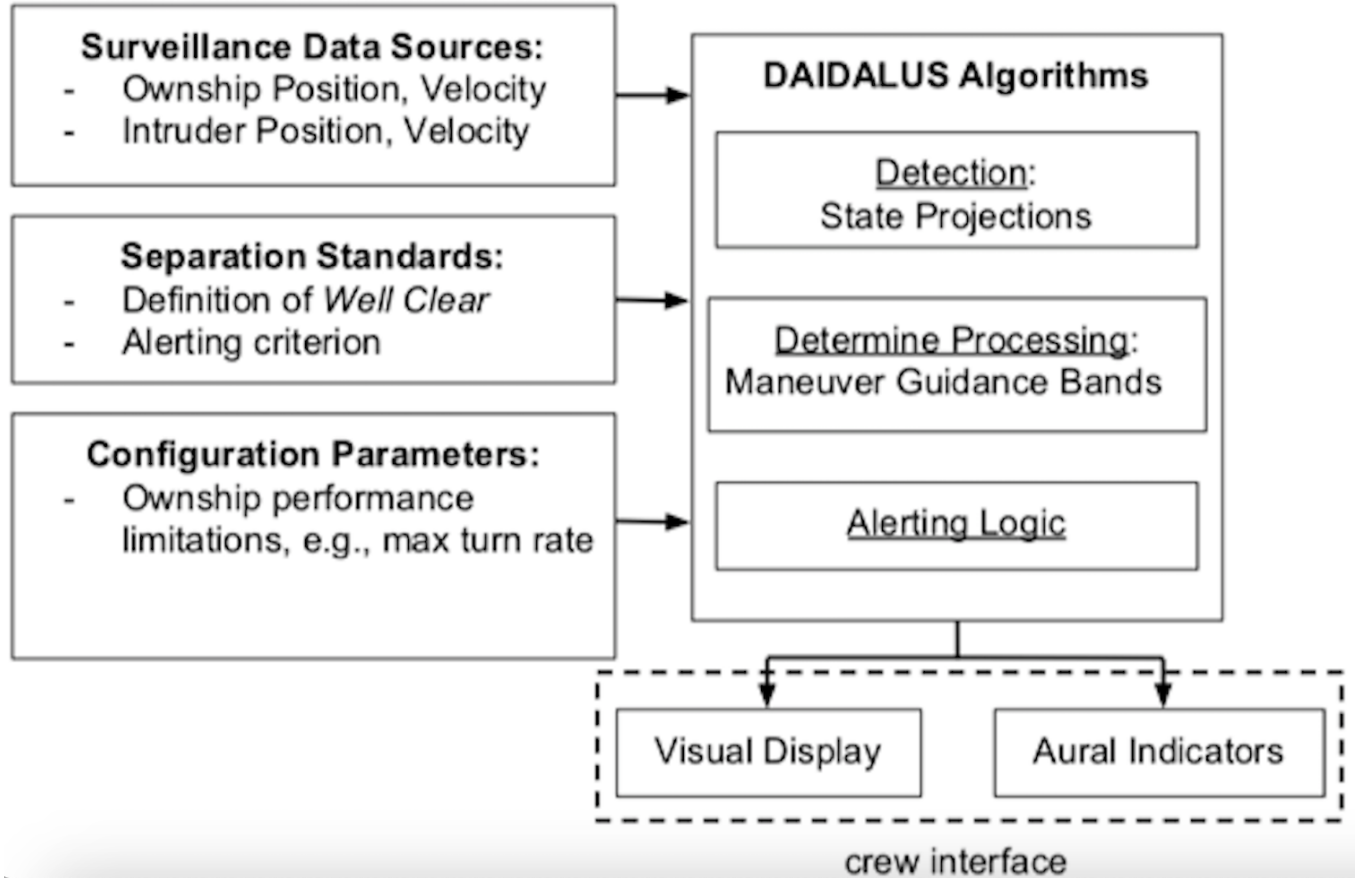
Wei-Ching Wang
Gilbert Wu

Simulated Surveillance Volume

- Radar characterization results showed that Honeywell's prototype airborne radar was unable to generate stable tracks of the intruders
- A simulated surveillance volume was used to only allow ADS-B track from the live intruder aircraft when within the following field of regard:
  - Range 3.5, 2.5, or 2.0 nmi
  - Azimuth $\pm 110^{\circ}$
  - Elevation $\pm 15^{\circ}$

Detect and AvoID Alerting Logic for Unmanned Systems (DAIDALUS)

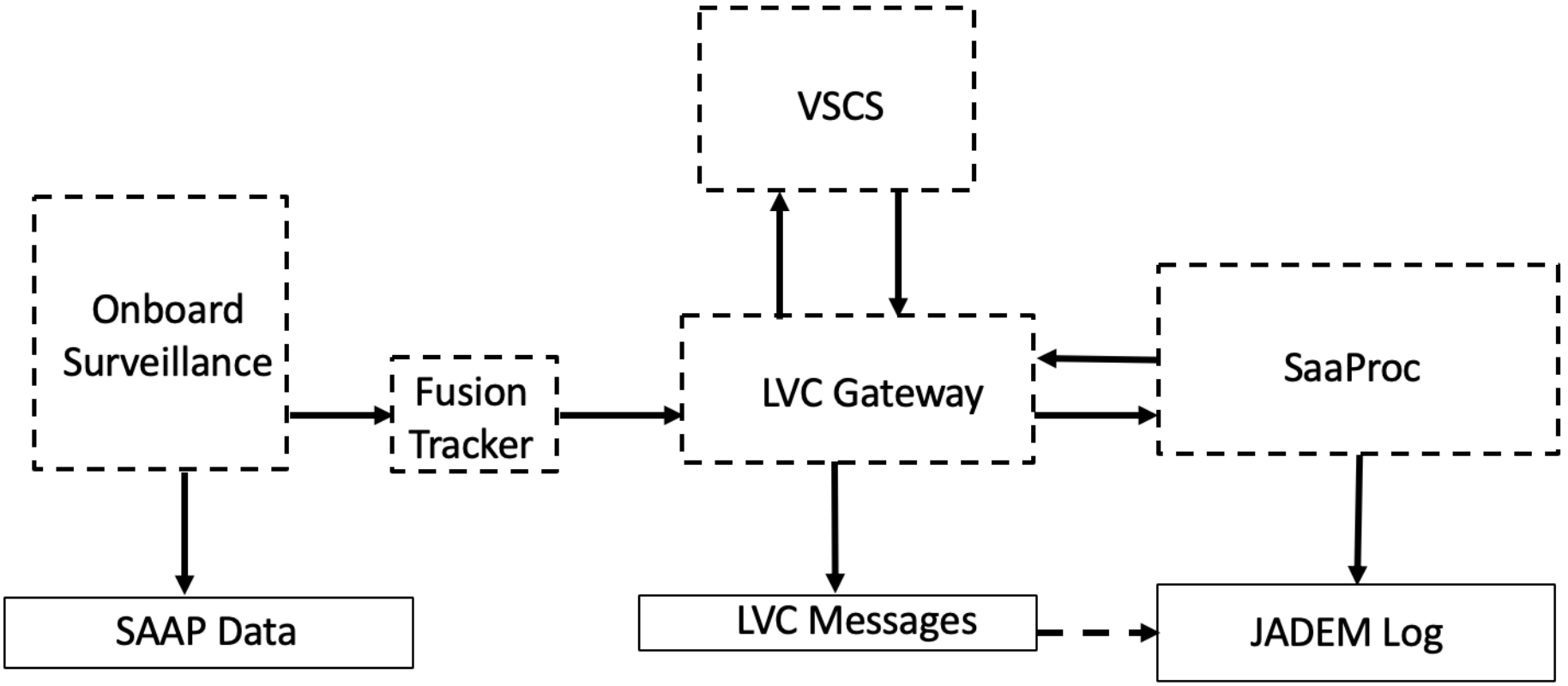
- DAIDALUS computes alerts and guidance during encounters
  - Alert types considered: Corrective and Warning
  - Maneuver types considered: Heading maneuver
  - Computation of maneuver guidance is based on
    - Constant turn rate of the ownship
    - Constant-velocity projections of traffic aircraft



Pilots' Procedure

- Target heading selection must be outside the conflict bands but within 15° of the edge of the heading bands
- Maneuver time
  - Execute a maneuver 8 seconds after a Corrective alert is triggered
  - Execute a maneuver 3 seconds after a Warning alert is triggered
  - Execute a maneuver upon initiation of a warning alert or the first alert that comes up

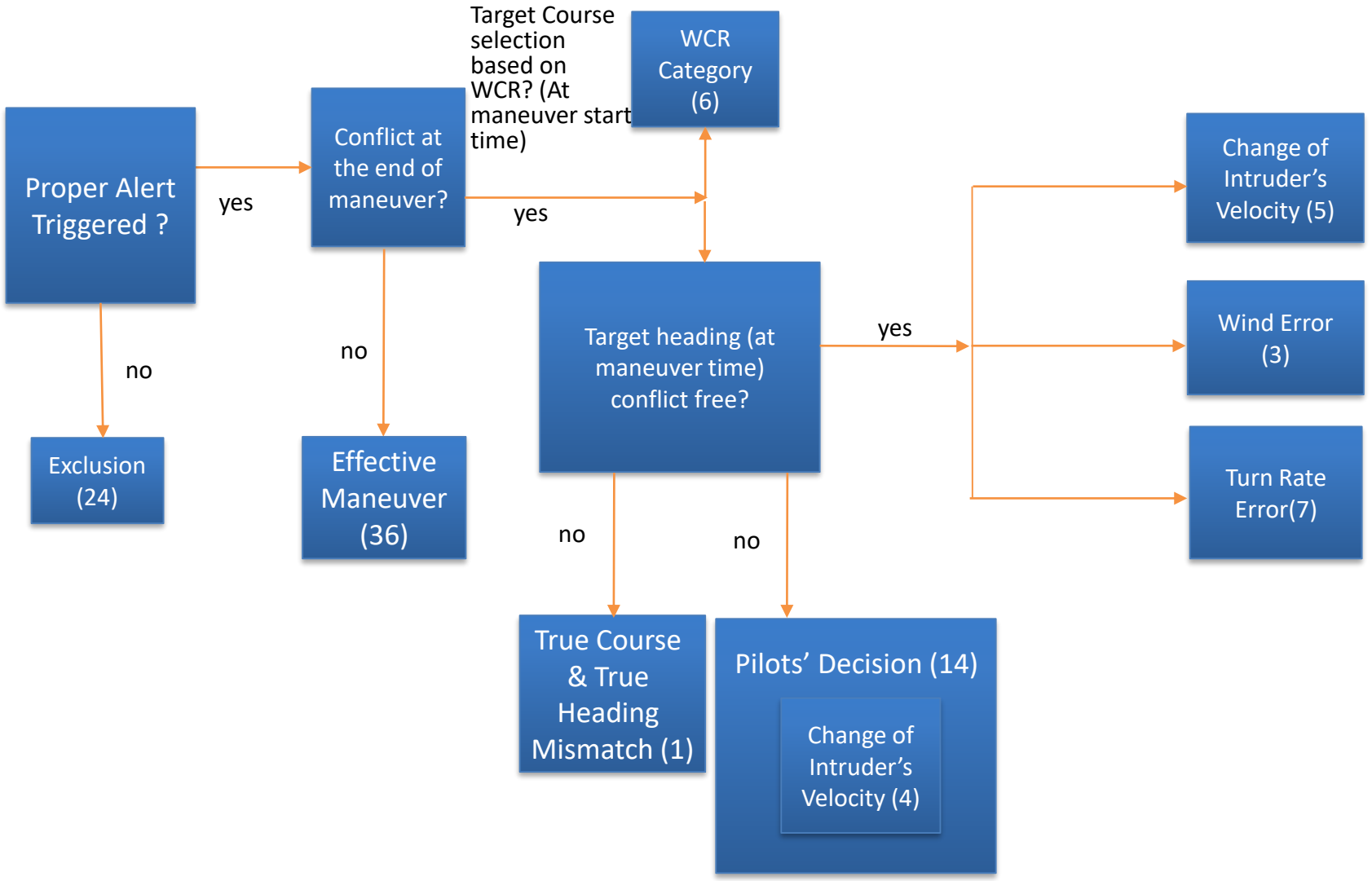
Data Flow Diagram



Flight Cards Summary

- Total number of flight days: 9 days (SCO#5, SCO#6, SCO#7, SCO#8, SCO#9, SE1, SE2, SE3, SCO#10)
- Total flight hours: 29.8
- Scripted encounters
  - Unmitigated: 6 of flight cards
  - Mitigated: 90 of flight cards
- Breakdown by simulated surveillance range (ADS-B)
  - 2.0 nmi surveillance range: 19 flight cards
  - 2.5 nmi surveillance range: 36 flight cards
  - 3.5 nmi surveillance range: 35 flight cards

Categorization by Maneuver Outcomes



Encounter Exclusion Criteria

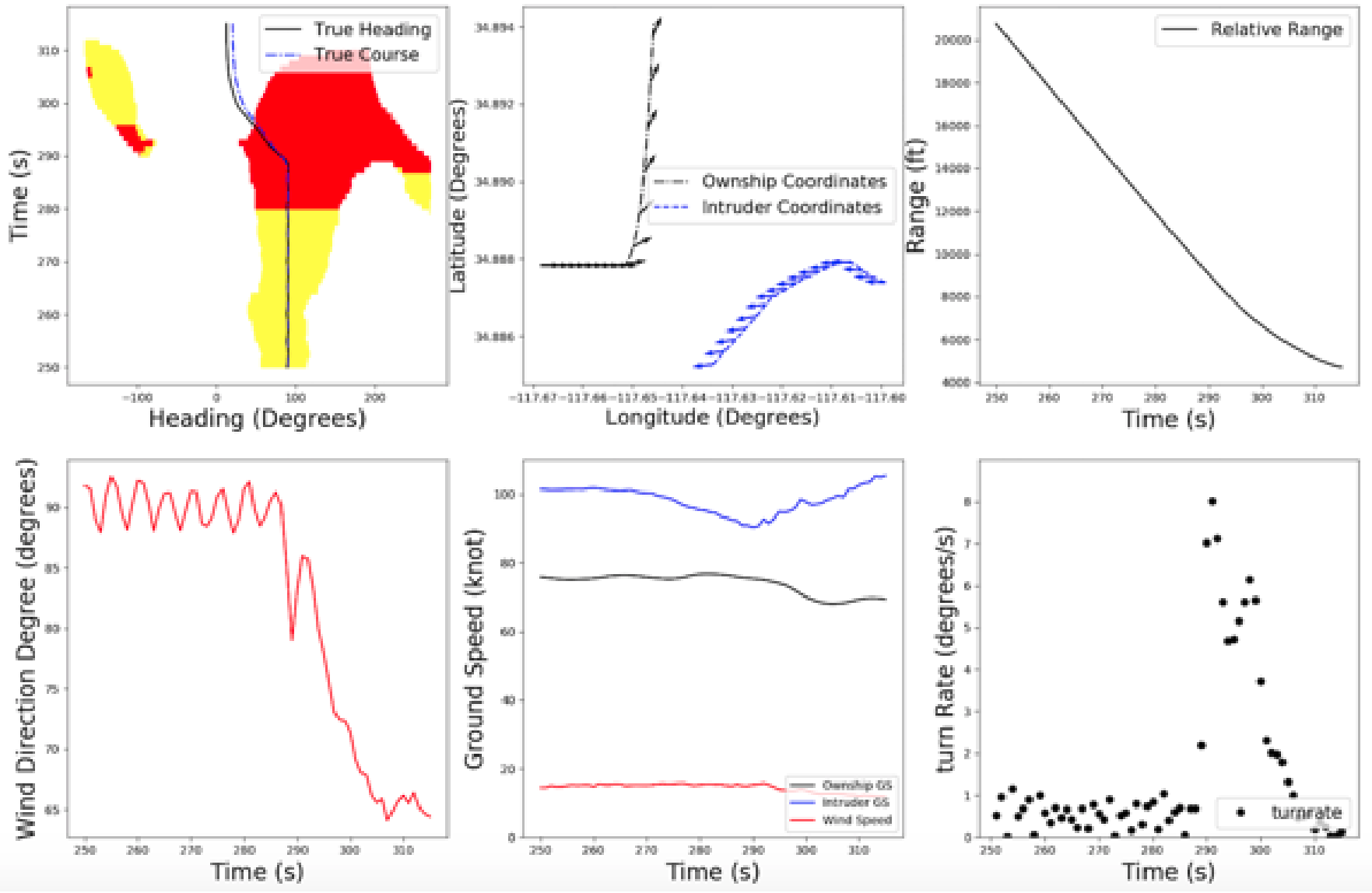
- Criteria:
  - Inadequate alerts and guidance
    - Timing is off
    - Unstable alerts
    - Sensor Uncertainty Mitigation leading to very early WCRs
  - Technical difficulties
    - Data not obtained on the VSCS
    - Segmentation fault on the UAP computer

UAP = Unmanned Aircraft Processor
VSCS = Vigilant Spirit Control Station

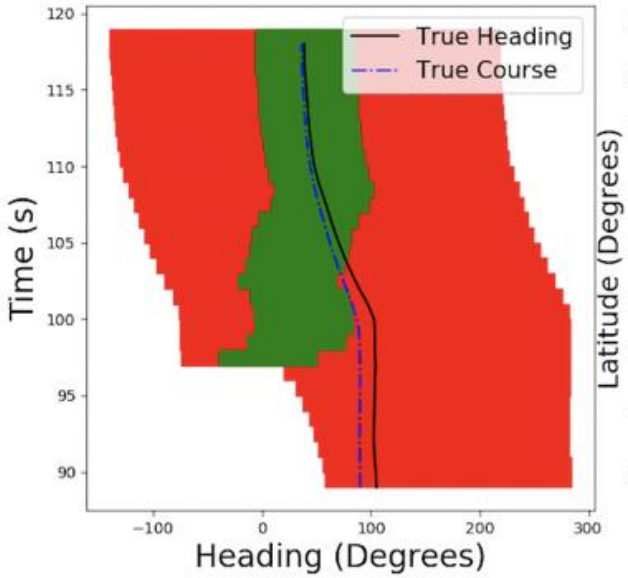
Breakdown by Surveillance Range

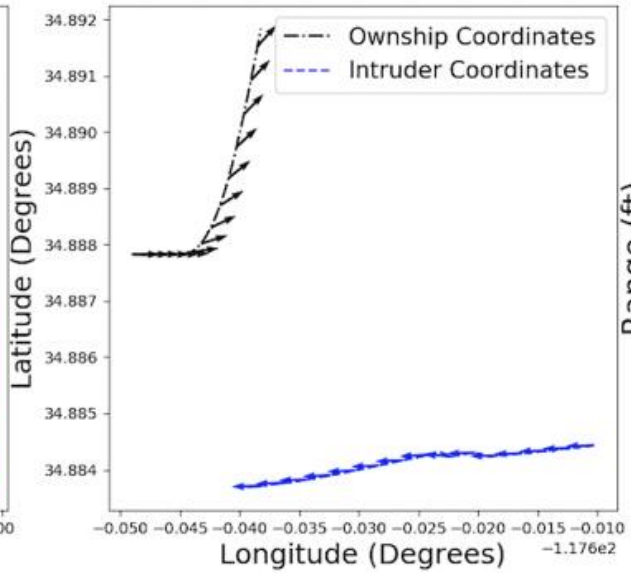
- 2.0 nmi surveillance range: 19 flight cards
  - Exclusion/WCR: 6
  - Effective: 7 (53.85%)
  - Ineffective (Pilots' Decision/Error /Mismatch): 6 (46.15%)
- 2.5 nmi surveillance range: 36 flight cards
  - Exclusion/WCR: 7
  - Effective: 16 (55.17%)
  - Ineffective (Pilots' Decision/Error /Mismatch): 13 (44.83%)
- 3.5 nmi surveillance range: 35 flight cards
  - Exclusion/WCR: 17
  - Effective: 13 (72.22%)
  - Ineffective (Pilots' Decision/Error /Mismatch): 5 (27.78%)

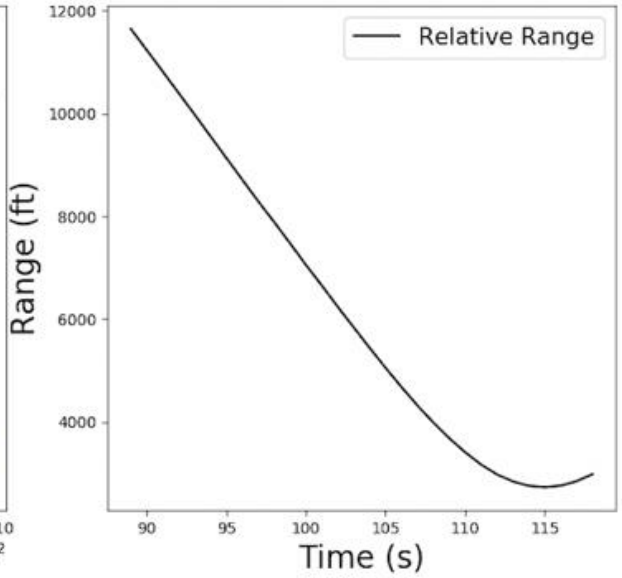
Example of An Effective Maneuver

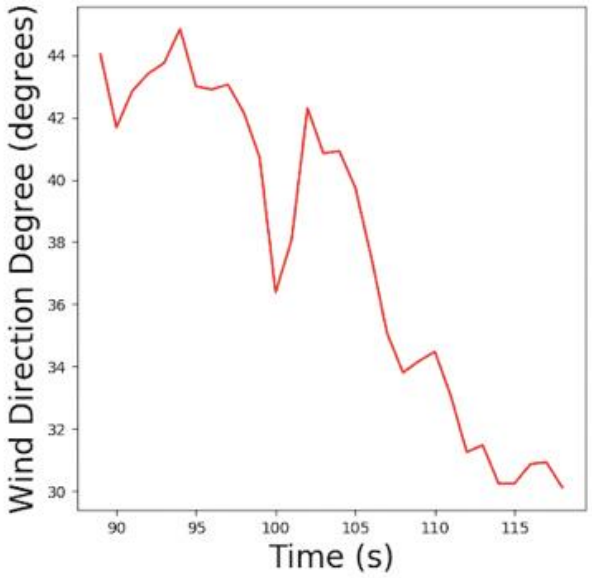


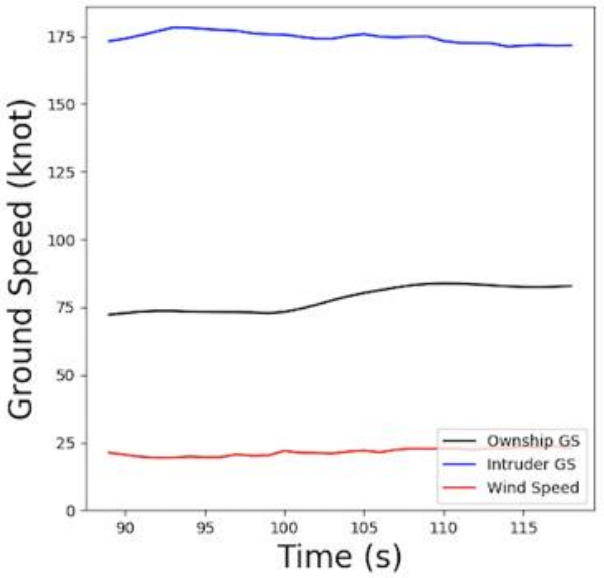
Example of Maneuver upon Well Clear Recovery (WCR)

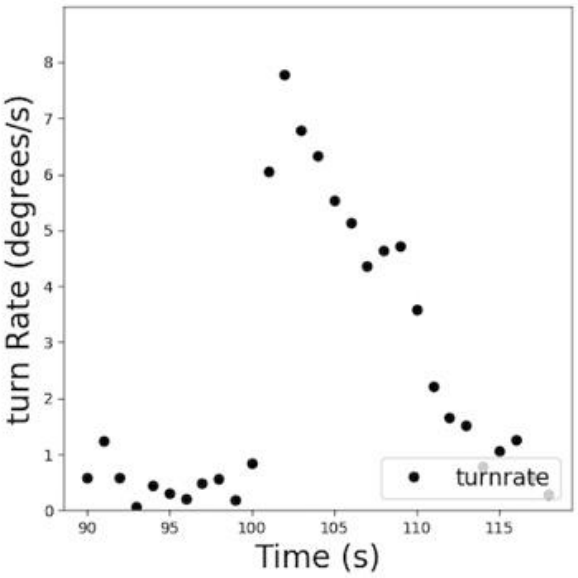






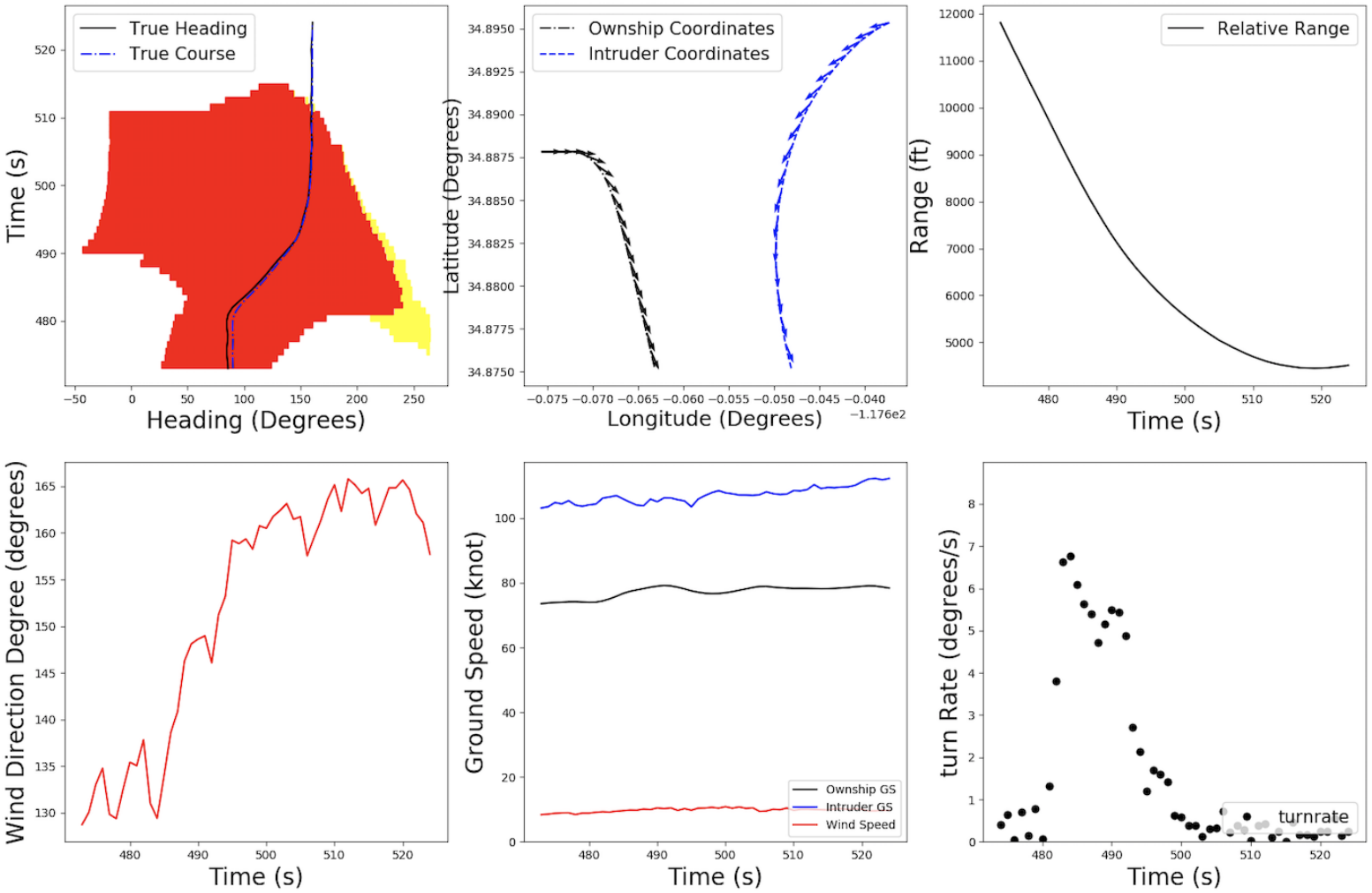






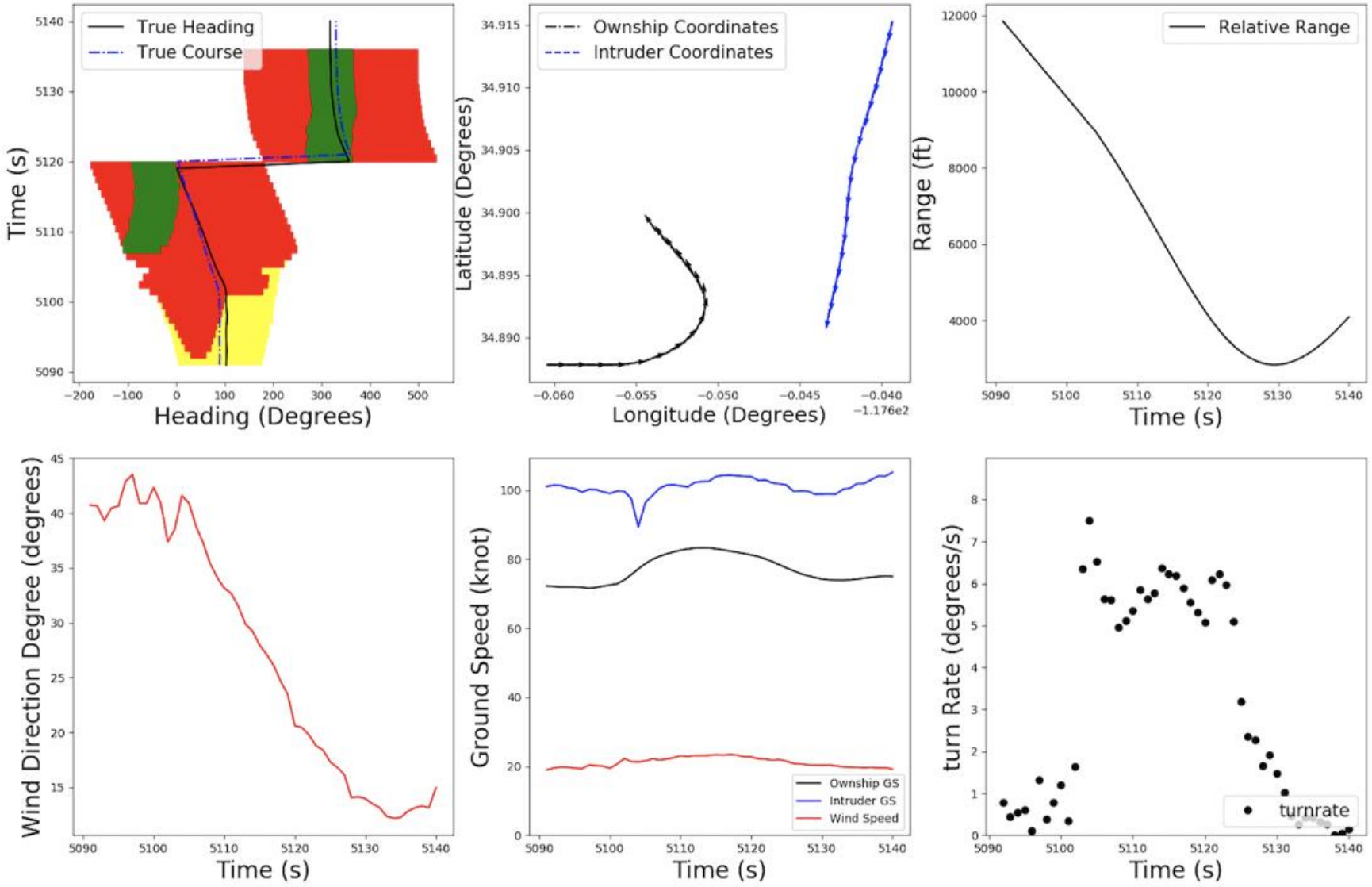
Example of Change of Intruder's Velocity

Intruder's velocity error criteria: $\left|\Delta\overrightarrow{V_{int}}\right| = \left|\overrightarrow{V(t)_{int}} - \overrightarrow{V_{int}}\,(t_{start,M,OS})\right|$ ≥10 kts



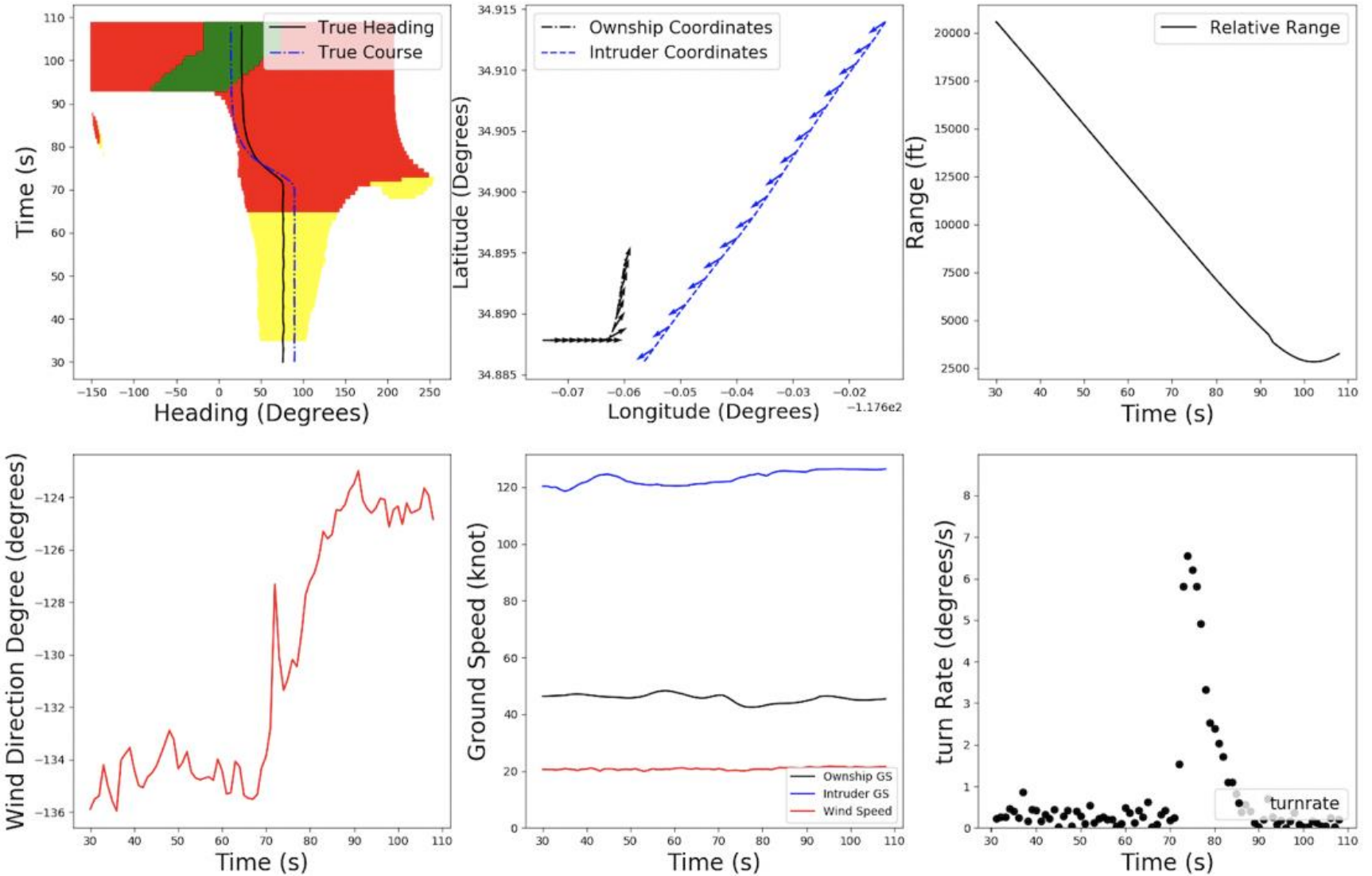
Example of Wind Error

Wind Error criteria: $\frac{|\overrightarrow{w_f} - \overrightarrow{w_i}|}{|\overrightarrow{w_i}|} \geq 40\%$

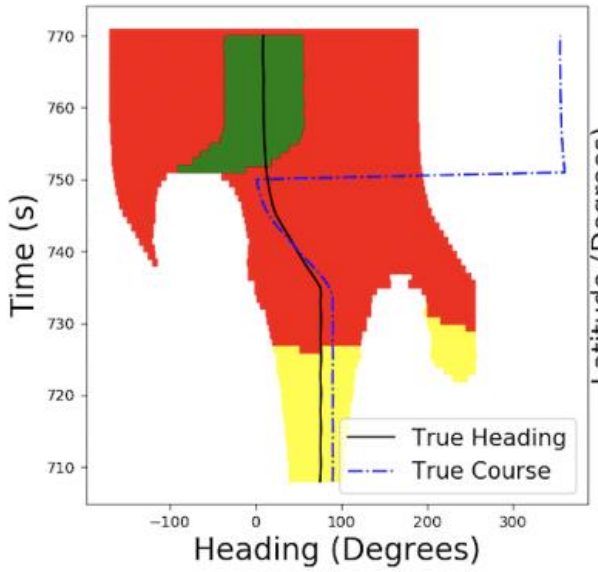


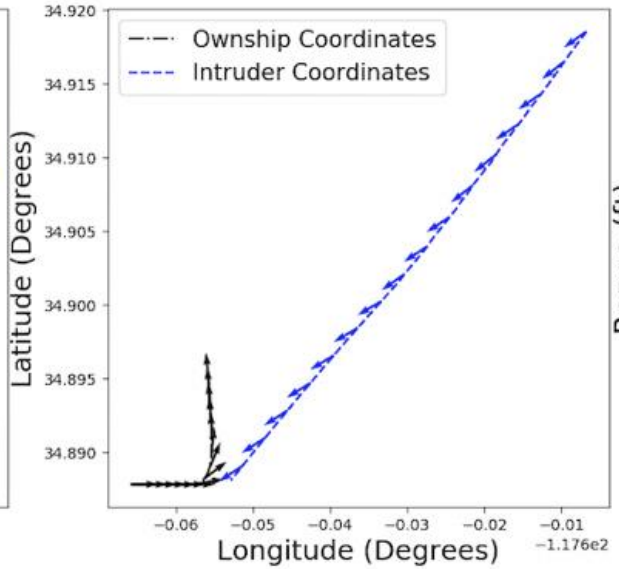
Example of Turn Rate Error

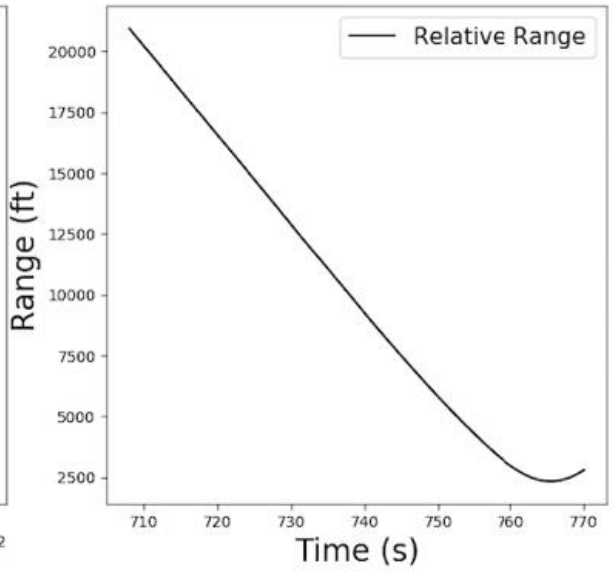
- Turn rate error criteria: $\frac{|\Delta t_{act} - \Delta t_{pred}|}{\Delta t_{pred}} \geq 50\%$

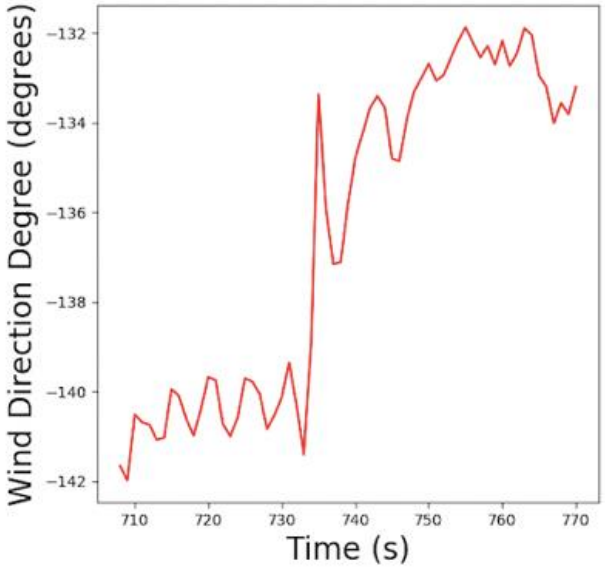


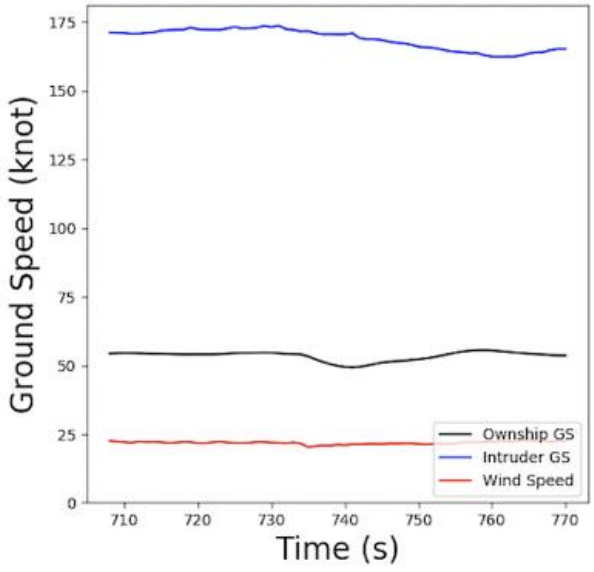
Example of True Course & True Heading Mismatch

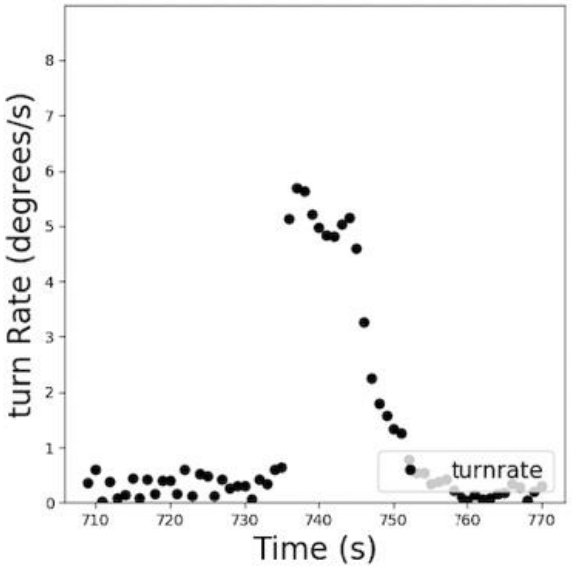




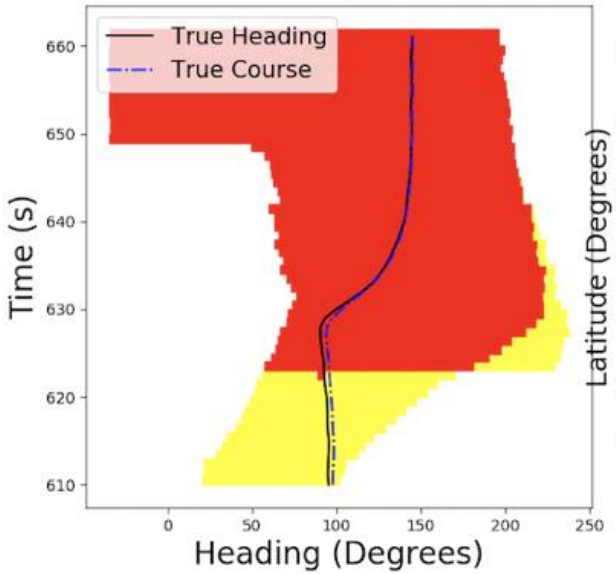


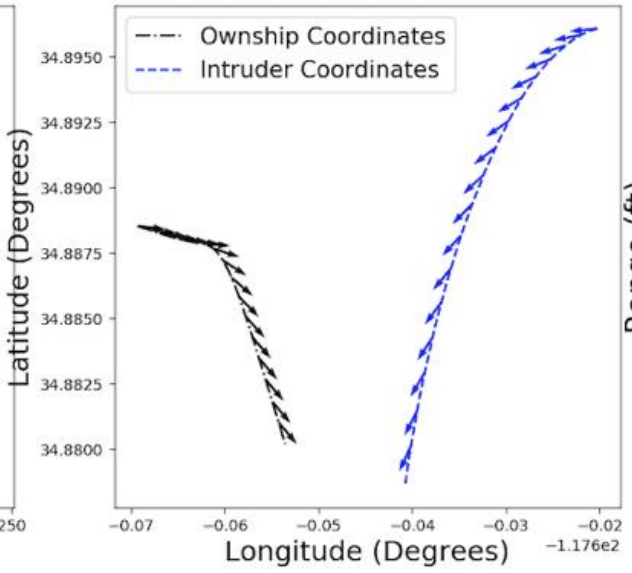


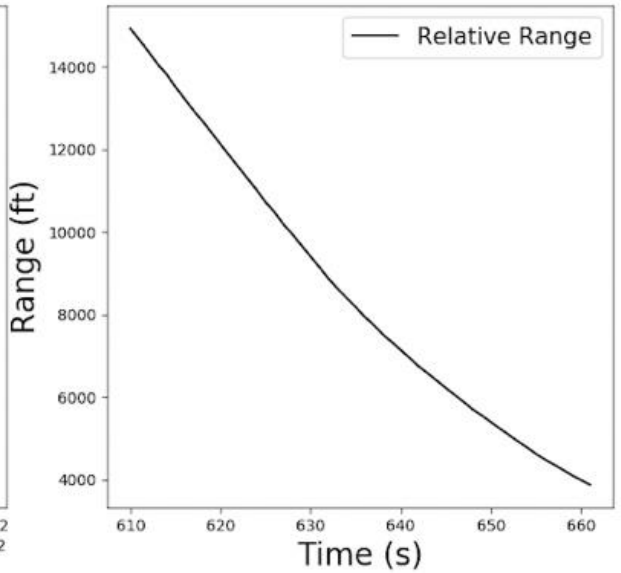


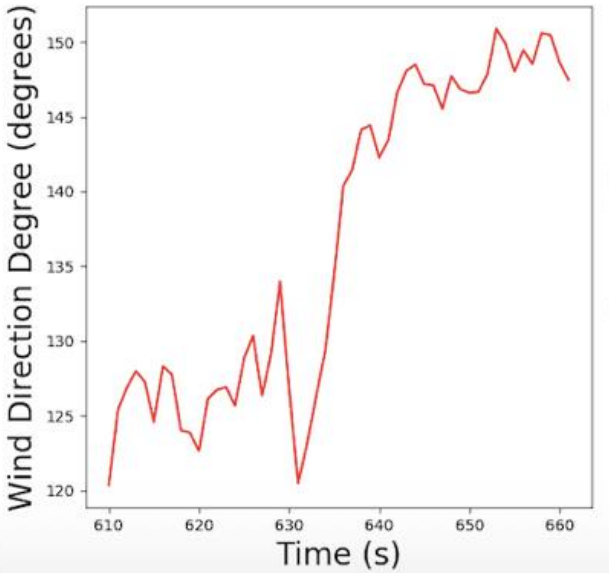


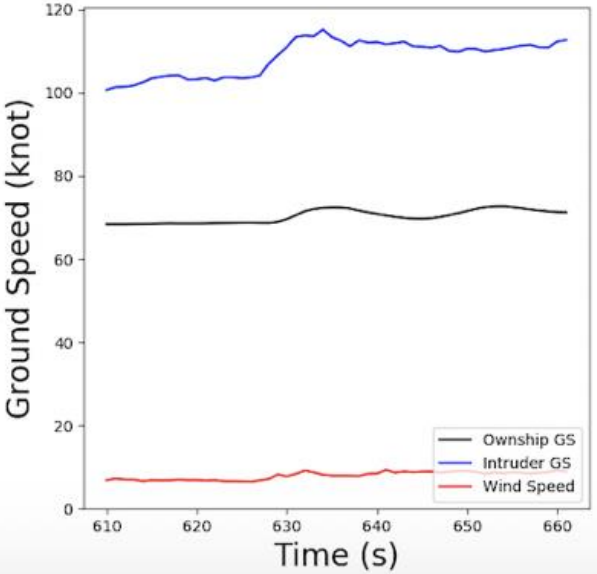
Example of Pilots' Decision

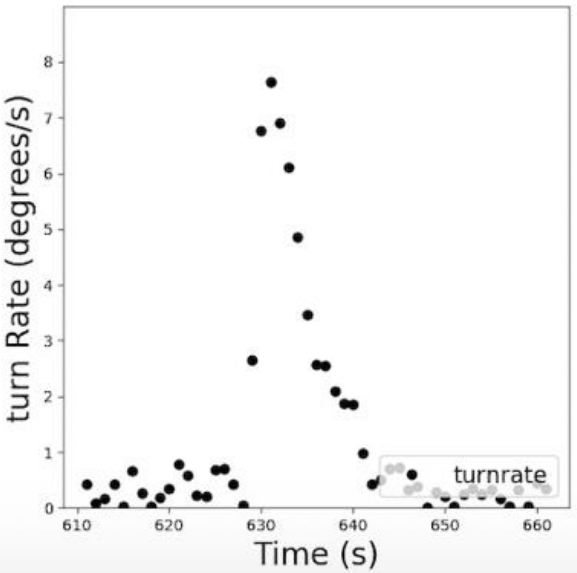




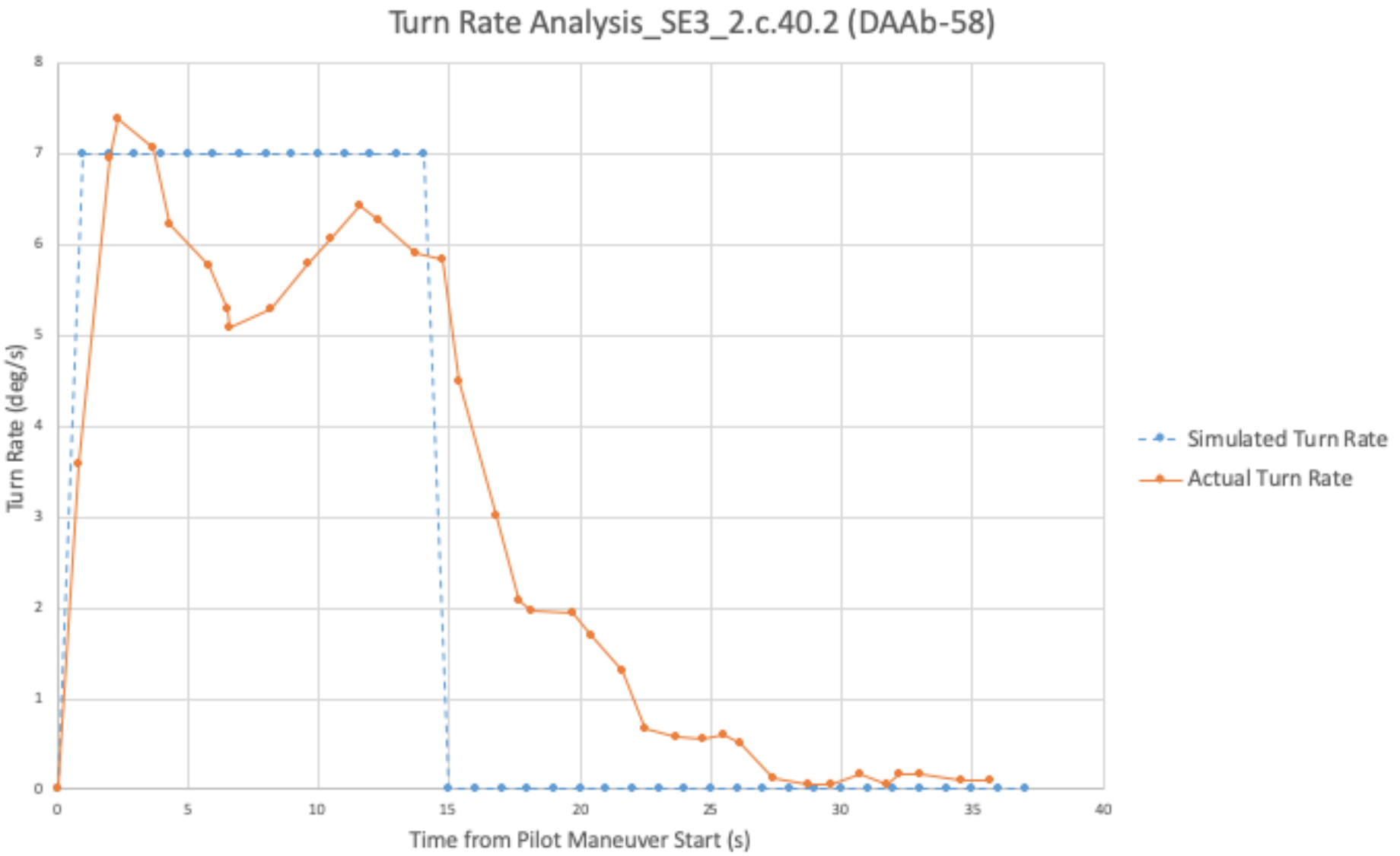




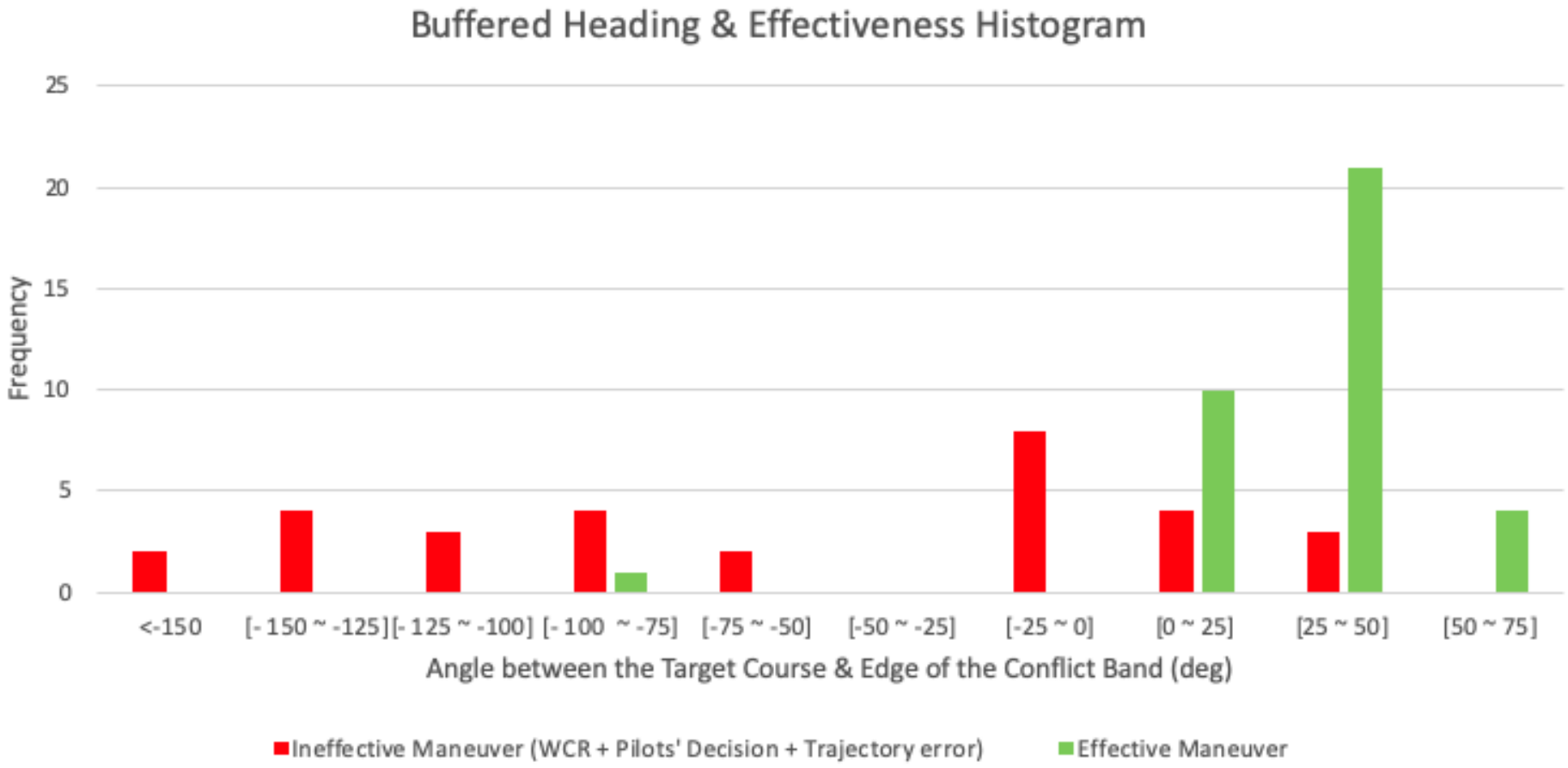




Trajectory Error Analysis



Buffered Heading & Encounter Effectiveness



Summary

- For maneuvers executed in a timely fashion (before WCR), more than half of these maneuvers effectively resolved conflicts
  - A 3.5 nmi surveillance range achieved a higher success rate (~70%) than 2.5 and 2.0 nmi (50%)
- For ineffective encounters, the lead contributing factors are
  - Pilots' decision
  - Change of Intruder's velocity
- It may be beneficial for pilots to add more maneuver "buffer" beyond the heading bands to the target heading
  - Maneuvers are more effective when buffers are larger
- A challenging case: maneuvering intruders
  - A turn in front of an intruder may appear to be feasible for resolving the conflict at one time. Intruder maneuvers may "close the gate" afterwards.
  - Accounting for intruder accelerations may improve predictions

FULL MISSION RESULTS

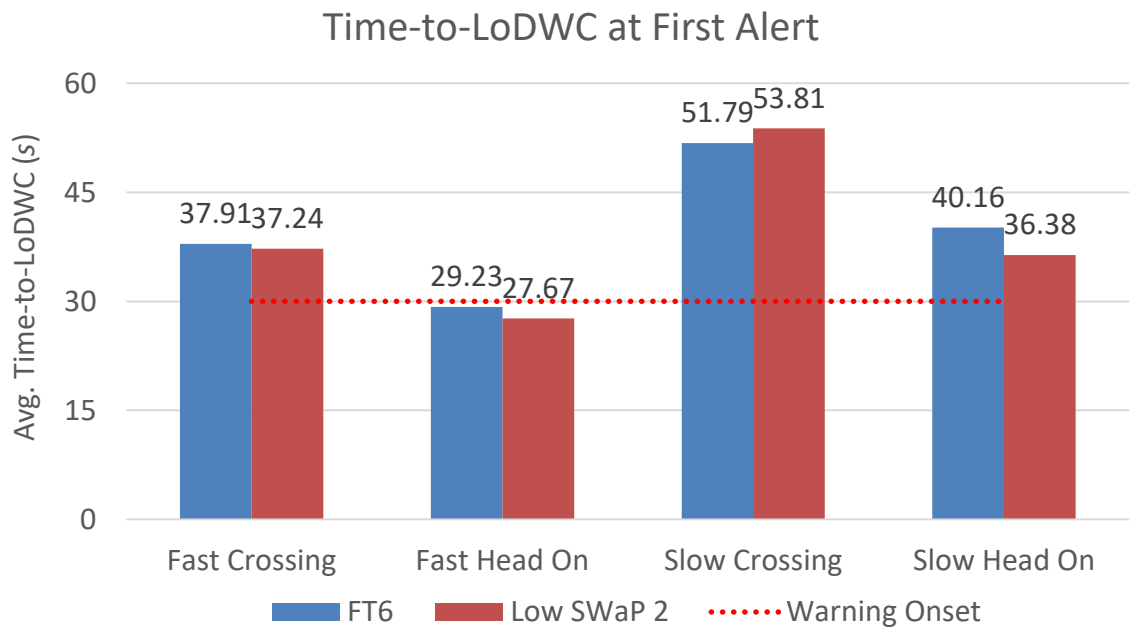
ALERTING & PILOT RESPONSES

(NON-COOPERATIVES)

Kevin Monk
Conrad Rorie
Casey Smith
Garrett Sadler
Jillian Keeler

Encounter Summary - Alerting

- Data sample = 27 non-cooperative encounters
- All encounters enabled Corrective alerting except Fast Head On

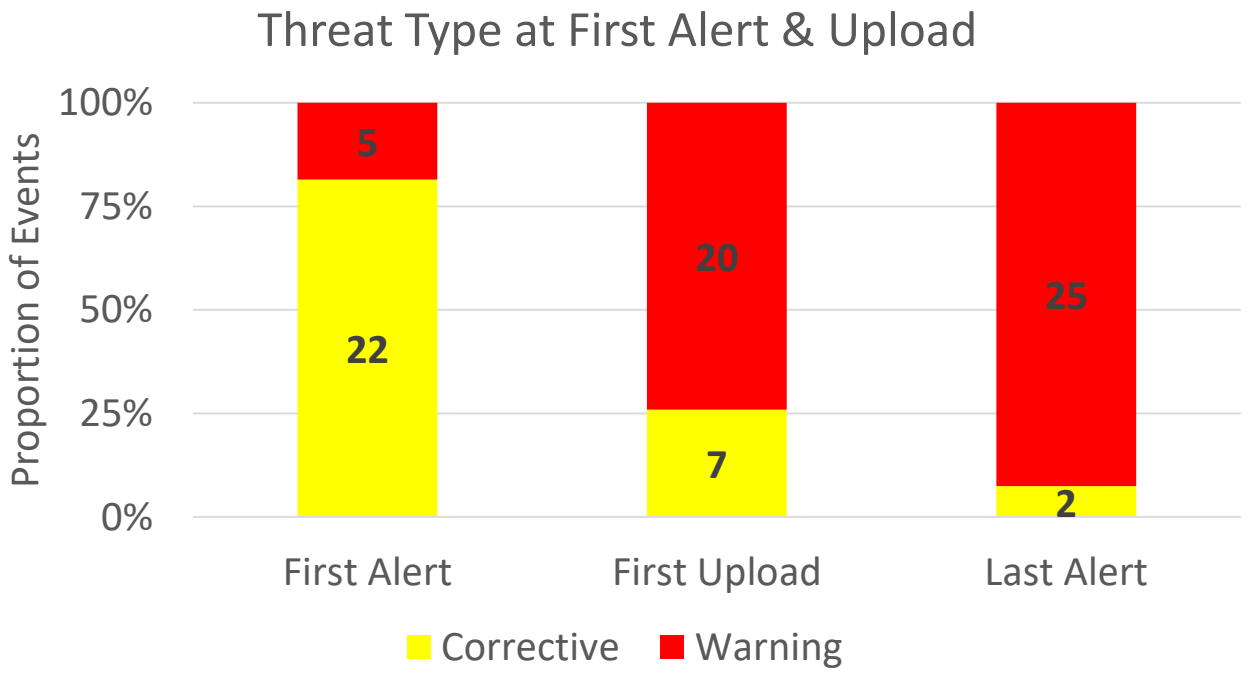


Encounter	Ownship Speed (avg.)	Intruder Speed (avg.)	*t*Loss (avg.)
Slow Crossing	71 kts	115 kts	51.8 sec
Slow Head On	64 kts	107 kts	40.2 sec
Fast Crossing	61 kts	173 kts	37.9 sec
Fast Head On	64 kts	170 kts	29.2 sec
ALL LSNC	**67 kts**	**150 kts**	**45.6 sec**

Alerting Performance - Remain DWC

- Corrective alerts were generated for 81% of non-coop conflicts
  - All were Corrective at First Alert except the Fast Head On encounter

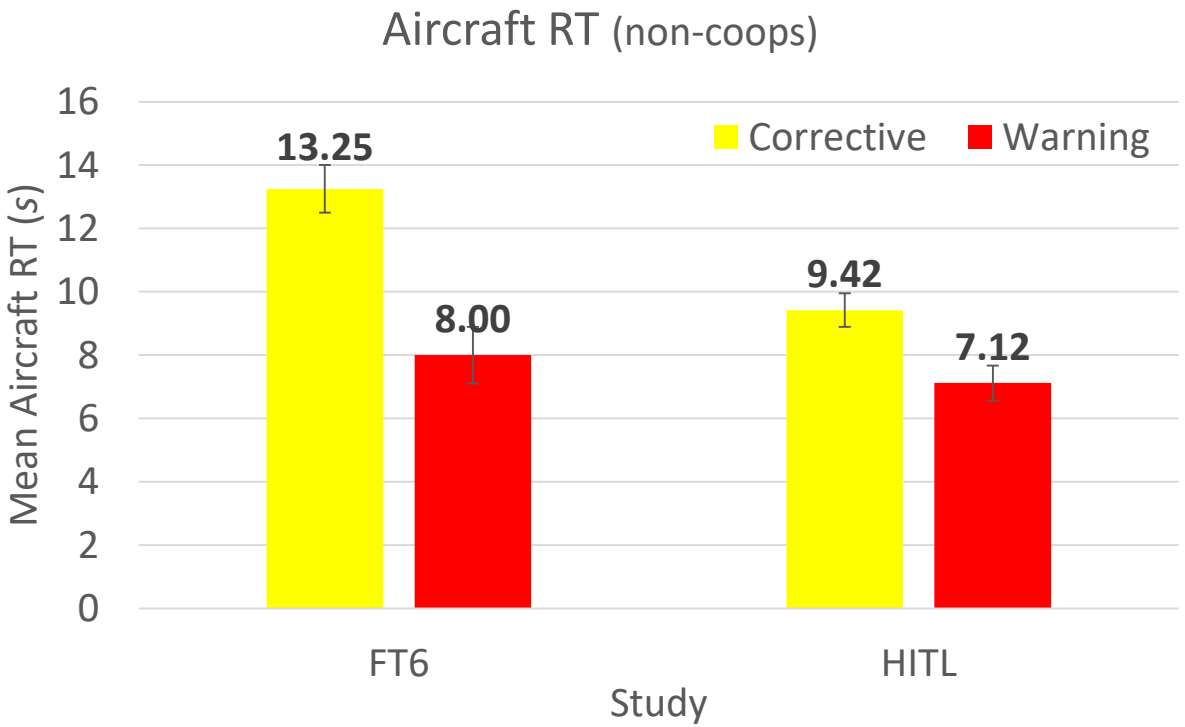
- Nearly all Corrective alerts eventually progressed to Warning
  - 74% progressed to Warning before first upload
  - Avg. Corrective duration (*before Warning*) = **11.6sec**
    - HITL = **7.6sec**
      - More fast-closure encounters



Aircraft Response Time

- Slower responses to Correctives compared to HITL results
  - Higher proportion of Correctives, longer alert duration
  - More pilots on common voice frequency

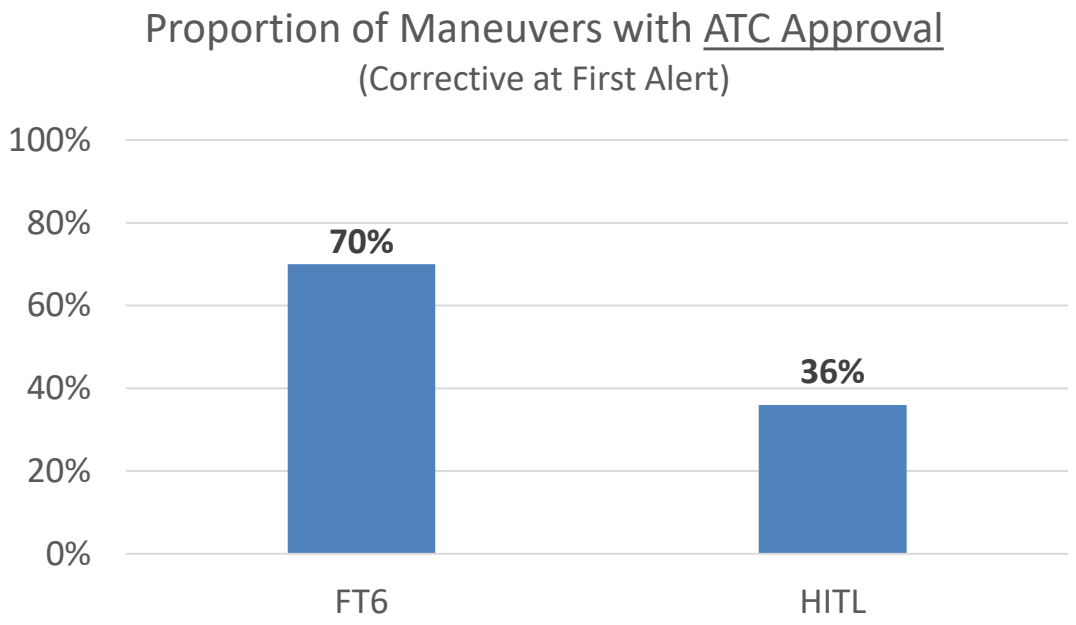
- RT distribution (non-cooperative traffic)
  - Corrective at First Alert: 80% of RTs within 15sec (Max = 20sec)
  - Warning at First Alert: 80% of RTs within 10sec (Max = 11sec)



Aircraft response time **– time elapsed from alert to first maneuver upload**

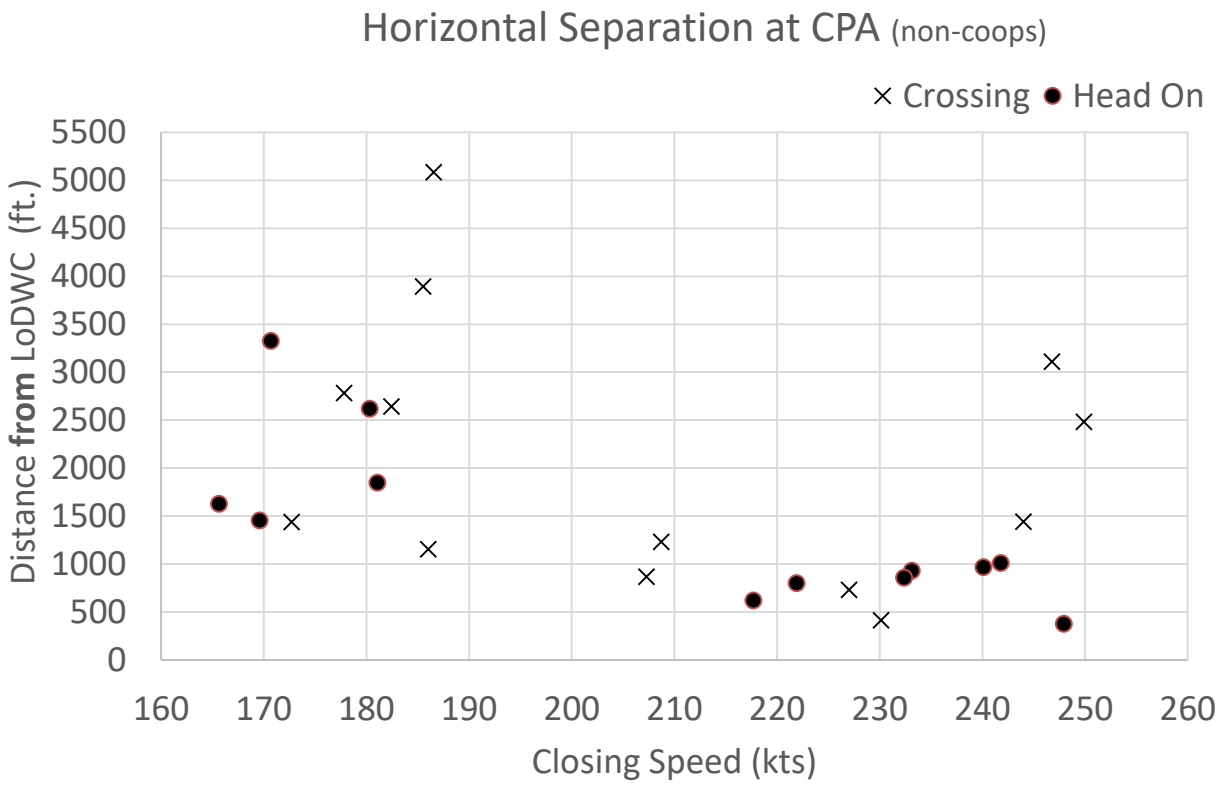
ATC Coordination

- ATC coordination rates nearly doubled in FT6 compared to HITL
  - More time to receive ATC approval before Warning onset (~12 sec)
  - Warning onset typically occurred during transmission
    - On average, pre-approved maneuver uploads came 14 seconds after first alert



Separation Performance

- Zero Losses of DWC with either equipage
  - 'Fast' intruders accounted for the closest CPAs
    - Closest call: 2577ft. Horz. CPA (Fast Head On, 27sec-to-LoDWC @ 1st alert)
      - Unintentional button click delayed pilot's response
  - No early returns to course



Field of Regard (FOR) Considerations

- Intruder A/C fell out of FOR during 26 of 27 avoidance events
  - Smaller detection range -> larger turns required for resolution
    - Stresses 110° azimuth limit, especially at fast closure rates
    - Wider turns observed in live flight compared to HITL
      - Training encouraged adding buffer to target headings to account for winds
  - DAA information remained absent for at least 13 seconds (max = 87sec)
    - Occasionally, symbology disappeared before Clear-of-Conflict
    - Half never re-appeared on display
  - 59% of intruders reached CPA while outside of FOR
    - Lost more separation without conflicting traffic in sight
    - Always diverged in time to avoid LoDWC or early return to course
      - Pilots spent more time off course than previous HITLs (63sec)

Study	Azimuth Drops before CoC	Avg. Turn Size (Fast Intruders)
FT6	11/27 **(41%)**	128deg
HITL	9/36 **(25%)**	90 deg

SUBJECTIVE FEEDBACK

NASA TLX (Post-Encounter)

- Overall, low workload ratings across all encounter types
- Slightly higher workload ratings for 'Fast' encounters
  - Temporal Demand received the highest ratings across the board

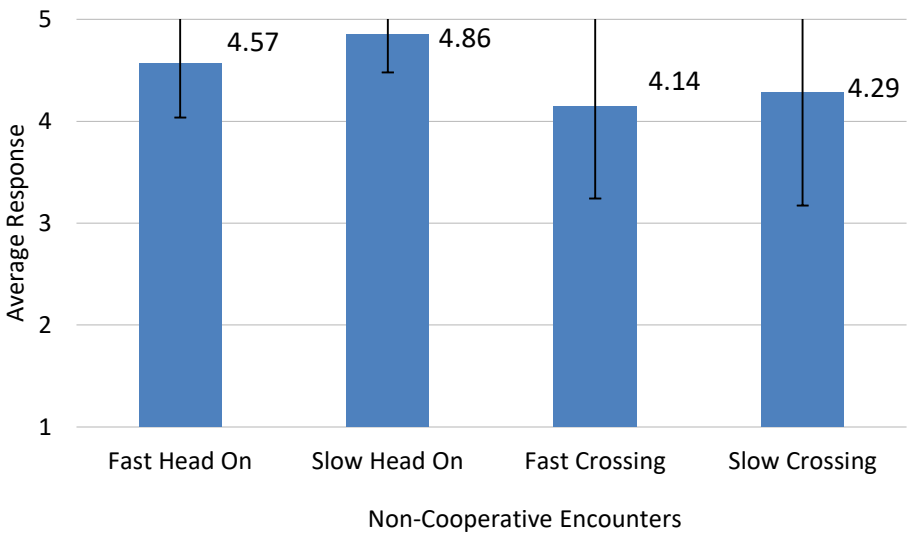
Metric	Fast Head On	Fast Crossing	Slow Head On	Slow Crossing
Mental Demand	*M* = 3.57 *SD* = 1.90 *Mdn* = 4	*M* = 4.14 *SD* = 2.12 *Mdn* = 4	*M* = 2.57 *SD* = 1.72 *Mdn* = 2	*M* = 3 *SD* = 2.16 *Mdn* = 2
Physical Demand	*M* = 1.14 *SD* = .38 *Mdn* = 1	*M* = 1.14 *SD* = .38 *Mdn* = 1	*M* = 1.14 *SD* = .38 *Mdn* = 1	*M* = 1.14 *SD* = .38 *Mdn* = 1
Temporal Demand	*M* = 4.14 *SD* = 2.04 *Mdn* = 5	*M* = 4.43 *SD* = 2.23 *Mdn* = 5	*M* = 3.14 *SD* = 1.77 *Mdn* = 3	*M* = 3.71 *SD* = 1.50 *Mdn* = 4
Performance*	*M* = 2.57 *SD* = .96 *Mdn* = 3	*M* = 2.29 *SD* = .76 *Mdn* = 2	*M* = 1.86 *SD* = .90 *Mdn* = 2	*M* = 2.43 *SD* = 1.40 *Mdn* = 2
Effort	*M* = 3.29 *SD* = 2.14 *Mdn* = 3	*M* = 3.29 *SD* = 1.95 *Mdn* = 3	*M* = 2.57 *SD* = 1.81 *Mdn* = 2	*M* = 2.86 *SD* = 1.89 *Mdn* = 2
Frustration	*M* = 2.57 *SD* = 1.81 *Mdn* = 2	*M* = 3.14 *SD* = 2.12 *Mdn* = 3	*M* = 1.86 *SD* = 1.46 *Mdn* = 1	*M* = 2.43 *SD* = 1.81 *Mdn* = 2
Composite	*M* = 17.29 *SD* = 8.48 *Mdn* = 17	*M* = 18.43 *SD* = 8.73 *Mdn* = 18	*M* = 13.14 *SD* = 7.34 *Mdn* = 11	*M* = 15.57 *SD* = 8.42 *Mdn* = 15

Post-Encounter

- Pilots felt that they were able to achieve sufficient separation in all four non-cooperative encounters, and found the DAA guidance bands useful

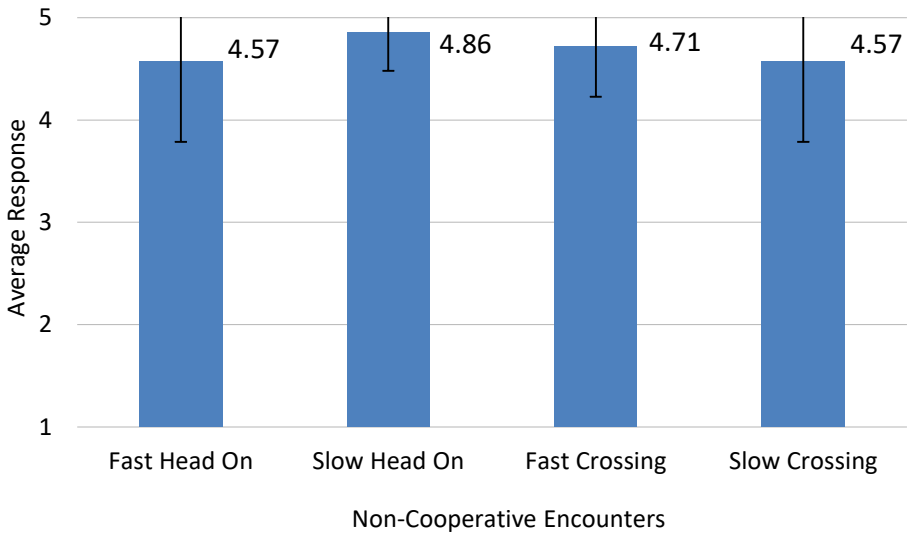
I was able to achieve sufficient separation from the intruder aircraft(s) using the alerting and guidance in this encounter:

1 = Strongly Disagree, 5 = Strongly Agree



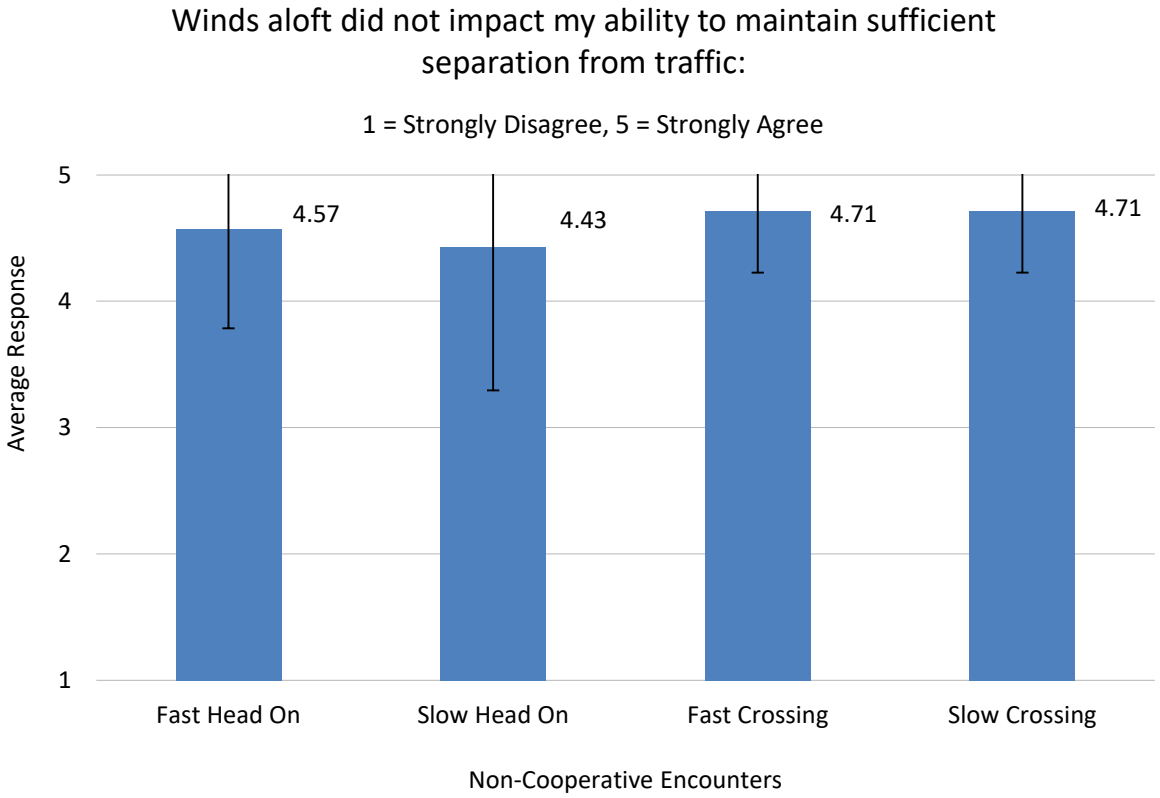
The DAA guidance bands were useful for solving this encounter:

1 = Strongly Disagree, 5 = Strongly Agree



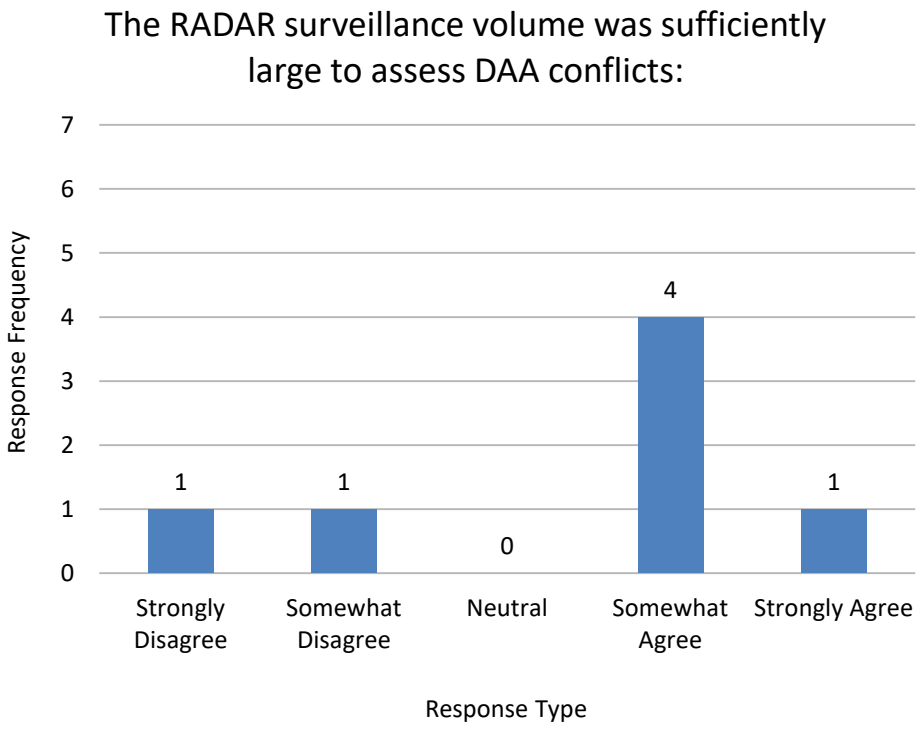
Post-Encounter

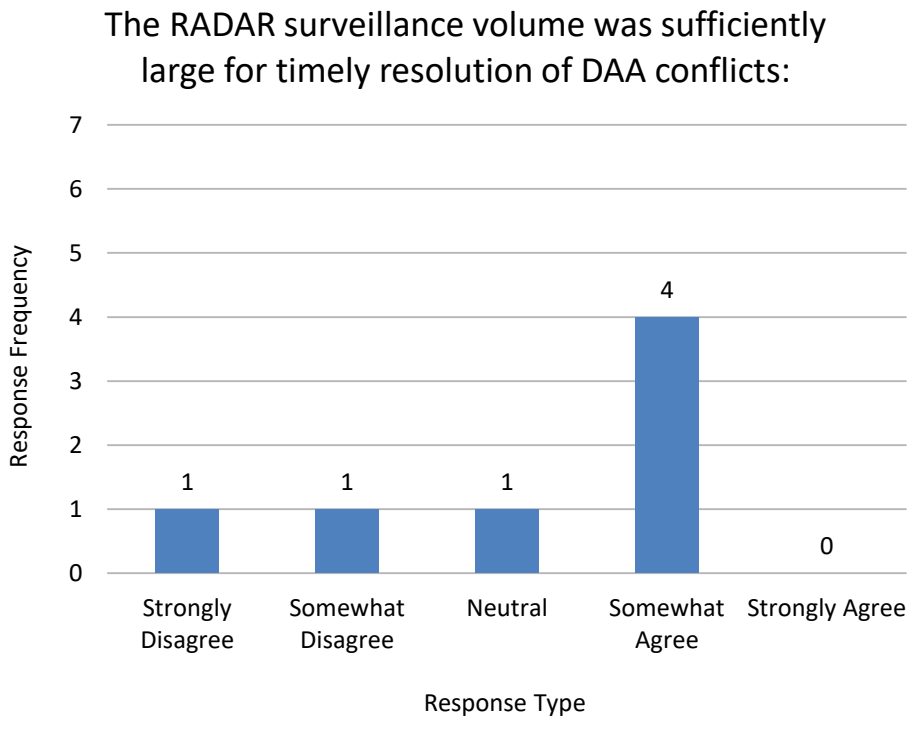
- Winds aloft did not ability impact pilots' subjective ability to achieve separation



Post-Test

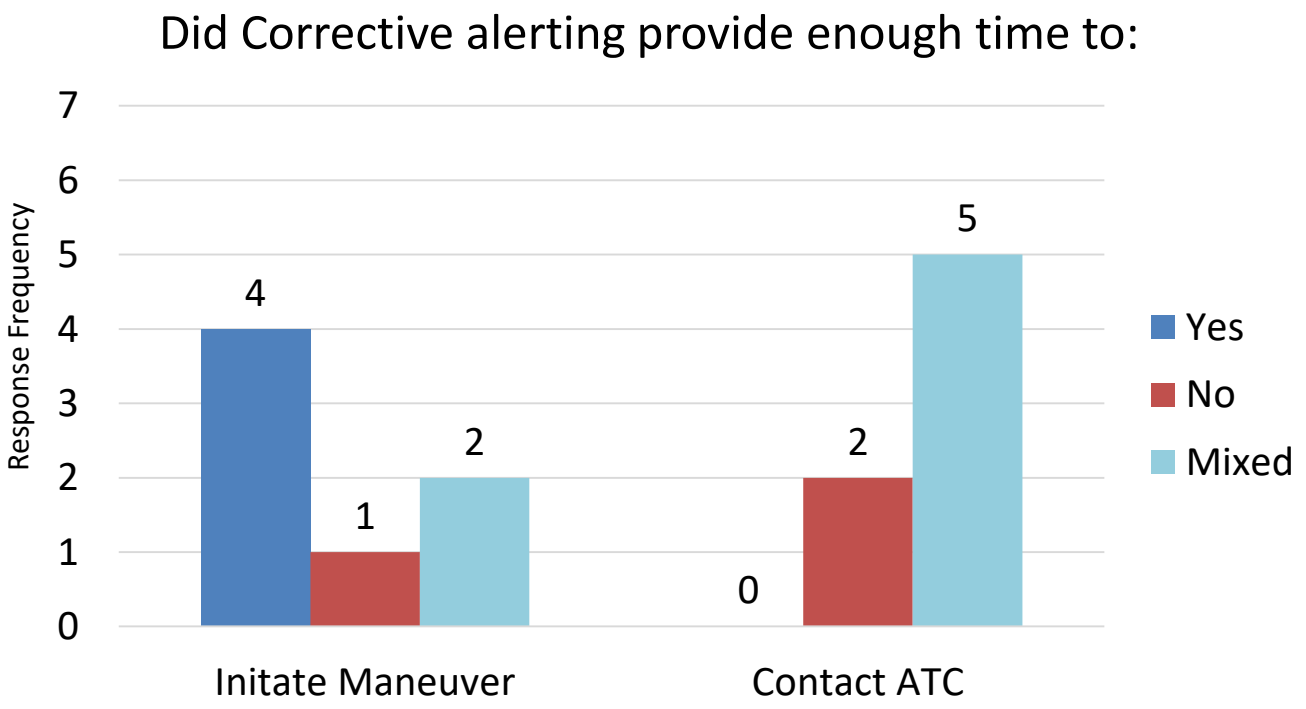
- Majority of pilots moderately agreed the 2.5 NM RADAR Declaration Range (RDR) enabled sufficient time for conflict assessment and timely resolution





Post-Test

- Majority thought alerting provided enough time to **initiate maneuver** in most cases
  - Slower aircraft intruding were okay, faster ones were “pushing it”
- Mixed responses on **timing to contact ATC** at corrective alert level
  - Pilots reported instances where encounter immediately elevated to Warning while attempting coordination
  - “Sometimes frequency congestion didn’t allow time to coordinate”



Post-Test

- **'What would help you remain well-clear if the radar detection range was significantly smaller?'**
  - IR camera – pick up intruder's engine before radar can
  - Fewer required button clicks for maneuvers
    - Pre-loaded maneuvers for warning-level threats (execute w/ pilot consent)
    - Automated Well Clear Recovery/CA
  - 'Coasting' logic for non-coops after dropping out of FOR
  - Have bands be predictive to account for how long pilots take to initiate a heading change

Full Mission Analysis Summary

- Pilot Performance (compared to HITL)
  - Zero Losses of DAA Well Clear
    - HITL: 1 LoDWC due to Early Return to Course
  - Slower response times, but more ATC-approved maneuvers
    - More caution alerting due to slower ownship speeds
  - Pilots were still often unable to respond to Corrective alerts
    - All but two encounters reached warning-level status
  - Larger path deviations & more time spent off course
    - Lost visual of intruder aircraft during all but one encounter

- Pilot Feedback
  - Low workload ratings overall
    - Moderate increases for fast-closure encounters
  - Sufficiency of DAA guidance bands rated favorably
  - Corrective alert timing inadequate for ATC coordination
  - More conservative on minimally-acceptable RDR during debrief
    - Pilots desired at least 3NM despite high subjective performance at 2.5NM
    - Factors: closure rate, necessity of ATC coordination, vigilance decrement

QUESTIONS?

BACKUP

Post-Test

- All participants believed they had “sufficient training on the ground control station and the DAA system to perform today’s flight test” (*N* = 7)

- GCS display provided enough info to maintain SA
  - Strongly Agree (*N* = 5)
  - Somewhat Agree (*N* = 2)

- Acceptable datalink latency between GCS and UAV
  - Strongly Agree (*N* = 6)
  - Somewhat Agree (*N* = 1)