

# NASA-CAL Analytics ACAS Xr v1 Integration

Encounter Generation, Simulation, and Analysis

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- Encounter Set Generation
  - Candidate Trajectories (AAM, Cargo, PDARs)
  - Methodology and Tradeoffs
- Simulation & Analysis
  - ACAS Xr v1 Integration
  - Current Results & Observations
    - Safety Metrics
    - Operational Suitability
  - Next Steps for Analysis
- Questions/Discussion

- 1 Set of UAM Passenger-flight Trajectories

- *Virginia Tech*

- 5 Sets of UAM Cargo-flight Trajectories

- *Intelligent Automation Incorporation*

AM, MD, PM, EVE, NT

- SoCal PDARS data

- 21 Days from 2017

Jan:	0105	0106	0111	0114	0124
Apr:	0404	0406	0412	0415	0421 0424
Jul:	0705	0706	0714	0717	0722
Oct:	1006	1012	1016	1021	1024

- Methodology

- Option 1: Simulate all trajectories including timestamp

- Captures temporal aspects of airspace, but encounters are rare

- Option 2: Compare all trajectories from common start time

- A lot of encounters. ✓

- Looking further at capturing temporally relevant Cargo sets



- **Criteria**
  - Vehicles must come within spatial volume 5nmi horiz, 2000ft vert.
  - CPA must occur at least 90s after start
  - CPA must occur at least 30s before end
  - Encounters are trimmed at each end to create 120s trajectories
- **Overall**
  - ~10M encounters generated
  - unmitigated (OL) and mitigated (CL) → 20M Simulations
- **AAM-vs-PDARS**
  - 21 encounter sets (~150k encounters per/set)
  - ~3.5M encounters
- **Cargo-vs-PDARS**
  - 105 encounter sets (variable sizes, but generally smaller than AAM)
  - ~7M encounters

# Encounter Set Generation



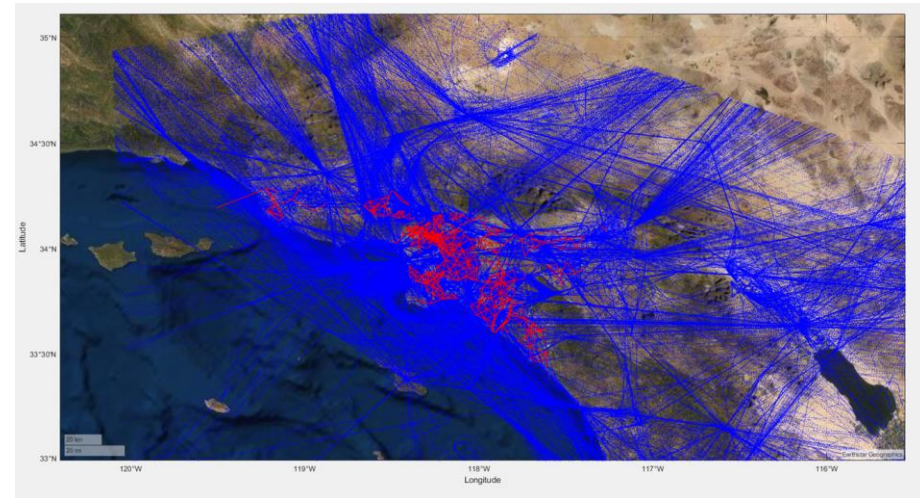
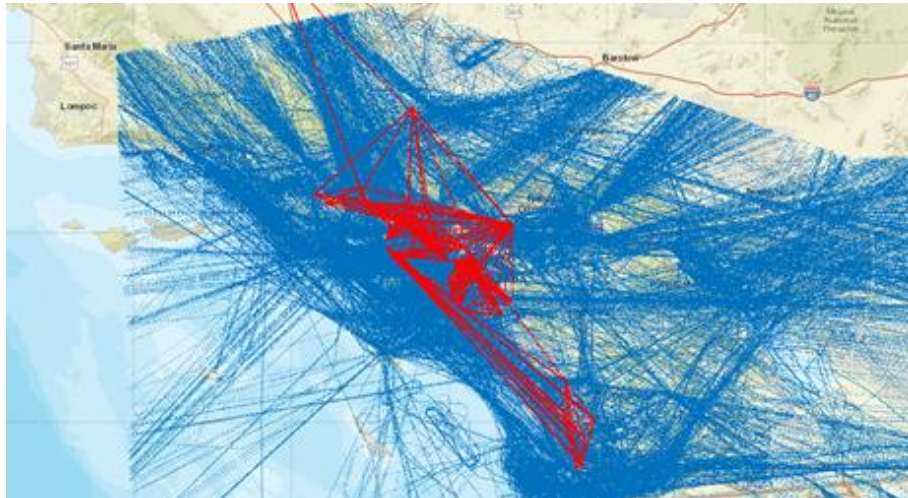
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	6942801				2219185		602532		2527414		2367675		4874162

## AAM & PDARS

Encounters	LoWC	NMAC
3,475,077	222,933	3,563

## CARGO UAS & PDARS

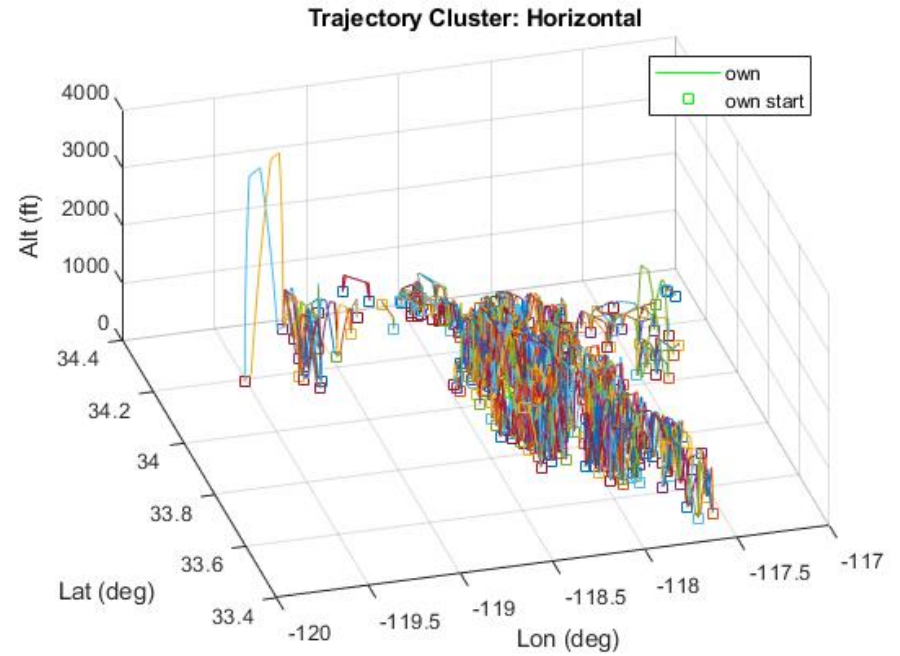
Cargo Data Set	Encounters	LoWC	NMAC
AM	1109599	57851	379
EVE	301266		
NT	1263707		
PM	1183845		
MD	2437081		



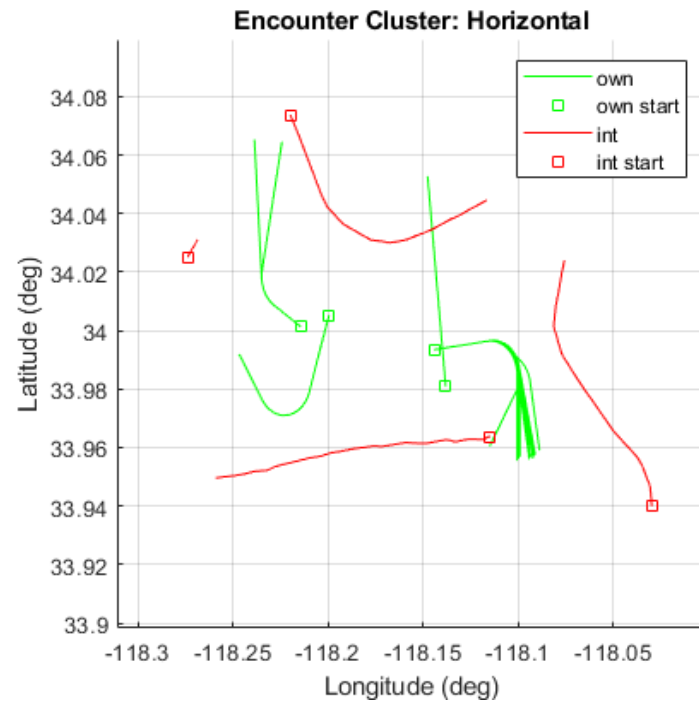
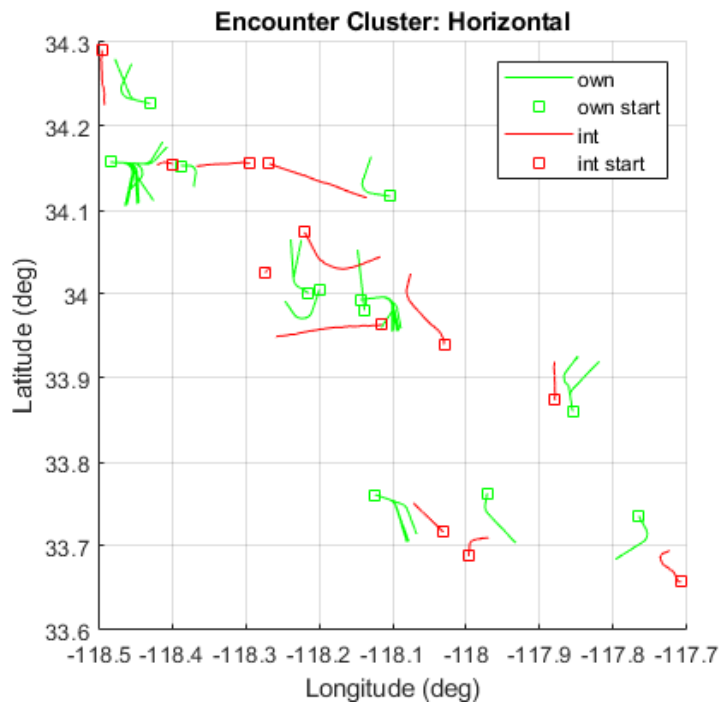
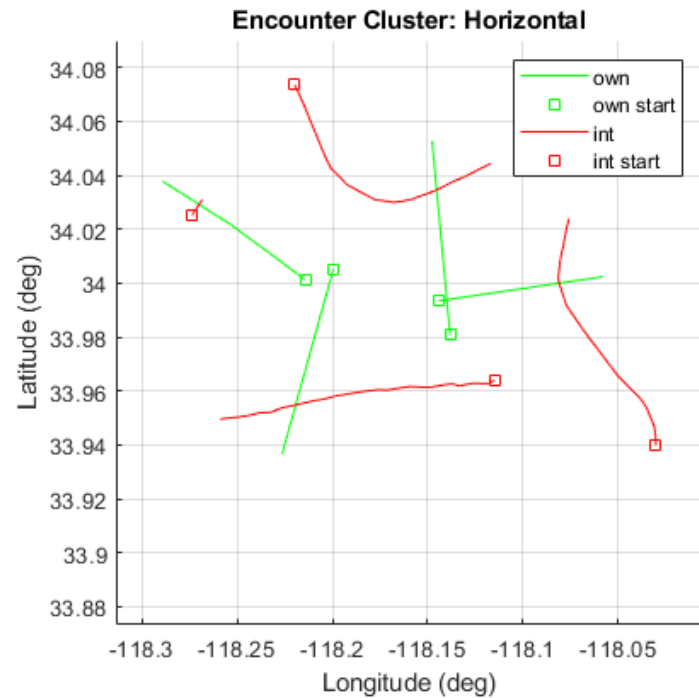
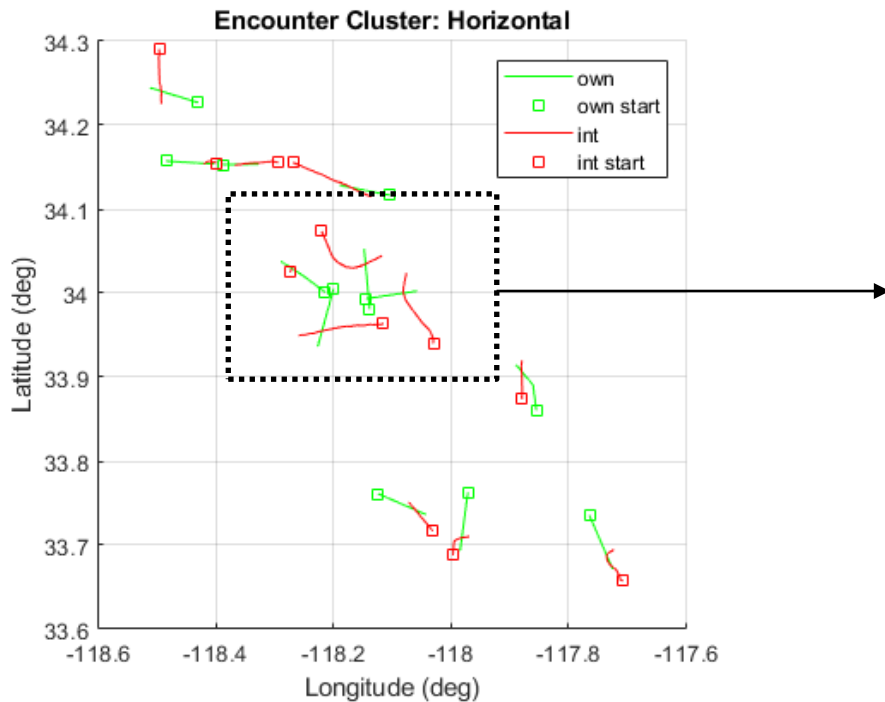
## UAS Cargo Flights

UAS Cargo Set	# of Trajectories
AM	3299
NT	3610
MD	6223
PM	3384
EVE	994
	<b>17510</b>

7 Million Cargo-UAS vs  
PDARS Encounters  
Overall



UAS\_AM\_SoCal



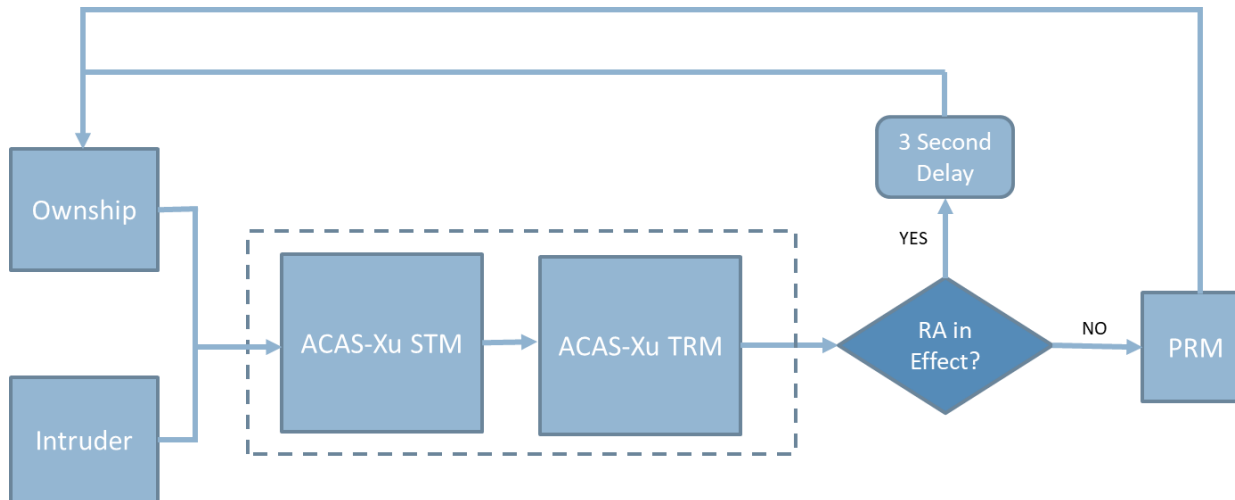
- Encounter Set Descriptions
  - AAM-vs-PDARs
    - ~3.5M one-on-one encounters
  - UAS Cargo-vs-PDARs
    - ~7M one-on-one encounters

ACAS-Xr Vehicle Configuration	
Turn Rate (turn_rate_limit)	3 deg/s
Vertical Rate (vertical_rate_limit)	1000 fpm

Separation Volumes

NMAC (All Intruders)  
**500ft – 100ft**

LoWC (Large UAS, Manned Intruders)  
**4000ft – 450ft – 35s**

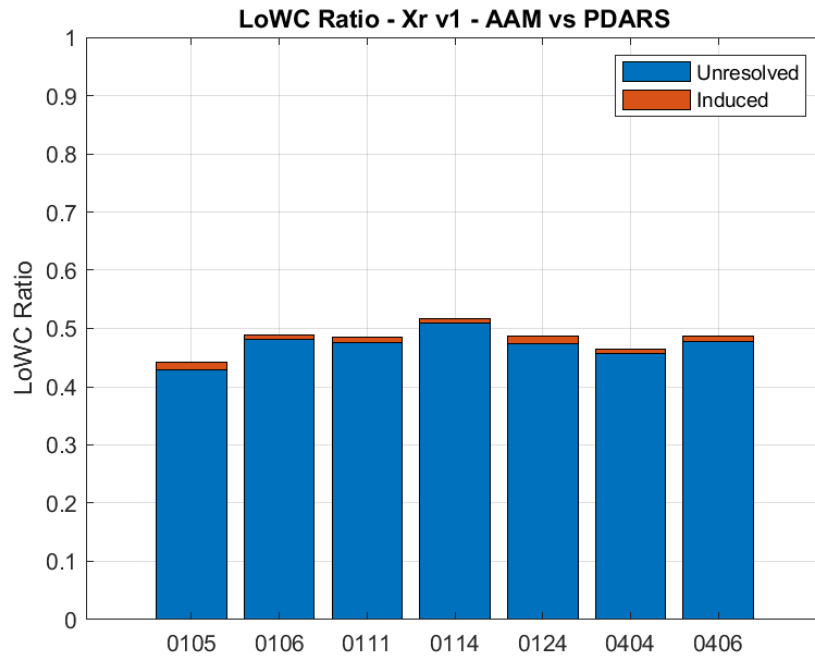


- Pilot Model responds to corrective alerts following a series of built-in delays.
- Can be initially up to 19s delay to respond to corrective alert

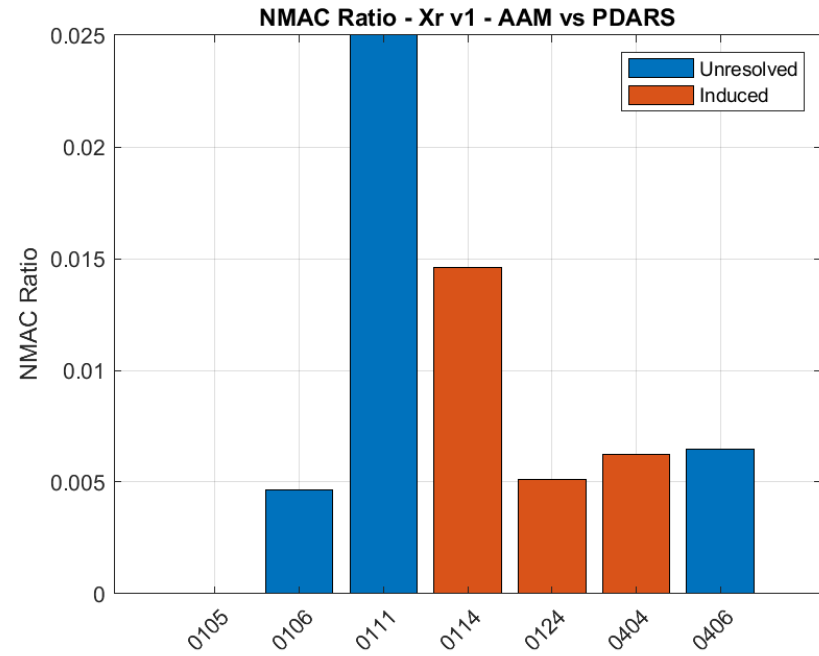
# Simulation & Analysis (AAM-vs-PDARS: Week 1)



## LoWC Ratio

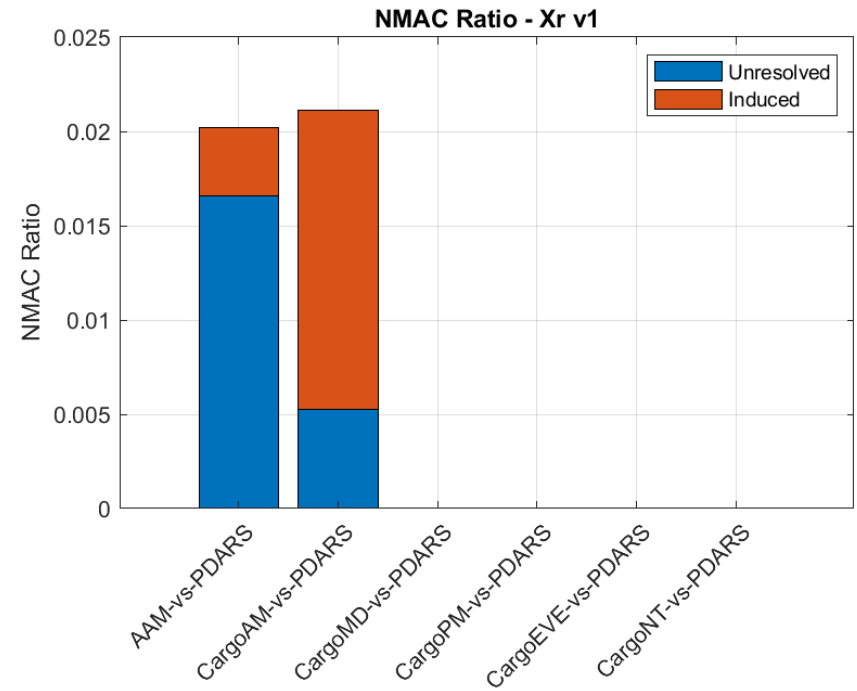
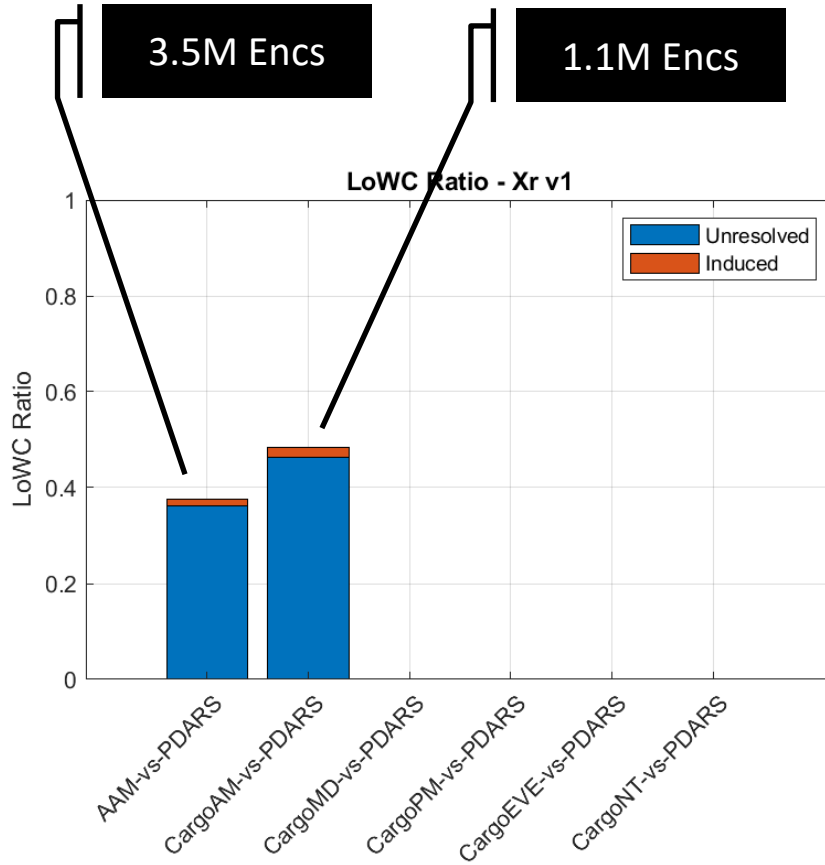


## NMAC Ratio



	OL	CL
<b>0111</b>	163	52
<b>0114</b>	274	4
<b>0124</b>	196	1
<b>0404</b>	160	1

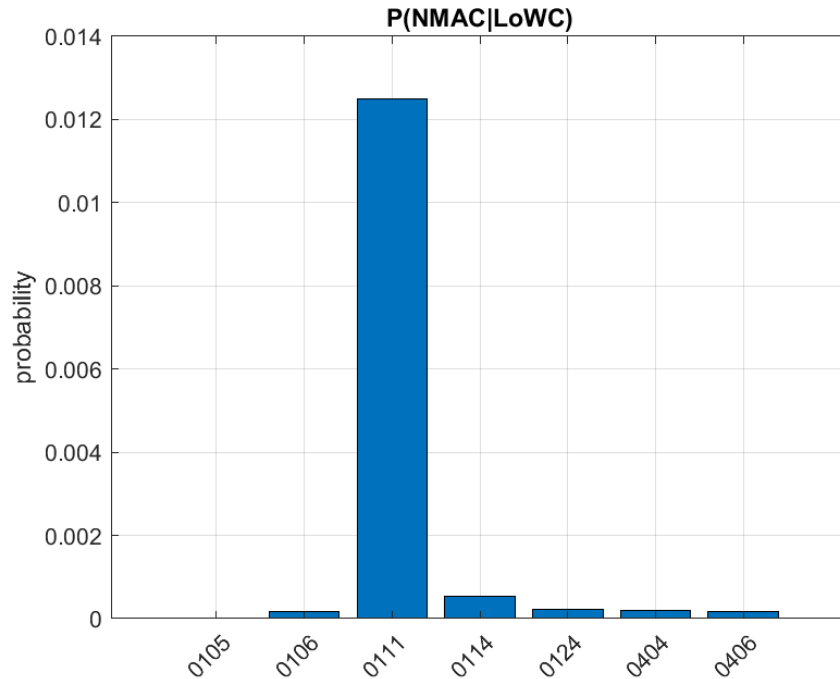
# Simulation & Analysis (Safety Metrics)



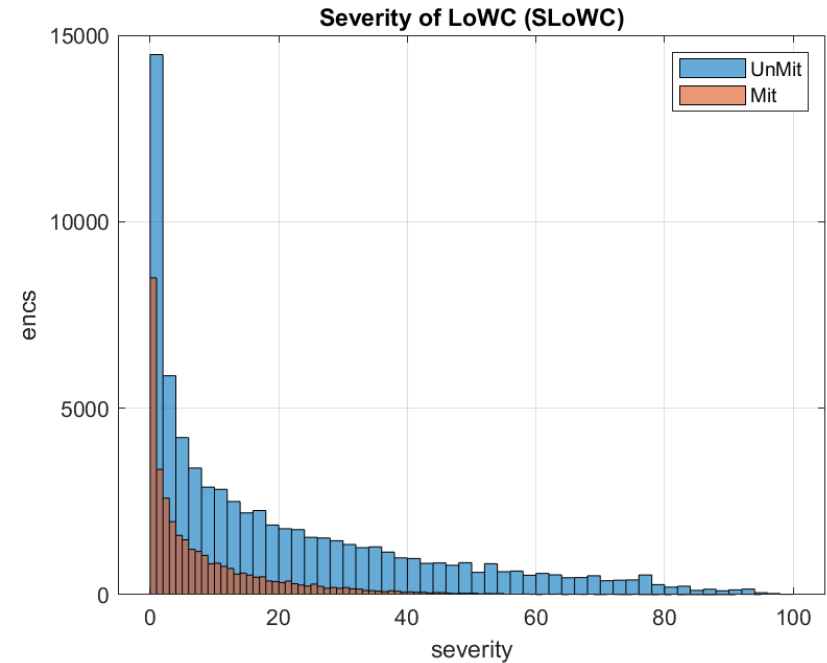
# Simulation & Analysis (AAM-vs-PDARS: Week 1)



## Probability of NMAC given LoWC

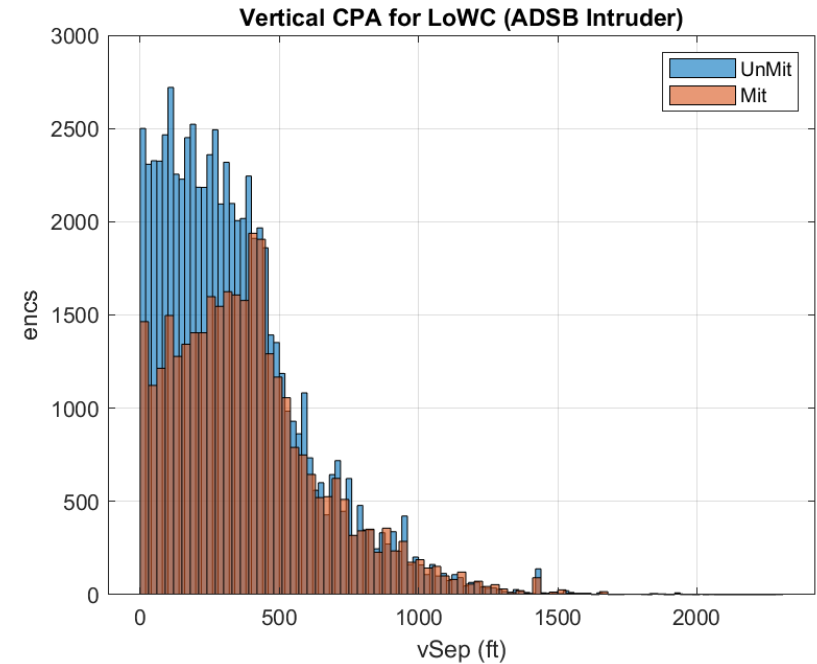
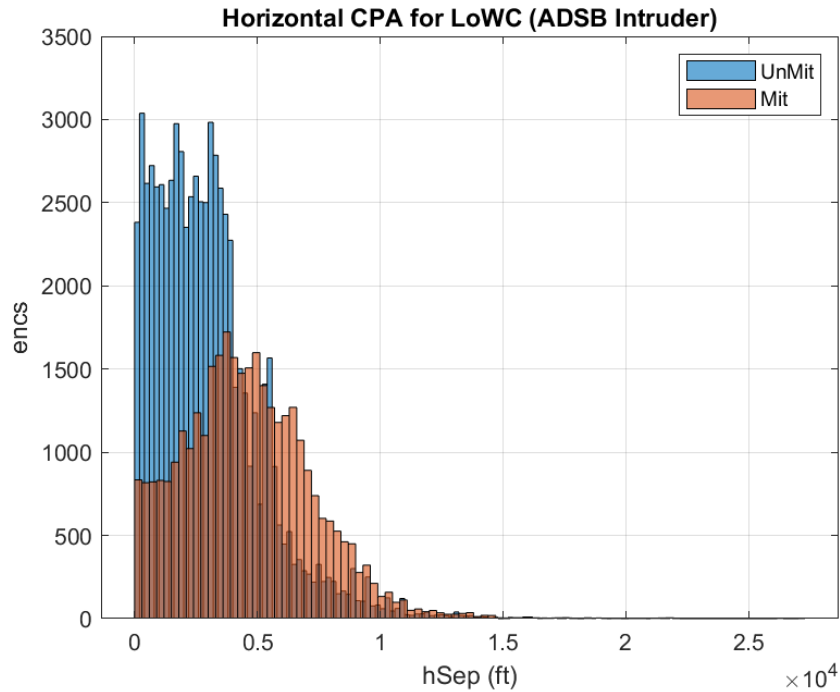


## Severity of LoWC

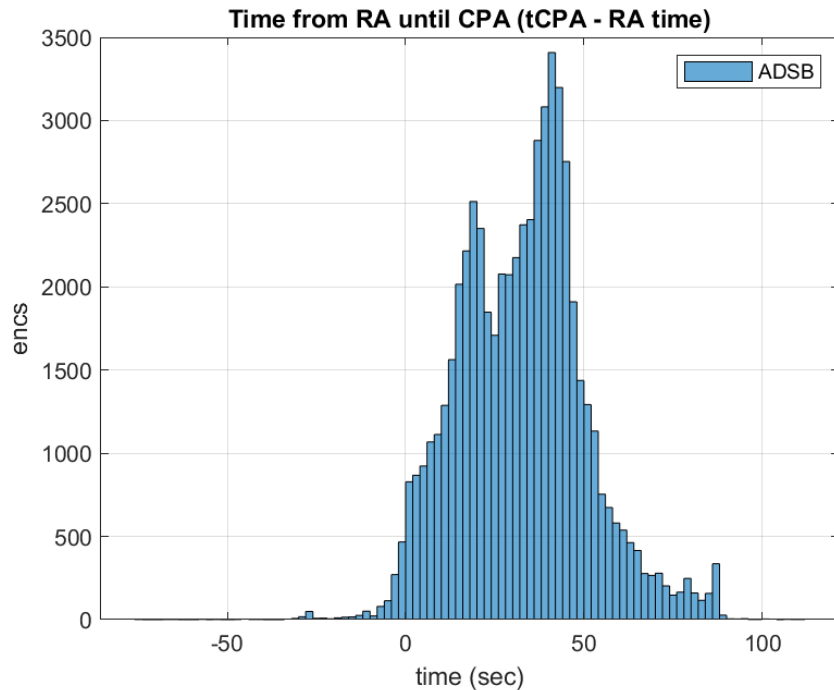


## Horizontal Miss Distance

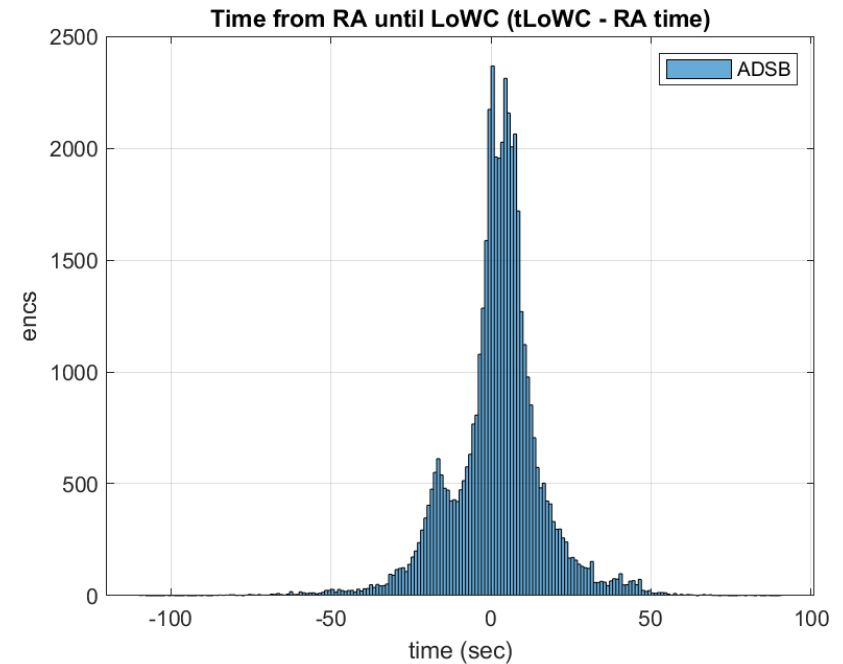
## Vertical Miss Distance



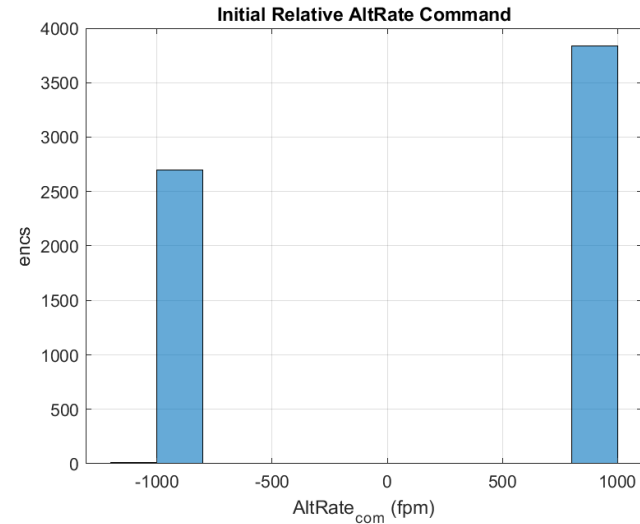
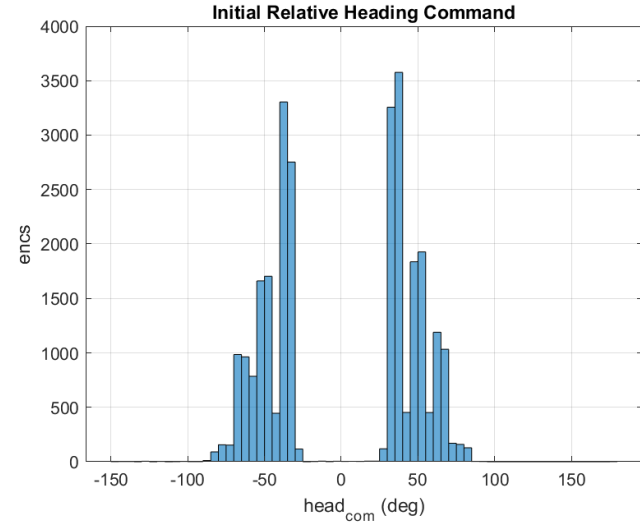
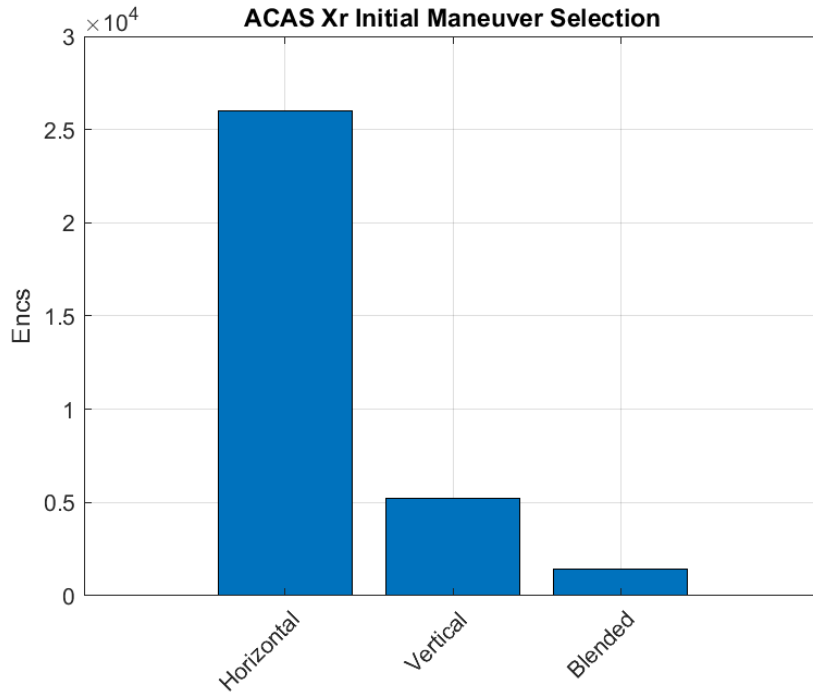
## RA-time Prior to CPA



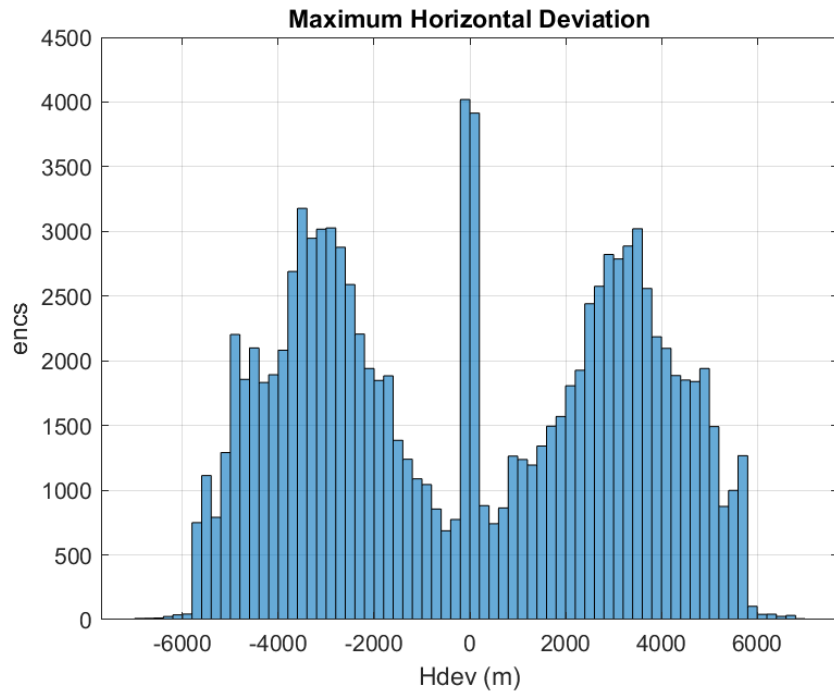
## Corrective Alert-time prior to RA



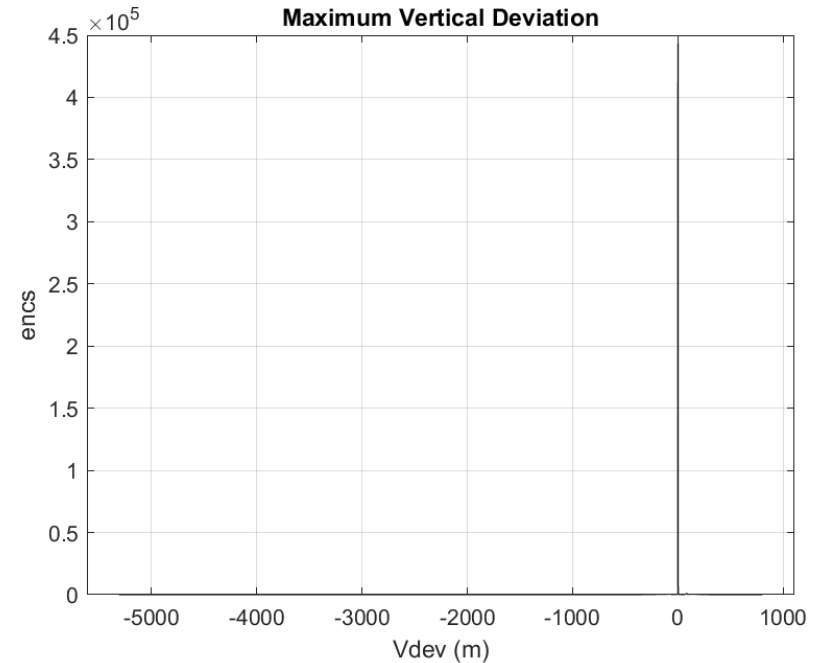
## Initial Maneuver Type, Magnitude, Direction

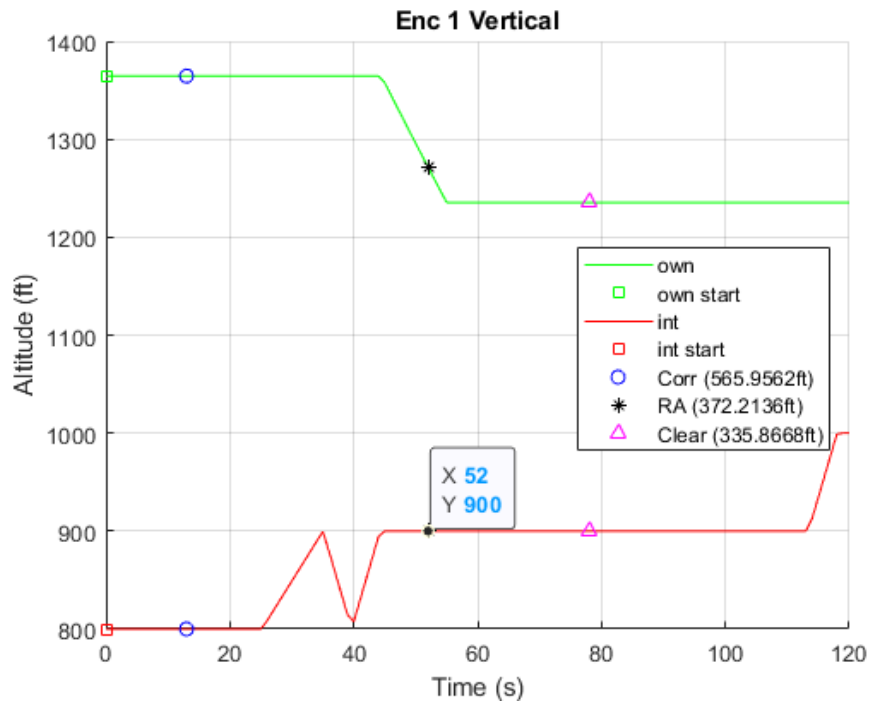
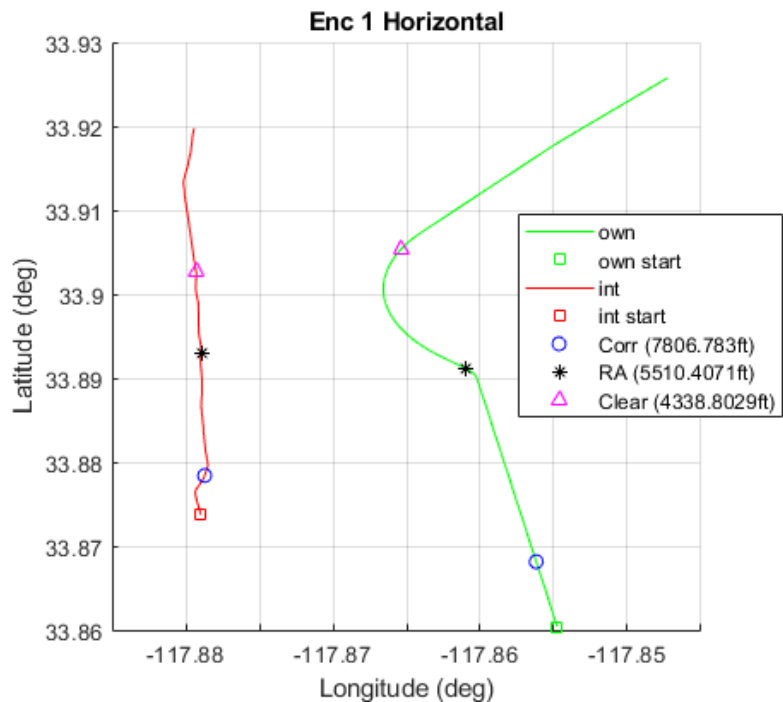
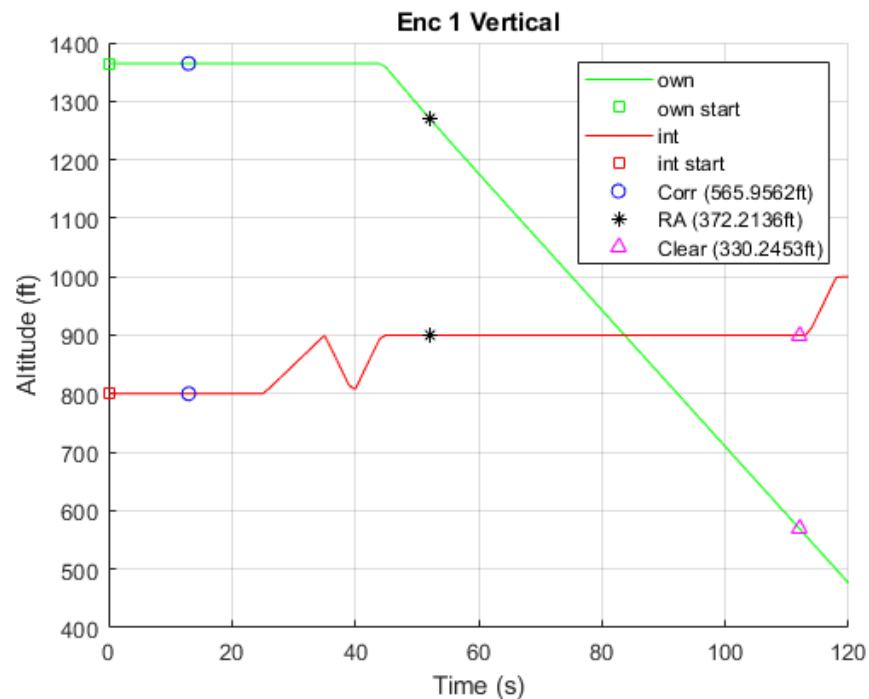
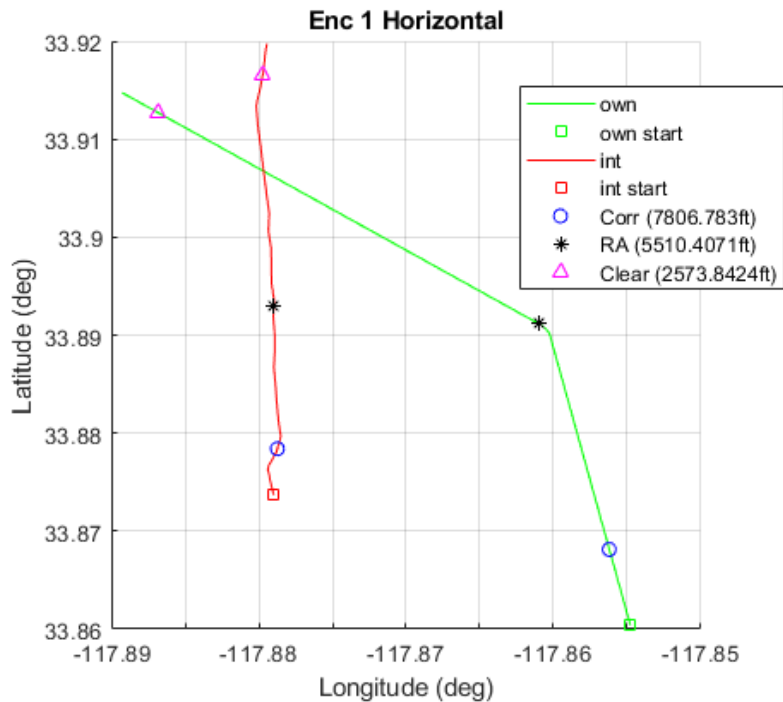


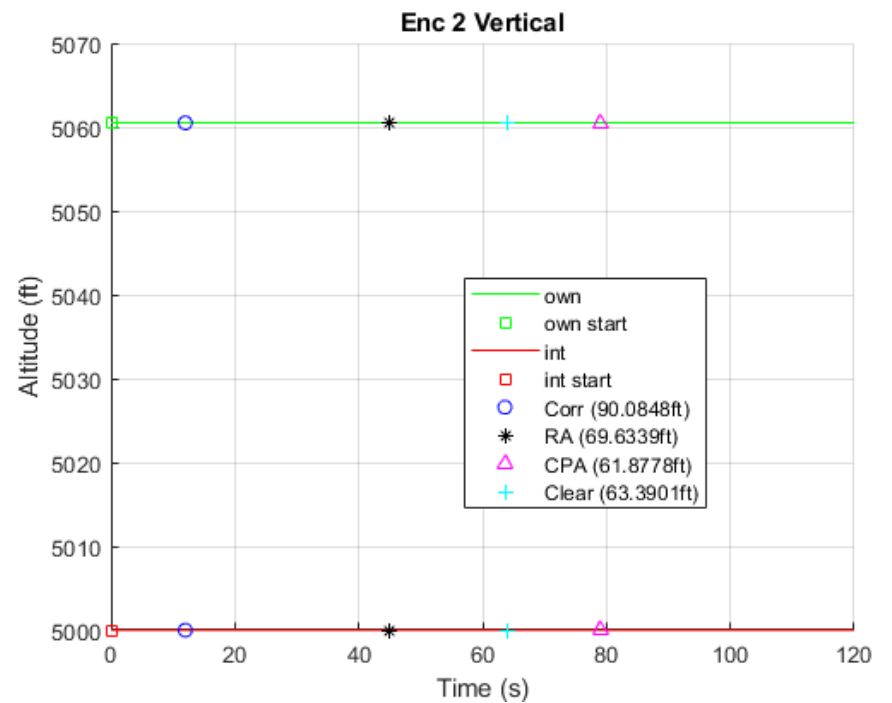
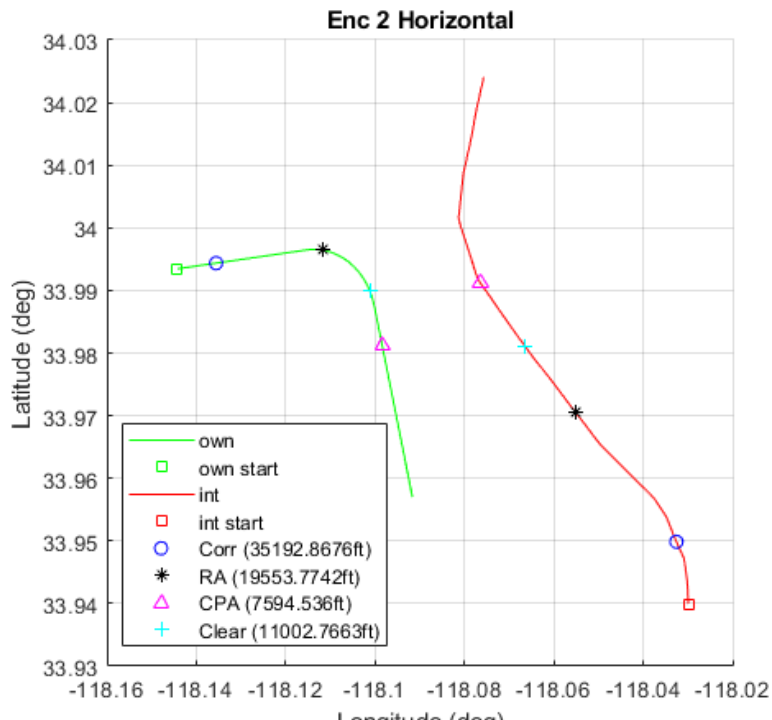
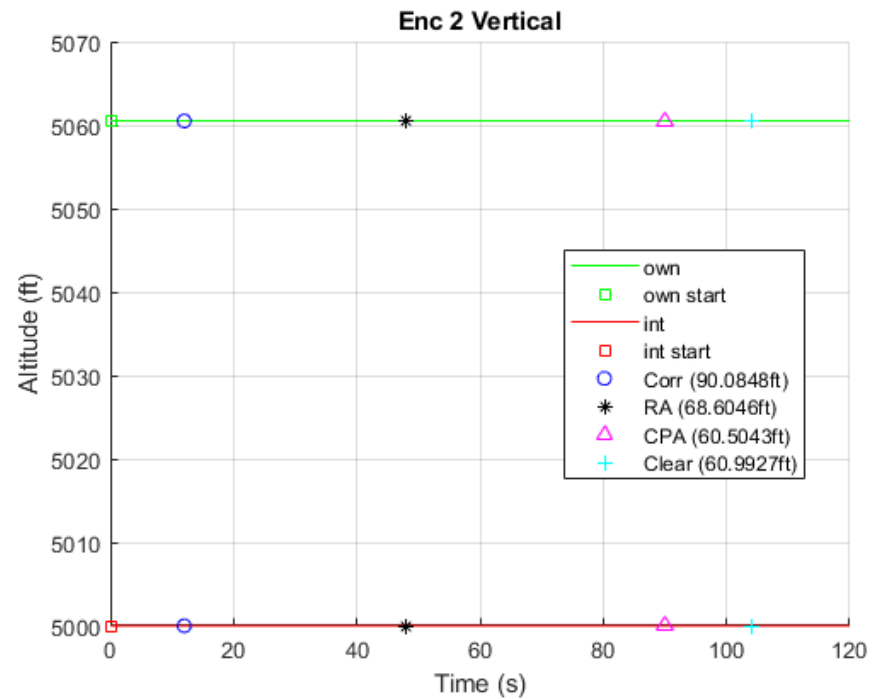
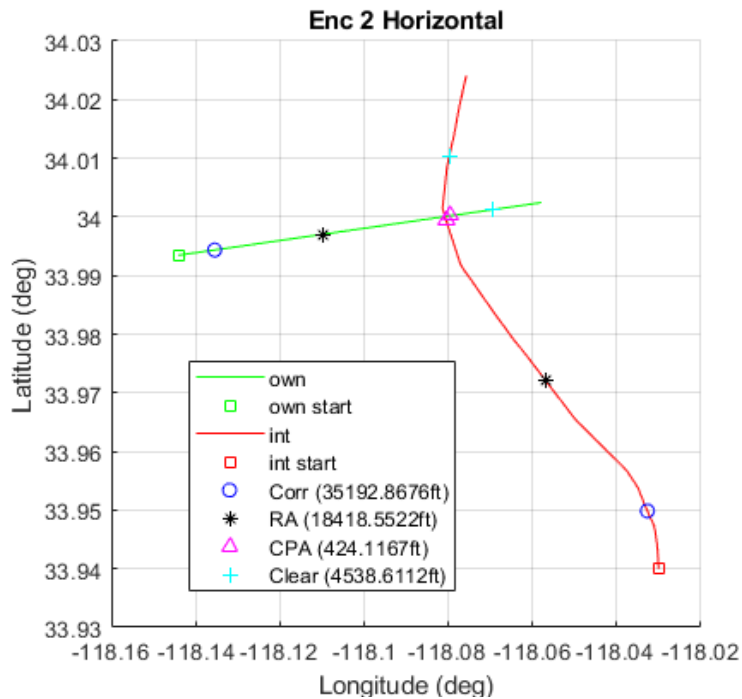
## Maximum Horizontal Deviation

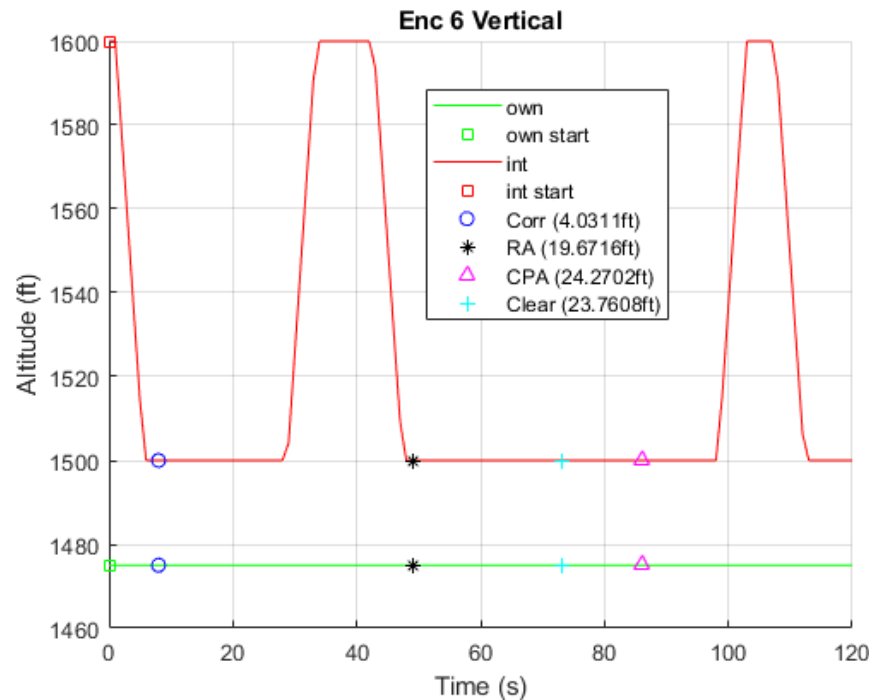
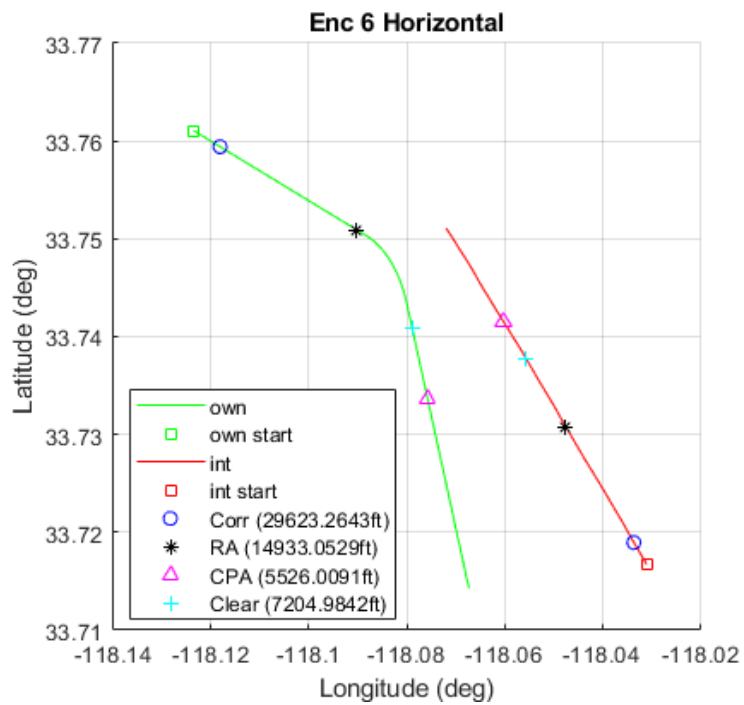
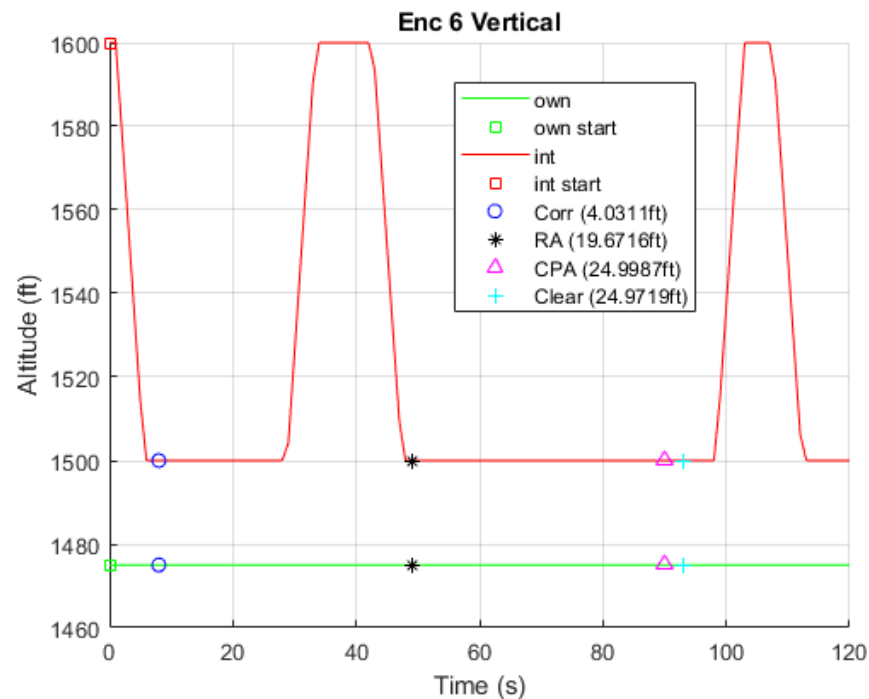
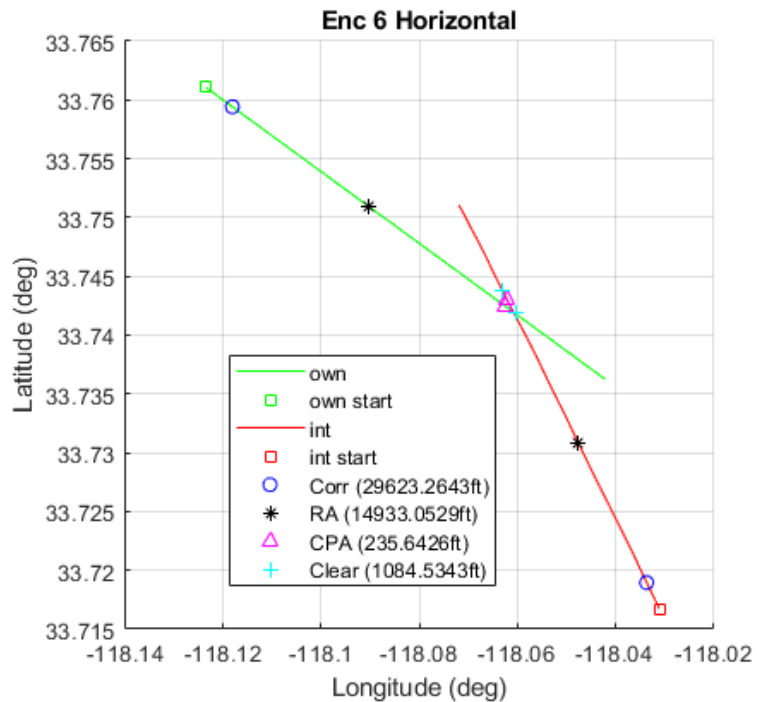


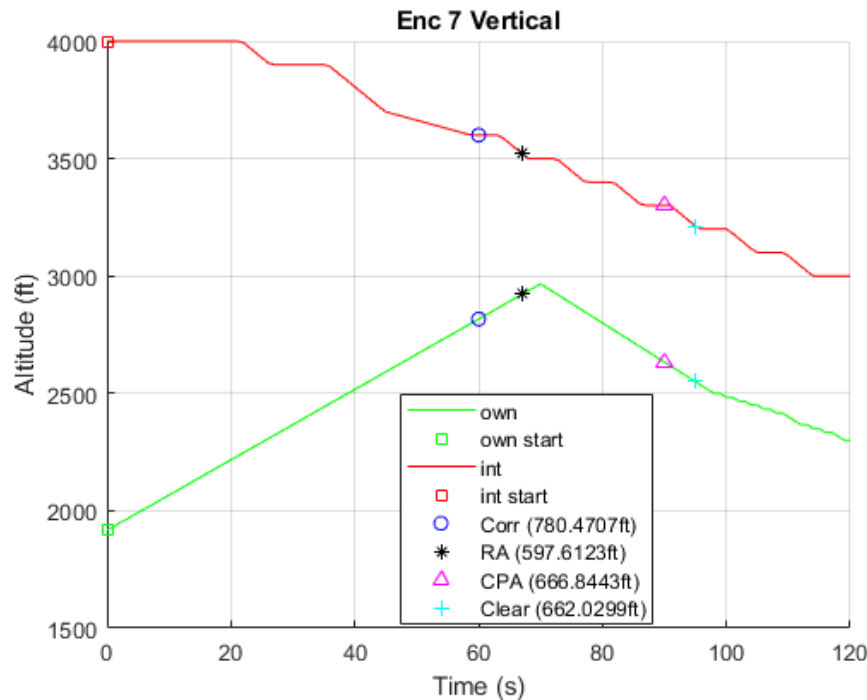
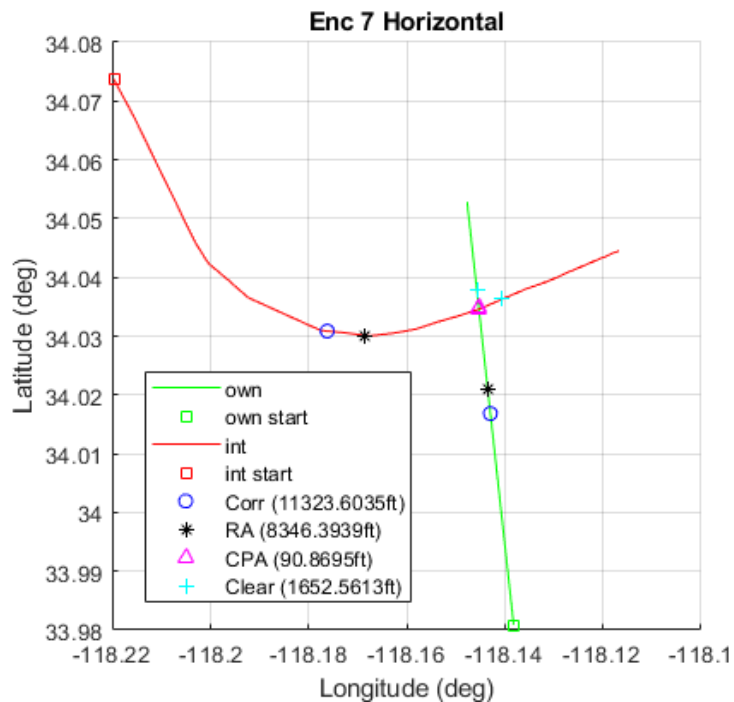
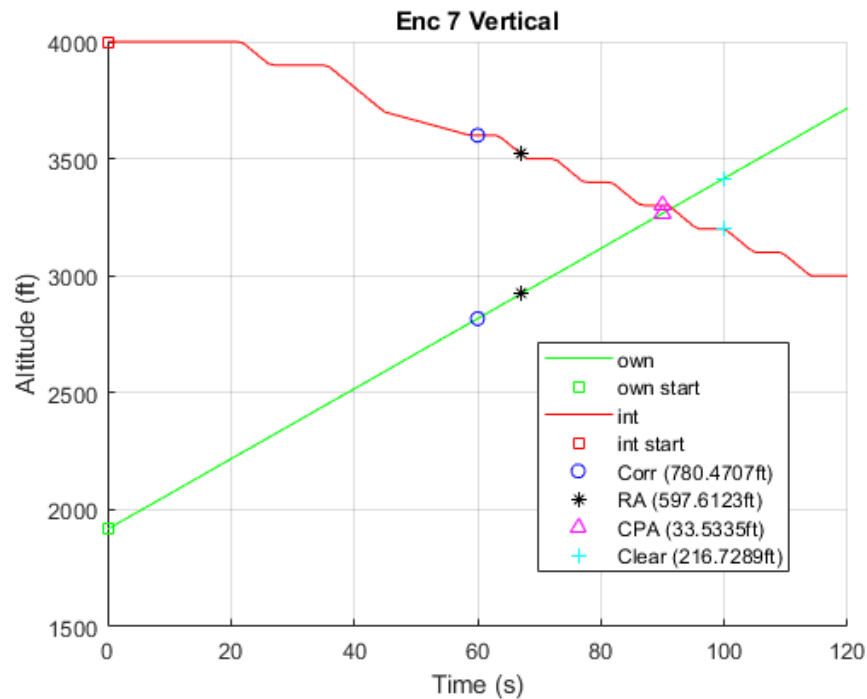
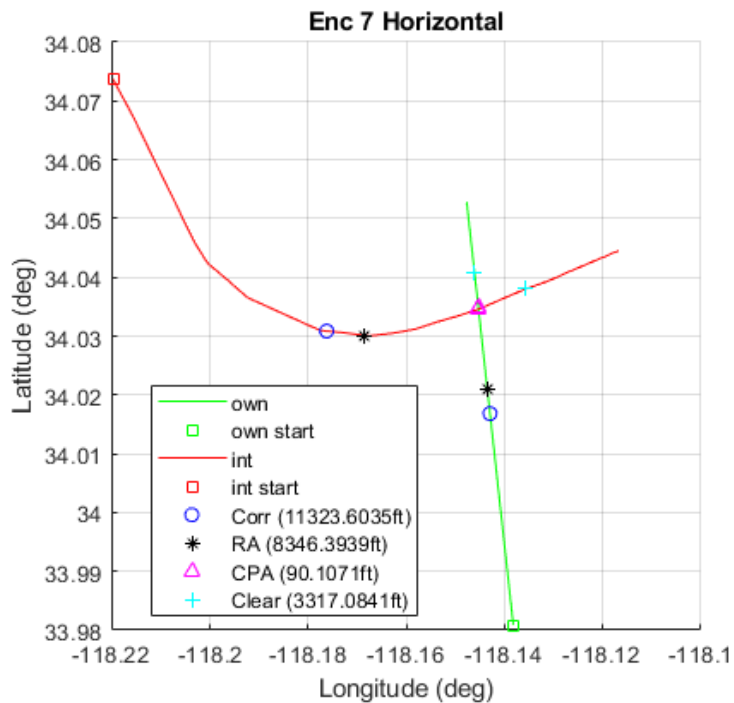
## Maximum Vertical Deviation



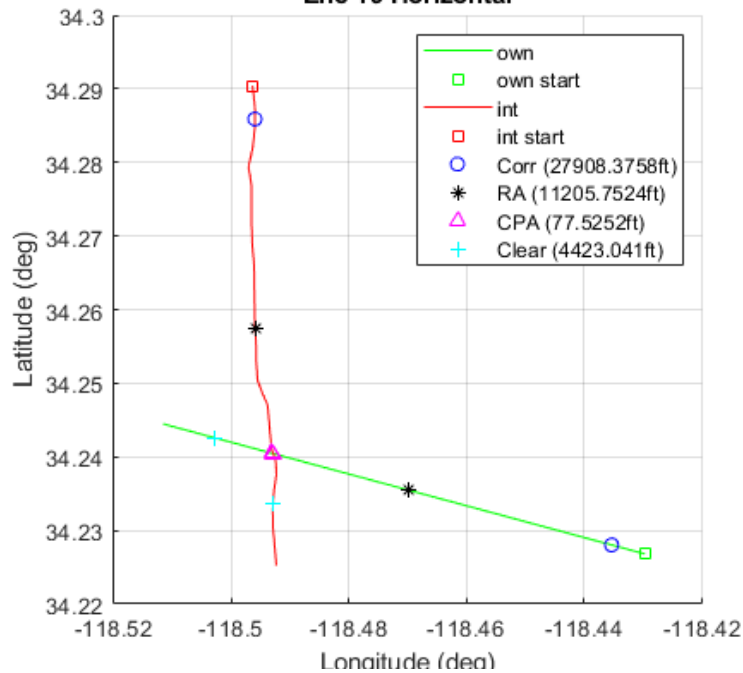




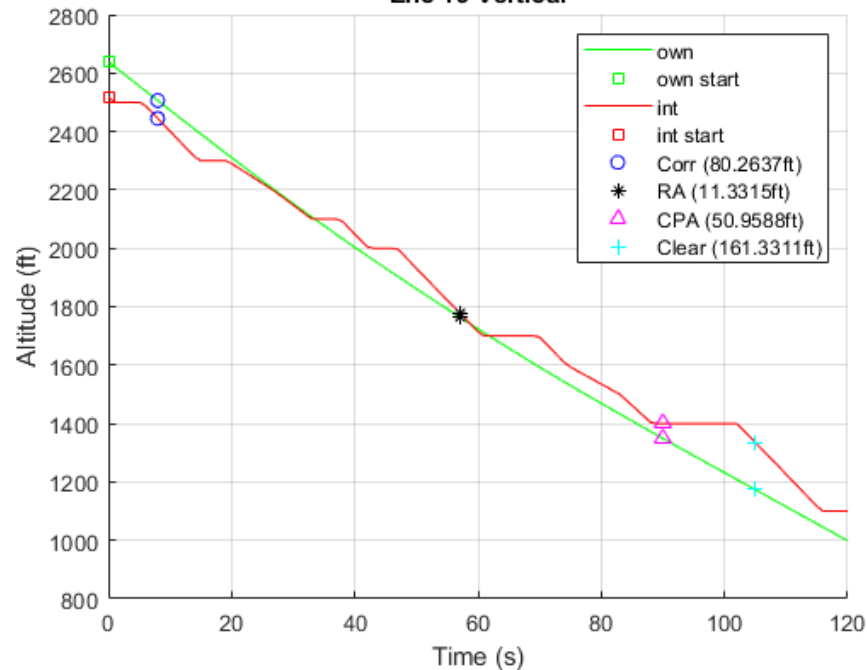




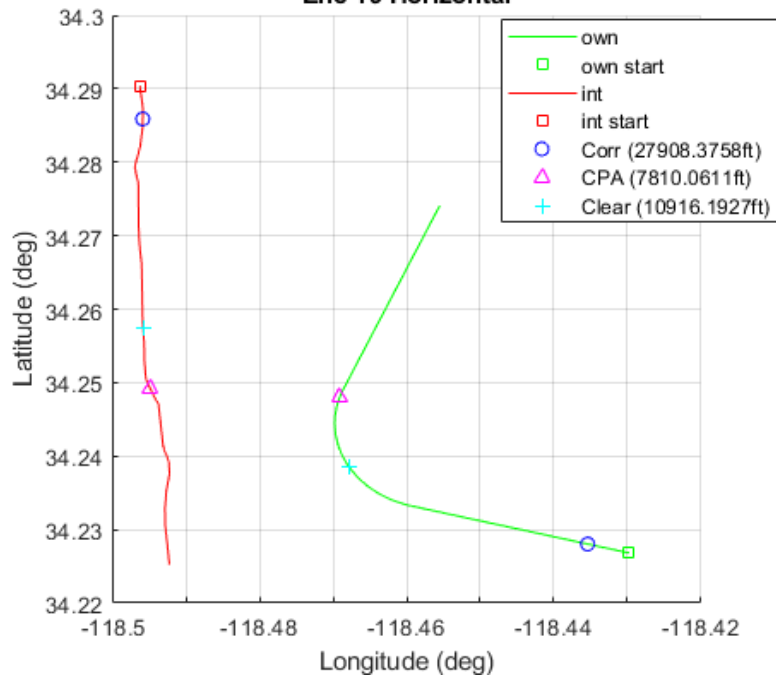
**Enc 19 Horizontal**



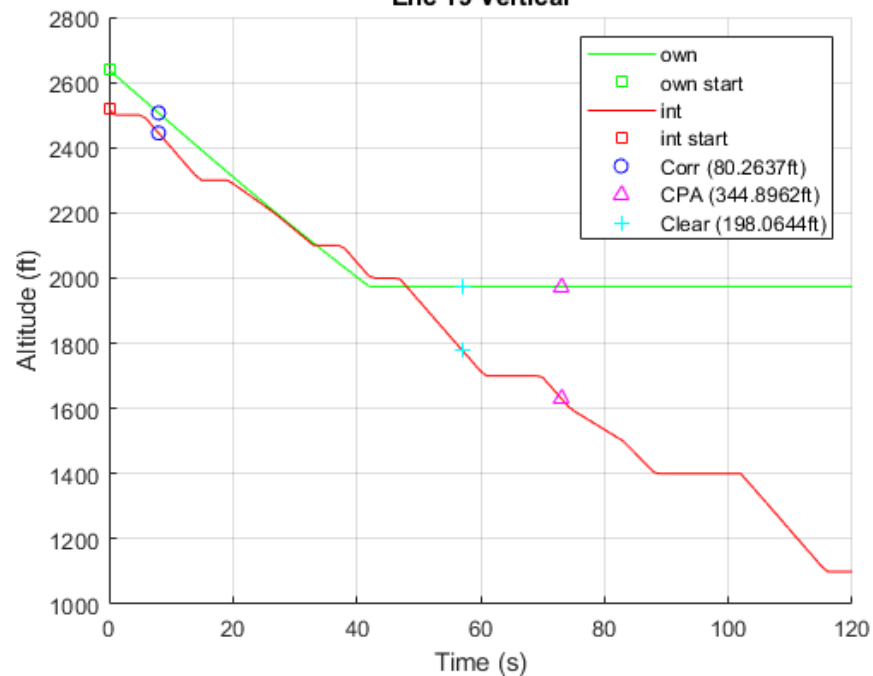
**Enc 19 Vertical**



**Enc 19 Horizontal**



**Enc 19 Vertical**





- Next Steps
  - Subsequent Maneuver Selection
  - Frequency of Reversals, Crossings, Split Ras, target heading updates
  - Alert Rates, Timings
- Preliminary Conclusions
  - ACAS Xr was successfully integrated into CAL's simulation environment
  - Data analysis is ongoing, but so far, the results are consistent with expectations with respect to safety and performance

# Questions/Discussion



For Questions and Comments contact:

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- PRM examines alert and guidance band information to produce a heading and/or vertical rate command as would be issued by a pilot
  - PRM responds to preventive and corrective alerts, and uses RWC bands to determine heading and/or vertical rate commands
  - CAL has modified PRM to interpret and respond to vertical speed bands
- This effort utilizes ‘Deterministic’ mode\* to obtain predictable, repeatable guidance commands.
- Various delays are modeled, including time to coordinate with ATC, time to execute commands, and time to respond to updated commands.
- In the presence of an RA, all PRM delays are dropped, and the RA guidance is tracked with a ~~5 second initial delay~~ followed by constant 3 second lag