

# TAO Test Vector Evaluation Rev. 1

(alert\_time updated from 40s → 48s)

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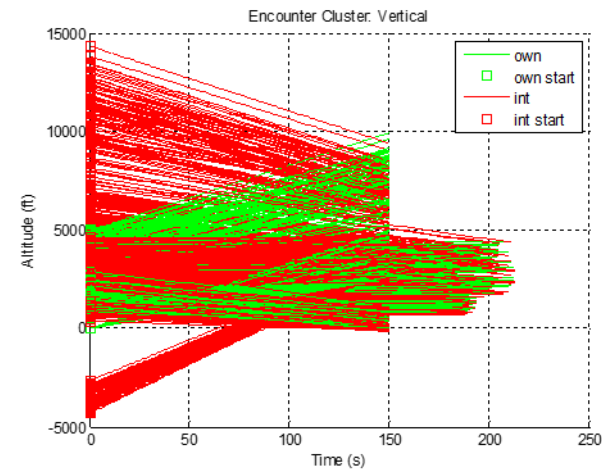
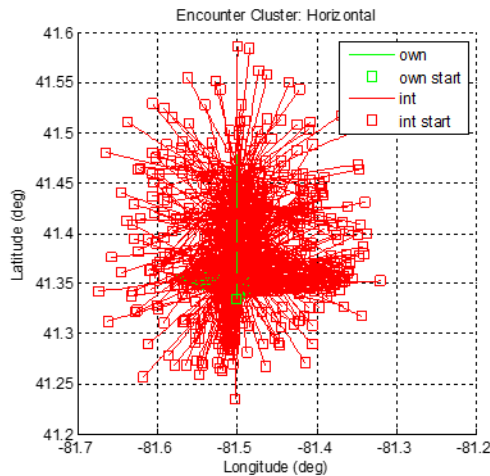


- A group of encounter sets is evaluated as a standard for defining and refining both performance-based and functional-based terminal area MOPS requirements.
- DAIDALUS-alerting is used together with a variety of sensor configurations
  - ADS-B level surveillance
  - Active Surveillance Tracking (AST)
  - Ground-based Radar (3 different sets of error parameters)



- In all cases, the ownship UA is on a straight-in IFR approach or normal departure (note that ownship and intruder can also be swapped)
  - TSAA Airport OSED – 800
    - Based on 9 actual NMAC cases, each perturbed to generate full set
  - TSAA Airport Must Alert – 72
    - Set of safety-driven encounters where the DAA system is expected to engage
  - TSAA Airport Must Not Alert – 103
    - Set of operational suitability encounters where the DAA system should NOT engage
  - NASA Terminal Alerting Engineering Analysis - 3912
    - Piston Powered, 45 deg pattern entry - 561
    - Piston Powered, Base leg pattern entry - 1400
    - Turbine Powered, 45 deg pattern entry - 551
    - Turbine Powered, Base leg pattern entry - 1400

- TSAA Airport OSED – 800
  - Ownship and intruder have been swapped in some cases to generate in-pattern encounters



- TSAA Airport Must Alert – 72
  - Ownship approaching for landing or touch-and-go, encounters intruder
  - Ownship and intruder roles may be swapped



Figure U-16. Overhead View



Figure U-18. Overhead View



Figure U-17. Isometric View



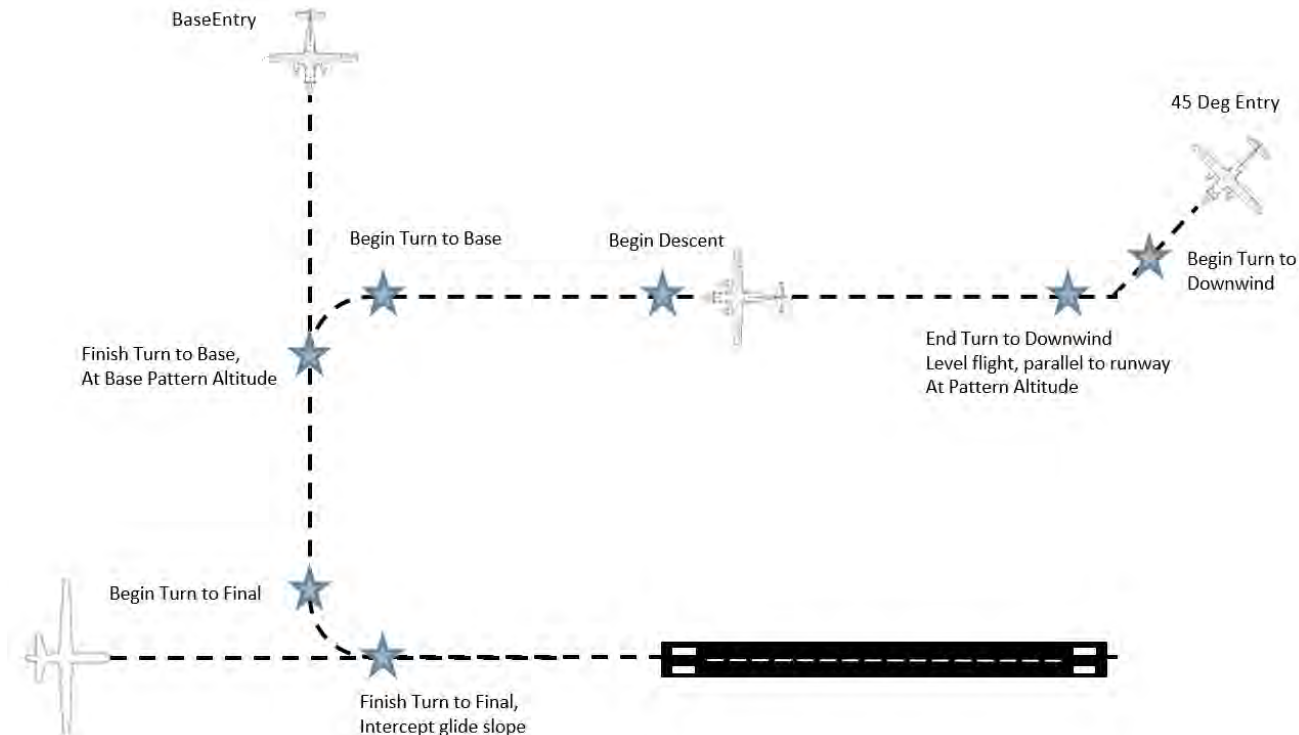
Figure U-19. Isometric View



- TSAA Airport Must NOT Alert (103 encounters)
  - Cases that study operational suitability, such as
    - target passes in front or behind ownship
    - ownship descends into or ascends out of pattern
    - departing ownship encounters target jet on IFR approach

Must Not Alert Tracks		
<i>Airport Environment</i>		
Set	Encounter Type	Number of Tracks (all traffic sources)
1	Convergence on Final to Parallel Runways	24
2	Convergence on Final to Same Runway	30
3	Convergence on Same Leg; Different Flight Phases	36
4	Convergence in Airport Pattern; Target Entering via Standard Procedure	60
5	Convergence in Airport Pattern; Target Entering via Non-standard Procedure	24
6	Convergence with Departing Jet	12
7	Convergence with Approaching Jet	16
8	Touch-and-Go Convergence	36
9	Rotorcraft Convergence on Final Approach	36
10	News or Firefighting Aircraft Operating in Same Area	24
<b>Total</b>		<b>298</b>

- Operational Suitability Encounters (3912)
  - A variety of geometries featuring ownship converging with an intruder while approaching or departing



## Updated timing Parameters

Modified Variable	v1	v2	Unit
min_alt	0.0	100.0	[ft]
min_horizontal_recovery	0.3	0.66	[nmi]
DWC_Phase_II_alert_1_alerting_time	45.0	48.0 <del>40.0</del>	[s]
DWC_Phase_II_alert_1_early_alerting_time	60.0	75.0	[s]
DWC_Phase_II_det_1_WCV_DTHR	0.3	0.247	[nmi]
DWC_Phase_II_det_1_WCV_ZTHR	750.0	450.0	[ft]
DWC_Phase_II_alert_2_alerting_time	45.0	48.0 <del>40.0</del>	[s]
DWC_Phase_II_alert_2_early_alerting_time	60.0	75.0	[s]
DWC_Phase_II_det_2_WCV_DTHR	0.3	0.247	[nmi]
DWC_Phase_II_alert_3_alerting_time	30.0	48.0 <del>40.0</del>	[s]
DWC_Phase_II_alert_3_early_alerting_time	40.0	75.0	[s]
DWC_Phase_II_det_3_WCV_DTHR	0.3	0.247	[nmi]

note: An updated set of Daidalus configuration parameters was received in August, 2019. The notation 'v2' refers to those new Daidalus configuration parameters (given in **Terminal\_DPJ\_20190814.daidalus**)

note: the statement in v1  
`conflict_level = 2`  
has been removed from v2

## Parameters introduced in v2

# Relative Bands Parameters
below_relative_hs = 0.0 [knot]
above_relative_hs = 0.0 [knot]
below_relative_vs = 0.0 [fpm]
above_relative_vs = 0.0 [fpm]
below_relative_alt = 0.0 [ft]
above_relative_alt = 0.0 [ft]
bands_persistence = false
hysteresis_time = 5.0 [s]
persistence_time = 4.0 [s]
max_delta_resolution_hdir = 0.0 [deg]
max_delta_resolution_hs = 0.0 [knot]
max_delta_resolution_vs = 0.0 [fpm]
max_delta_resolution_alt = 0.0 [ft]
alerting_m = 2
alerting_n = 4
# Sensor Uncertainty Mitigation Parameters
h_pos_z_score = 0.0
h_vel_z_score_min = 0.0
h_vel_z_score_max = 0.0
h_vel_z_distance = 0.0 [nmi]
v_pos_z_score = 0.0
v_vel_z_score = 0.0
# Alerting Logic
ownship_centric_alerting = true
corrective_region = NEAR
alerters = DWC_Phase_II





## GBR error parameter sets

Dimension	Avg +Vel (GBRH)	Avg ++Vel (GBRM)	Best +Vel (GBRL)
Horz Pos	71.54 m	71.54 m	31.11 m
Vert Pos	52.49 m	52.49 m	27.22 m
Horz Vel	2.62 mps	1.31 mps	1.31 mps
Vert Vel	2.62 mps	2.62 mps	1.31 mps

# Results Summary

# TAO Warnings Issued



Encounter Set	truth		ADSB		AST		GBRAH		GBRAM		GBRAL	
	Warn	%	Warn	%	Warn	%	Warn	%	Warn	%	Warn	%
Piston_45entry (561)	0	0	10	2	9	2	19	4	27	5	19	4
Piston_Baseentry (1400)	0	0	9	1	88	6	14	1	15	1	7	0.5
Turbine_45entry (551)	0	0	6	1	4	1	42	7	39	7	40	7
Turbine_Baseentry (1400)	0	0	4	0.3	83	6	17	0.5	8	0.5	8	0.5
TSAA_TAO_MA (72)	72	100	72	100	55	76	72	100	72	100	72	100
TSAA_TAO_MNA (103)	9	9	11	11	73	70	11	11	10	10	12	12
TSAA_TAO_OSED (800)	800	100	800	100	795	99	800	100	800	100	800	100

- Using truth data, all encounters alerted as expected, except for 9 MNA encounters that did alert (see slides 16-24)
- Use of ADS-B level surveillance introduced a slight increase in anomalous warnings, though no expected warnings were missed
- The use of AST introduced a large number of missed alerts, as well as alerts in 70% MNA encounters
- The three sets of GBR parameters each performed similarly to each other and to the ADSB case

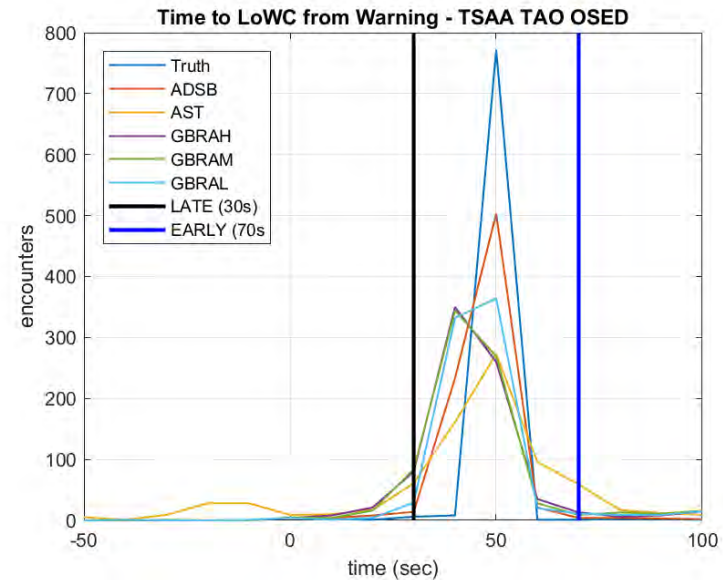
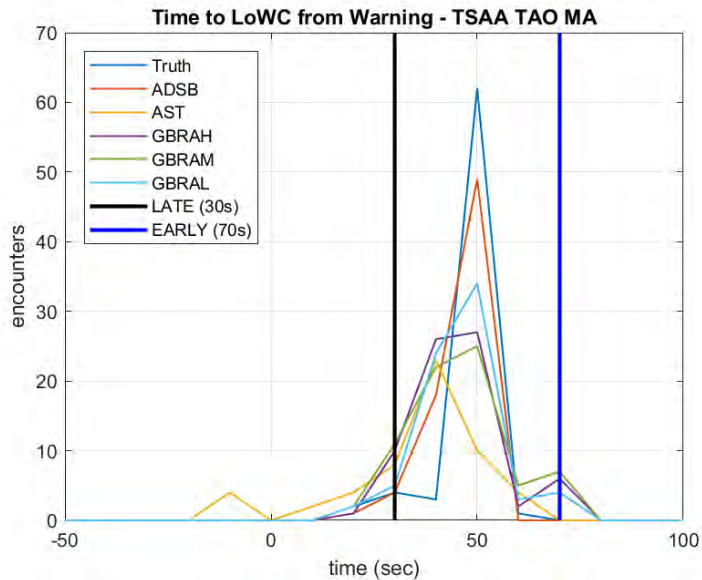
# Time of Warning w/r to LoWC



## Average time to LoWC from Warning

	Must Alert	OSED
Truth	45.1389	46.8088
ADSB	44.5417	46.2425
AST	36.0000	43.3119
GBRAH	45.7917	44.9663
GBRAL	45.5139	45.5063
GBRAM	45.8889	47.0187

- The 45s requirement in the revised MOPs is satisfied here except using active surveillance tracking
- Use of AST leads to lesser performance
  - much shorter average time to LoWC
  - a high percentage of early and late warnings
- Some performance benefit using the smallest GBR error parameters





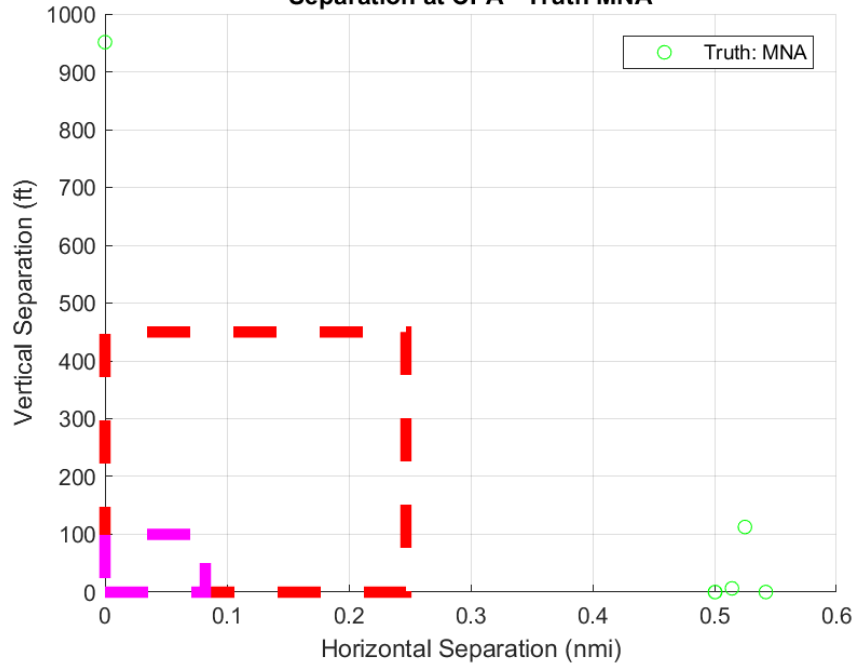
- Using truth data,
  - all encounters alerted as expected except for 9 MNA encounters that did alert
- Use of ADS-B level surveillance
  - introduced a slight increase in anomalous warnings
  - no expected warnings were missed
- Results using AST showed:
  - a large number of missed alerts,
  - shorter average time to LoWC
  - a high percentage of early and late warnings
- The three sets of GBR parameters each performed similarly to each other
  - some benefit was seen using the smallest errors
- The 45s requirement in the revised MOPs is satisfied here for all but active surveillance.

# Separation at CPA

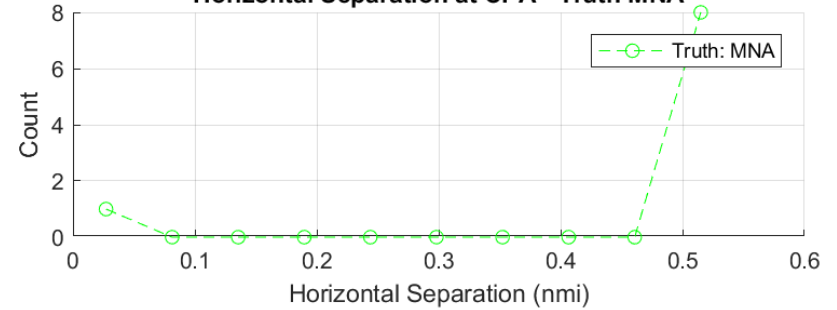
MNA cases

9 out of 103 MNA encounters alerted using Truth data (see following slides for encounter geometries)

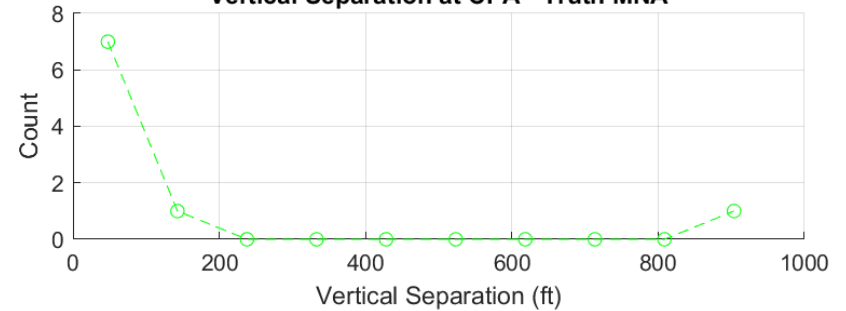
**Separation at CPA - Truth MNA**



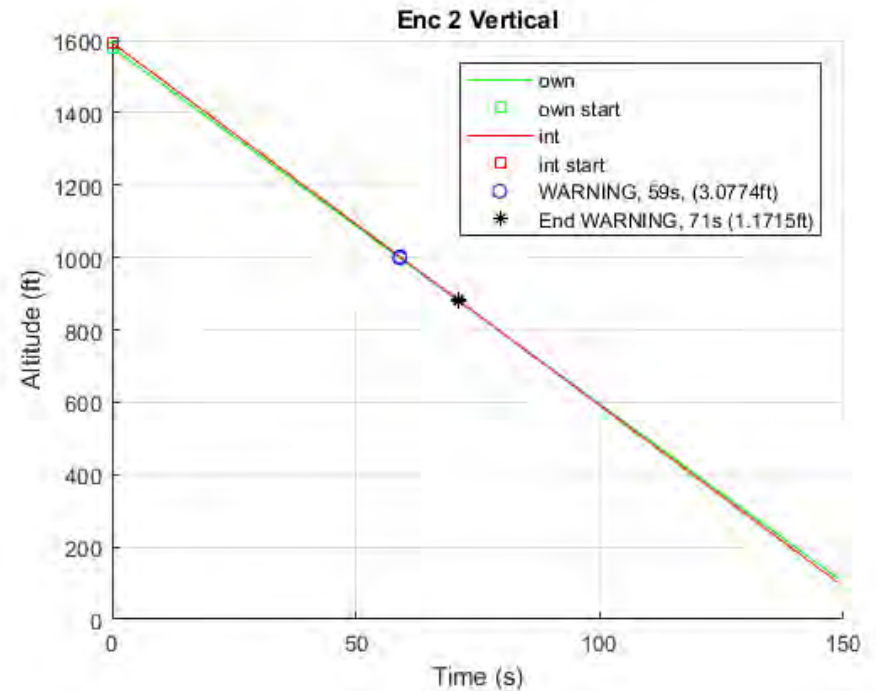
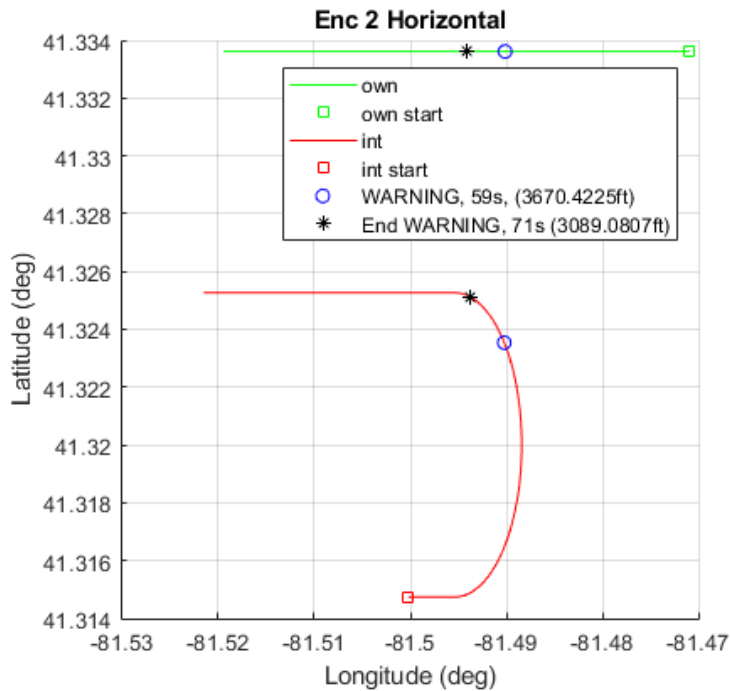
**Horizontal Separation at CPA - Truth MNA**



**Vertical Separation at CPA - Truth MNA**

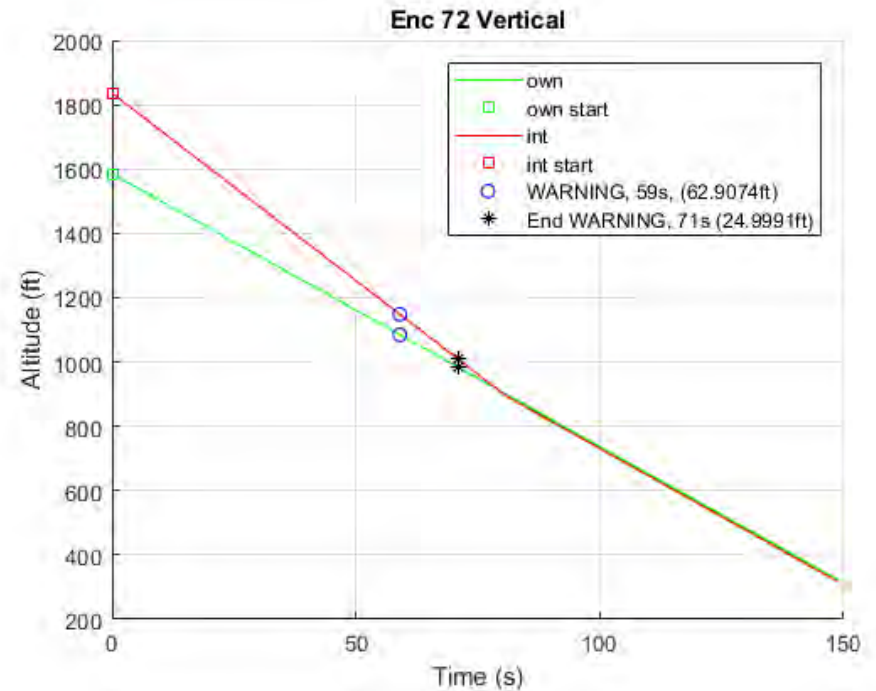
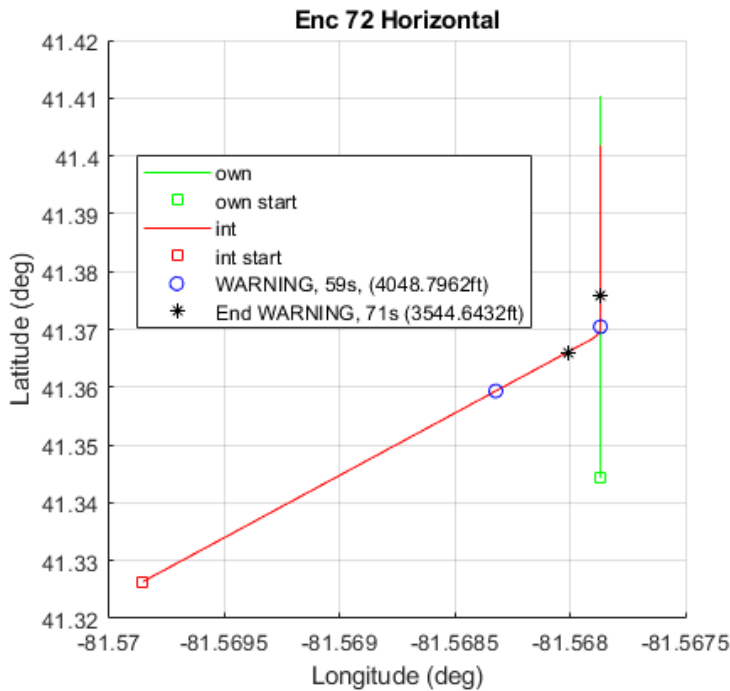


# Truth – MNA (Enc 2)

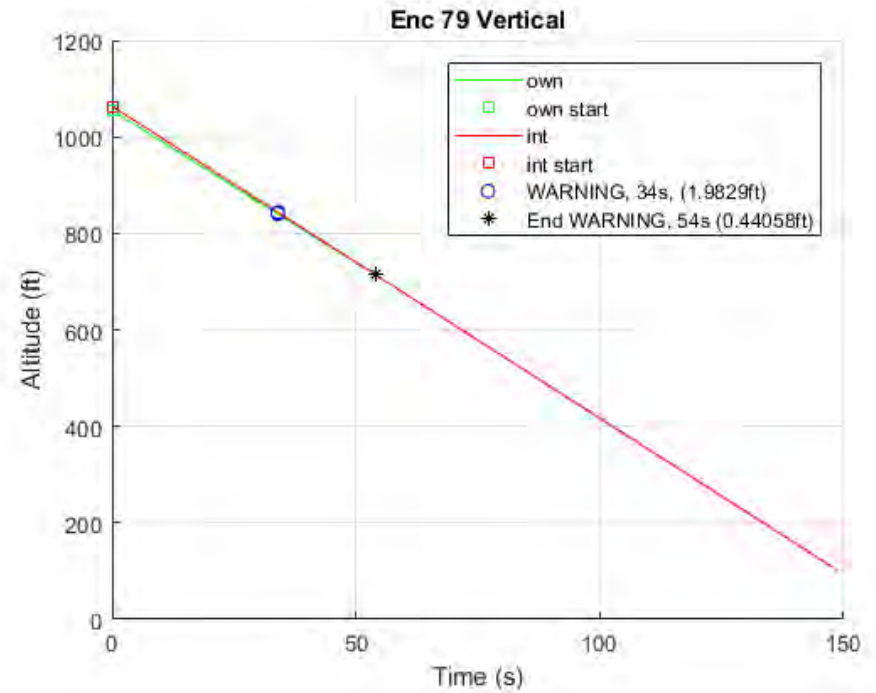
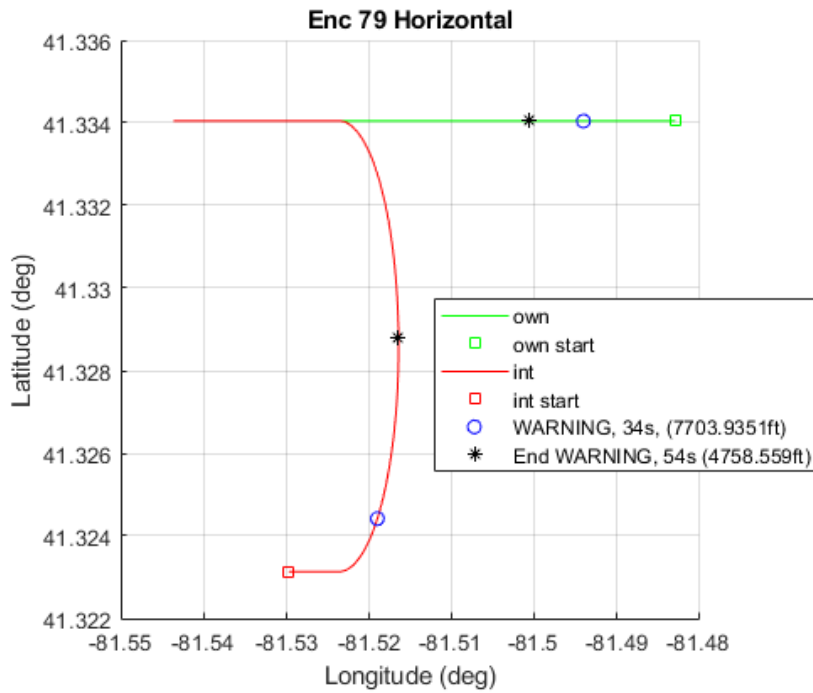




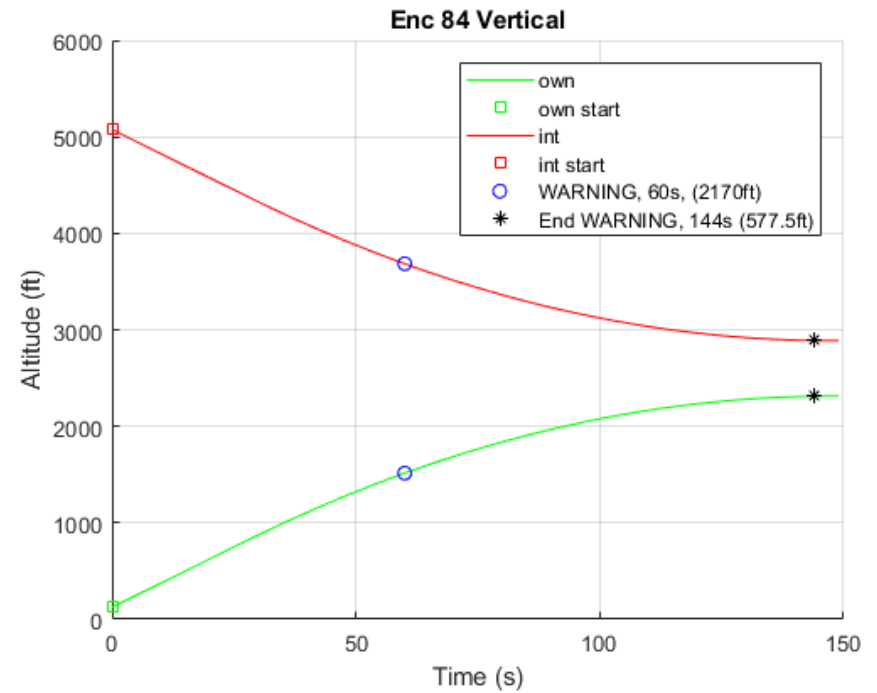
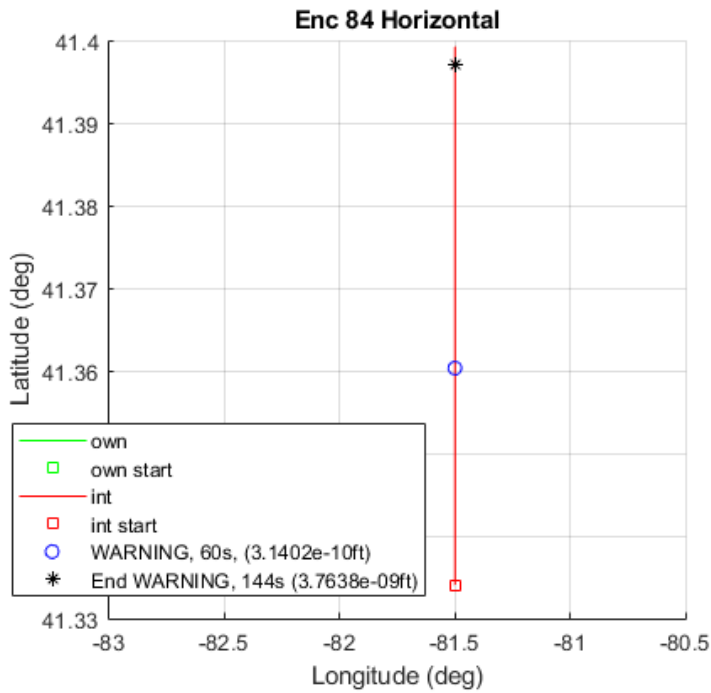
# Truth – MNA (Enc 72)



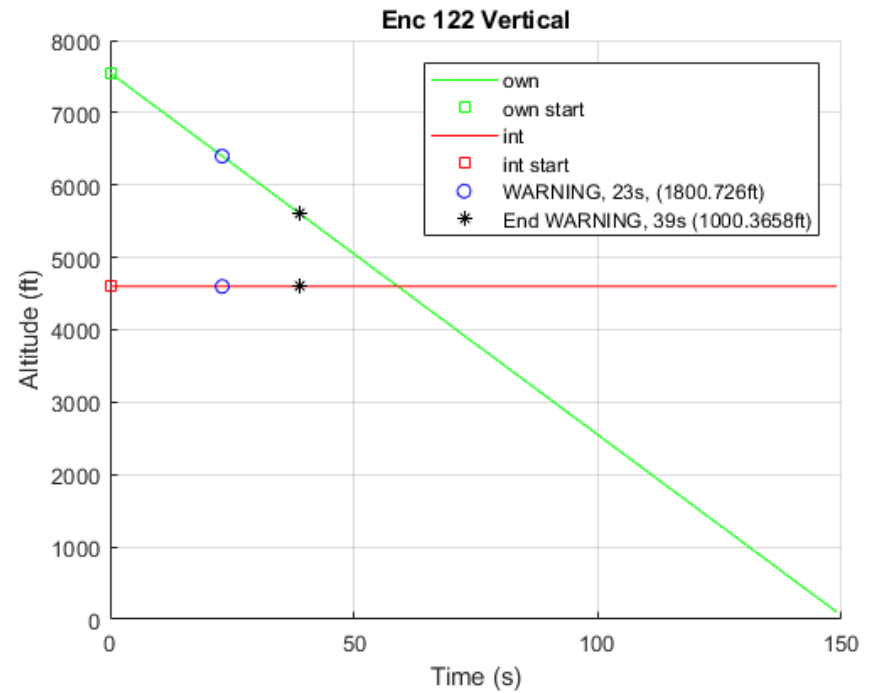
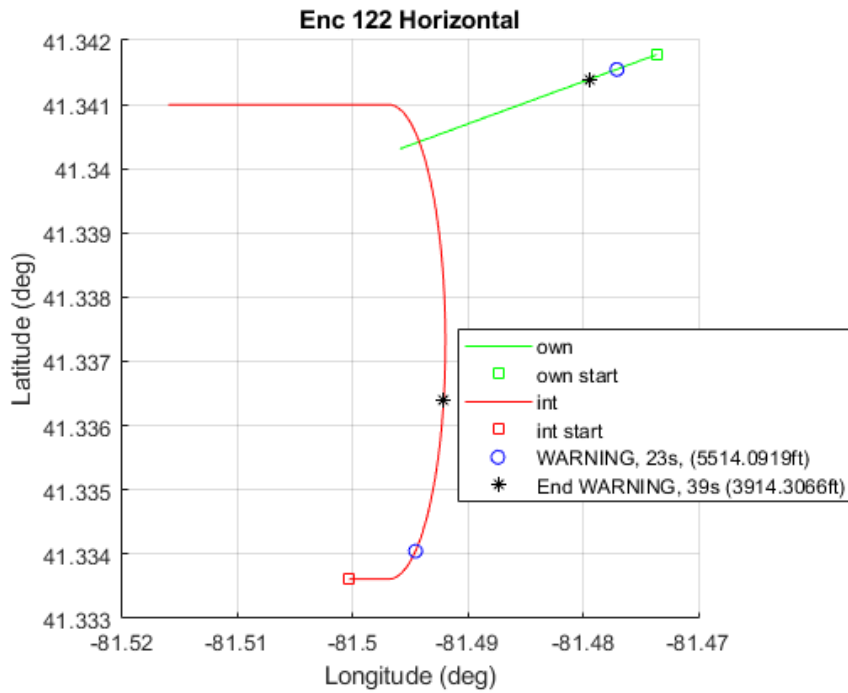
# Truth – MNA (Enc 79)



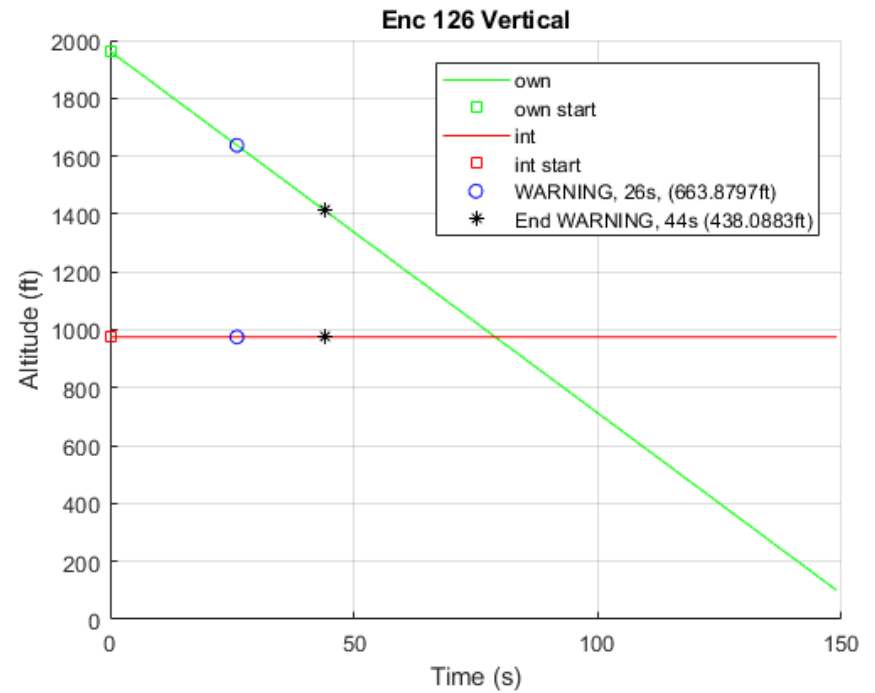
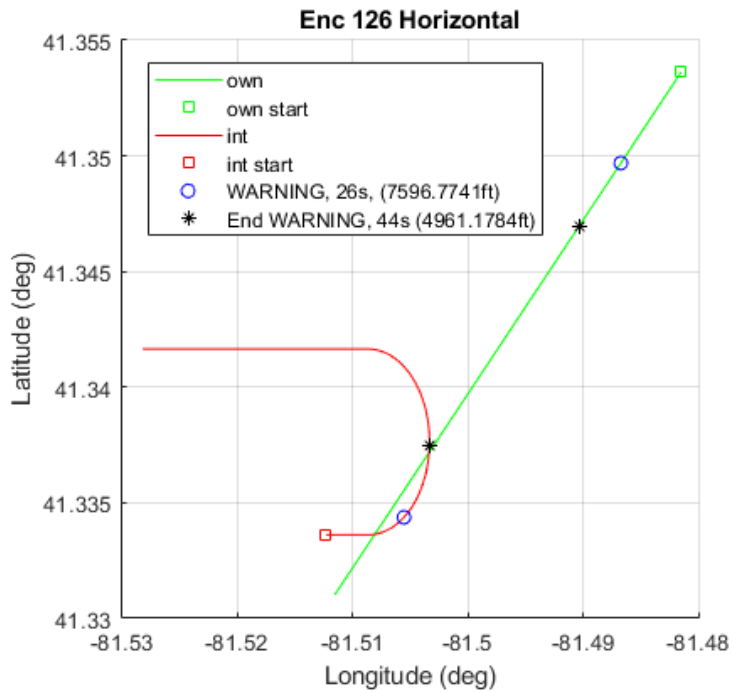
# Truth – MNA (Enc 84)



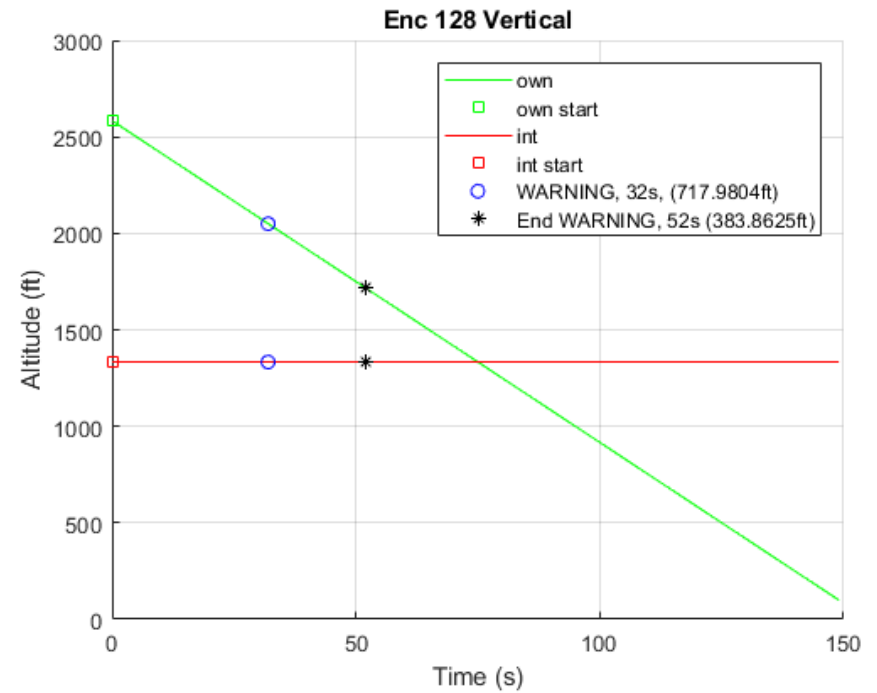
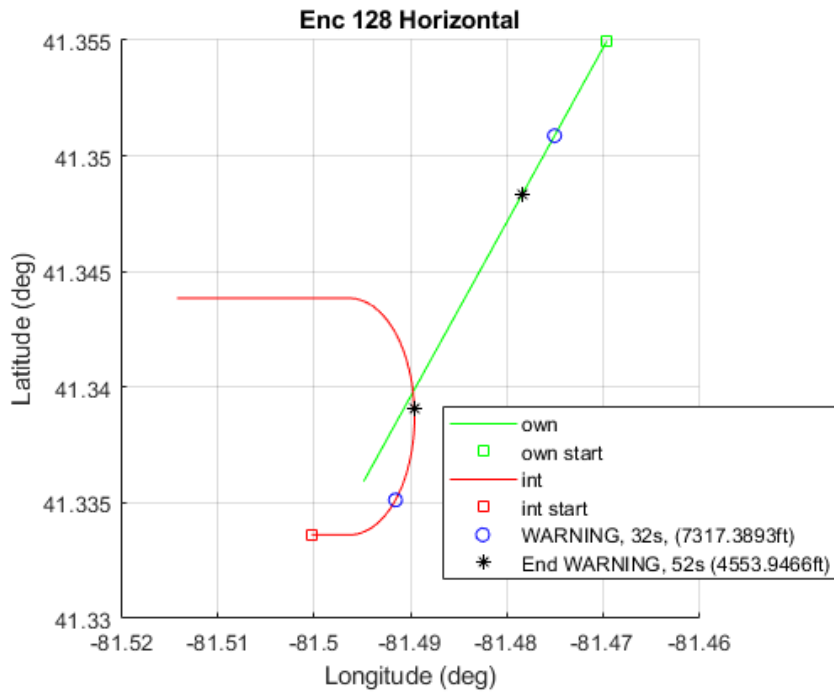
# Truth – MNA (Enc 122)



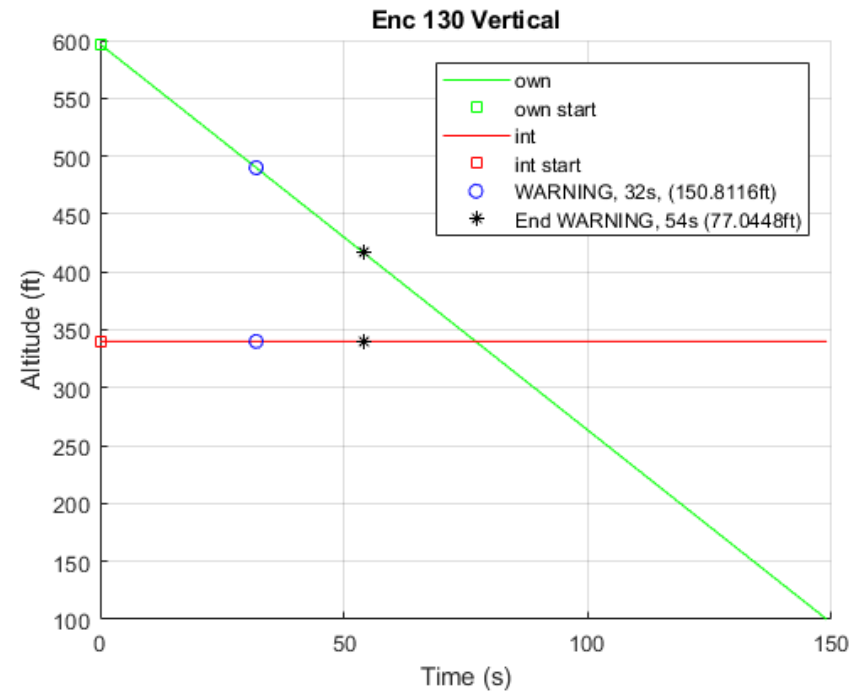
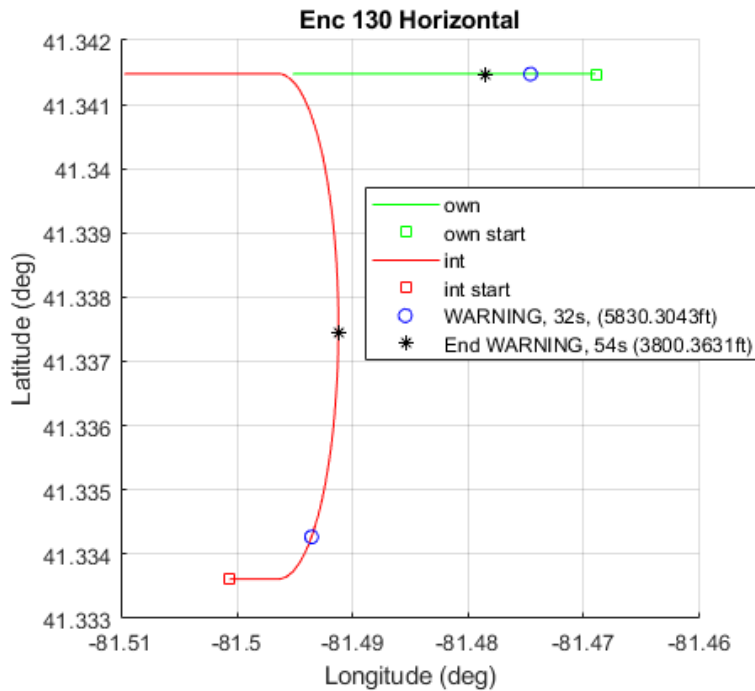
# Truth – MNA (Enc 126)



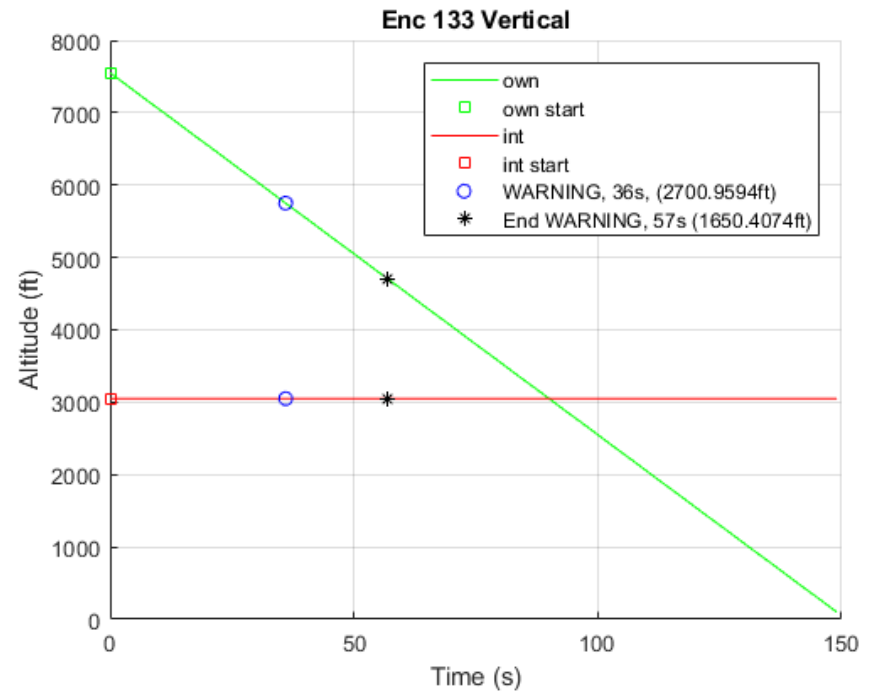
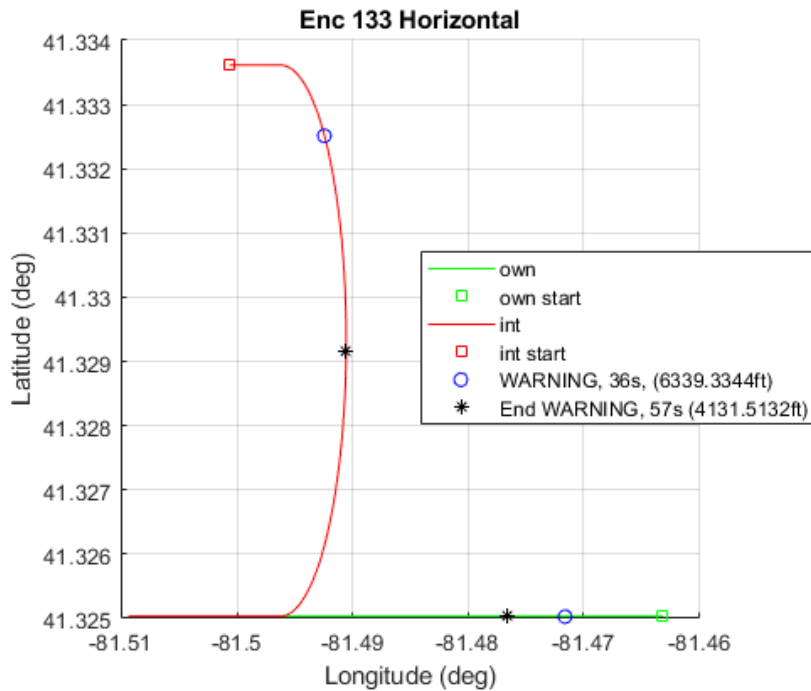
# Truth – MNA (Enc 128)



# Truth – MNA (Enc 130)



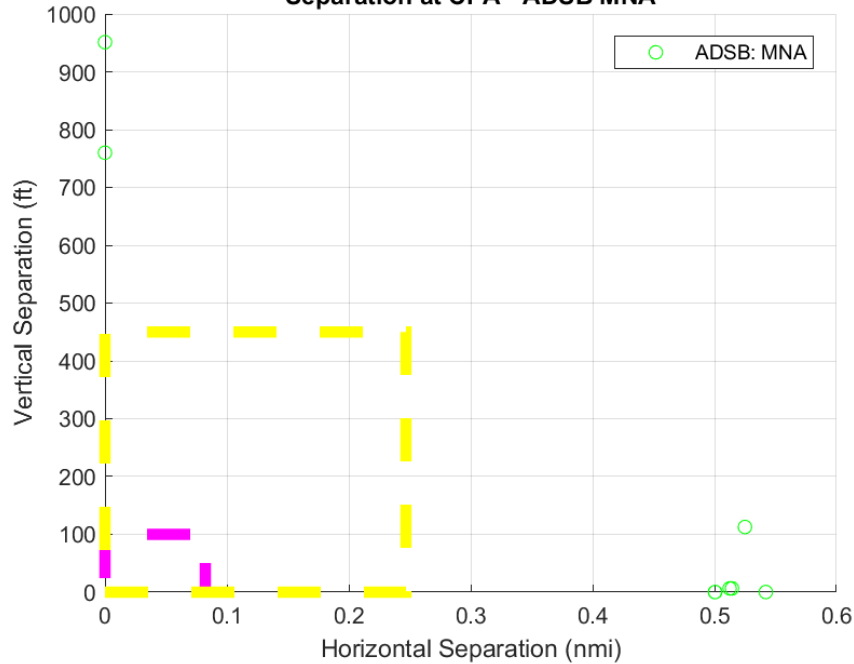
# Truth – MNA (Enc 133)



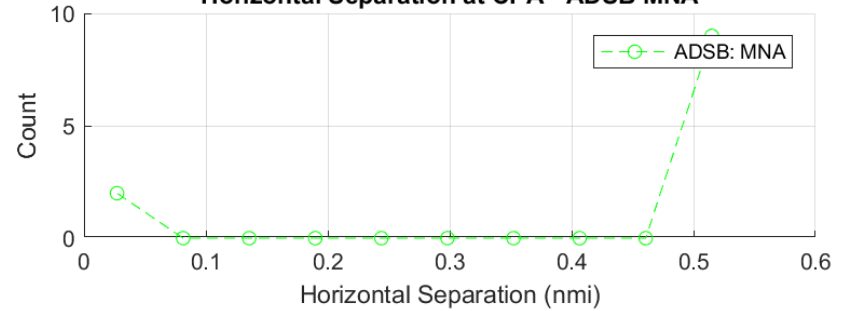


11 out of 103 MNA encounters alerted using ADSB data

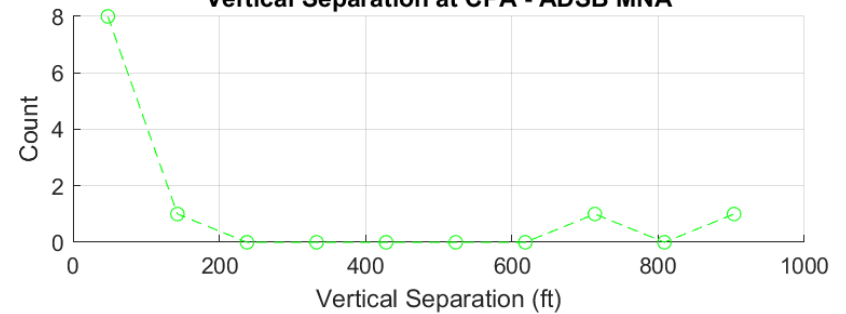
**Separation at CPA - ADSB MNA**



**Horizontal Separation at CPA - ADSB MNA**

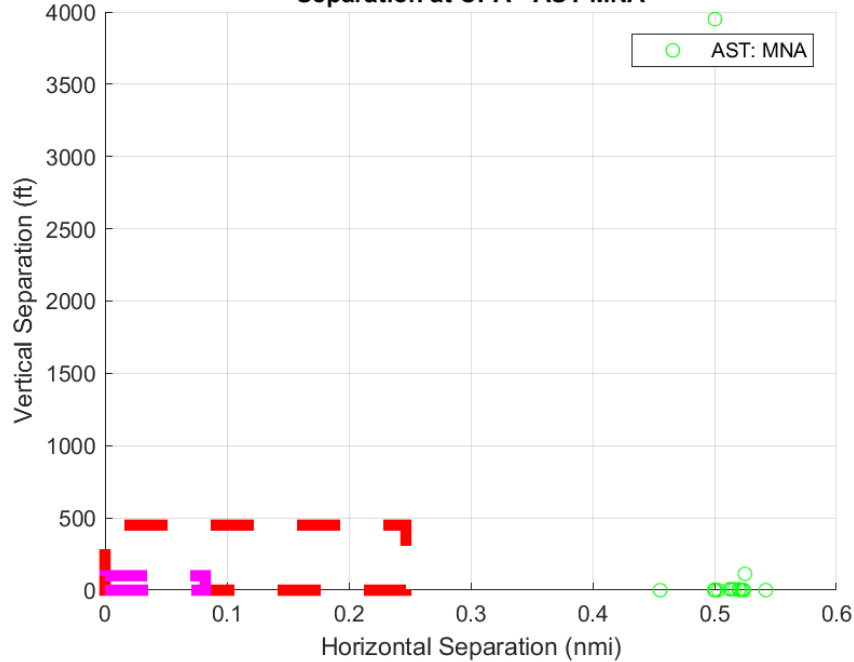


**Vertical Separation at CPA - ADSB MNA**

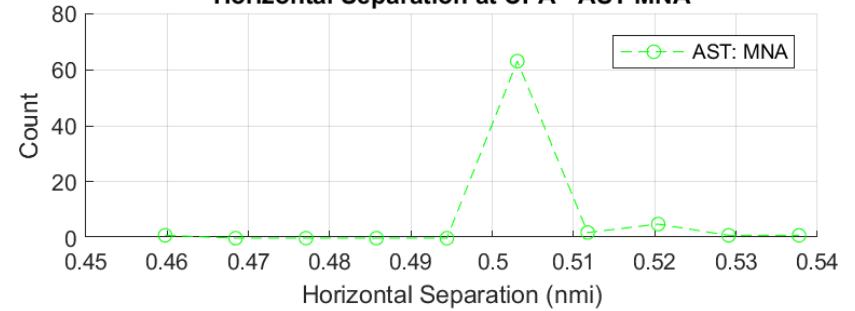


73 out of 103 MNA encounters alerted using AST data (all clustered at 0.5 nm horizontal separation)

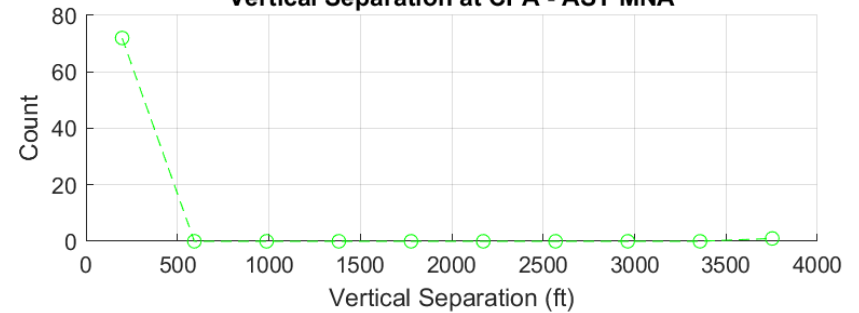
Separation at CPA - AST MNA



Horizontal Separation at CPA - AST MNA

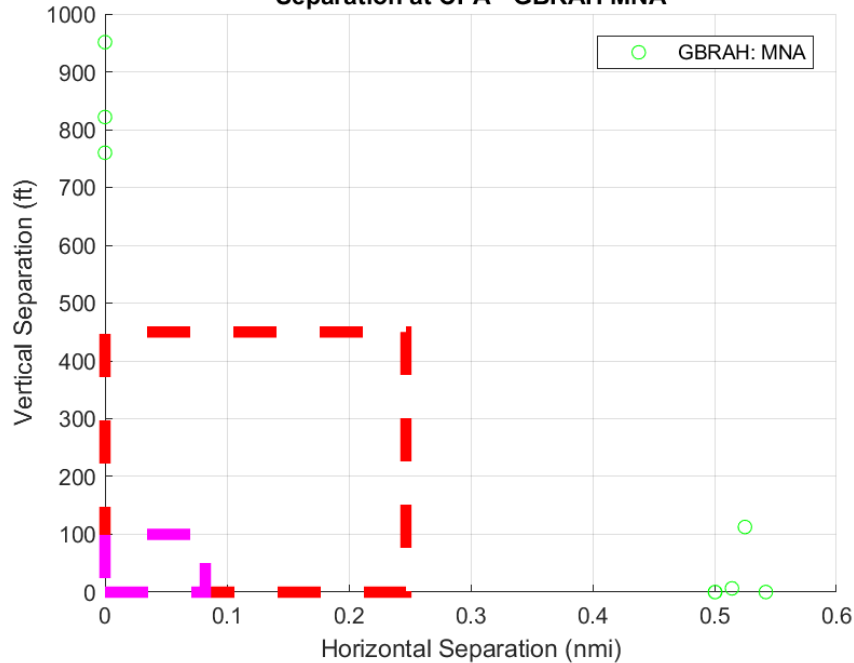


Vertical Separation at CPA - AST MNA

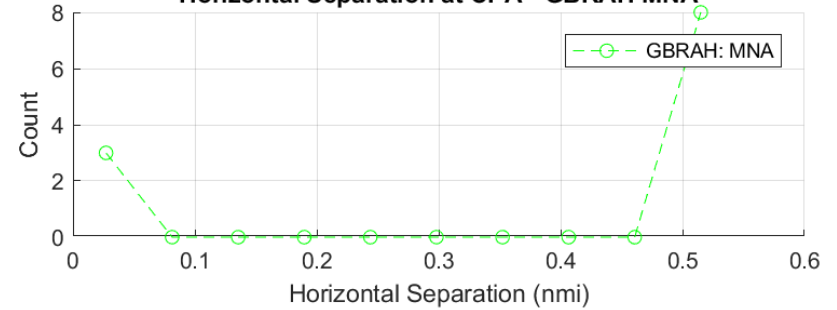


All 3 sets of GBR error parameters yielded about 10% alert rate, and alerted on the same encounters (except 1)

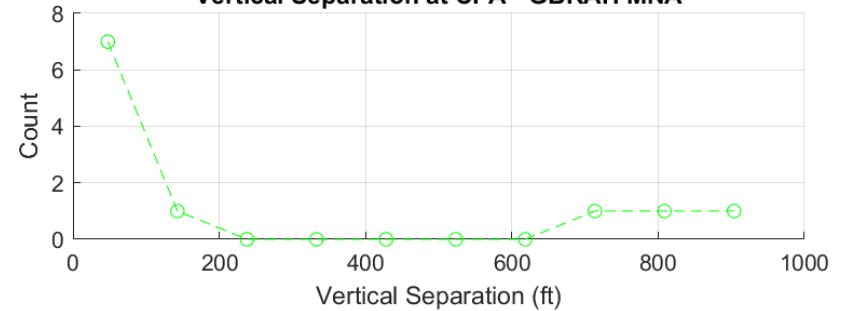
Separation at CPA - GBRAH MNA



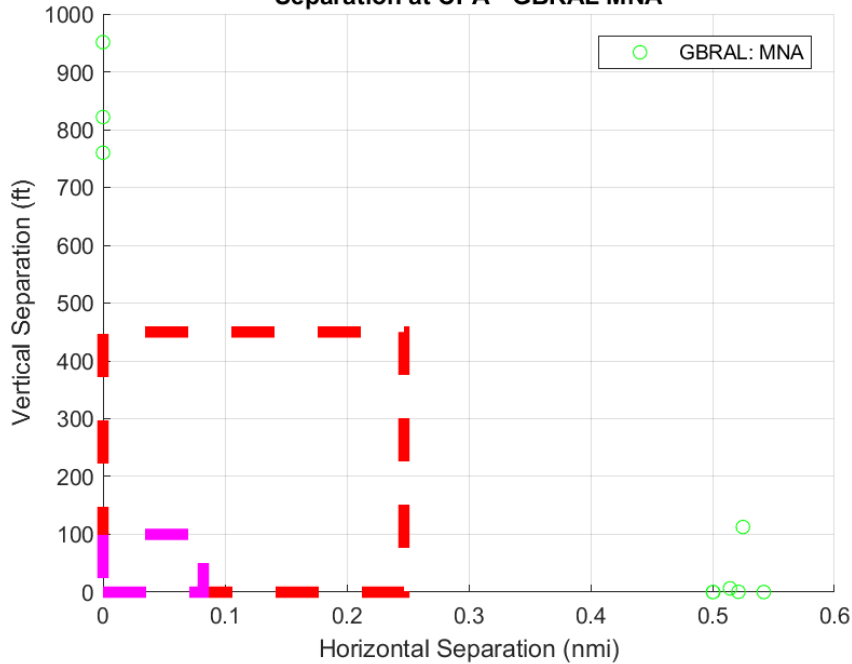
Horizontal Separation at CPA - GBRAH MNA



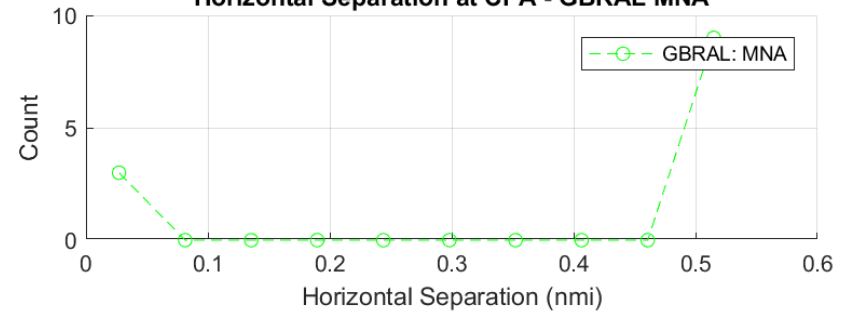
Vertical Separation at CPA - GBRAH MNA



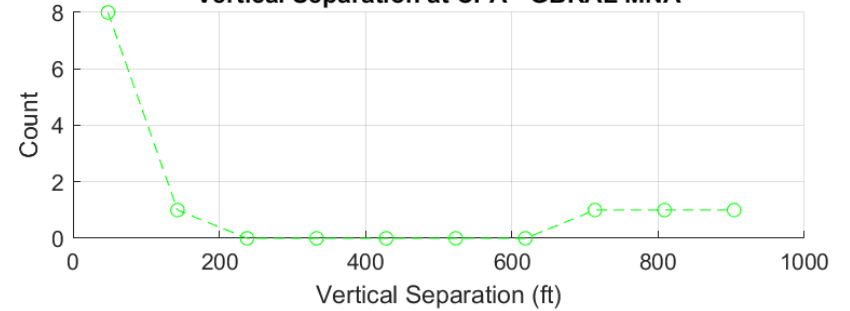
Separation at CPA - GBRAL MNA



Horizontal Separation at CPA - GBRAL MNA



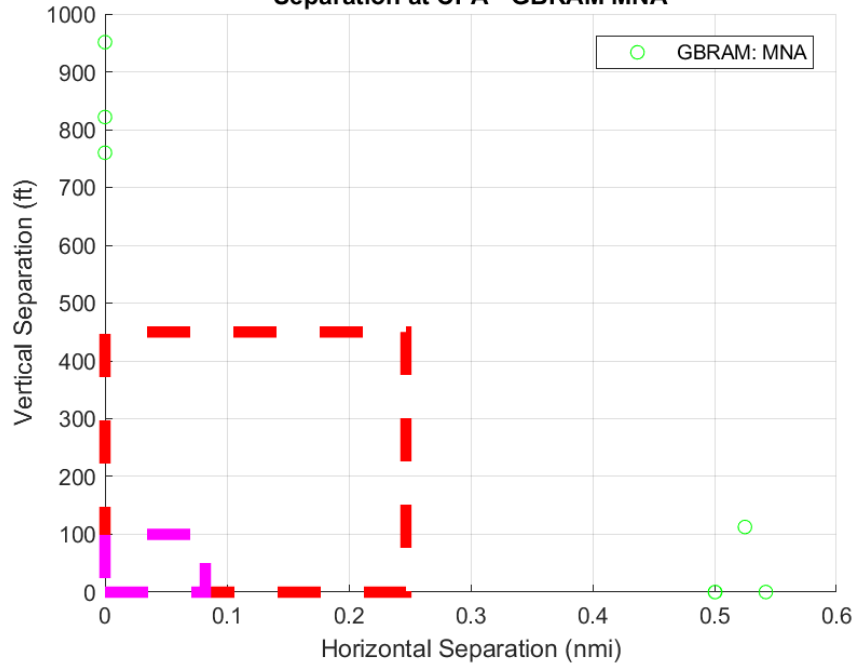
Vertical Separation at CPA - GBRAL MNA



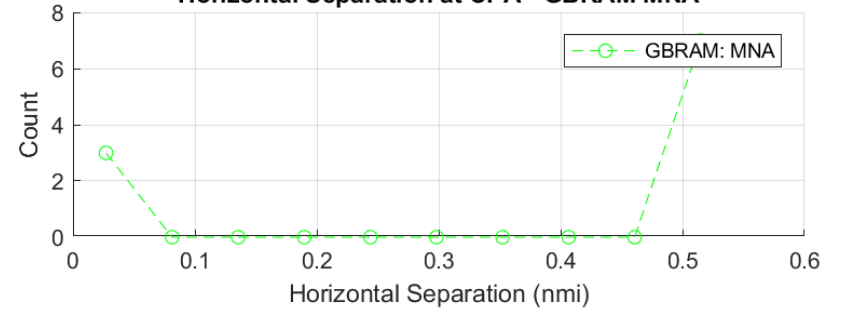
# GBRAM - MNA



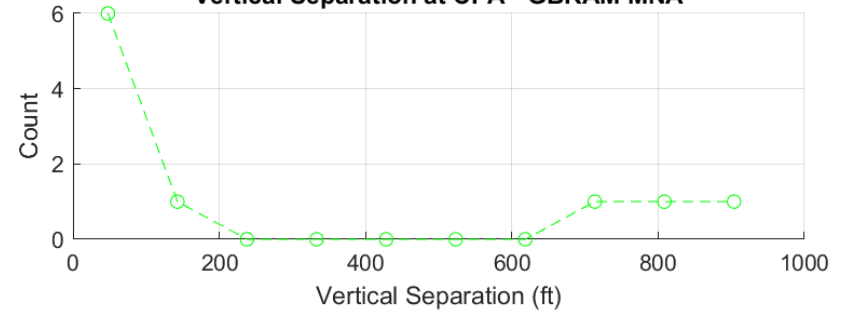
Separation at CPA - GBRAM MNA



Horizontal Separation at CPA - GBRAM MNA



Vertical Separation at CPA - GBRAM MNA



# Backup

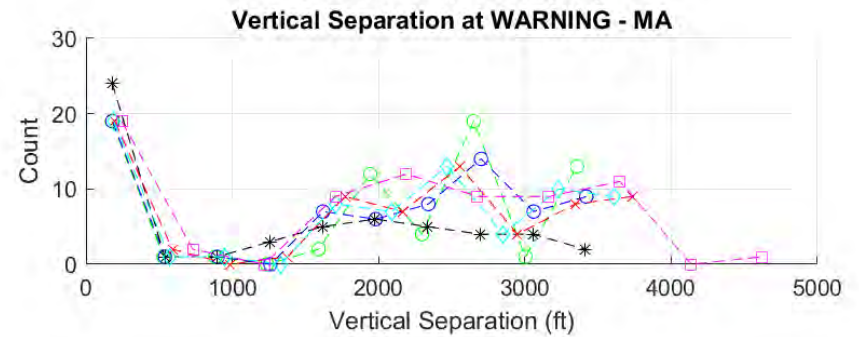
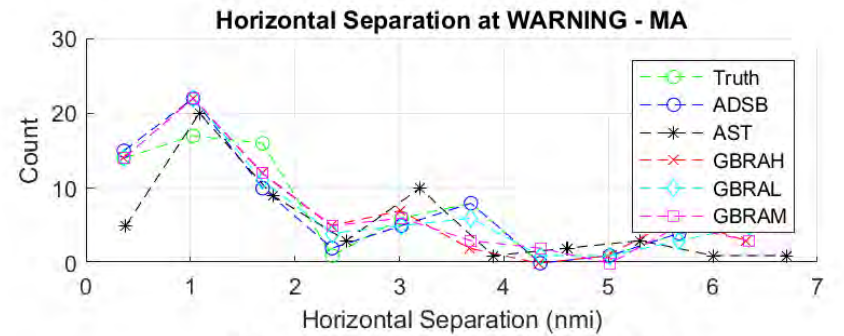
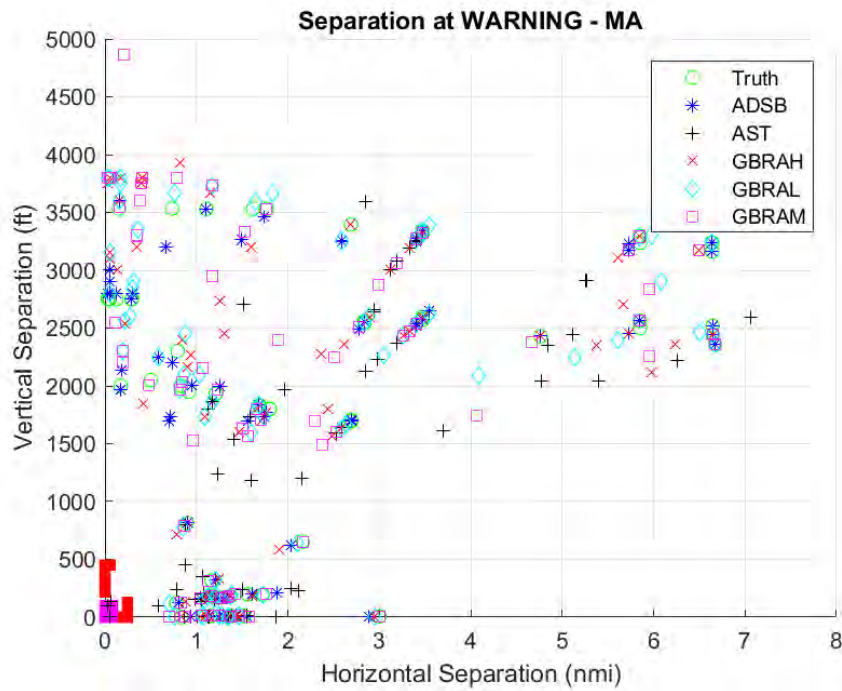
**Table 2-23 Parameters for Terminal DWC Alerting Requirements**

Alert Type →		Warning
Alert Level →		Warning
HAZ	$\tau_{mod}^*$ (Seconds)	0
	DMOD and HMD* (Feet)	1,500
	$h^*$ (Feet)	450
HAZ Alert Times	Minimum Average Time of Alert (Seconds)	45
	Late Threshold ( $THR_{Late}$ ) (Seconds)	30
	Early Threshold ( $THR_{Early}$ ) (Seconds)	70
NHZ	$\tau_{mod}^*$ (Seconds)	75
	DMOD and HMD* (NM)	2000
	VMOD (Feet)	450

# Separation at Warning



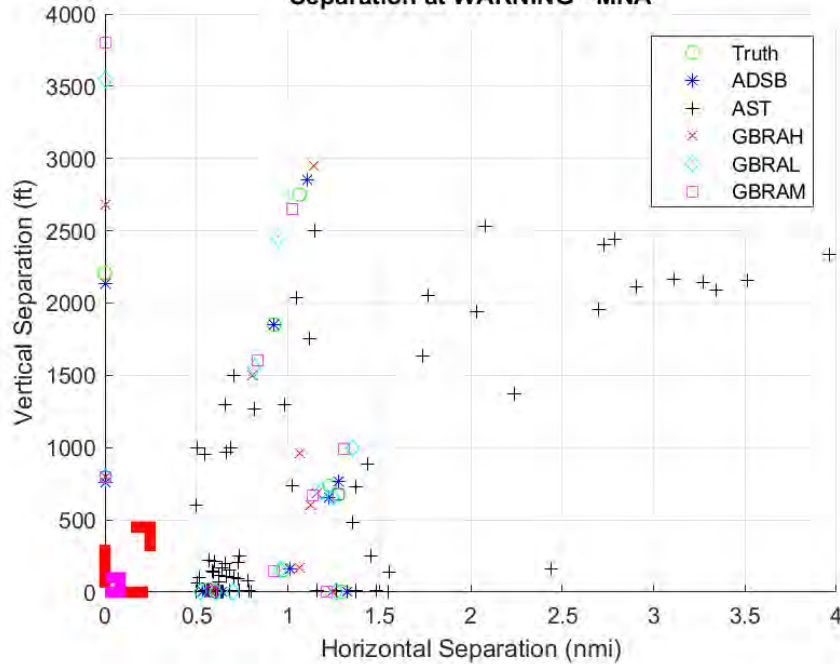
# Separation at Warning – MA



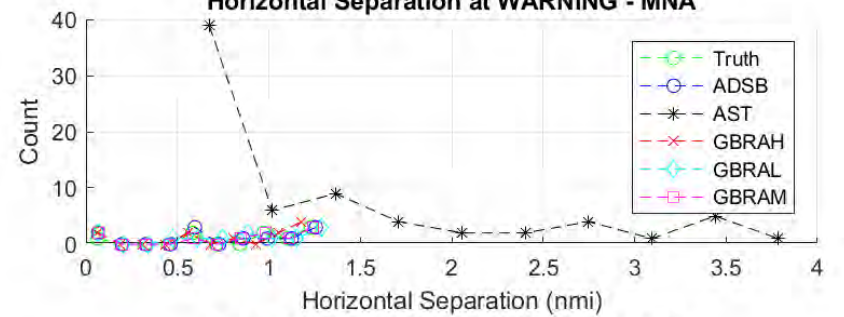
# Separation at Warning – MNA



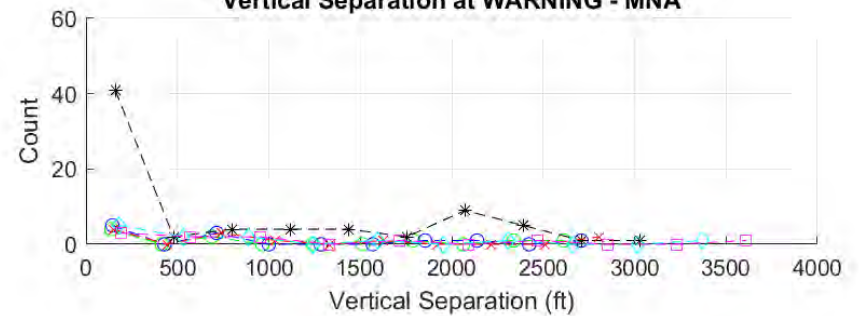
Separation at WARNING - MNA



Horizontal Separation at WARNING - MNA



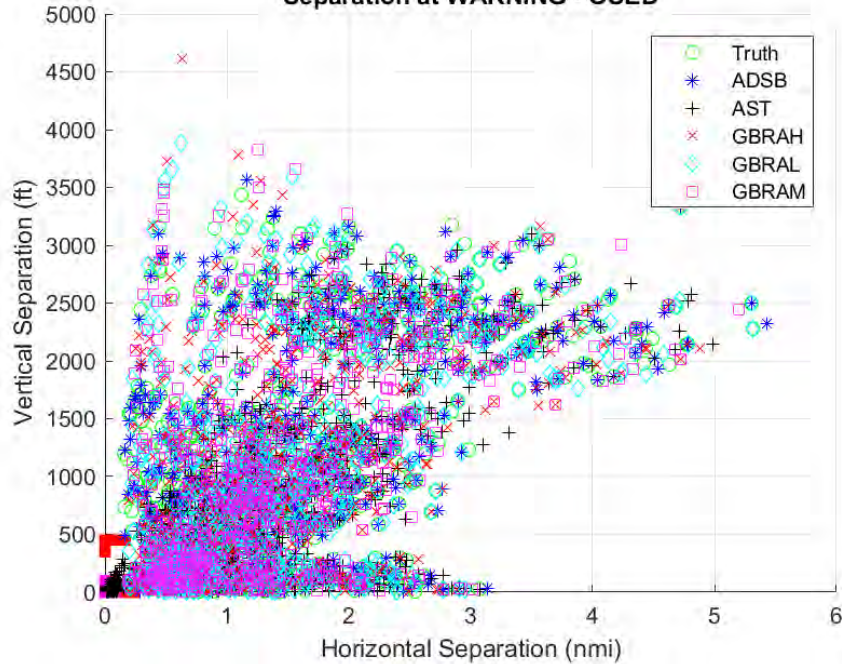
Vertical Separation at WARNING - MNA



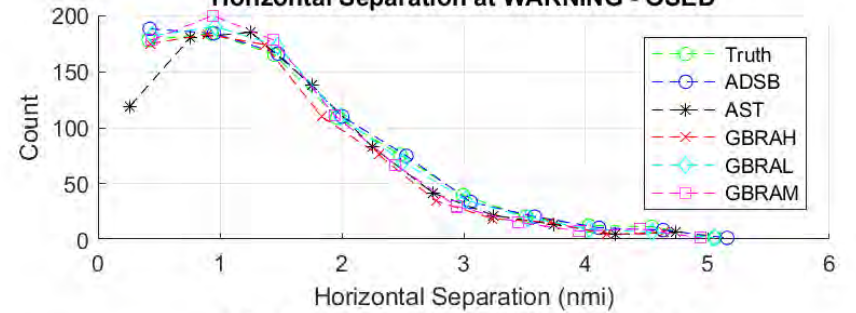
# Separation at Warning – OSED



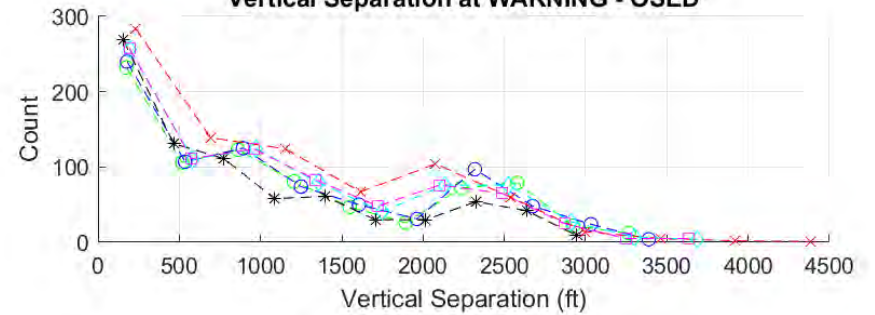
**Separation at WARNING - OSED**



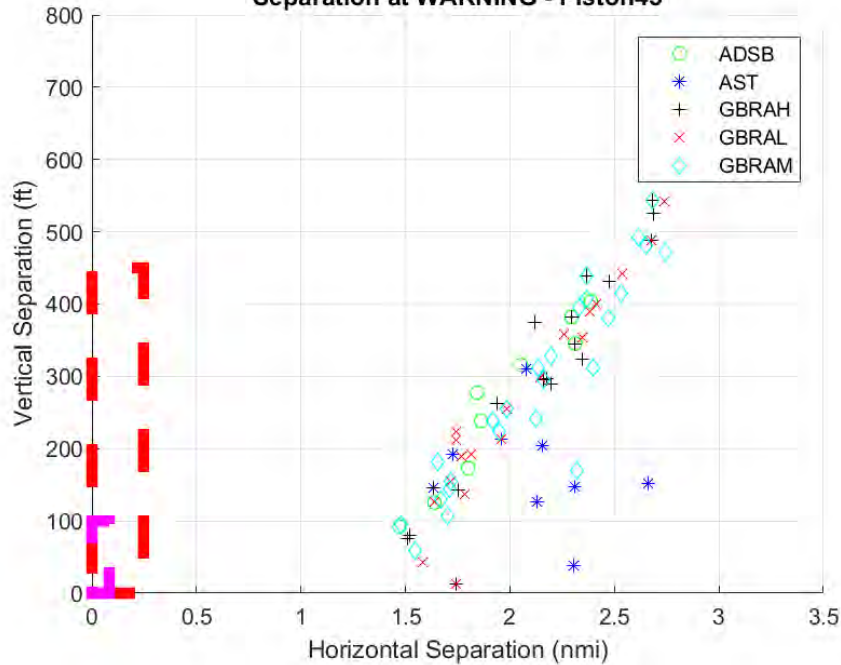
**Horizontal Separation at WARNING - OSED**



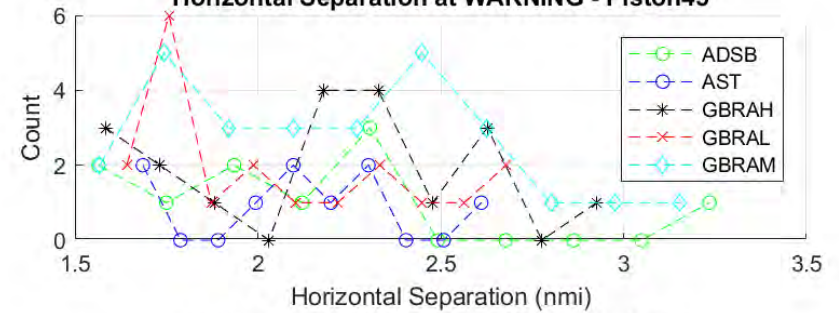
**Vertical Separation at WARNING - OSED**



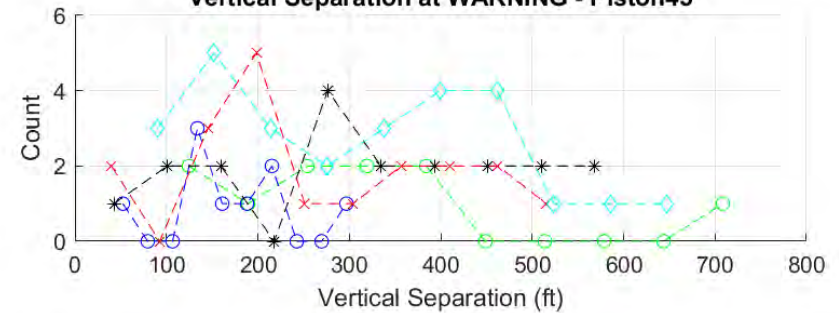
**Separation at WARNING - Piston45**

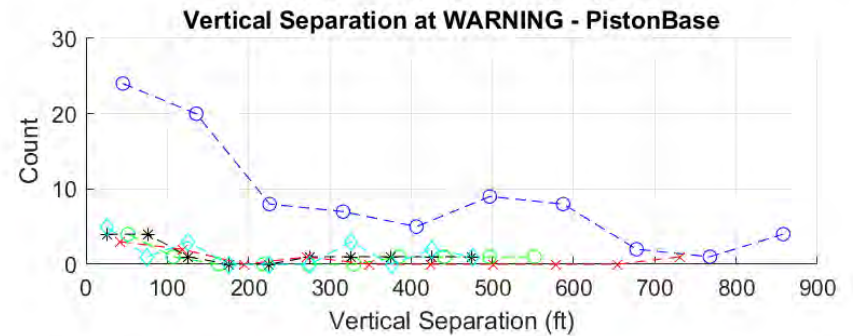
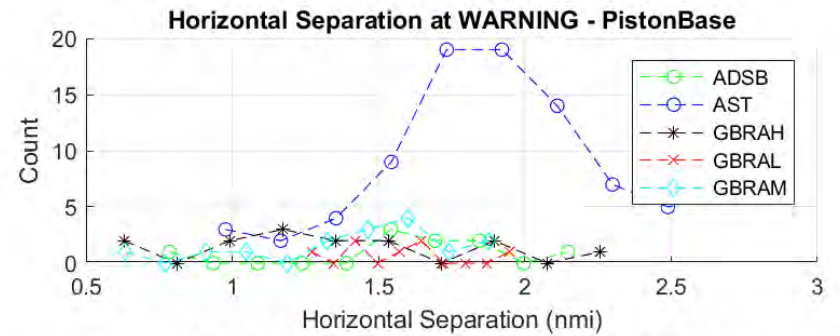
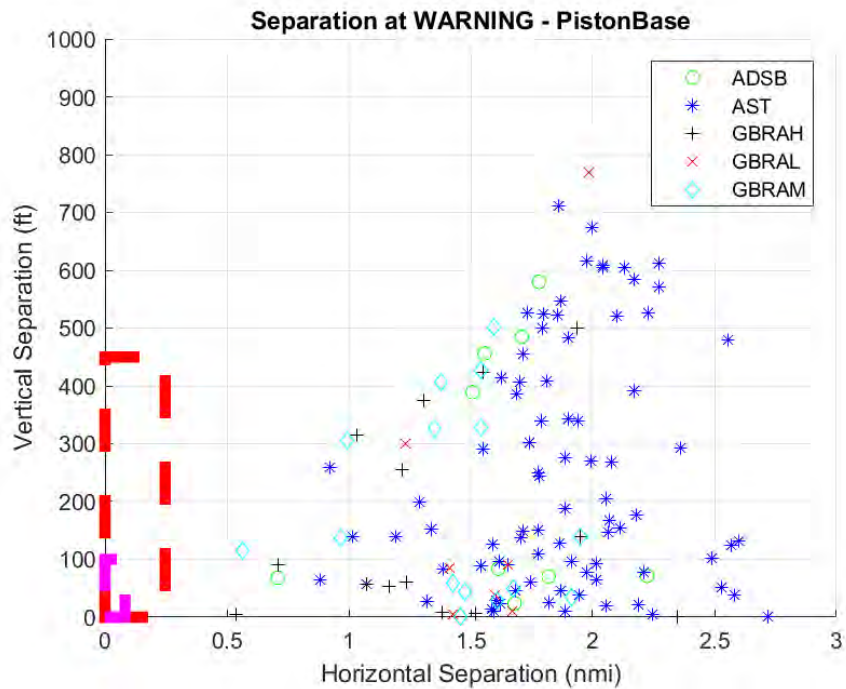


**Horizontal Separation at WARNING - Piston45**

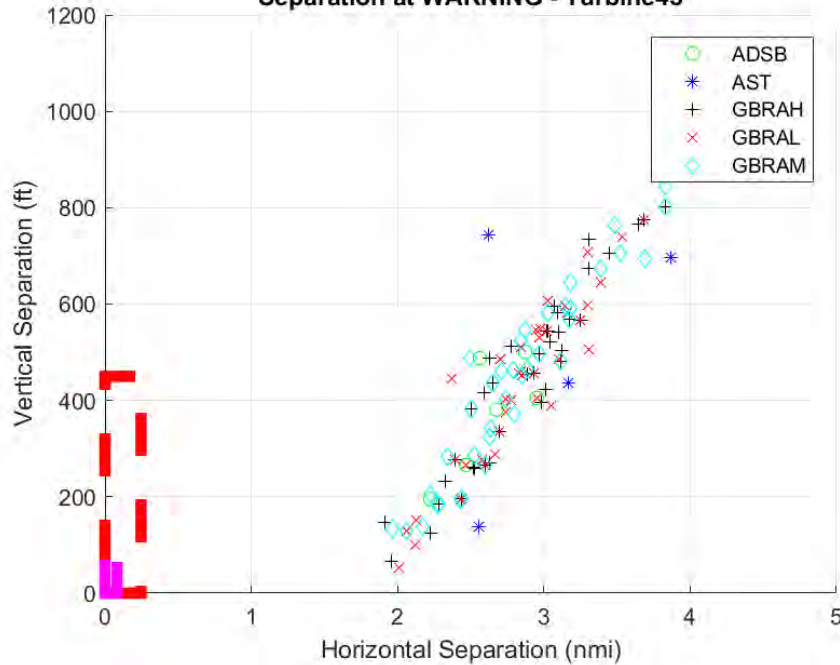


**Vertical Separation at WARNING - Piston45**

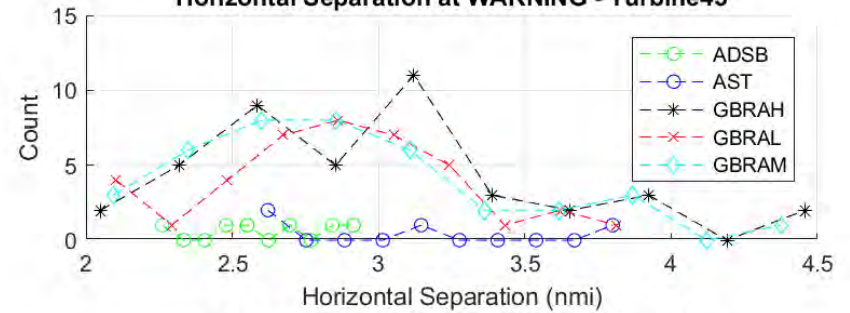




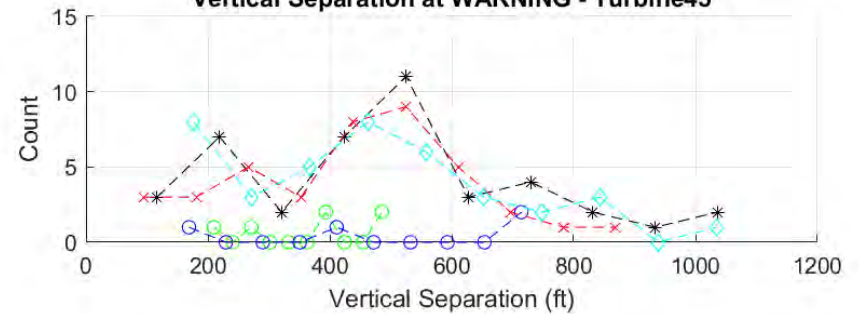
Separation at WARNING - Turbine45

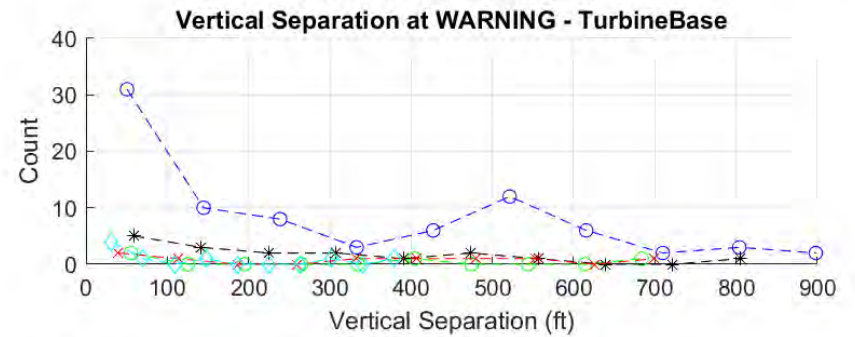
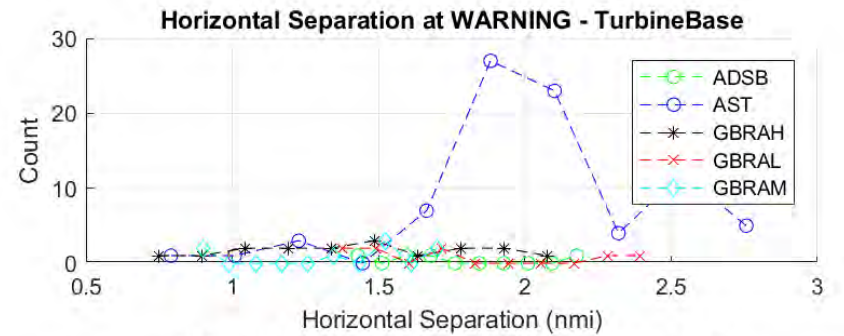
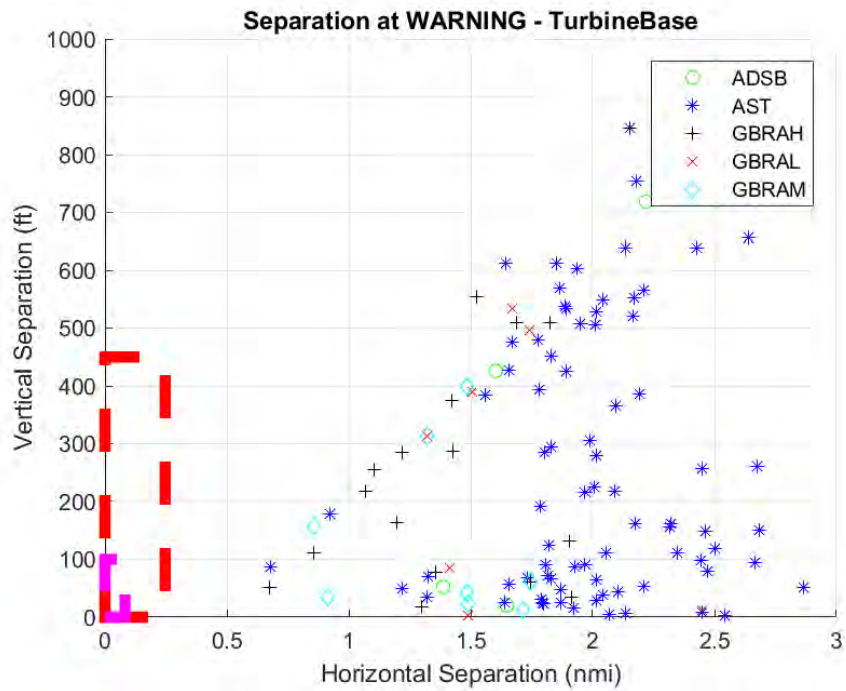


Horizontal Separation at WARNING - Turbine45



Vertical Separation at WARNING - Turbine45



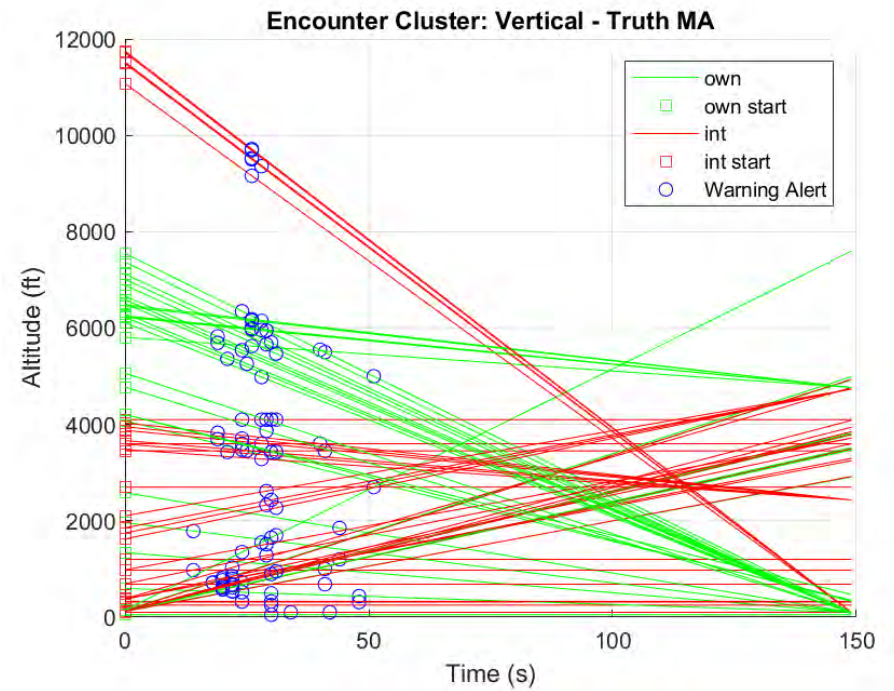
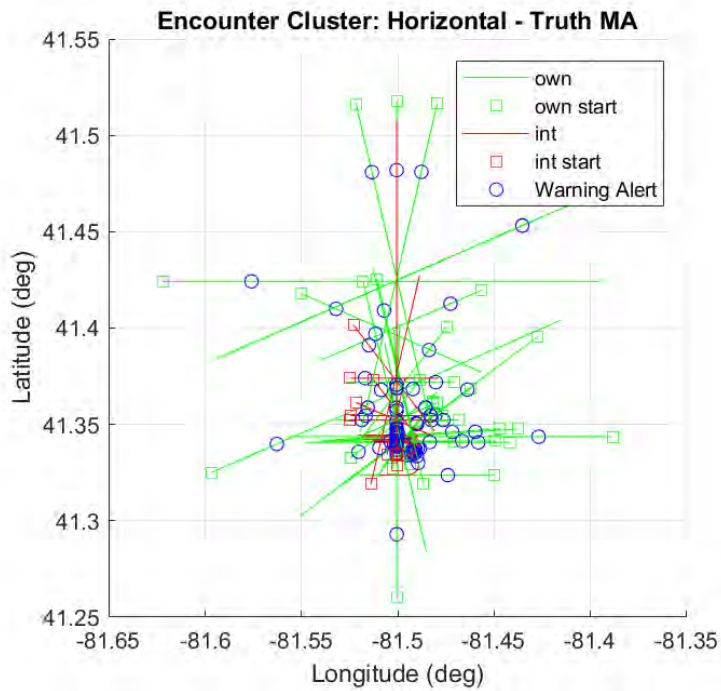


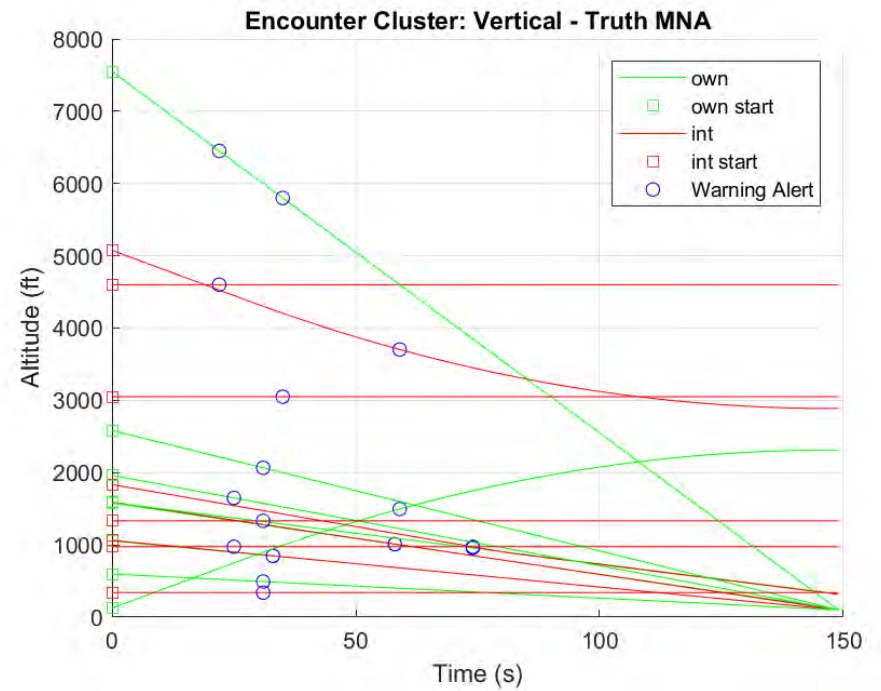
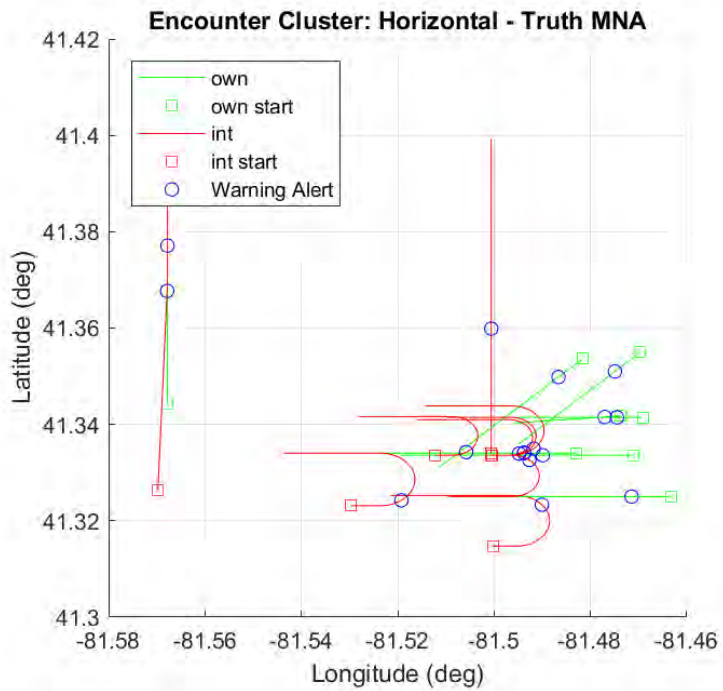
# Encounter Cluster Plots

The plots in this section show the trajectories for those encounters that included a Warning Alert

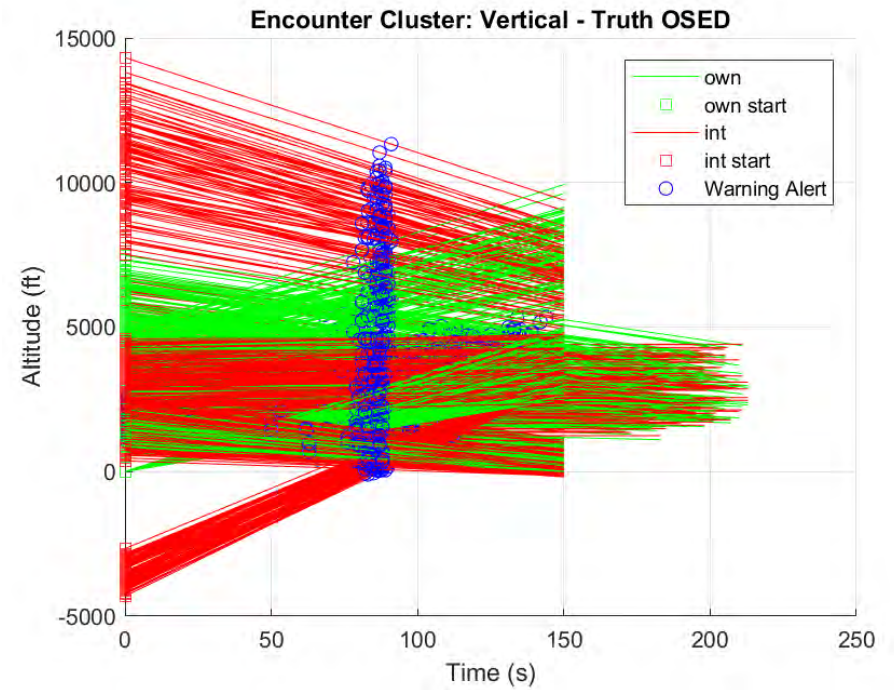
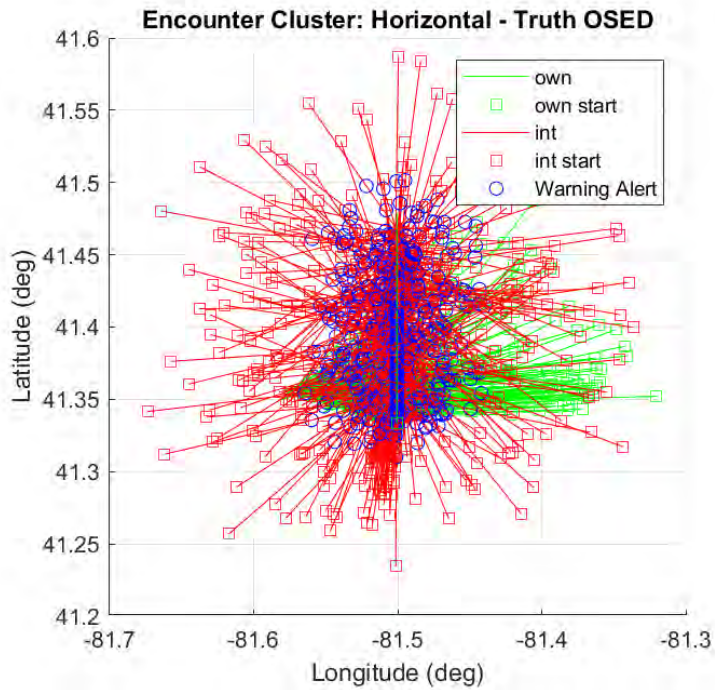


# Truth MA

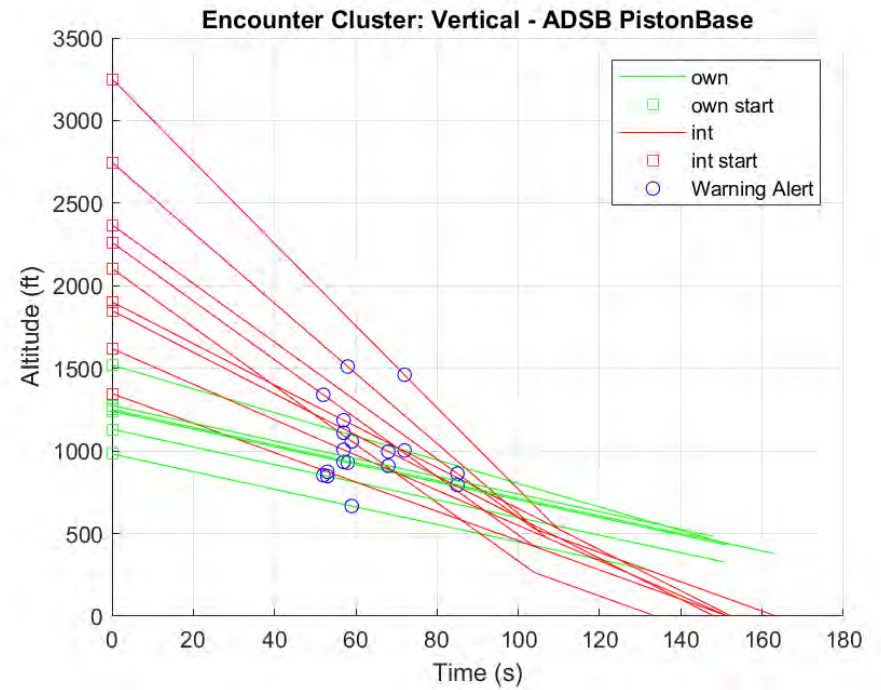
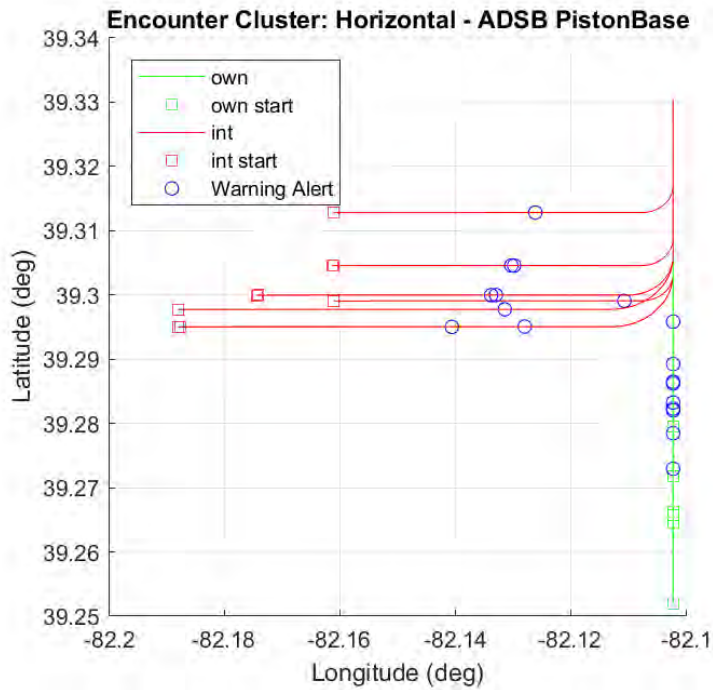




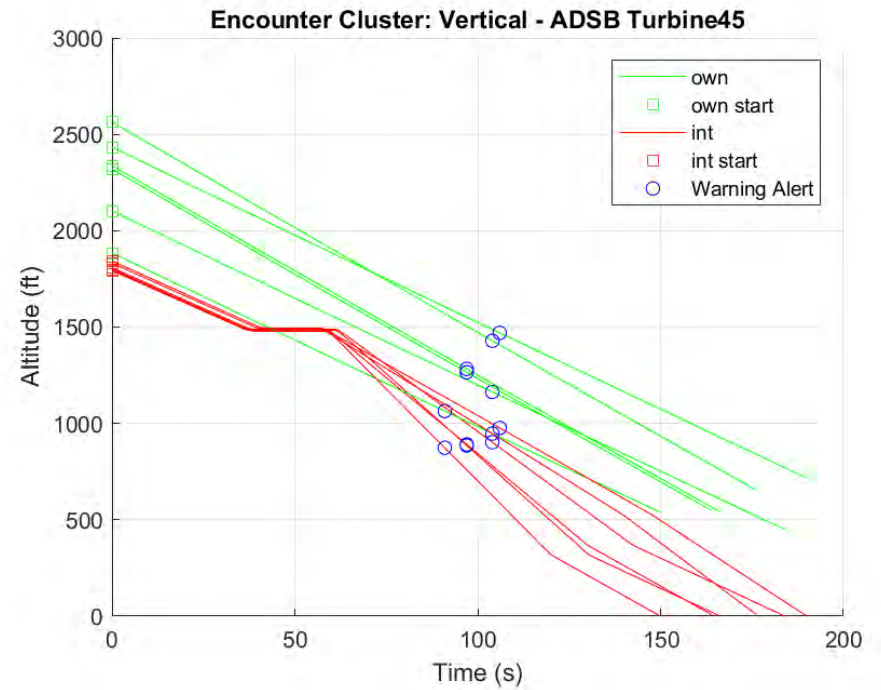
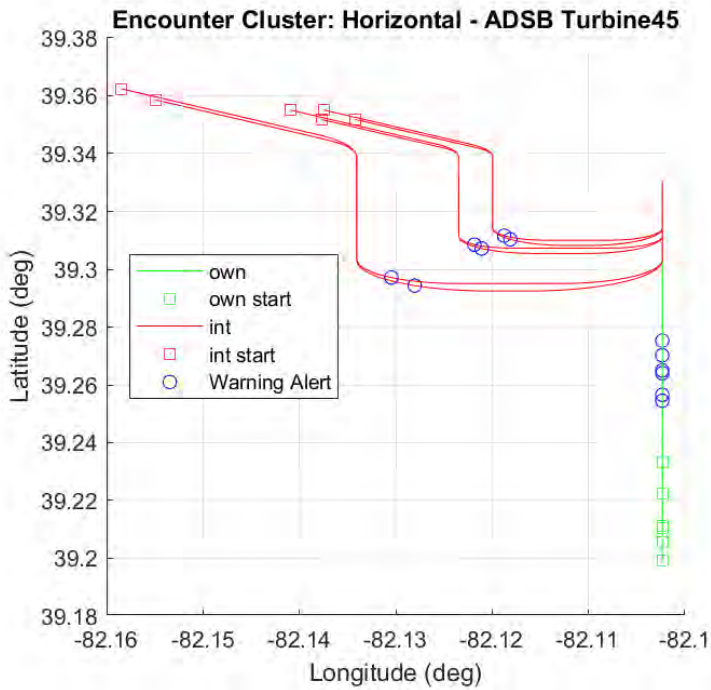
# Truth OSED



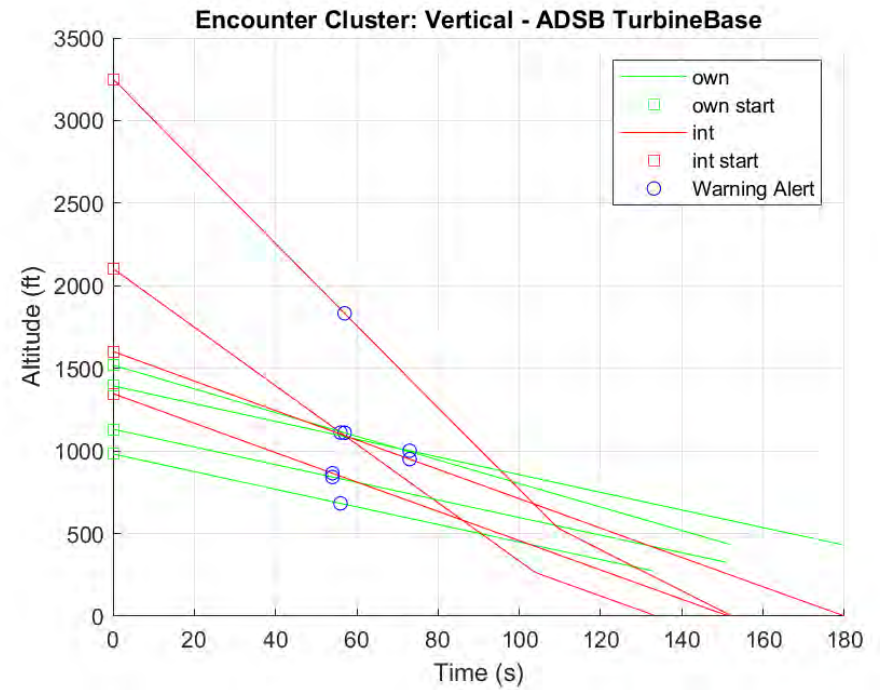
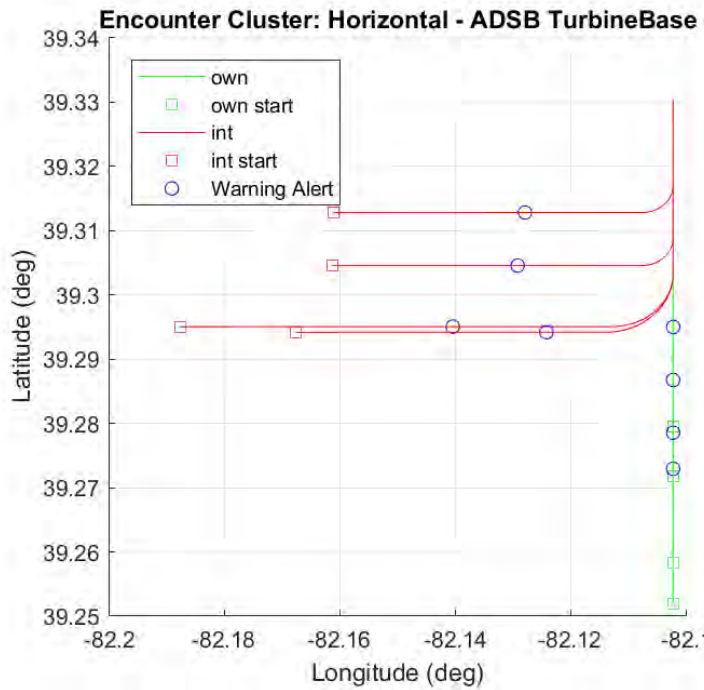
# ADSB PistonBase



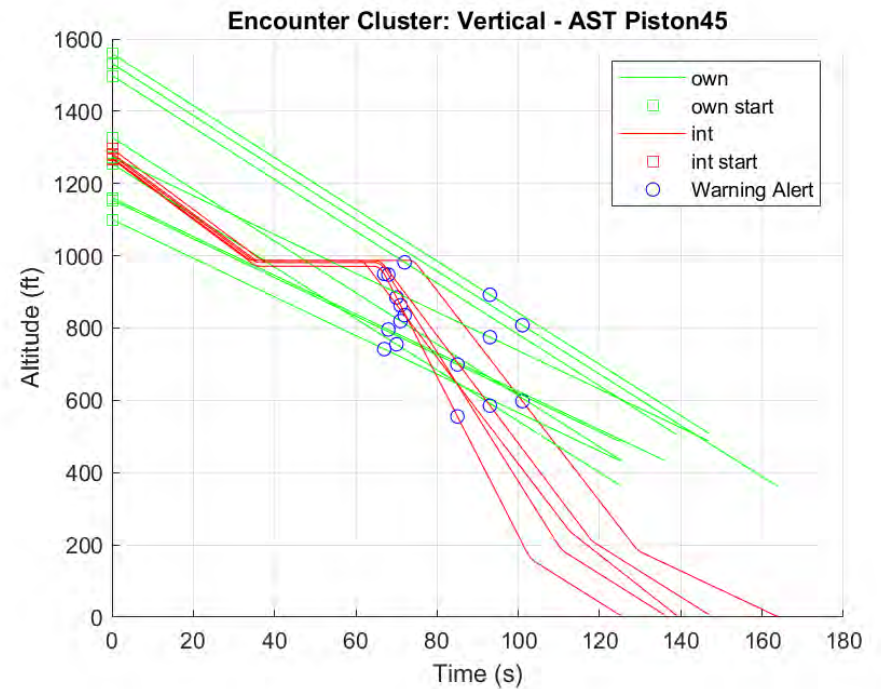
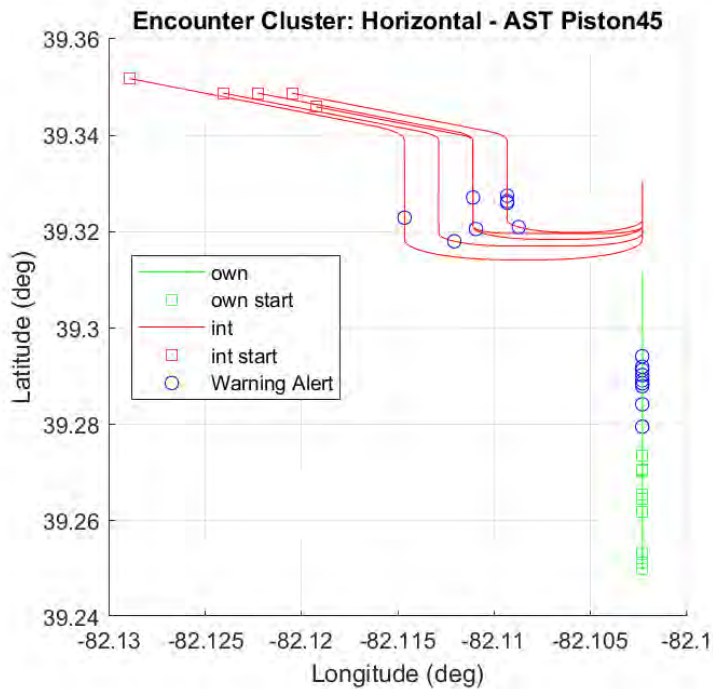
# ADSB Piston45



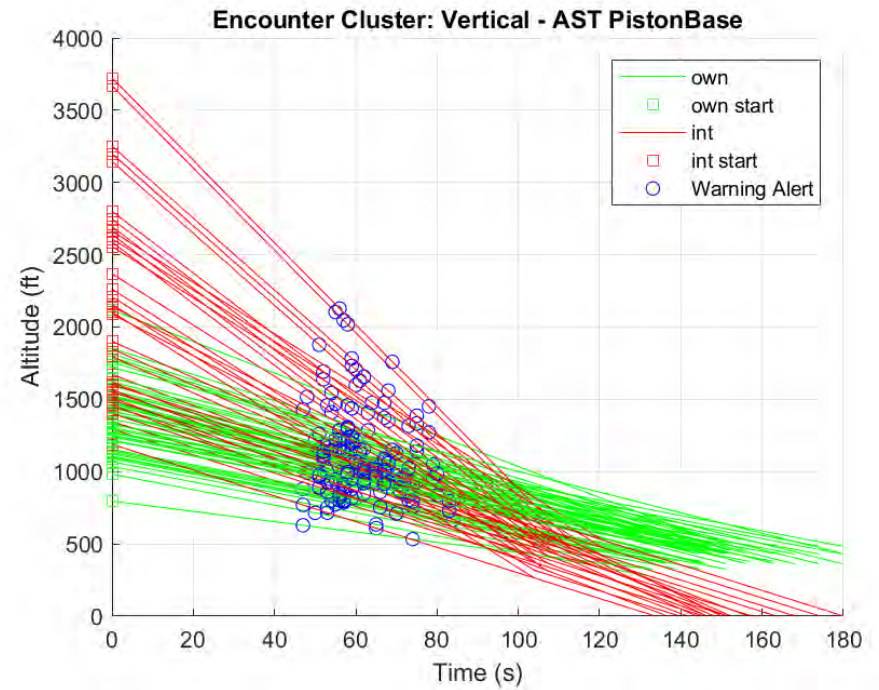
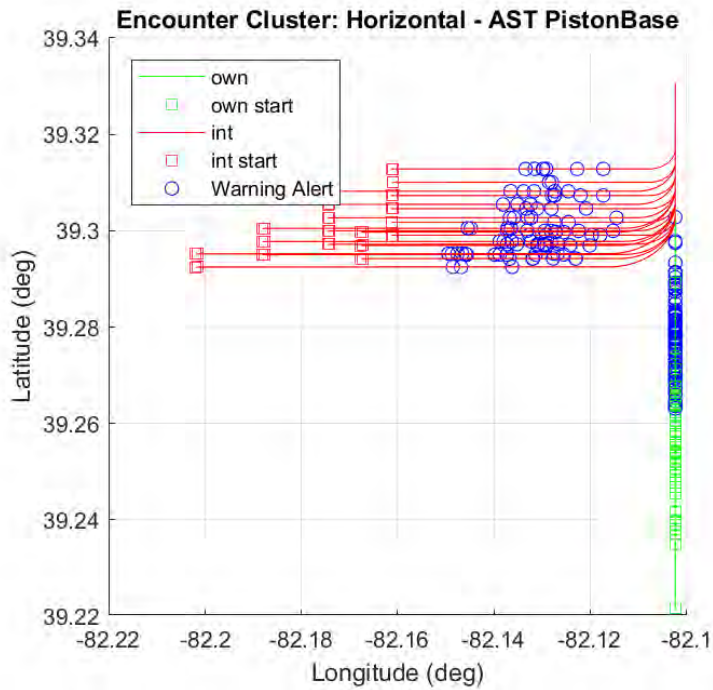
# ADSB TurbineBase



# AST Piston45

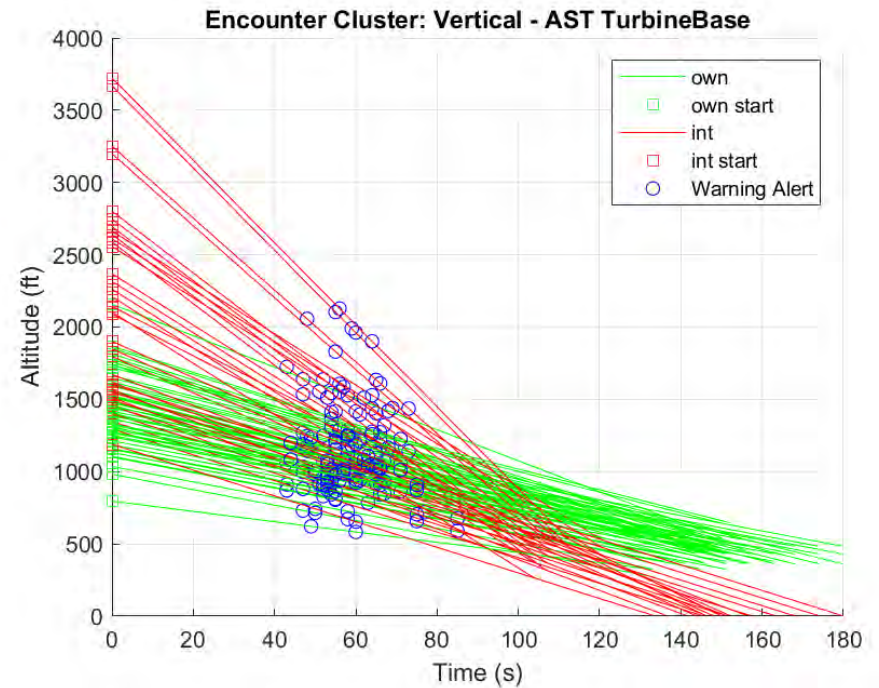
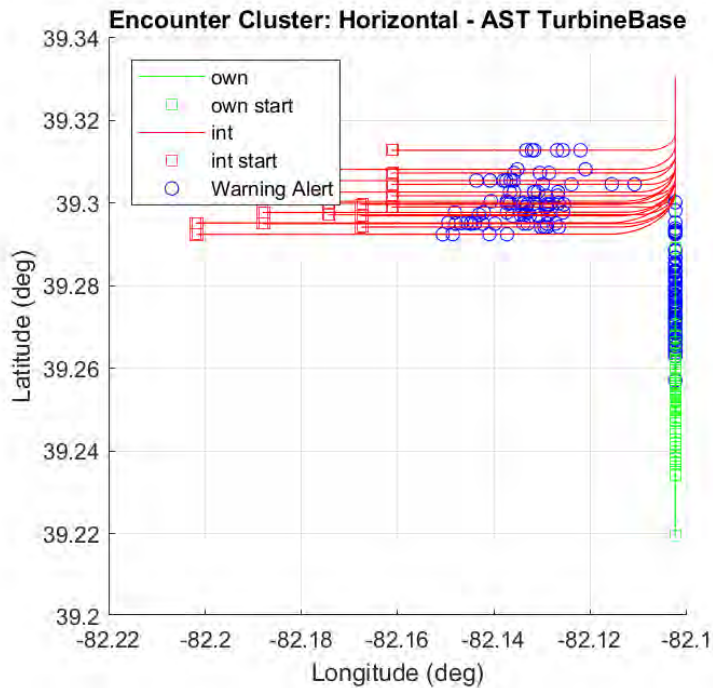


# AST PistonBase

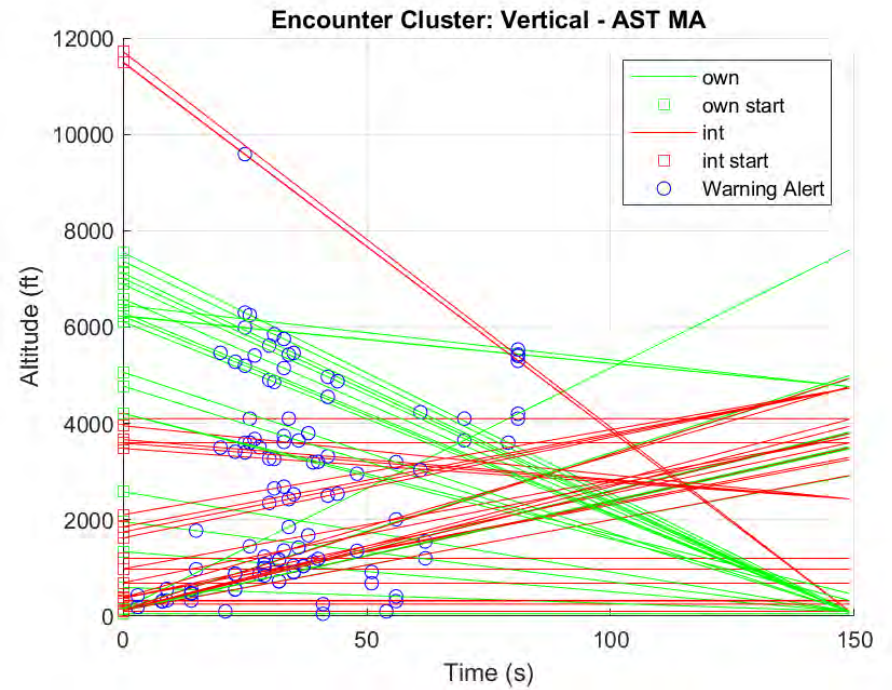
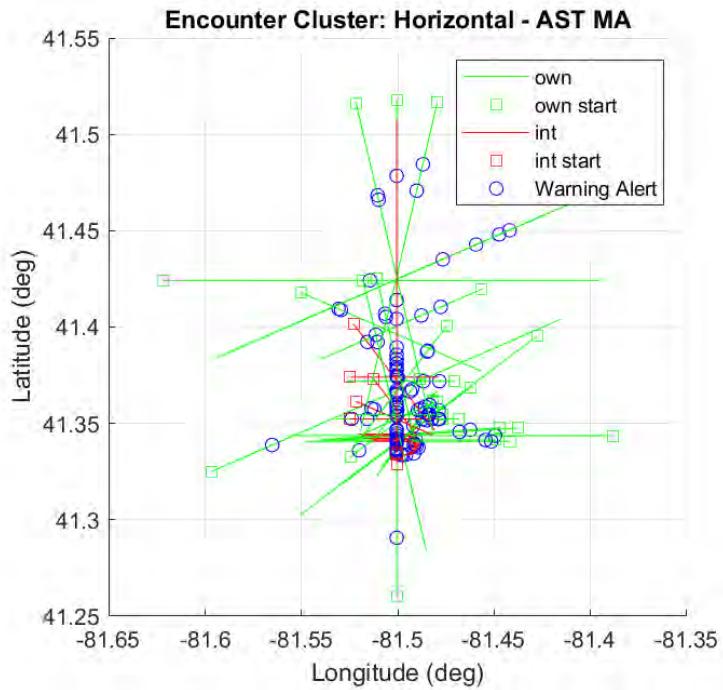




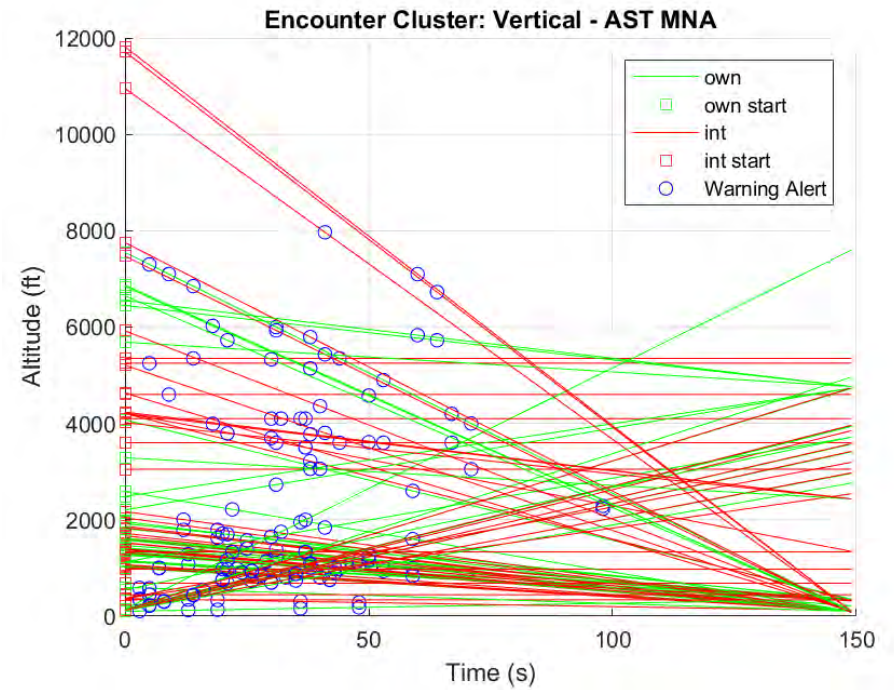
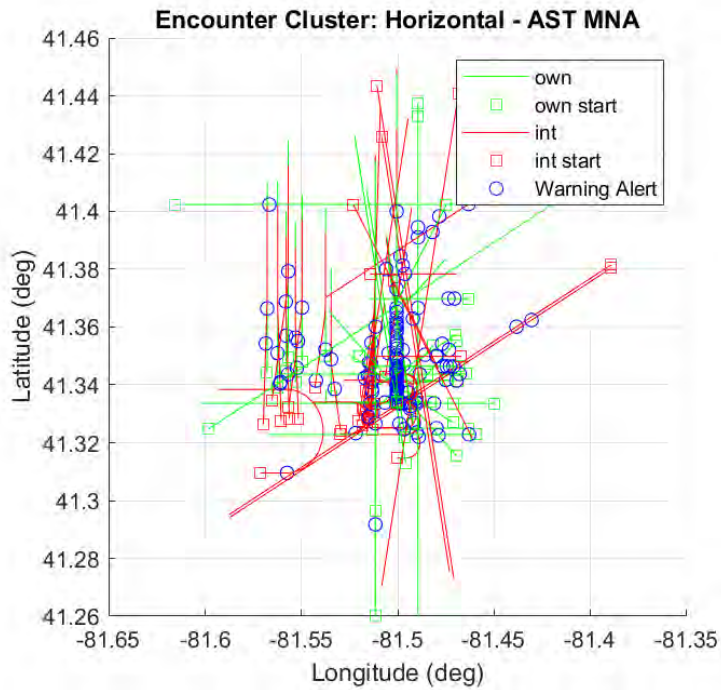
# AST TurbineBase



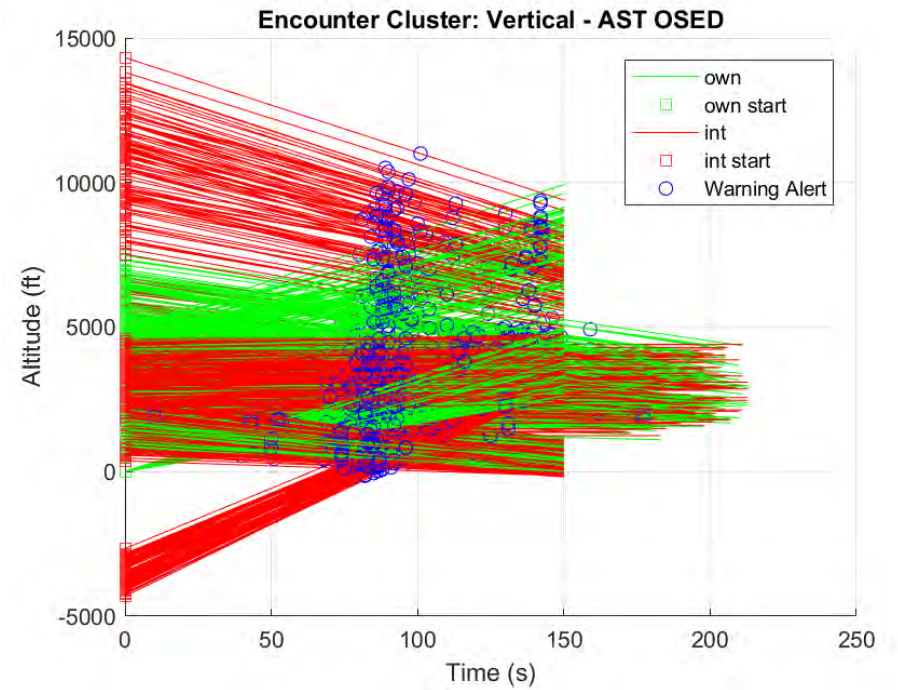
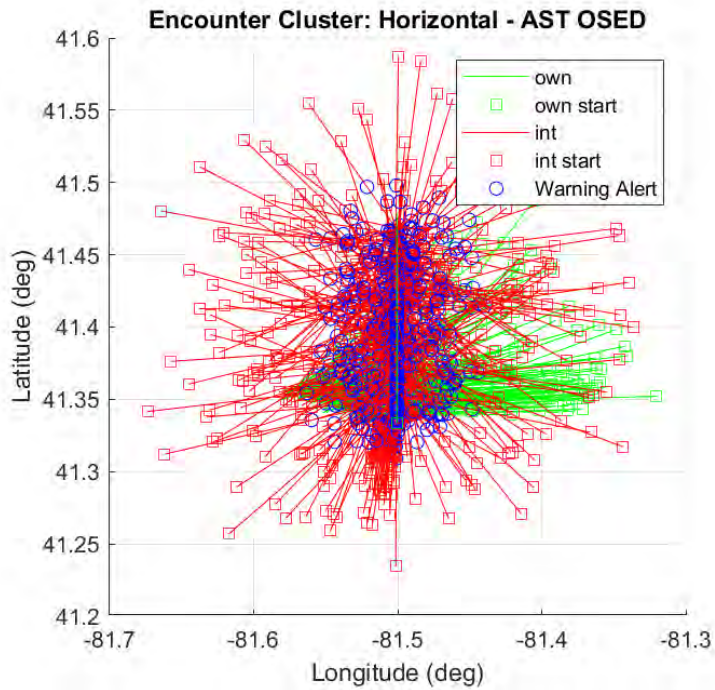
# AST MA



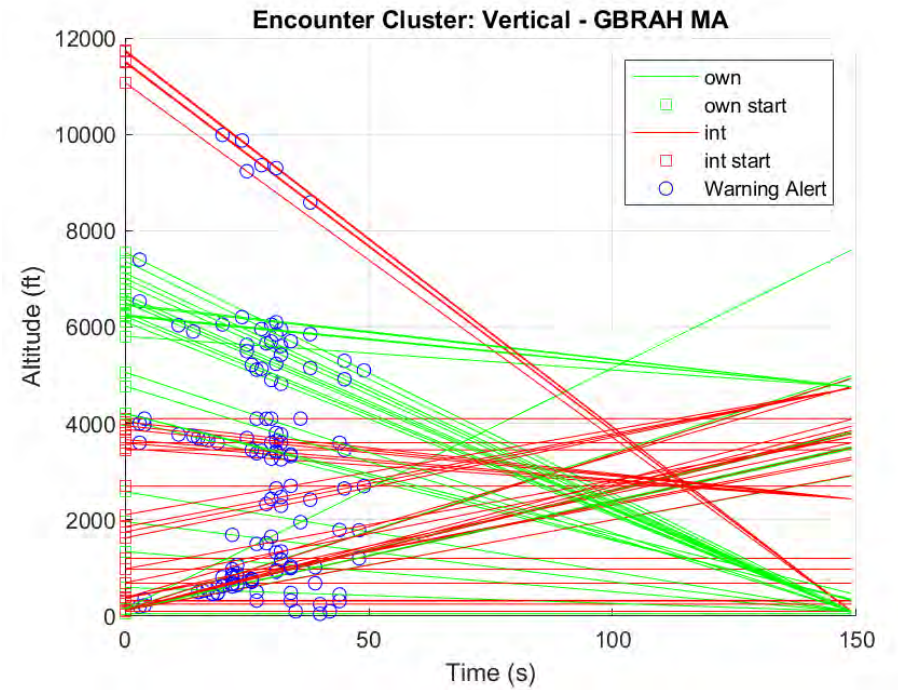
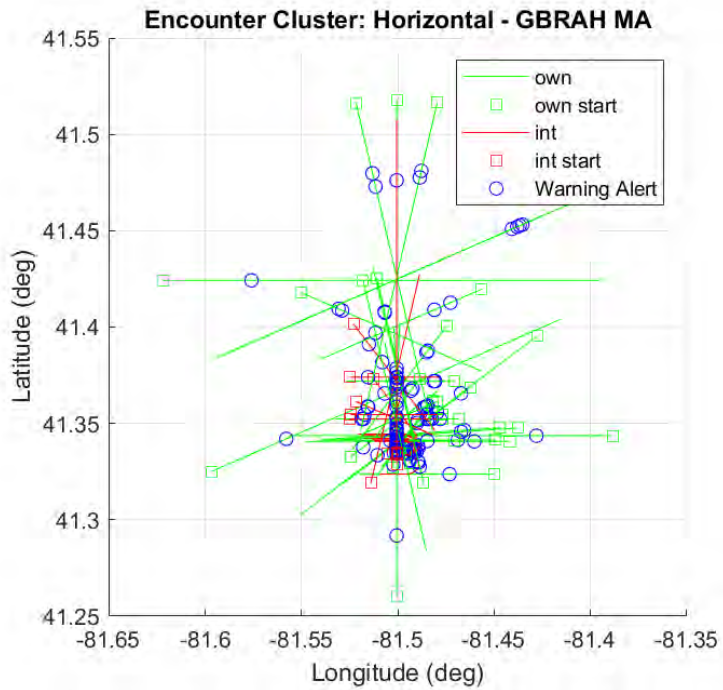
# AST MNA



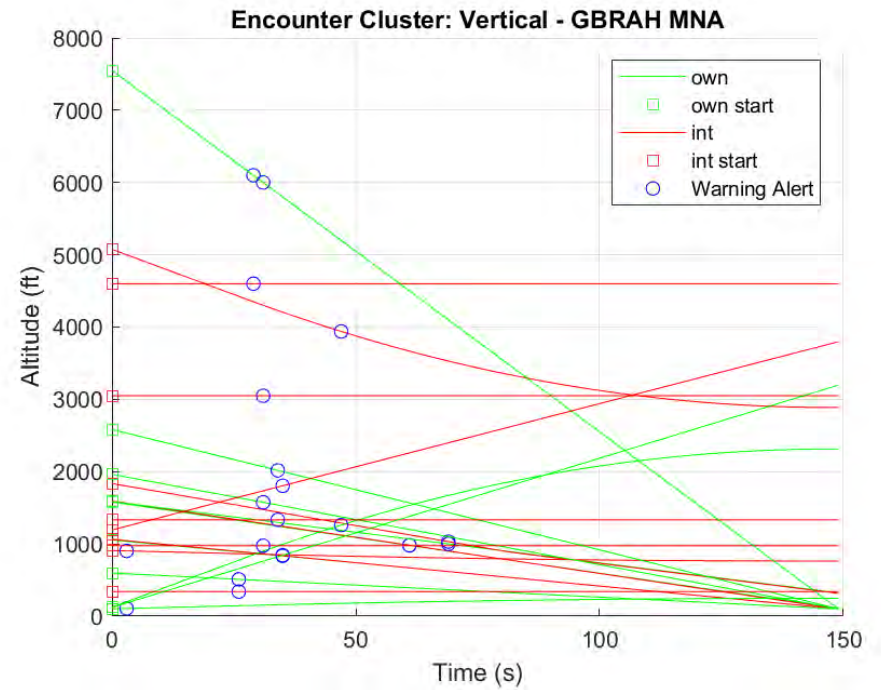
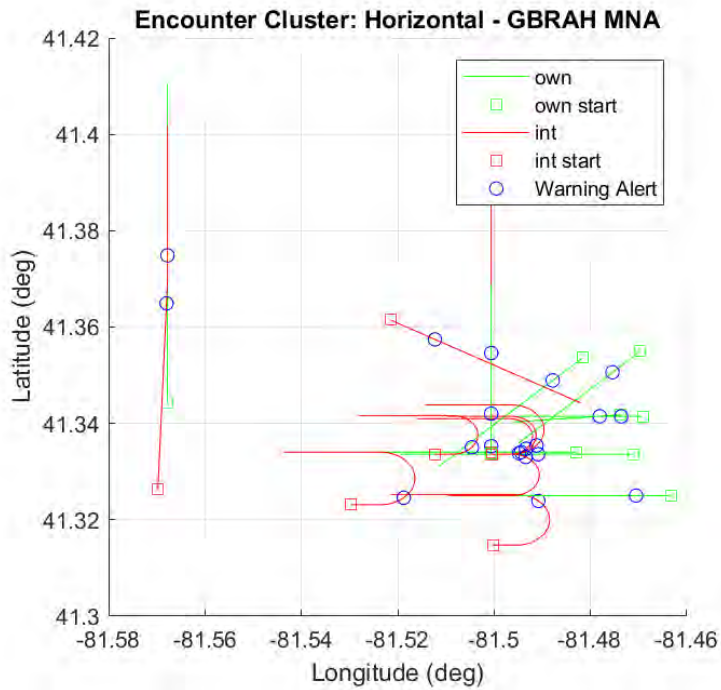
# AST OSED



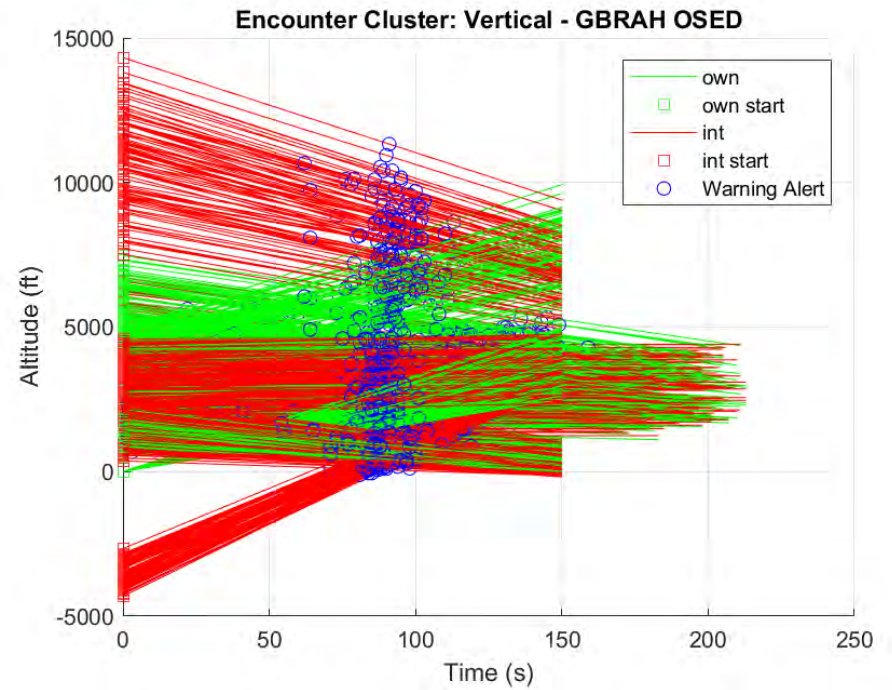
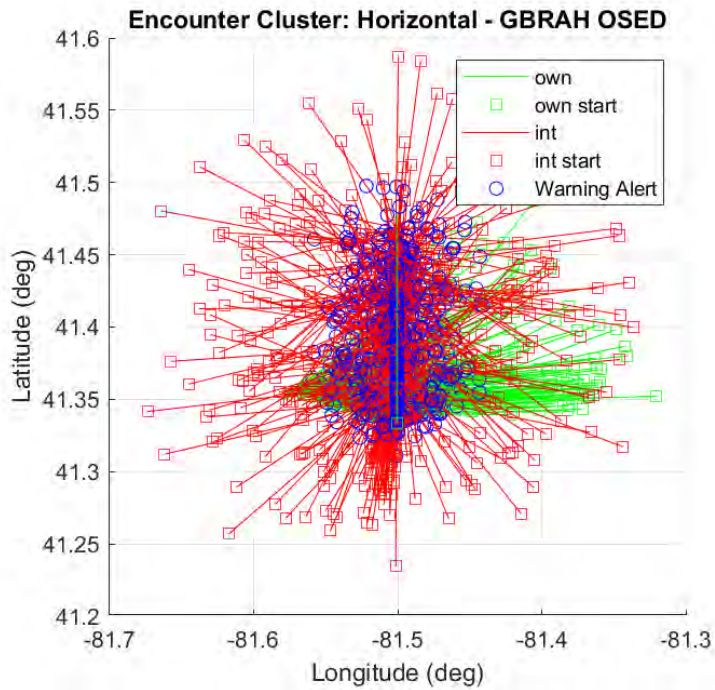
# GBRAH MA



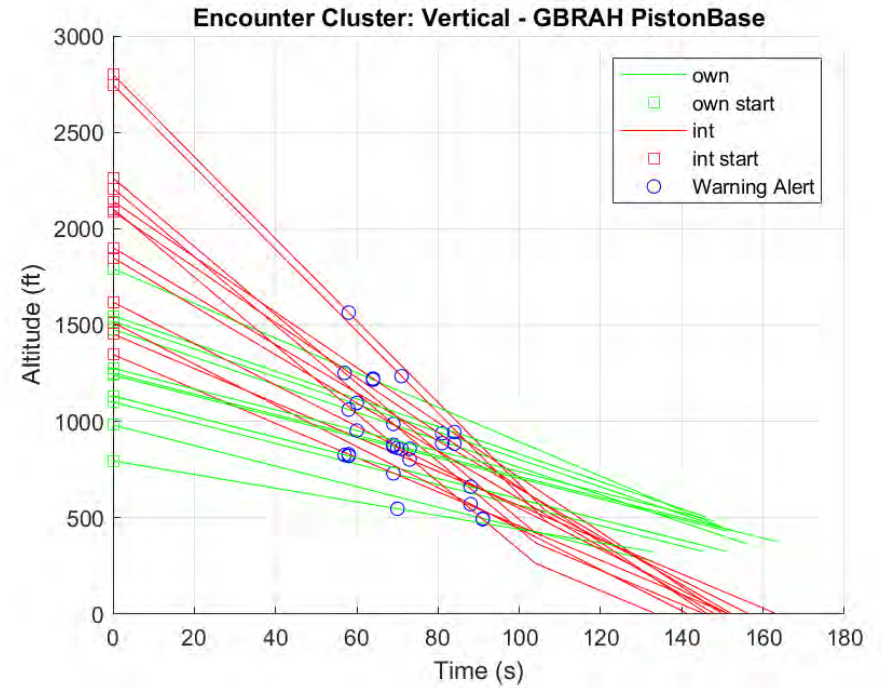
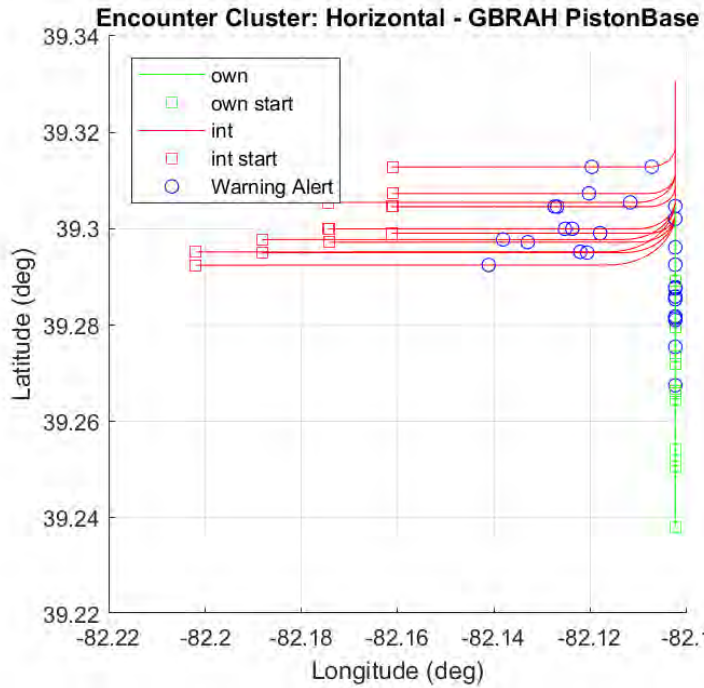
# GBRAH MNA



# GBRAH OSED

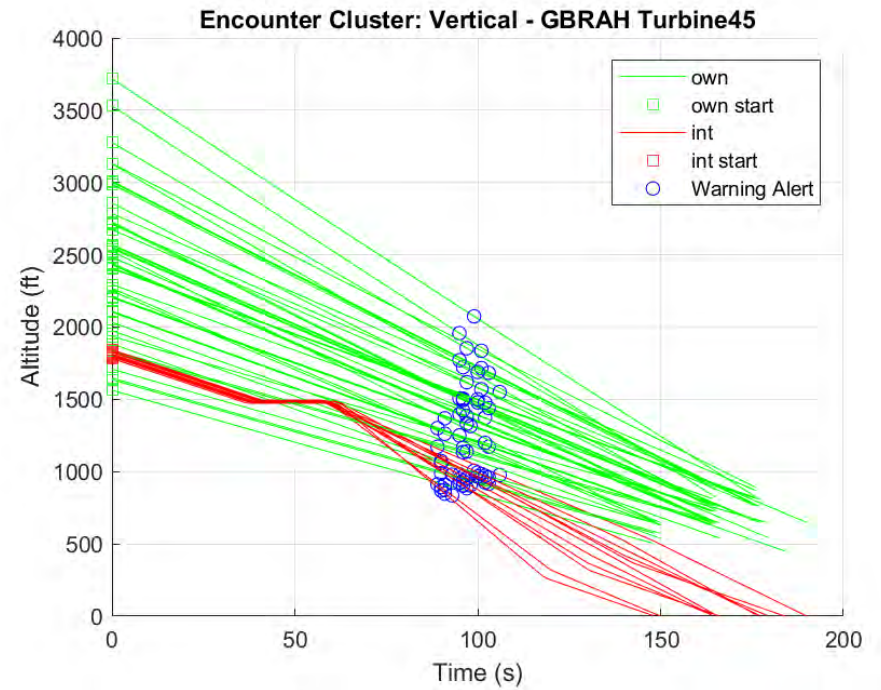
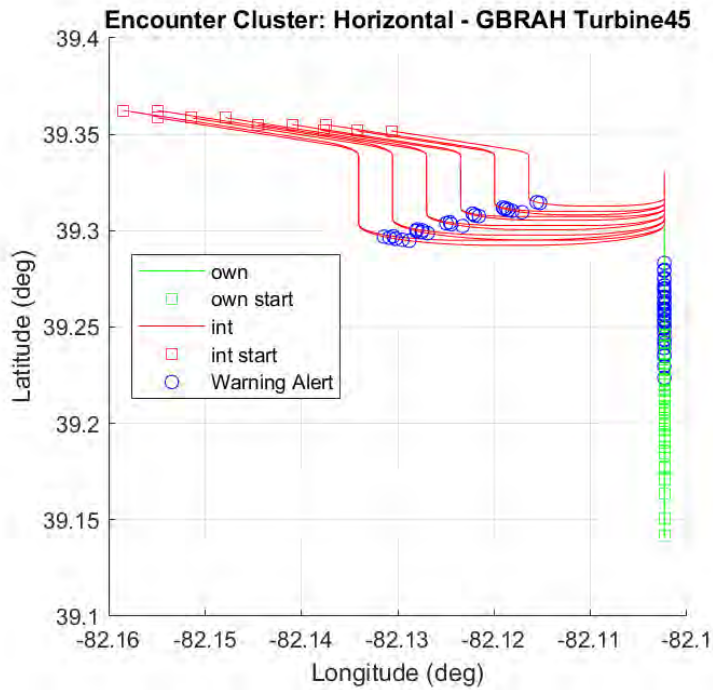


# GBRAH PistonBase

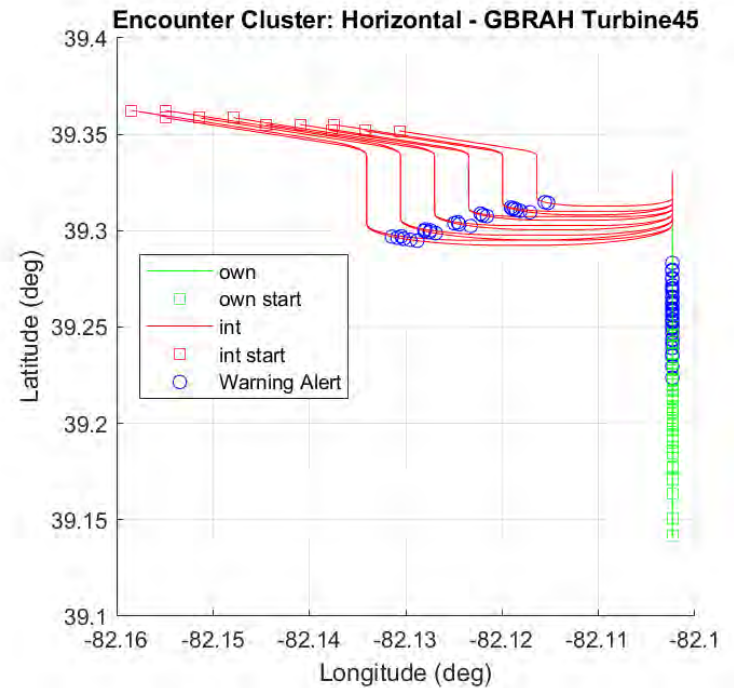
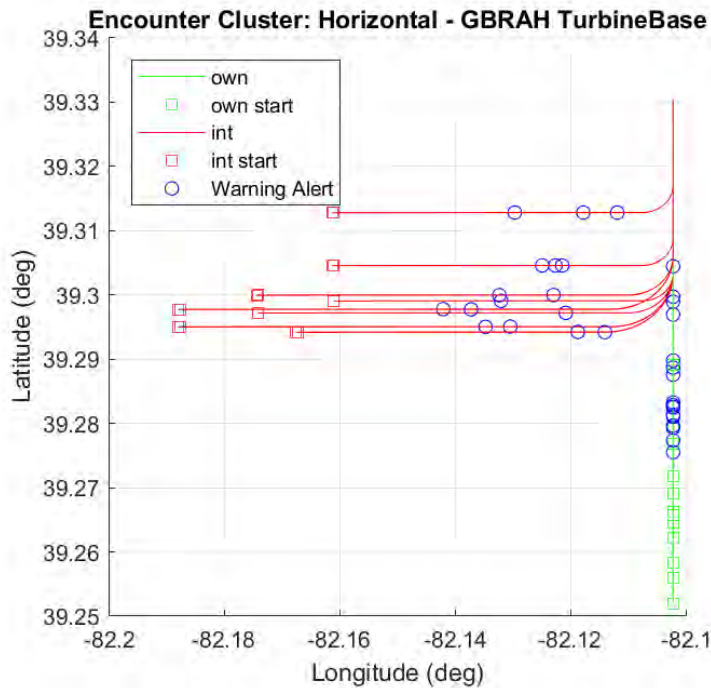


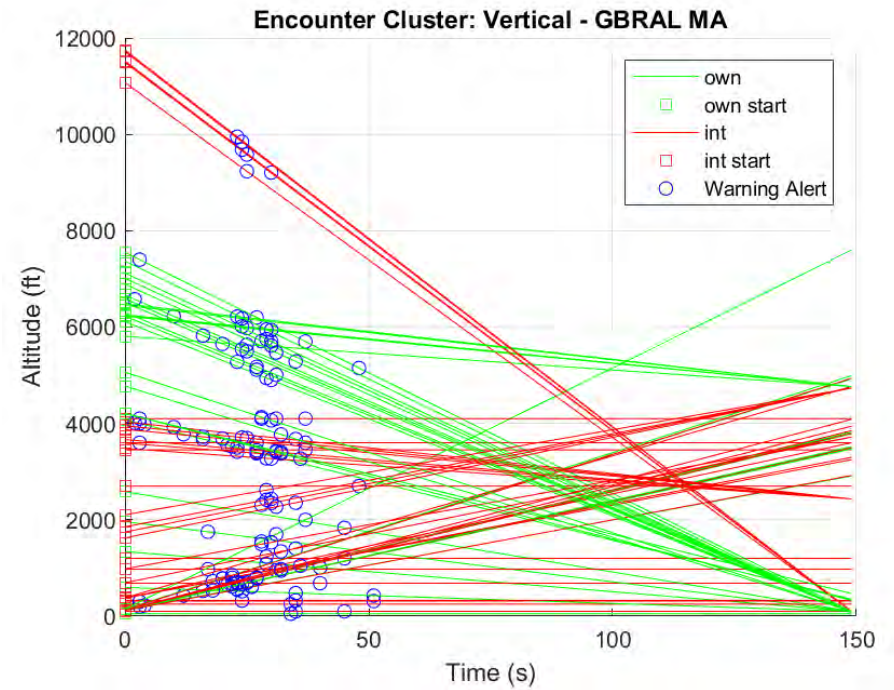
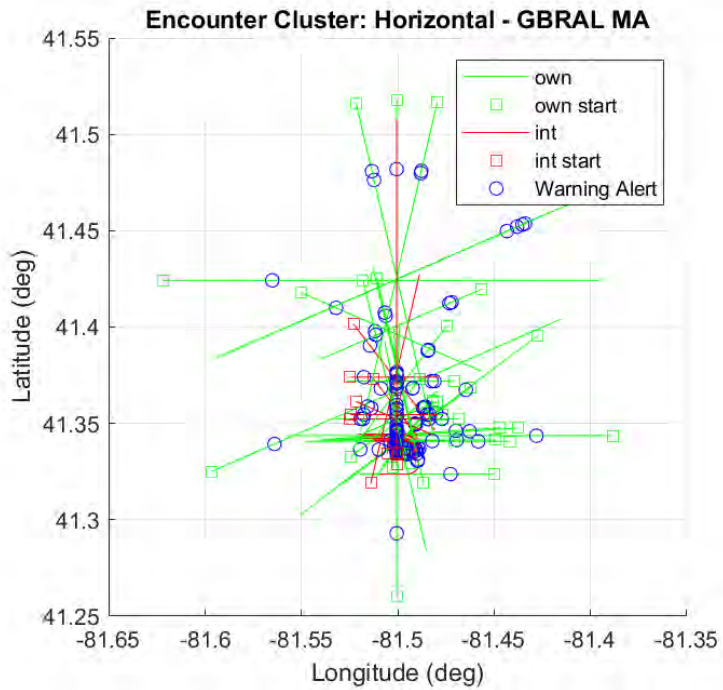


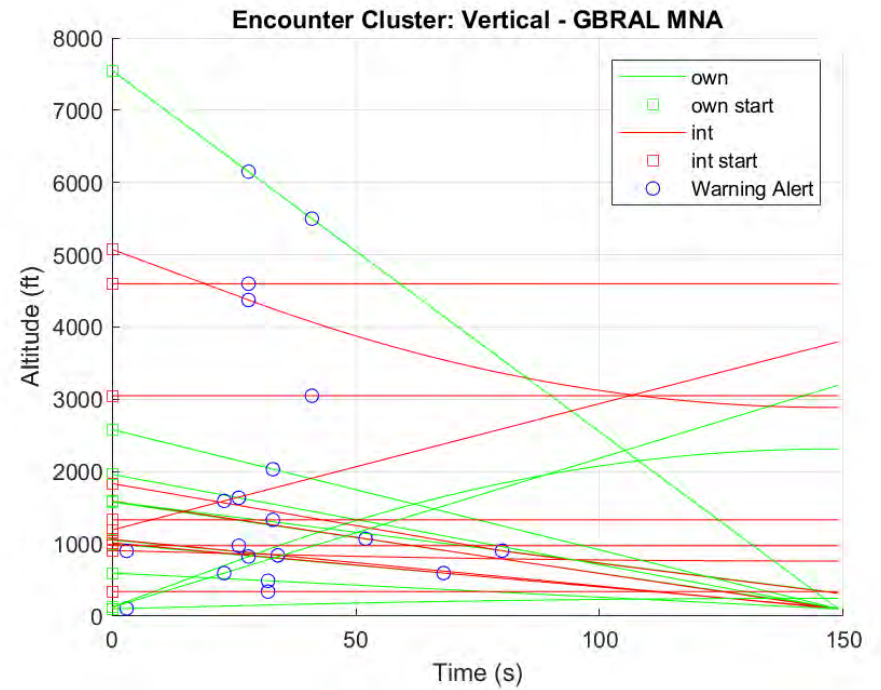
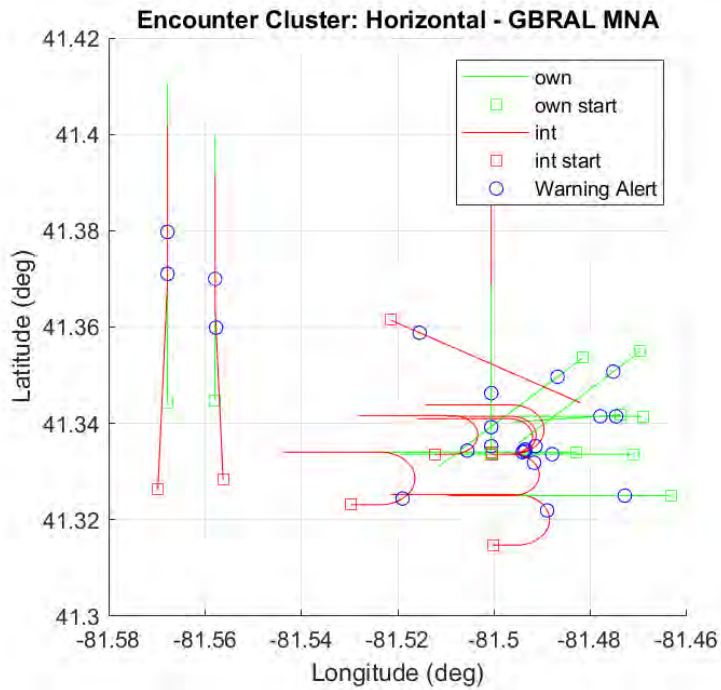
# GBRAH Turbine45



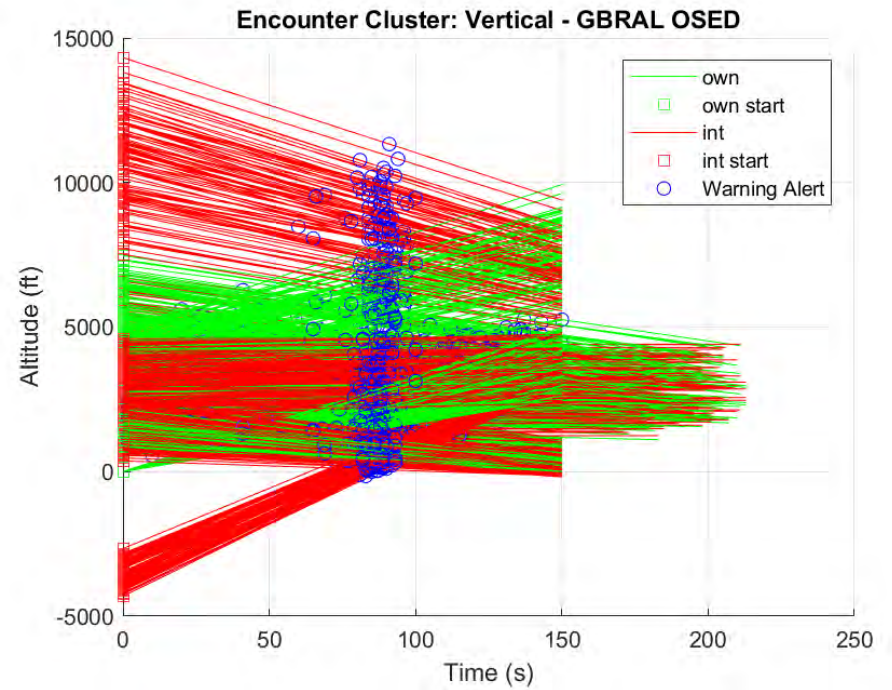
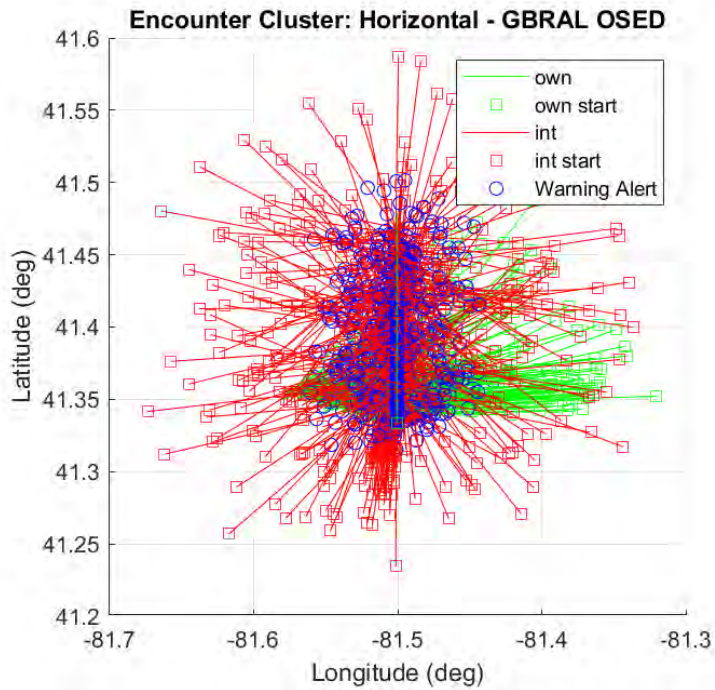
# GBRAH TurbineBase



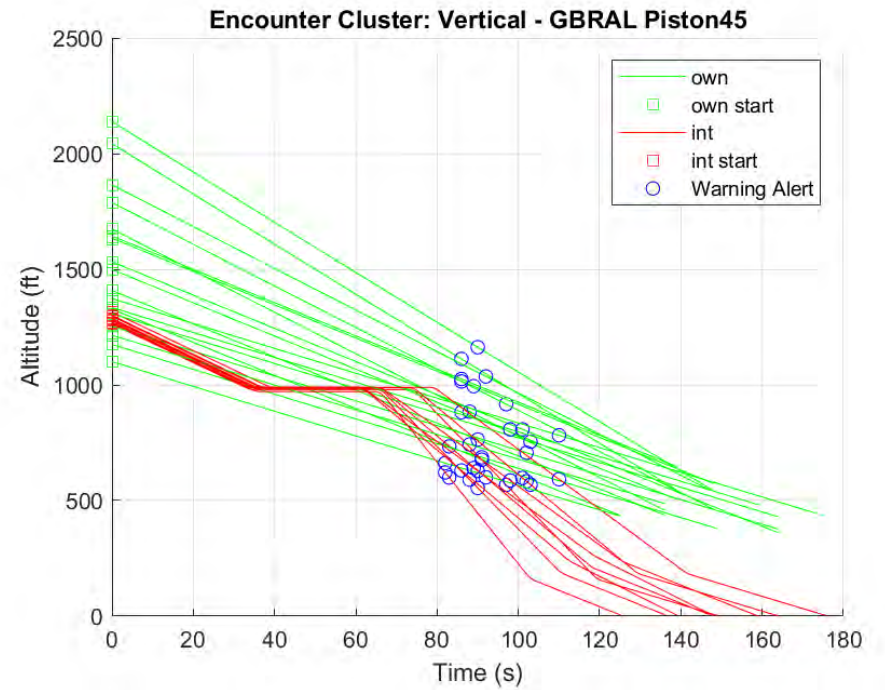
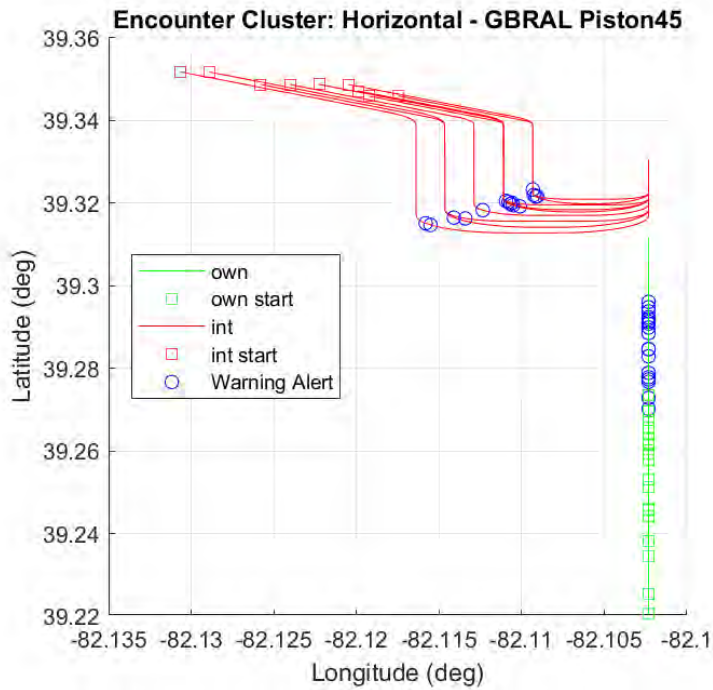




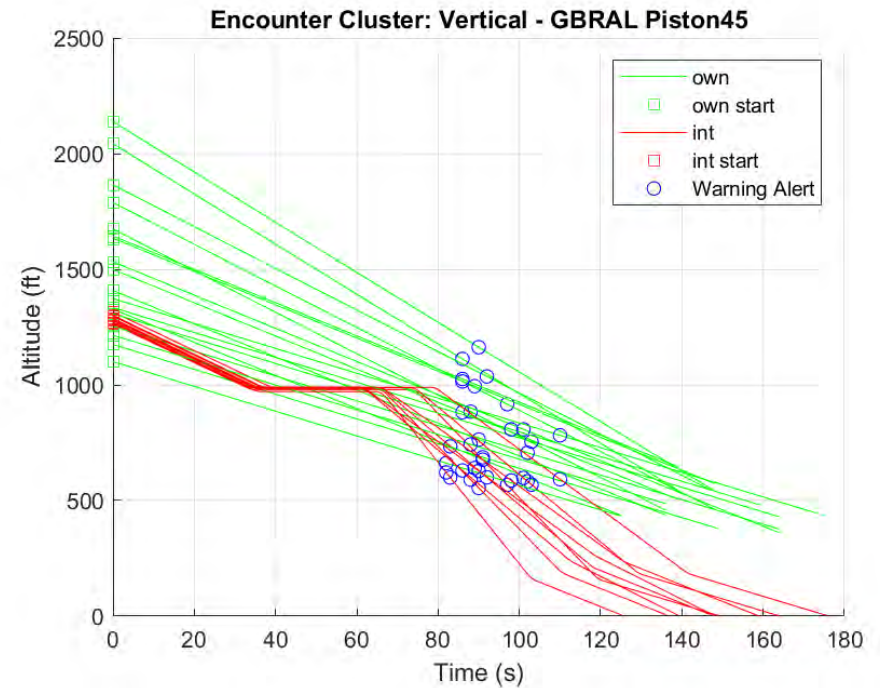
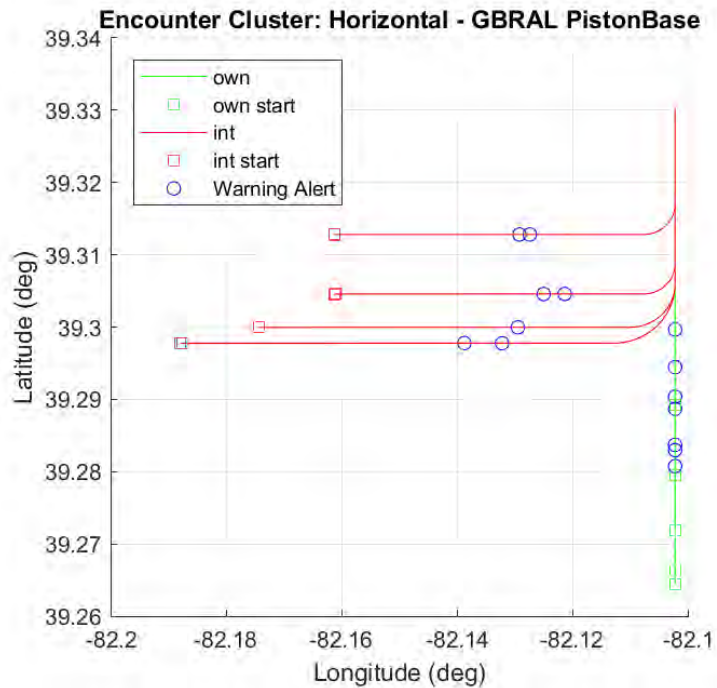
# GBRAL OSED



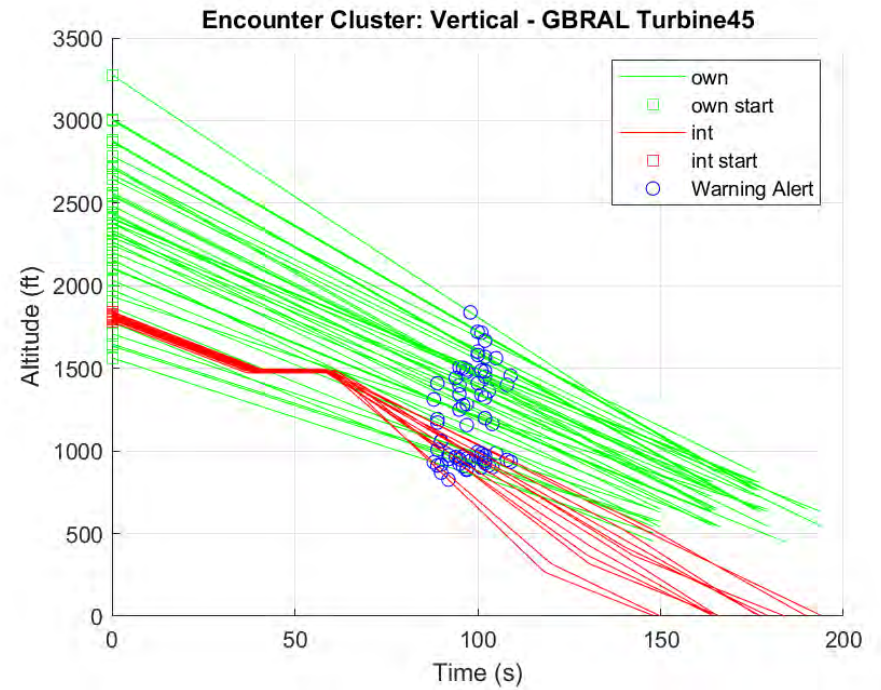
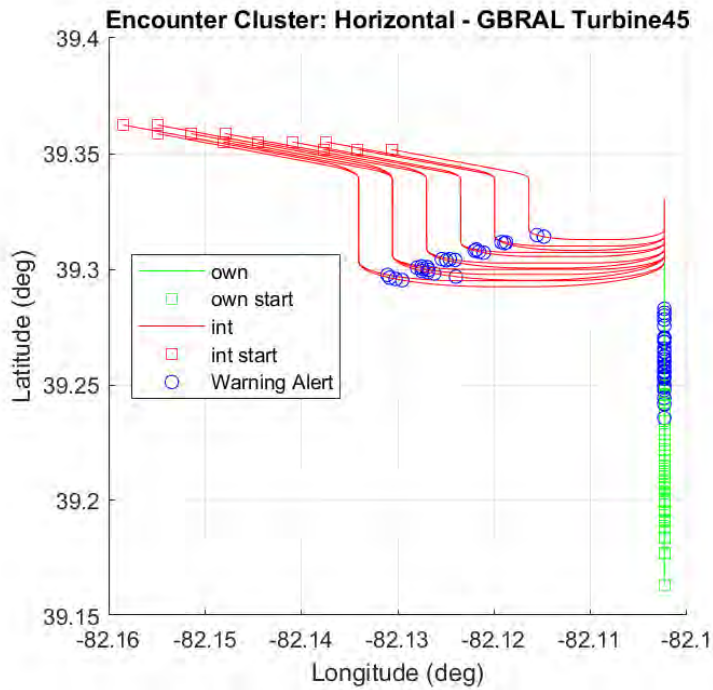
# GBRAL Piston45



# GBRAL PistonBase

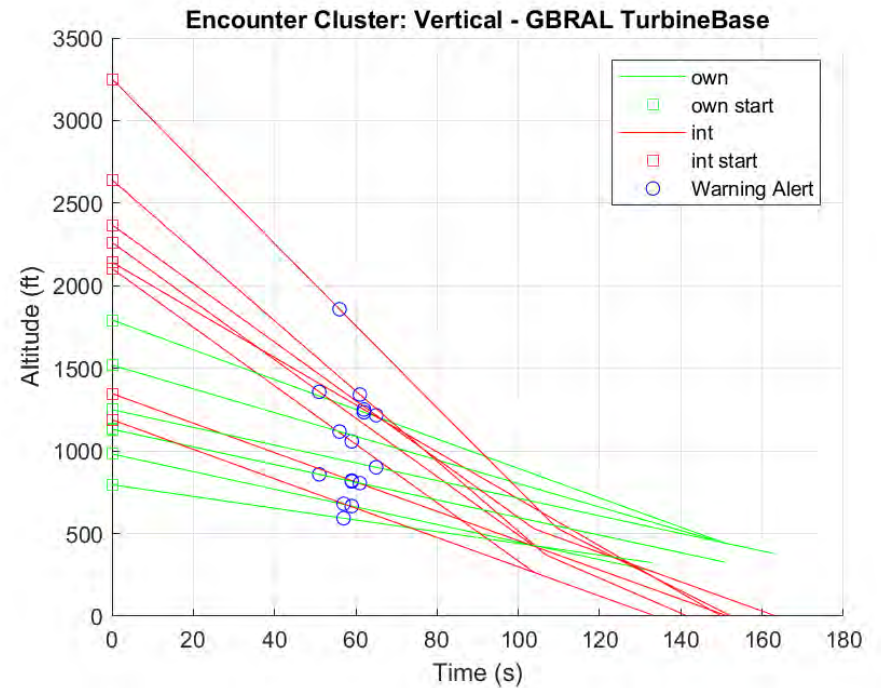
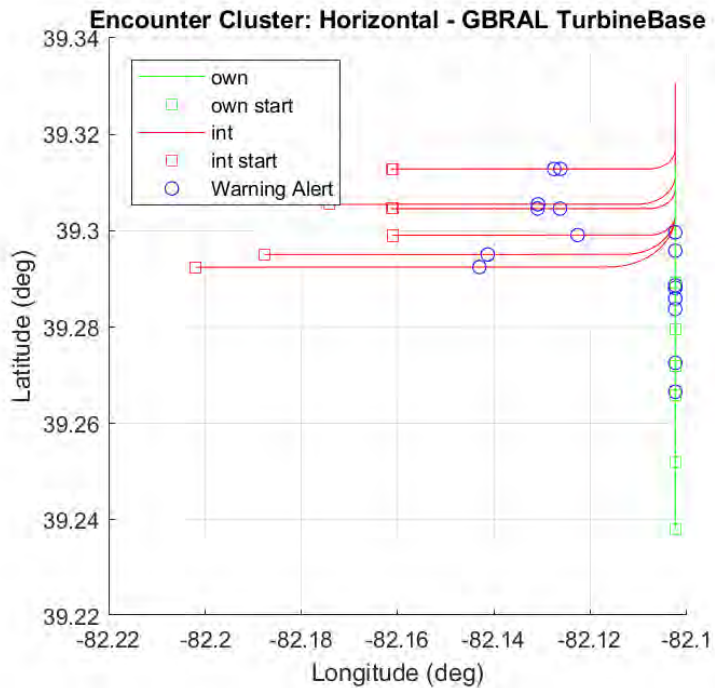


# GBRAL Turbine45

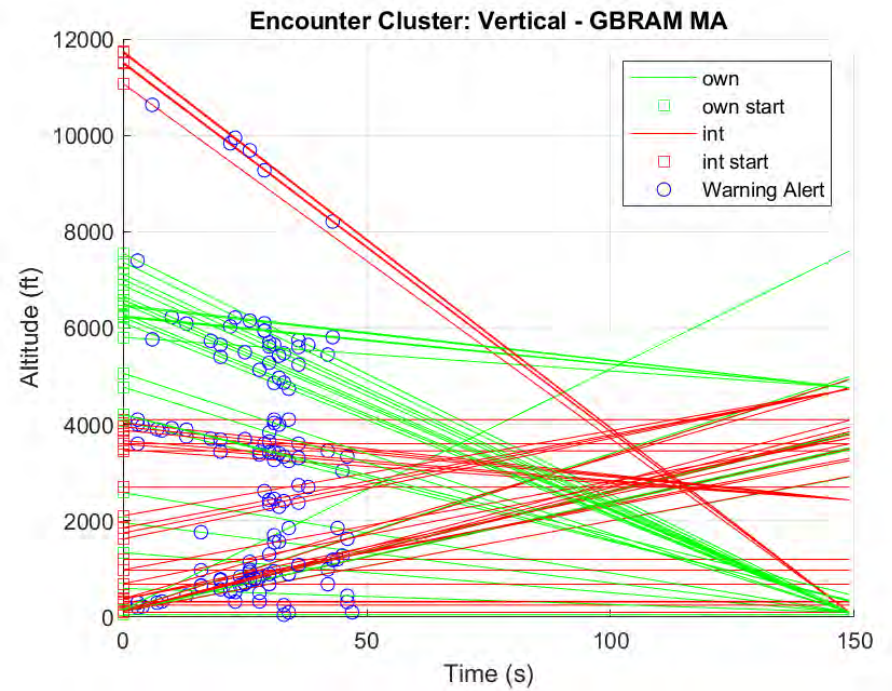
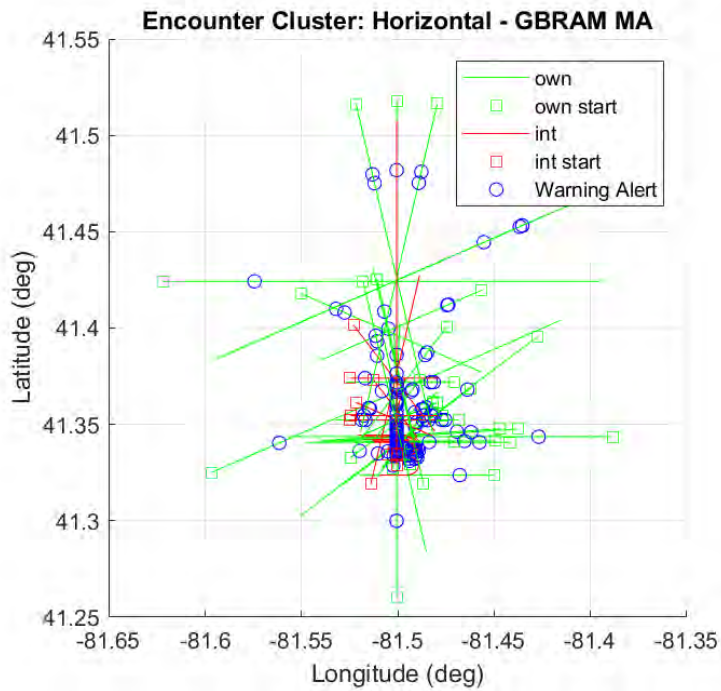




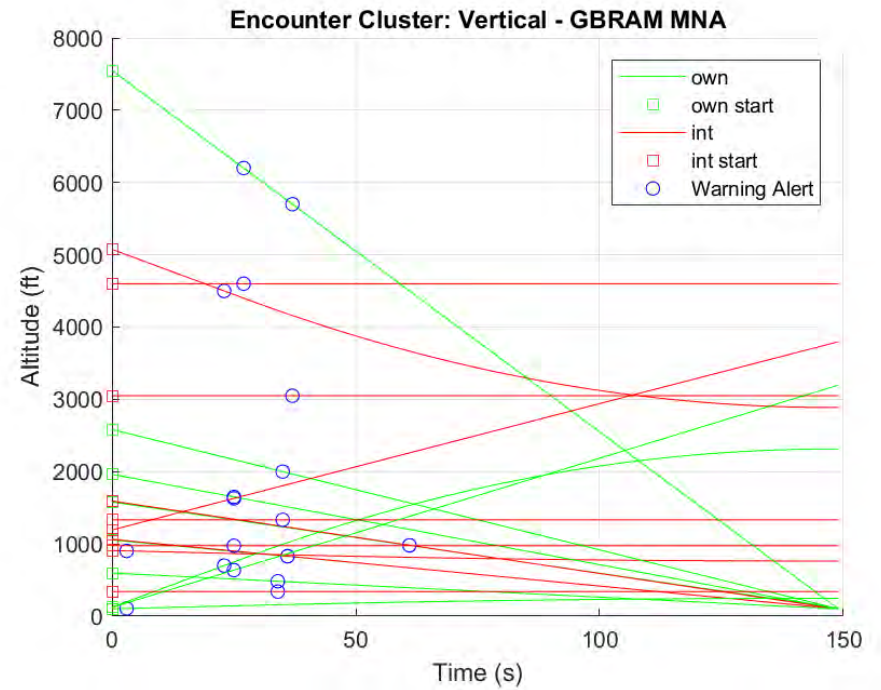
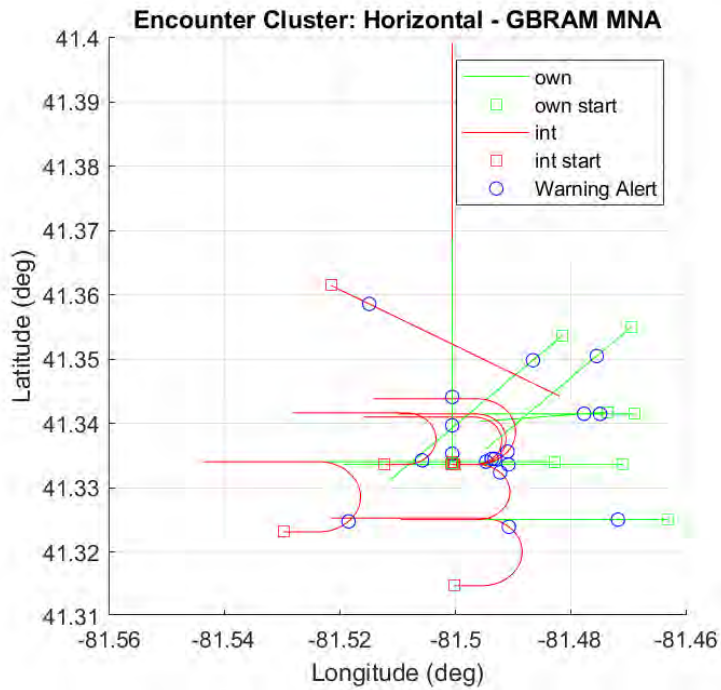
# GBRAL TurbineBase



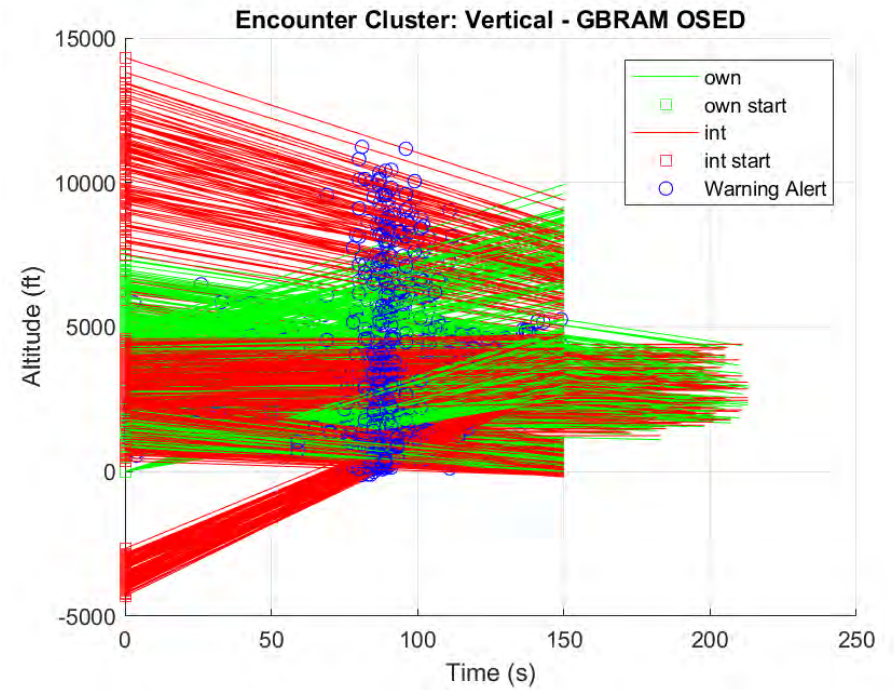
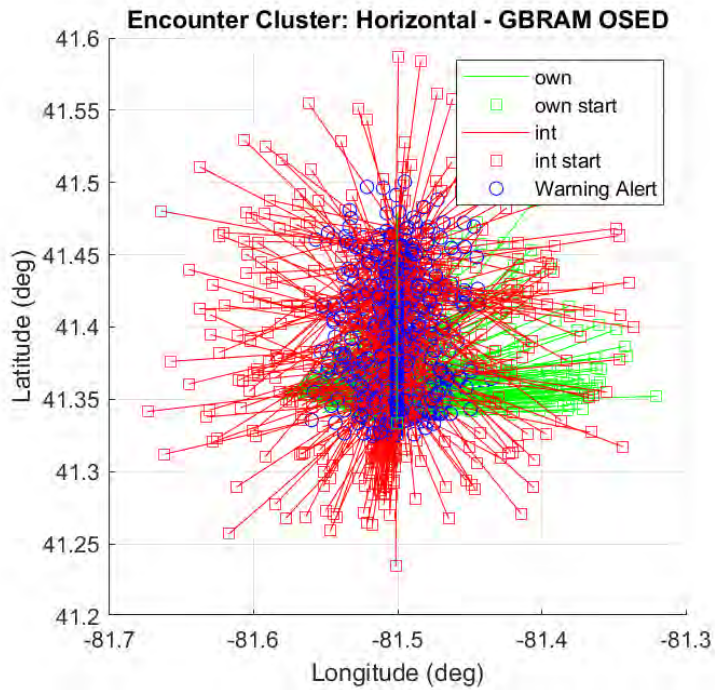
# GBRAM MA



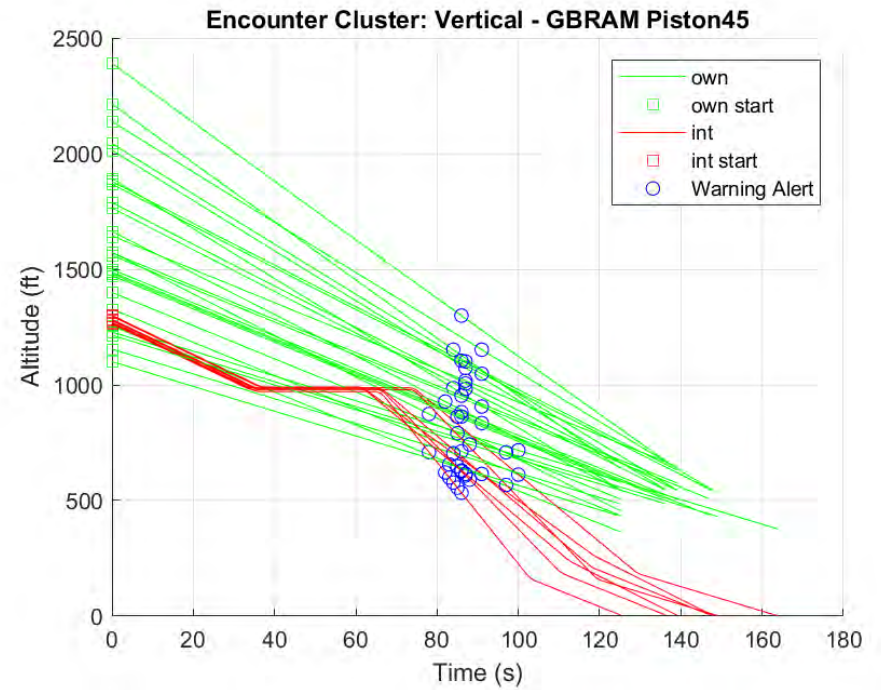
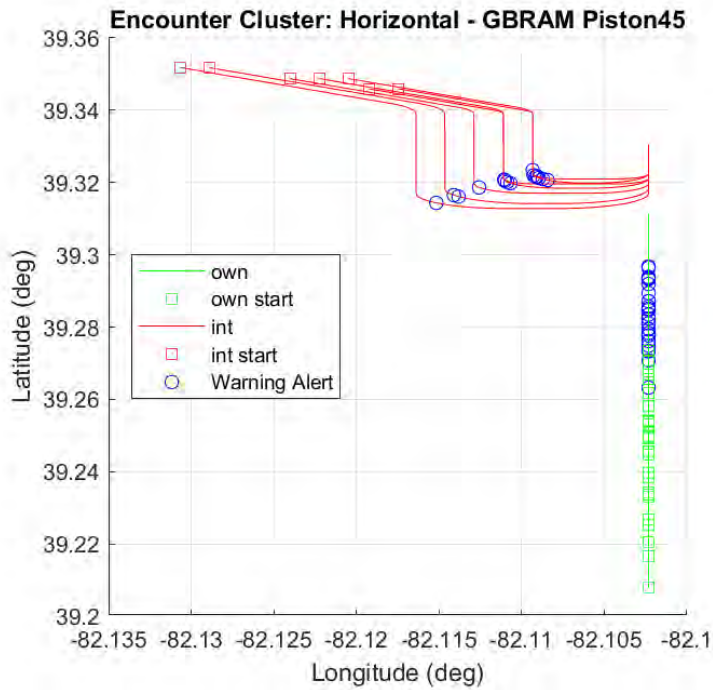
# GBRAM MNA

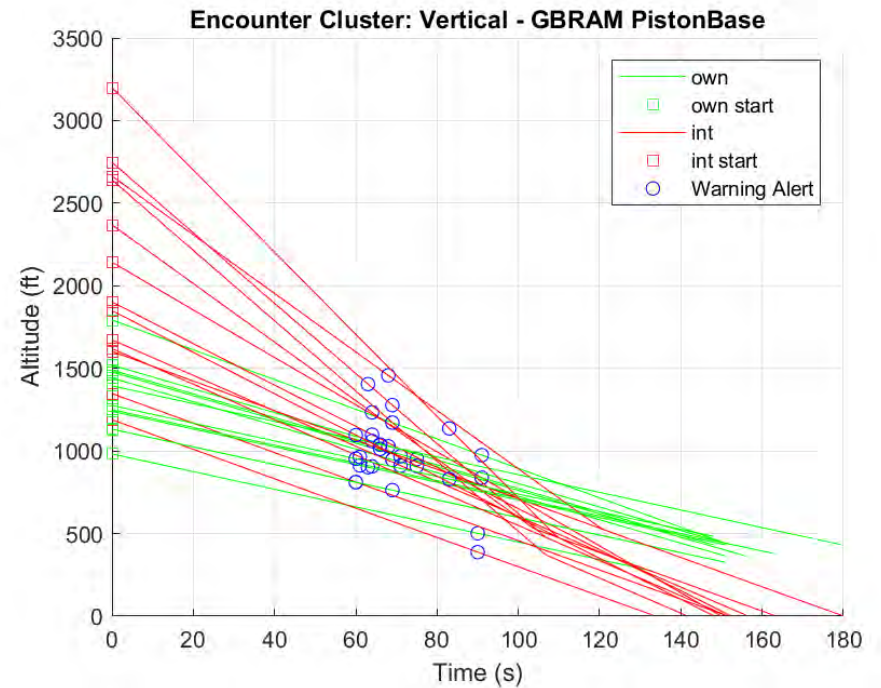
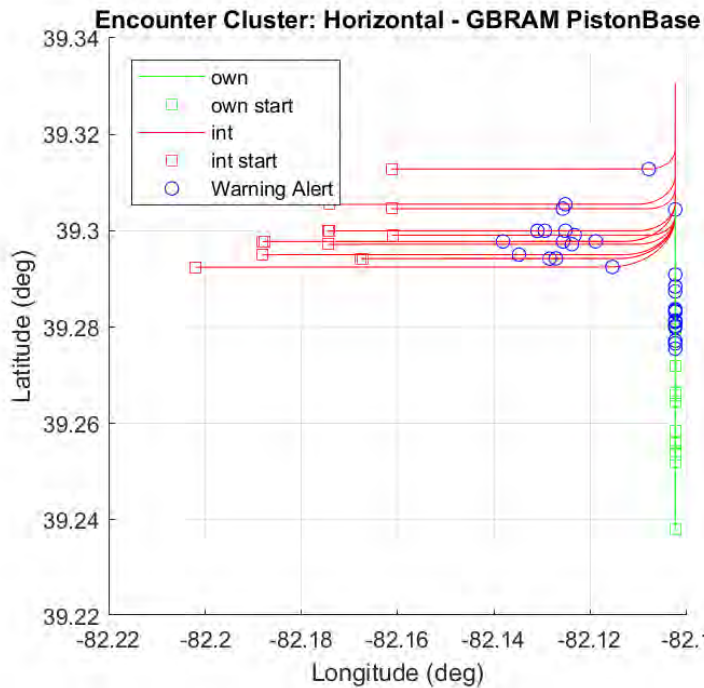


# GBRAM OSED

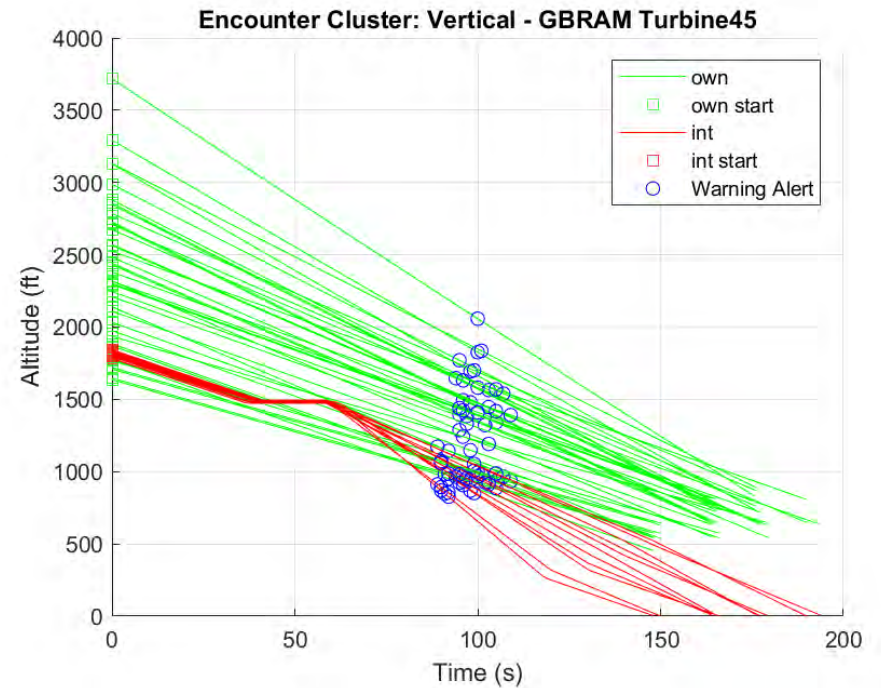
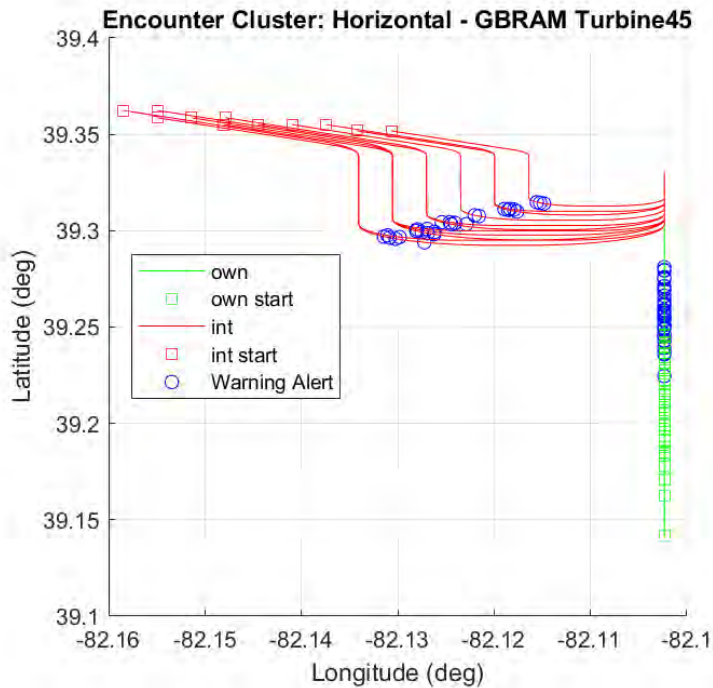


# GBRAM Piston45





# GBRAM Turbine45



# GBRAM TurbineBase

