Terminal Area Test Vector Development

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Task Overview

- Leverage existing encounter data to develop a set of encounters to be used to define and refine both performance-based and functionally-based terminal area MOPS requirements.
- Encounter set would be used across various organizations supporting MOPS terminal area requirements development to provide some level of consistency in terms of terminal area assumptions.
- Investigate other potentially applicable data sets and make any similarly needed adjustments to arrive at a consolidated set of terminal area encounters.

Encounter Set Criteria

- Statistically sufficient set of encounters to tune and evaluate the DAA system operating in the terminal environment
  - Must Alert Set: Set of safety-driven encounters where the DAA system is expected to engage
  - Must Not Alert: Set of operational suitability encounters where the DAA system should NOT engage
- Assumes the UA is on a straight-in IFR approach or normal departure

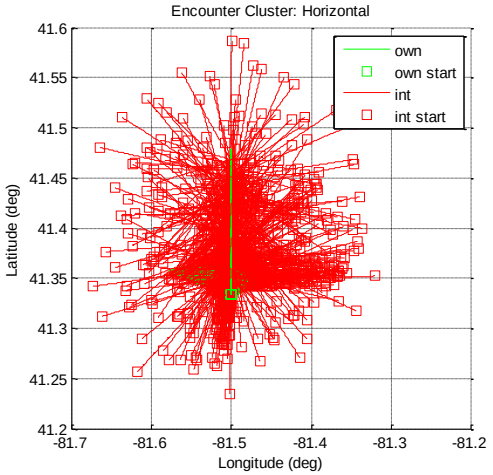
Encounter Sets

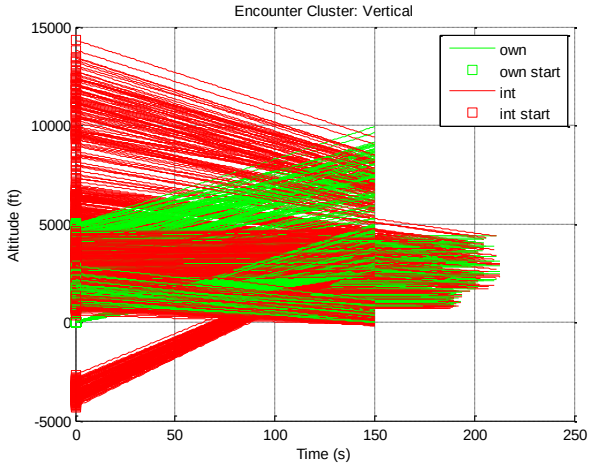
- TSAA Airport OSED - 900
- TSAA Airport Must Alert – 95+
- TSAA Airport Must Not Alert – 122+
- NASA Terminal Alerting Engineering Analysis - 4725
- NASA TOPS 1b Trajectories
  - Instrument - 34, Visual – 38

Safety Performance Encounters

TSAA OSED Encounters

- Used during the development of RTCA DO-317B
- Based on actual NMAC cases which were whittled down to 9 geometries, which were then slightly perturbed (incidence angle, etc.) to explore the means by which the aircraft may have arrived in that particular NMAC situation resulting in 900 “unique” encounters
- Only small set of “dynamic”, pattern geometries





TSAA Must Alerts

Table U-3 Summary of Must Alert Test Tracks

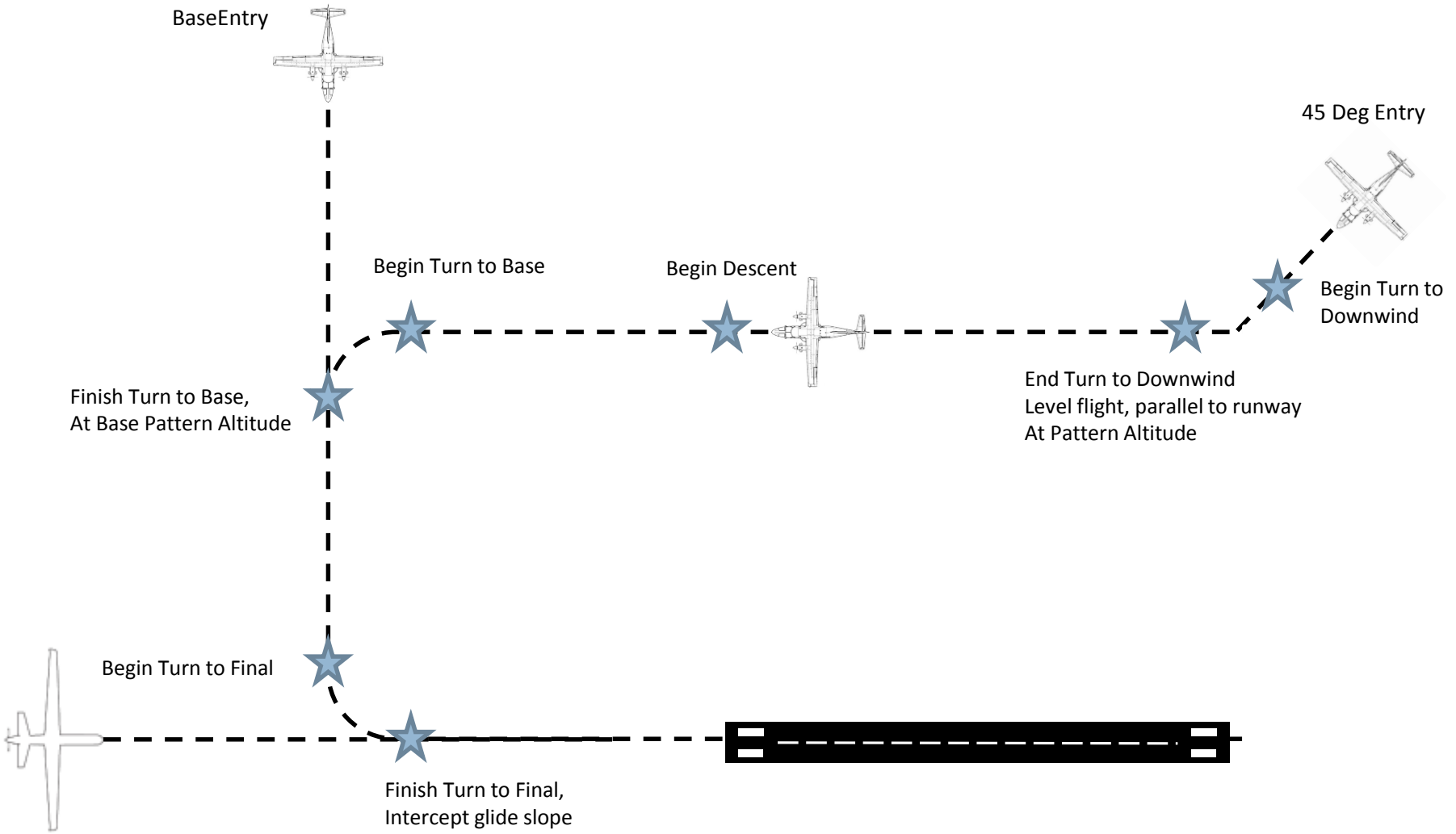
Must Alert Tracks		
Non-Accelerating		
Set	Encounter Type	Number of Tracks
NA	Uncategorized	15
	Total	**15**
Airport Environment		
Set	Encounter Type	Number of Tracks (all traffic sources)
1	Convergence on Final to Same Runway	24
2	Convergence on Same Leg; Different Flight Phases	36
3	Convergence in Airport Pattern; Target Entering via Standard Procedure	78
4	Convergence in Airport Pattern; Target Entering via Non-standard Procedure	28
5	Convergence with Departing Jet	8
6	Convergence with Approaching Jet	16
7	Touch-and-Go Convergence	36
8	Rotorcraft Convergence on Final Approach	36
9	News or Firefighting Aircraft Operating in Same Area	32

Table U-5 Test Tracks with Rotorcraft as Ownship

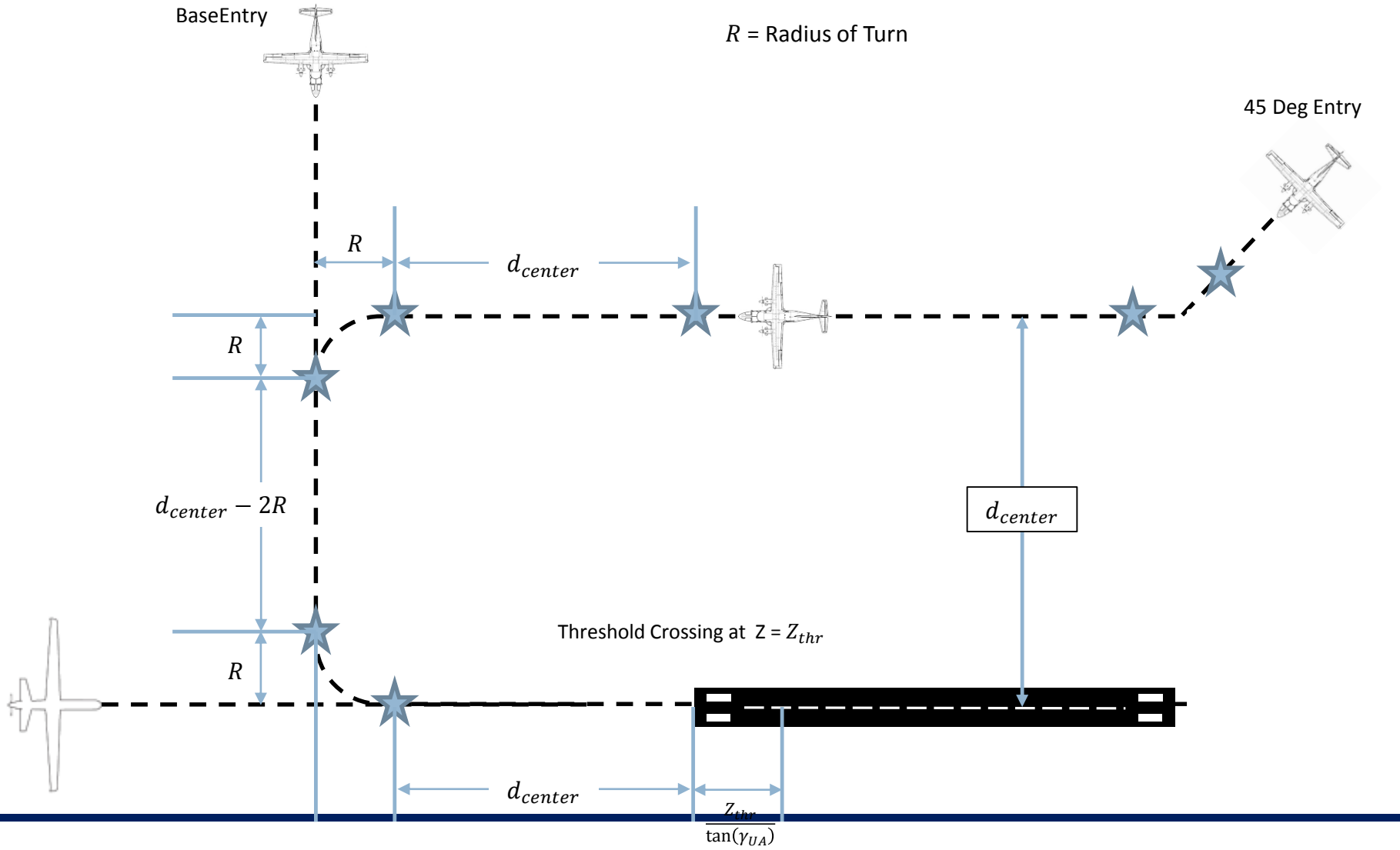
Must Alert Tracks		
Airport Environment		
Set	Encounter Type	Test track numbers
7	Touch-and-Go Convergence	1-ii, 3-ii, 5-ii, 7-ii, 9-ii, 11-ii
8	Rotorcraft Convergence on Final Approach	1-ii, 3-ii, 5-ii, 7-ii, 9-ii, 11-ii
9	News or Firefighting Aircraft Operating in Same Area	All tracks
	Total	**38**

Operational Suitability Encounters

Encounter Geometry



Encounter Geometry



Parameter Variations

- UA
  - Airspeed (KTAS) – **40 to 200 KTAS in 20 kt increments**
  - Glide Slope (deg) – **-3 deg**
  - Time Offset (sec) – **50 – 90 in 10 sec increments**
  - Threshold Crossing Altitude (feet) – **50 ft**
- Intruder
  - Airspeed (KTAS) – **Piston: 60:20:120 KTAS, Turbine: 100:20:200 KTAS**
  - Bank Limit (deg) – **15 and 30 deg**
  - Normal Acceleration (g's) – **1.25 g's**
  - Entry [45 or Base]
    - Vertical Rate (fpm) – **45: 500 fpm, Base: -3 or -6 deg**
  - Time (sec) – **45: 30 sec, Base: 90 sec**
- Terminal Area
  - Downwind Centerline Offset (feet) – **Piston: 4000ft, Turbine: 8000 ft**
  - Pattern Altitude
  - Downwind Leg (feet) – **Piston: 1000 ft, Turbine: 1500 ft**
    - Base Leg (feet) – defaults to 0.75xAltitude Downwind Leg
  - Runway Length (feet) – **8000 ft**
  - Glide slope intercept (deg) – **-3 deg**
- DAA Well Clear
  - τ^*_{mod} = **0 sec**
  - HMD* = **1500 ft**
  - H* = **450 ft**
  - t_{COA}= **0 sec**

TSAA Must Not Alerts

Table U-4 Summary of Must Not Alert Test Tracks

Must Not Alert Tracks		
Airport Environment		
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	32
	Total	**306**

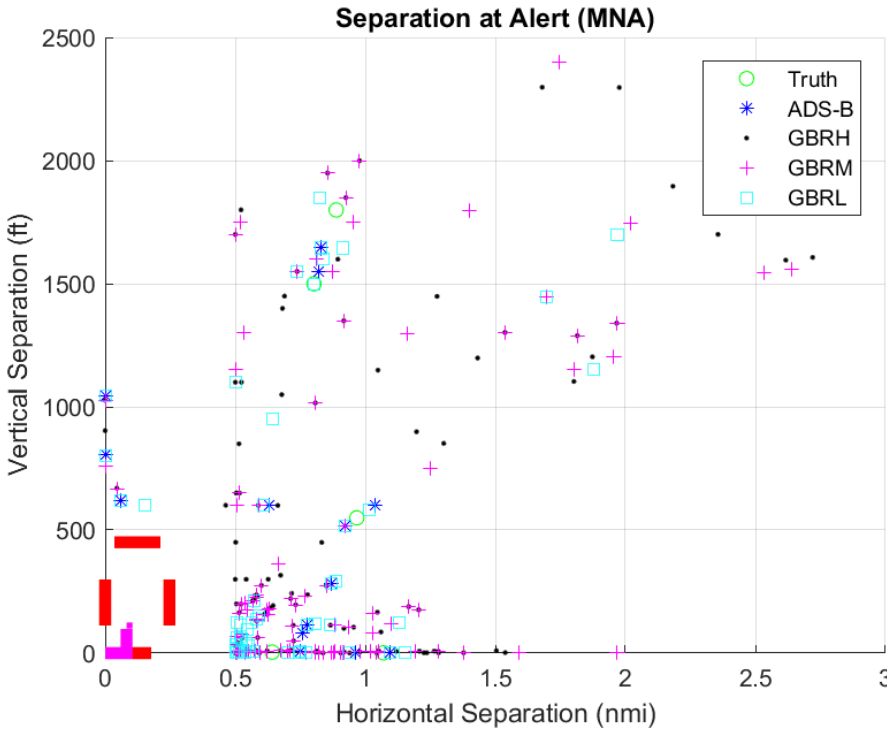
Table U-5 Test Tracks with Rotorcraft as Ownship

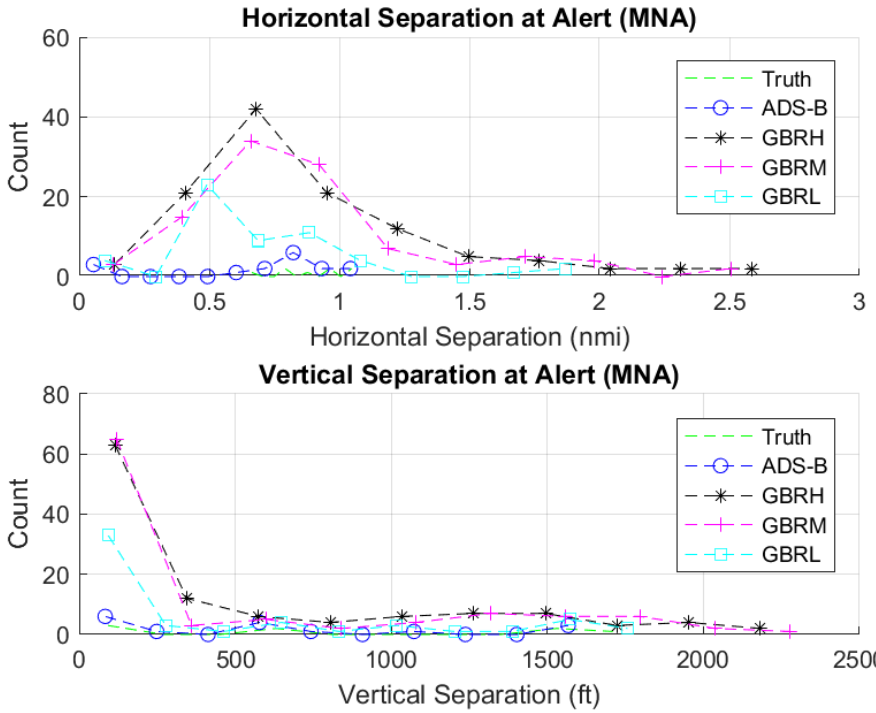
Must Not Alert Tracks		
Airport Environment		
Set	Encounter Type	Test track numbers
8	Touch-and-Go Convergence	1-ii, 3-ii, 5-ii, 7-ii, 9-ii, 11-ii
9	Rotorcraft Convergence on Final Approach	1-ii, 3-ii, 5-ii, 7-ii, 9-ii, 11-ii
10	News or Firefighting Aircraft Operating in Same Area	All tracks
	Total	**38**

DAIDALUS Params

```
# Alert Levels
alert_1_alerting_time = 45.000000 [s]
alert_1_detector = det_1
alert_1_early_alerting_time = 60.000000 [s]
alert_1_region = NONE
alert_1_spread_alt = 0.000000 [ft]
alert_1_spread_gs = 0.000000 [knot]
alert_1_spread_trk = 0.000000 [deg]
alert_1_spread_vs = 0.000000 [fpm]
alert_2_alerting_time = 45.000000 [s]
alert_2_detector = det_2
alert_2_early_alerting_time = 60.000000 [s]
alert_2_region = MID
alert_2_spread_alt = 0.000000 [ft]
alert_2_spread_gs = 0.000000 [knot]
alert_2_spread_trk = 0.000000 [deg]
alert_2_spread_vs = 0.000000 [fpm]
alert_3_alerting_time = 30.000000 [s]
alert_3_detector = det_3
alert_3_early_alerting_time = 40.000000 [s]
alert_3_region = NEAR
alert_3_spread_alt = 0.000000 [ft]
alert_3_spread_gs = 0.000000 [knot]
alert_3_spread_trk = 0.000000 [deg]
alert_3_spread_vs = 0.000000 [fpm]
conflict_level = 2
det_1_WCV_DTHR = 0.3000 [nmi]
det_1_WCV_TCOA = 0.0000 [s]
det_1_WCV_TTHR = 0.0000 [s]
det_1_WCV_ZTHR = 750.0000 [ft]
det_2_WCV_DTHR = 0.3000 [nmi]
det_2_WCV_TCOA = 0.0000 [s]
det_2_WCV_TTHR = 0.0000 [s]
det_2_WCV_ZTHR = 450.0000 [ft]
det_3_WCV_DTHR = 0.3000 [nmi]
det_3_WCV_TCOA = 0.0000 [s]
det_3_WCV_TTHR = 0.0000 [s]
det_3_WCV_ZTHR = 450.0000 [ft]
```

TSAA Must-Not Alert Airport

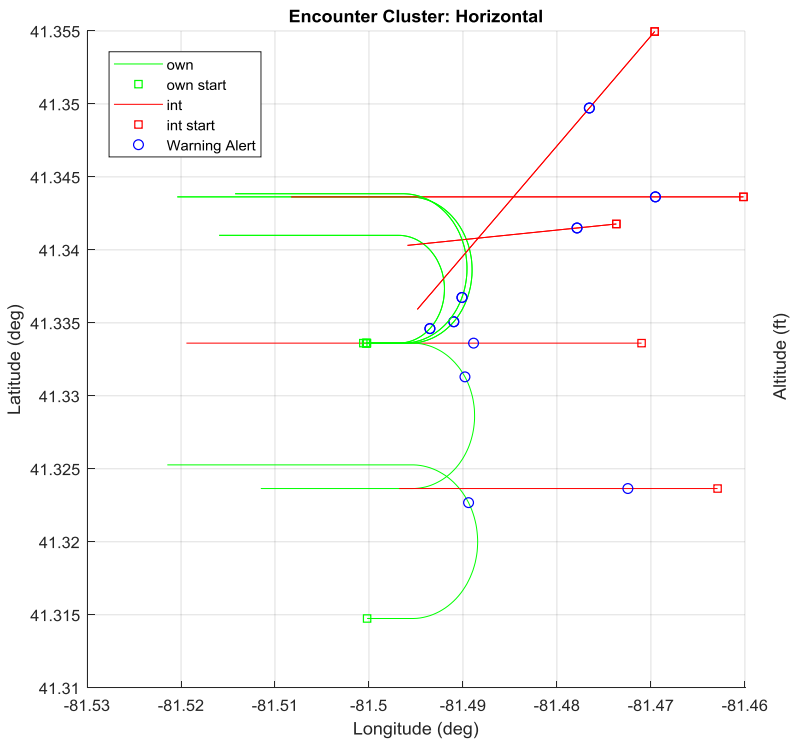


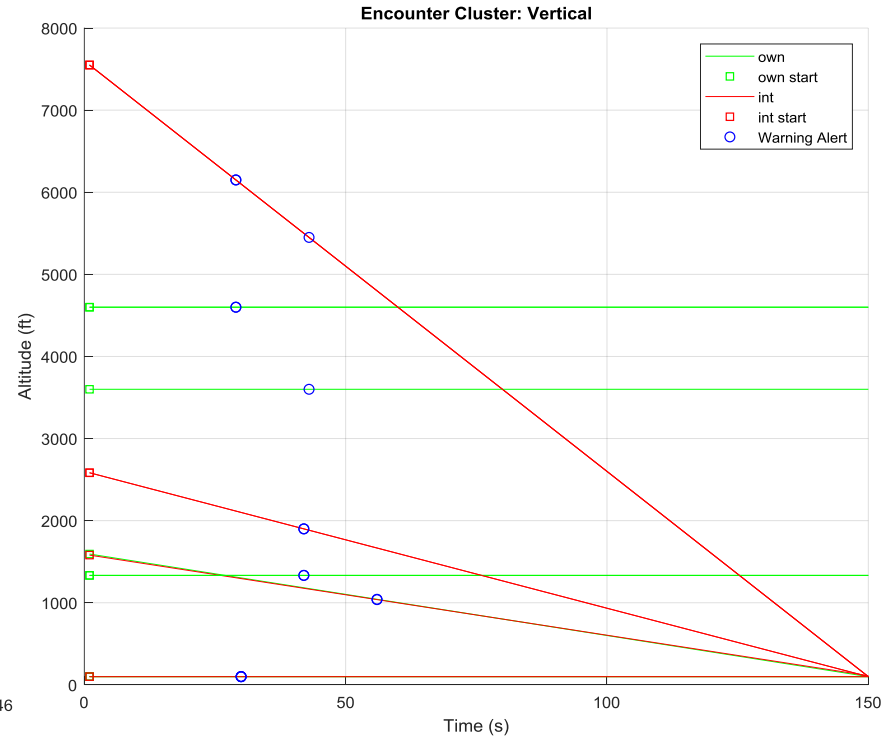


Statistical Results

Scenario	Surveillance	P(TAO LoWC)	P(NMAC)	P(Corr)	P(Warn)
Instr	Truth	5.88%	0.00%	8.82	5.88
	ADS-B			8.82	8.82
	GBRH			14.71	11.76
	GBRM			8.82	8.82
	GBRL			11.76	8.82
Visual	Truth	7.89%	0.00%	10.53	10.53
	ADS-B			5.26	10.53
	GBRH			7.89	10.53
	GBRM			10.53	10.53
	GBRL			5.26	10.53
OSED	Truth	100.00%	67.56%	97.11	100.00
	ADS-B			97.00	100.00
	GBRH			81.56	100.00
	GBRM			93.89	100.00
	GBRL			97.67	100.00
MNA	Truth	0.00%	0.00%	11.57	6.61
	ADS-B			22.31	13.22
	GBRH			71.90	94.21
	GBRM			79.34	83.47
	GBRL			60.33	44.63

TSAA MNA Truth Alerts





Schedule

- Finalize screening and regeneration of TSAA airport encounter sets
  - June 30, 2019
- Perform open and closed loop assessment of all encounters
  - Produce various alerting / safety metrics
  - Will not consider transitions between transit and TAO LoWC definitions

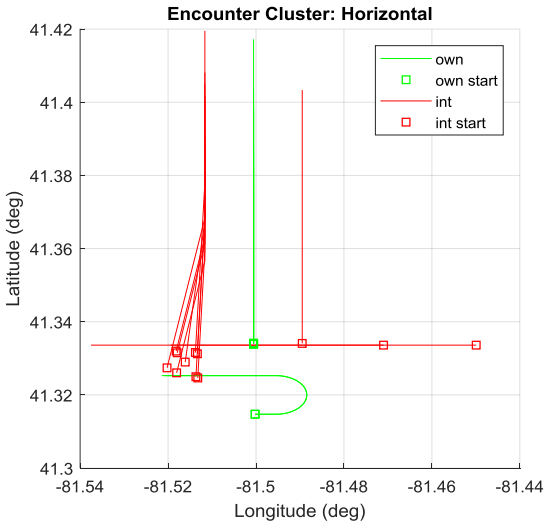
Backup

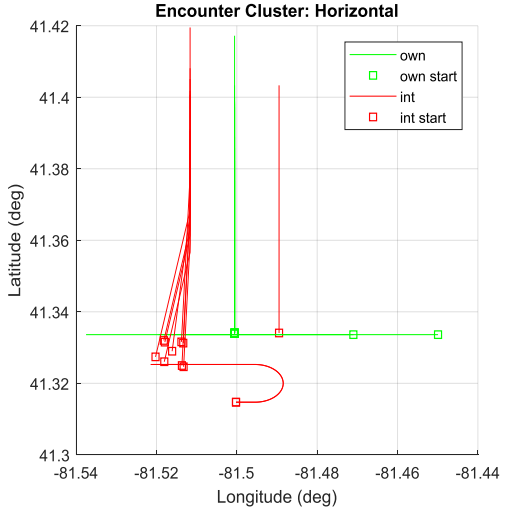
Set #1

U.3.1.1.1 **Must Not Alert Track Set #1: Convergence on Final to Parallel Runways**

Must Not Alert Track Set #1 is designed to verify that there are no alerts in ownship for a parallel runway approach with incoming target at initial specified RVV, RHV, and IA encounter parameters. The encounter can occur on either a base to final turn and approach (A) or direct final approach (B). The target decreases speed and changes trajectory to a parallel course with respect to the ownship as it approaches 0.5 NM horizontal separation with the ownship. Figure U-28 and Figure U-29 show schematics of the encounter. Table U-23 gives the range of scenarios to be tested for this encounter.

Figure U-28 Overhead View

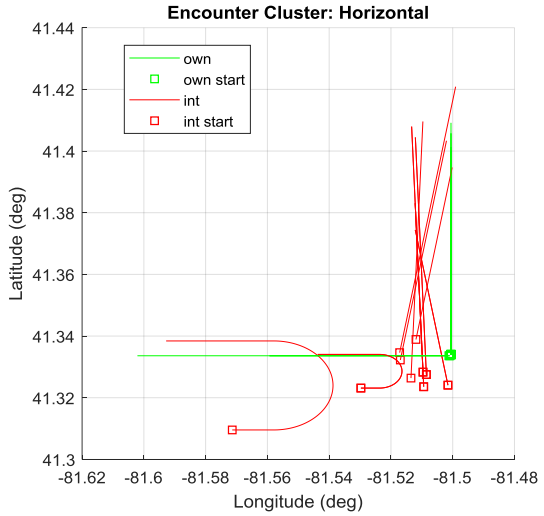


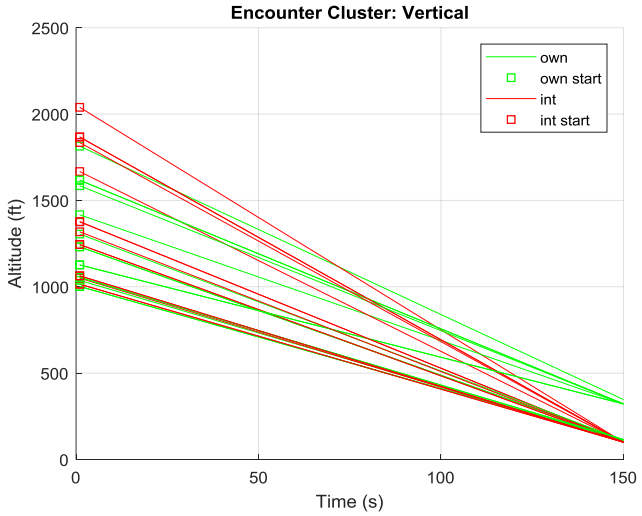


Set #2

U.3.1.1.2 Must Not Alert Track Set #2: Convergence on Final to Same Runway

Must Not Alert Track Set #2 is designed to verify that there are no alerts in ownship for incoming target at initial specified RVV, RHV, and IA encounter parameters where the target decreases speed and changes trajectory such that RVV, RHV, and IA values approach zero as horizontal separation approaches 0.5 NM, keeping the same glideslope as the ownship. Target always begins above and behind ownship. However, this scenario can also occur with switched target and ownship roles. Scenarios marked with (i) occur with ownship in front. Scenarios marked with (ii) occur with ownship as the chasing aircraft. See Section U.2.2.1.1 for schematic that demonstrates the encounter. Table U-24 gives the range of scenarios to be tested for this encounter.

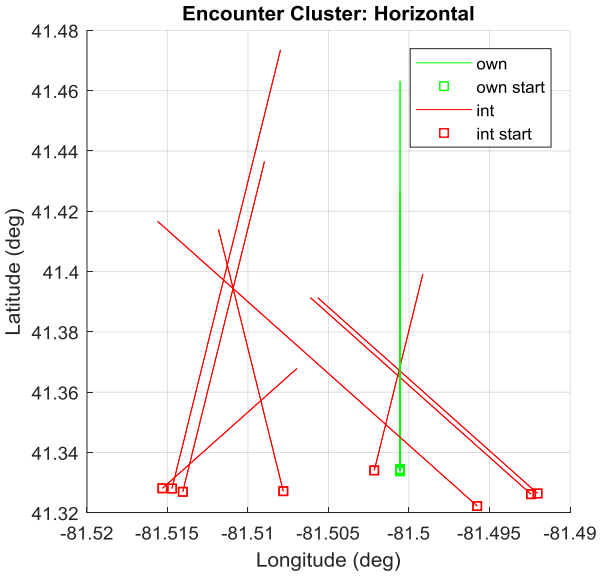


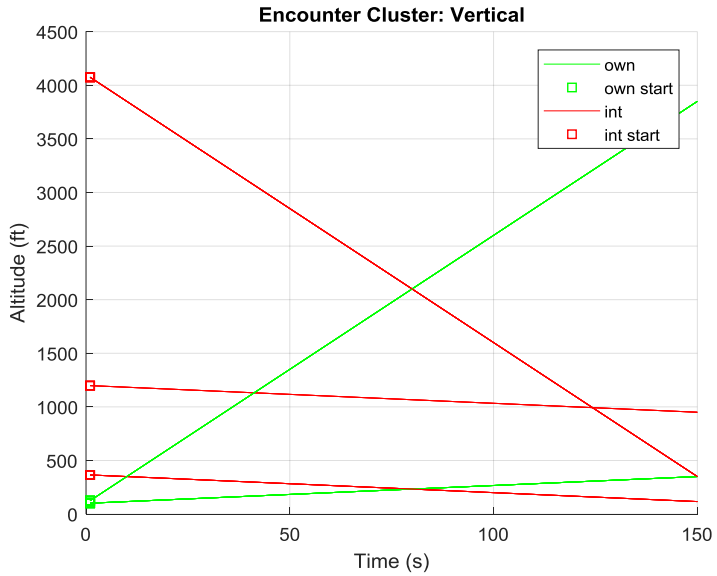


Set #3

U.3.1.1.3 Must Not Alert Track Set #3: Convergence on Same Leg; Different Flight Phases

Must Not Alert Track Set #3 is designed to verify that there are no alerts in ownship for incoming target at specified RVV, RHV, and IA encounter parameters such that the ownship-target horizontal separation reduces to 0.5 NM. The scenarios will test cases where the target either passes in front or behind the ownship as well as cases where the ownship descends into the airport pattern (A) or ascends out of the airport pattern (B). Two scenarios will test a vertical separation with horizontal separation of 0 ft. See Section U.2.2.1.2 for schematic that demonstrates the encounter. Table U-25 gives the range of scenarios to be tested for this encounter.

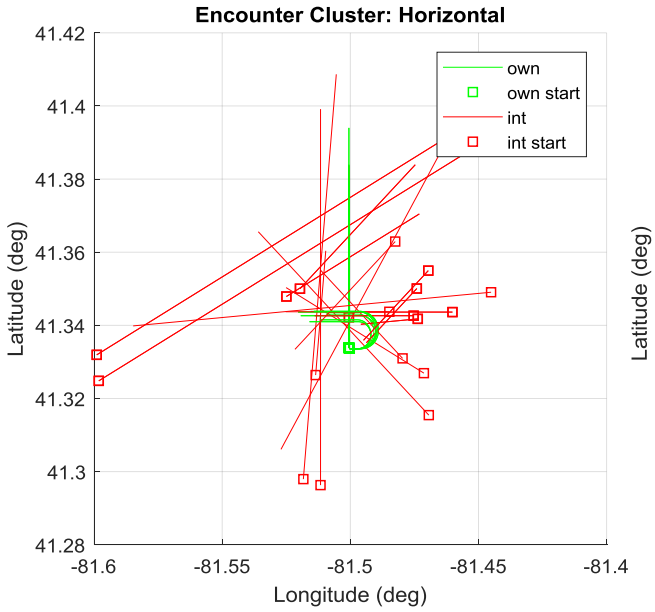


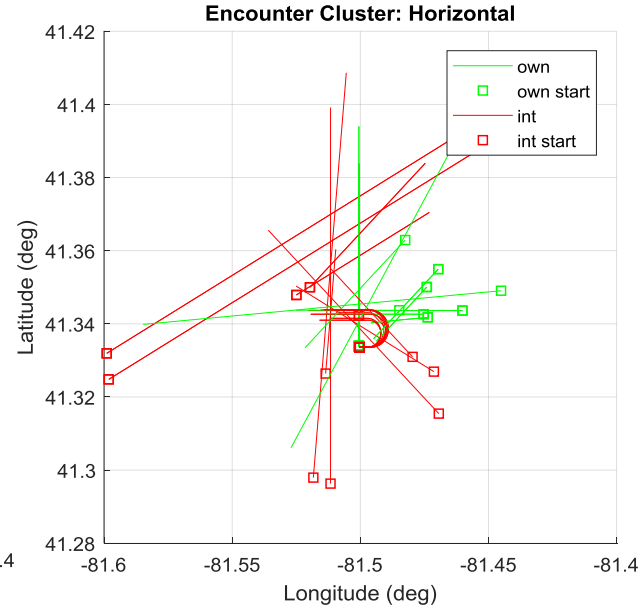


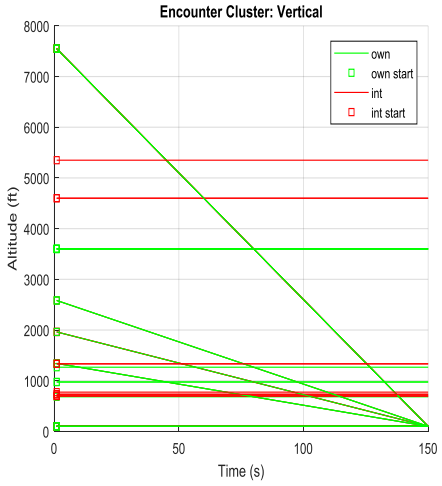
Set #4

U.3.1.3 **Must Not Alert Track Set #4: Convergence in Airport Pattern with Target Entering via Standard Procedure**

Must Not Alert Track Set #4 is designed to verify that there are no alerts in ownship for incoming target at specified RVV, RHV, and IA encounter parameters such that the ownship-target horizontal separation reduces to 0.5 NM. The scenarios will test cases where the target descends into the traffic pattern from the en route environment and meets the ownship either as it turns from the crosswind to downwind leg (B) or while it's on the downwind leg (A). Both cases test situations where the target passes in front or behind the ownship. In scenarios where the ownship turns from crosswind to downwind leg, the RHV and IA parameters vary as the ownship changes heading. This scenario can also occur with switched target and ownship roles. Scenarios marked with (i) occur with ownship already established in the pattern. Scenarios marked with (ii) occur with ownship descending into the pattern. See Section U.2.2.2.1 for schematic that



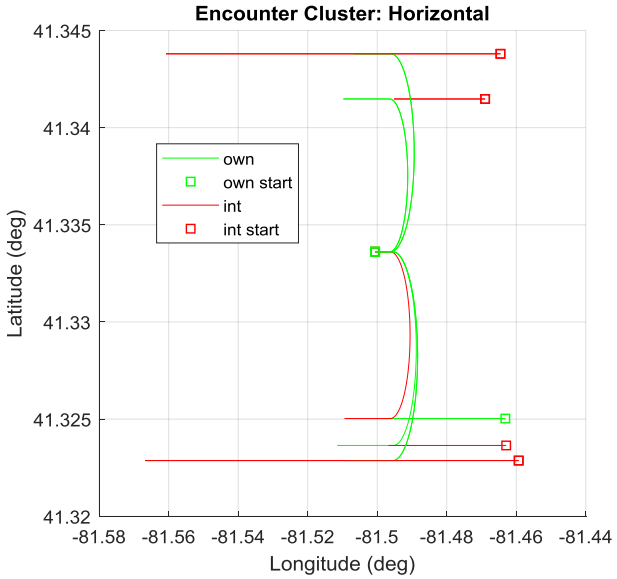


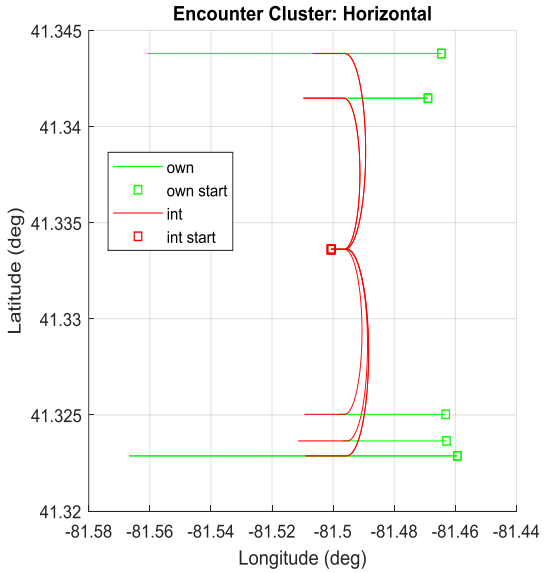


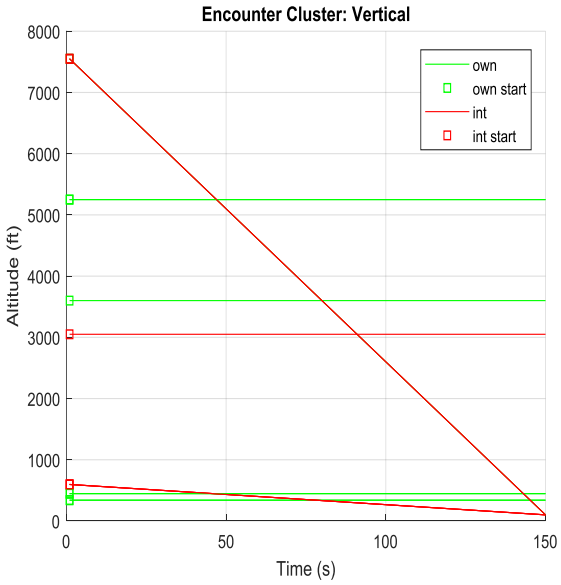
Set #5

U.3.1.3.1 **Must Not Alert Track Set #5: Convergence in Airport Pattern with Target Entering via Non-standard Procedure**

Must Not Alert Track Set #5 is designed to verify that there are no alerts in ownship for incoming target at specified RVV, RHV, and IA encounter parameters such that the ownship-target horizontal separation reduces to 0.5 NM. The scenarios will test two cases: 1) the target descends into the pattern on direct final, meeting the ownship turning from the downwind leg to final; 2) the target makes an opposite turn into the pattern, meeting the ownship turning from the crosswind to downwind leg. Both cases test situations where the target passes in front or behind the ownship. The RHV and IA parameters vary as the ownship changes heading. This scenario can also occur with switched target and ownship roles. Scenarios marked with (i) occur with ownship already established in the pattern. Scenarios marked with (ii) occur with ownship entering into the pattern. See Section U.2.2.2.2 for schematic that demonstrates the encounter. Table U-27 gives the range of scenarios to be tested for this encounter.





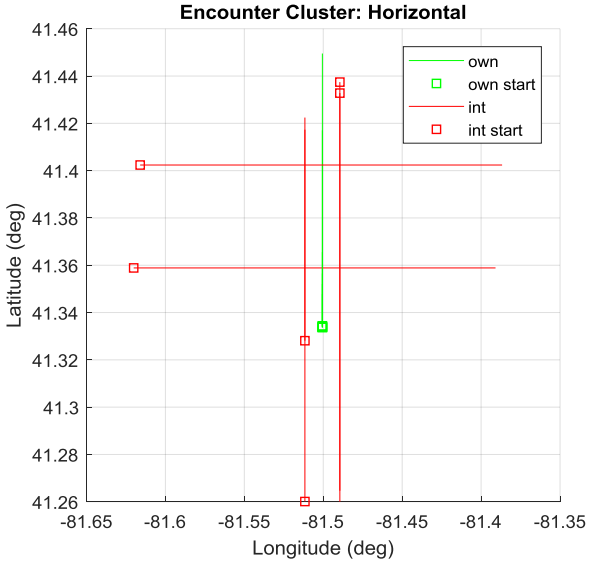


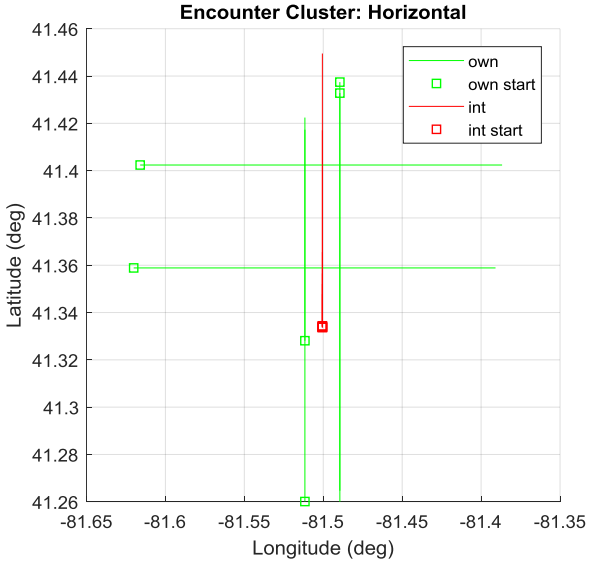
Set #6

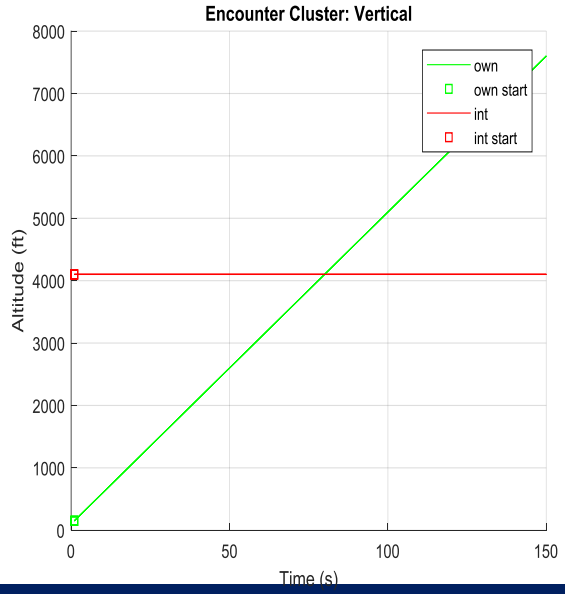
U.3.1.4.1 Must Not Alert Track Set #6: Convergence with Departing Target Jet

Must Not Alert Track Set #6 is designed to verify that there are no alerts in ownship for incoming target at specified RVV, RHV, and IA encounter parameters such that the ownship-target horizontal separation reduces to 0.5 NM. The scenarios will test cases where a VFR ownship cruising above the traffic pattern altitude encounters a target jet aircraft departing from a nearby airport such that the target either passes in front or

Possibly add some more vertical rates





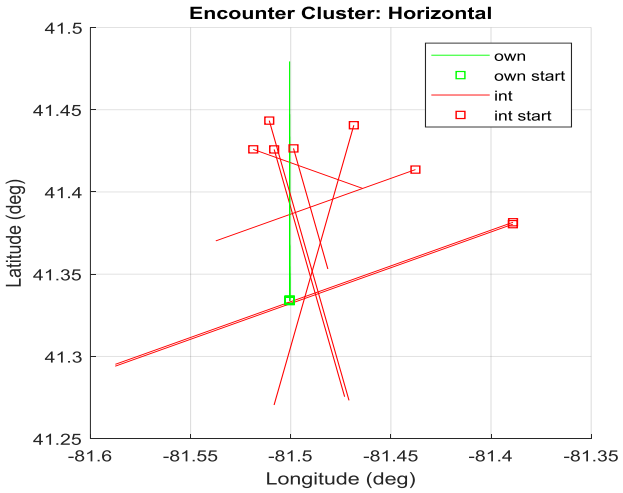


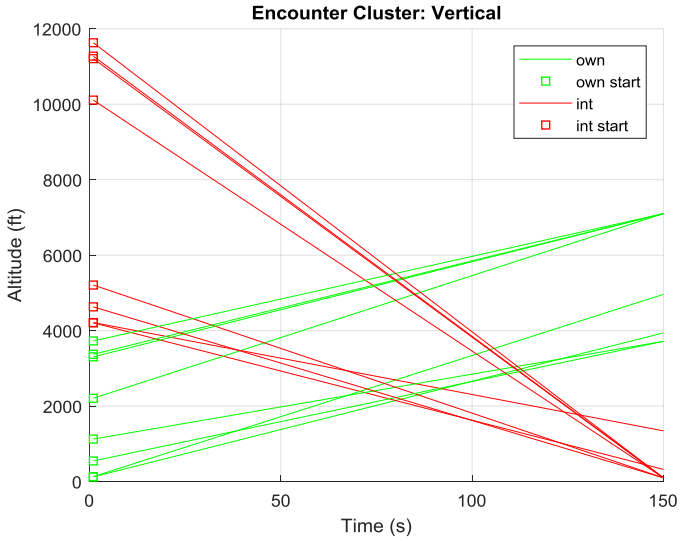
Set #7

U.3.1.4.2 Must Not Alert Track Set #7: Convergence with Approaching Target Jet

Must Not Alert Track Set #7 is designed to verify that there are no alerts in ownship for incoming target at specified RVV, RHV, and IA encounter parameters such that the ownship-target horizontal separation reduces to 0.5 NM. The scenarios will test cases where a departing ownship encounters a target jet on an IFR approach to the same airport such that the target either passes in front or behind the ownship. See Section U.2.2.3.2 for schematic that demonstrates the encounter. Table U-29 gives the range of scenarios to be tested for this encounter.

Probably valid both ways



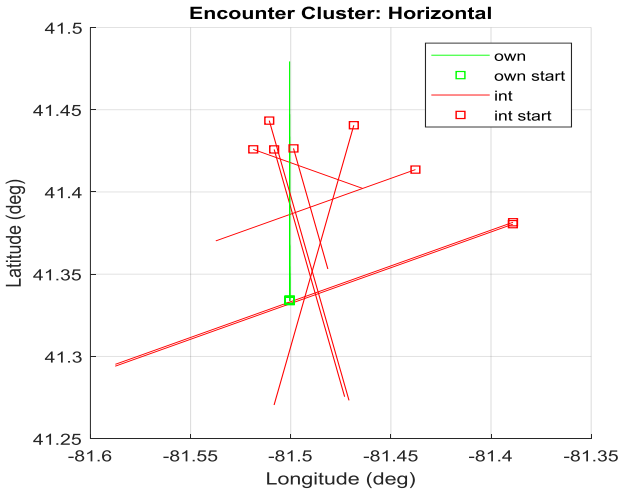


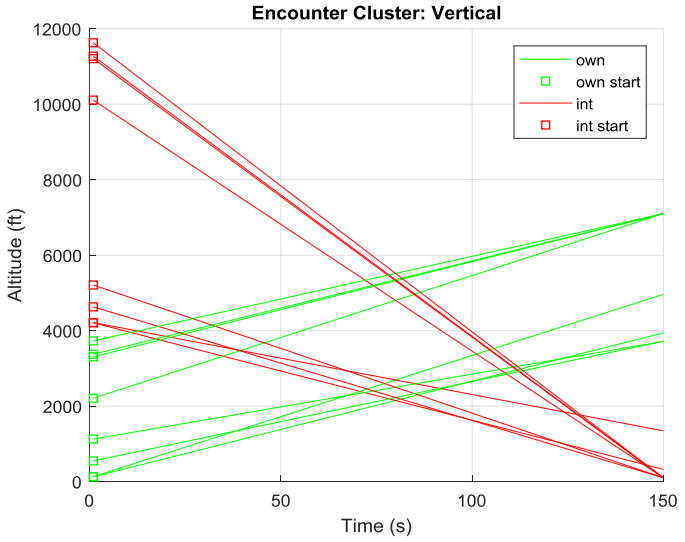
Set #7

U.3.1.4.2 Must Not Alert Track Set #7: Convergence with Approaching Target Jet

Must Not Alert Track Set #7 is designed to verify that there are no alerts in ownship for incoming target at specified RVV, RHV, and IA encounter parameters such that the ownship-target horizontal separation reduces to 0.5 NM. The scenarios will test cases where a departing ownship encounters a target jet on an IFR approach to the same airport such that the target either passes in front or behind the ownship. See Section U.2.2.3.2 for schematic that demonstrates the encounter. Table U-29 gives the range of scenarios to be tested for this encounter.

Probably valid both ways



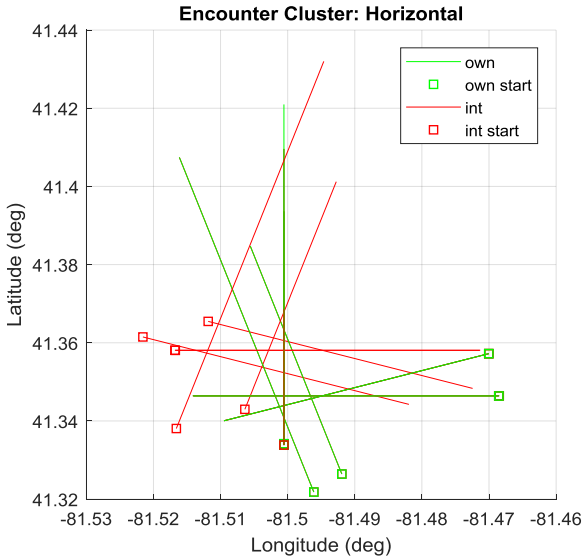


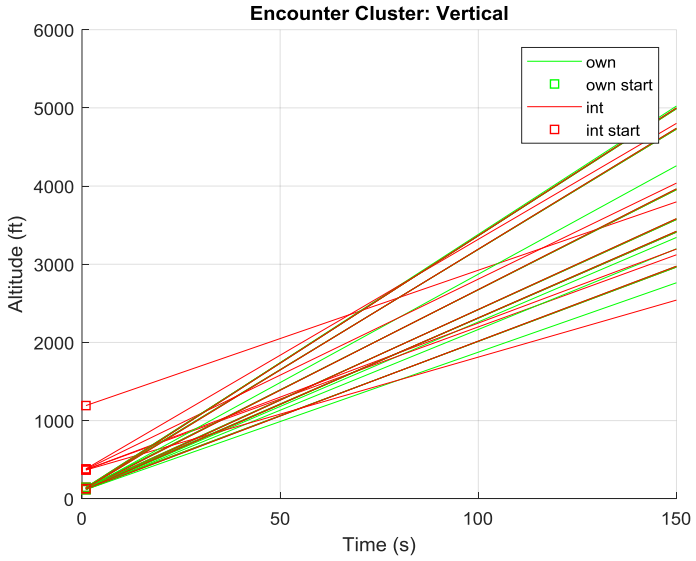
Set #8

U.3.1.5.1 Must Not Alert Track Set #8: Touch-and-Go Convergence

Must Not Alert Track Set #8 is designed to verify that there are no alerts in an ownship for incoming target at specified RVV, RHV, and IA encounter parameters such that the ownship-target horizontal separation reduces to 0.5 NM. The scenarios will test cases where an ownship performs a touch-and-go at a non-towered airport and encounters a target rotorcraft on the upwind leg. The target rotorcraft expects the ownship to do a full stop landing and departs on ownship touchdown. The scenarios will test cases where the target passes either in front or behind the ownship. This scenario can also occur with switched target and ownship roles. Scenarios marked with (i) occur with ownship as the fixed-wing doing the touch-and-go. Scenarios marked with (ii) occur with ownship as the rotorcraft. See Section U.2.2.4.1 for schematic that demonstrates the encounter. Table U-30 gives the range of scenarios to be tested for this encounter.

Need to do further analysis to verify





Set #9

U.3.1.5.2 Must Not Alert Track Set #9: Rotorcraft Convergence on Final Approach

Must Not Alert Track Set #9 is designed to verify that there are no alerts in an ownship for incoming target at specified RVV, RHV, and IA encounter parameters such that the ownship-target horizontal separation reduces to 0.5 NM. The scenarios will test cases where an ownship on final to a non-towered airport encounters a target rotorcraft approaching via a non-standard procedure. The ownship and target rotorcraft encounter each other on short final. The target can approach from all angles, likely during an autorotation maneuver. The scenarios will test cases where the target passes either in front or behind the ownship. See Section U.2.2.4.2 for schematic that demonstrates the encounter. Table U-31 gives the range of scenarios to be tested for this encounter.

Need to do further analysis to verify

Must Alerts

Table U-3 Summary of Must Alert Test Tracks

Must Alert Tracks		
Non-Accelerating		
Set	Encounter Type	Number of Tracks
NA	Uncategorized	15
	Total	**15**
Airport Environment		
Set	Encounter Type	Number of Tracks (all traffic sources)
1	Convergence on Final to Same Runway	24
2	Convergence on Same Leg; Different Flight Phases	36
3	Convergence in Airport Pattern; Target Entering via Standard Procedure	78
4	Convergence in Airport Pattern; Target Entering via Non-standard Procedure	28
5	Convergence with Departing Jet	8
6	Convergence with Approaching Jet	16
7	Touch-and-Go Convergence	36
8	Rotorcraft Convergence on Final Approach	36
9	News or Firefighting Aircraft Operating in Same Area	32

Table U-5 Test Tracks with Rotorcraft as Ownship

Must Alert Tracks		
Airport Environment		
Set	Encounter Type	Test track numbers
7	Touch-and-Go Convergence	1-ii, 3-ii, 5-ii, 7-ii, 9-ii, 11-ii
8	Rotorcraft Convergence on Final Approach	1-ii, 3-ii, 5-ii, 7-ii, 9-ii, 11-ii
9	News or Firefighting Aircraft Operating in Same Area	All tracks
	Total	**38**

Set #1

U.2.2.1.1 Must Alert Track Set #1: Convergence on Final to Same Runway

Must Alert Track Set #1 is designed to evaluate the alerting capabilities of an ownship on final to a runway when a target aircraft is also attempting to land on the runway. In all cases, the ownship pilot has limited out-the-window view of the target because it is either above or behind the ownship. Both aircraft descend on a nominal 3° glideslope with variance depending on RVV. Ownship and target track profiles are similar with small RVV and RHV values. The IA should not be more than ten degrees. This scenario can also occur with switched target and ownship roles. Scenarios marked with (i) occur with ownship in front. Scenarios marked with (ii) occur with ownship as the chasing aircraft. Figure U-4 and Figure U-5 show schematics of the encounter. Table U-8 gives the range of scenarios to be tested for this encounter.

Figure U-4 Overhead View

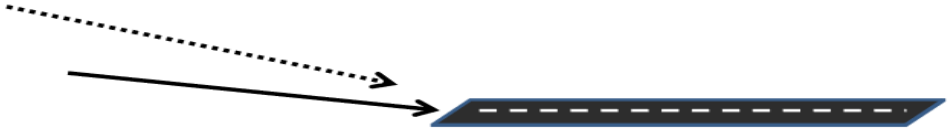
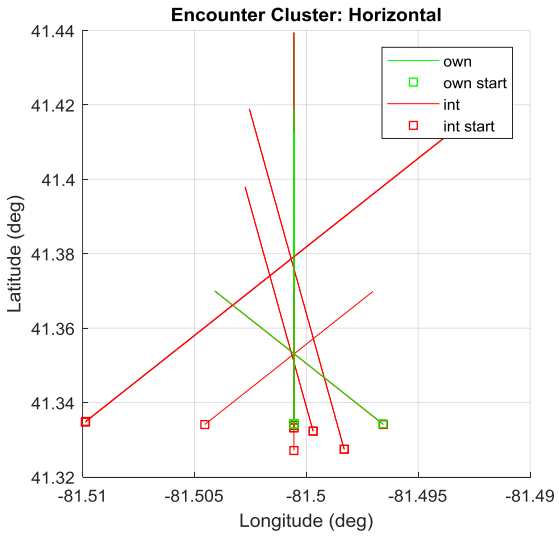
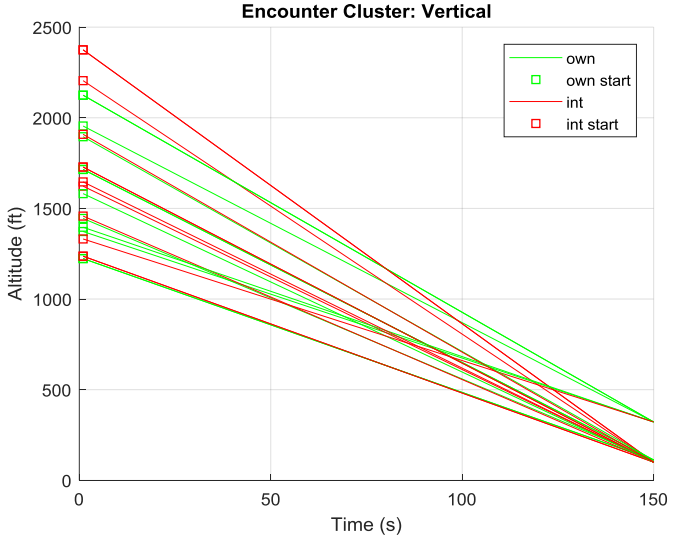


Figure U-5 Isometric View





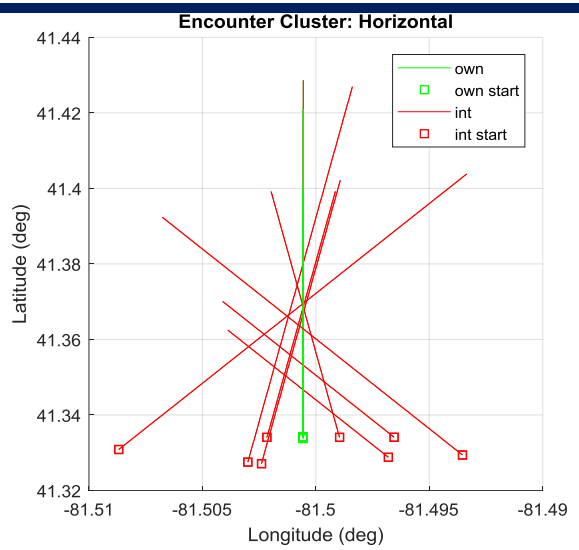
Set #2

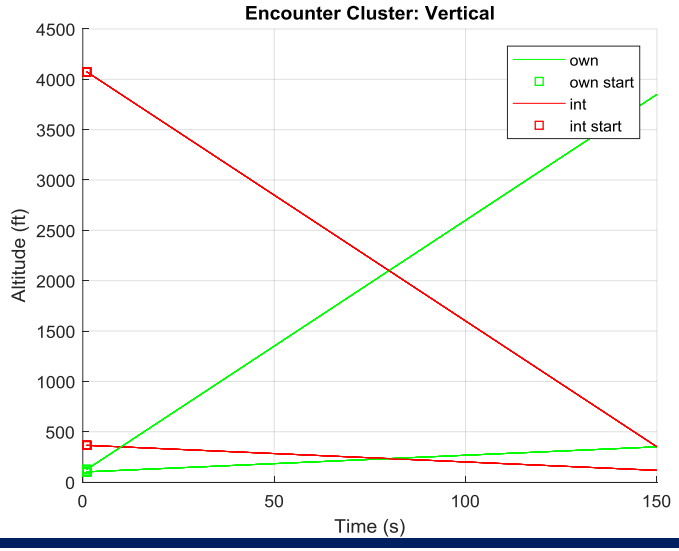
Must Alert Track Set #2: Convergence on Same Leg; Different Flight Phases

Must Alert Track Set #2 is designed to evaluate the alerting capabilities of an ownship either departing an airport and climbing through the airport pattern (A) or descending into the airport pattern (B) such that the target is either descending into the airport pattern (A) or climbing through the airport pattern on the same leg (B), respectively. Ownship and target track profiles are similar except for altitude. The IA should not be more than ten degrees and RHV is small, but RVV can range from 200 – 3000 ft/min. Figure U-6 and Figure U-7 show schematics of the encounter. Table U-9 gives the range of scenarios to be tested for this encounter. Each scenario shall be tested twice such that ownship and target play both the ascending and descending roles.

Figure U-6 Overhead View

Figure U-7 Isometric View





Set #3

Must Alert Track Set #3: Convergence in Airport Pattern with Target Entering via Standard Procedure

Must Alert Track Set #3 is designed to evaluate the alerting capabilities of an ownship established in the traffic pattern that encounters a target joining the pattern via a standard procedure. Ownship altitude and speed are constant while either following the traffic pattern downwind leg (A) or turning from crosswind to downwind (B). The target enters the downwind leg from above and behind the ownship. The IA should not be more than sixty degrees. This scenario can also occur with switched target and ownship roles. Scenarios marked with (i) occur with ownship already established in the pattern. Scenarios marked with (ii) occur with ownship descending into the pattern. Figure U-8 and Figure U-9 show schematics of the encounter. Table U-10 gives the range of scenarios to be tested for this encounter.

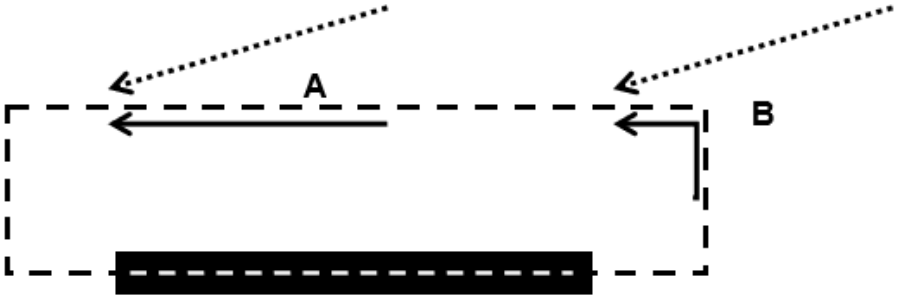
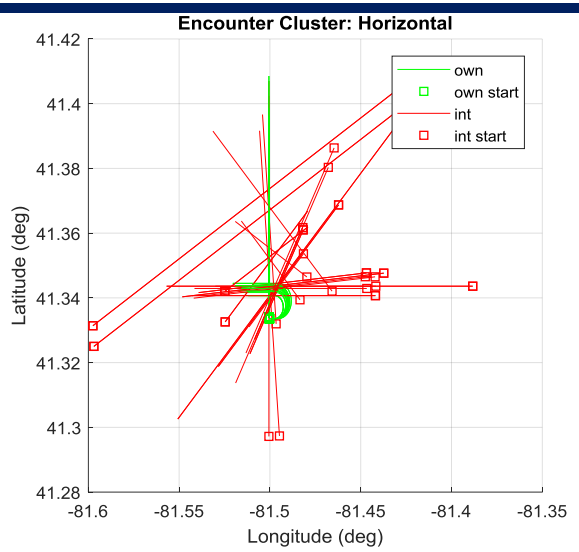
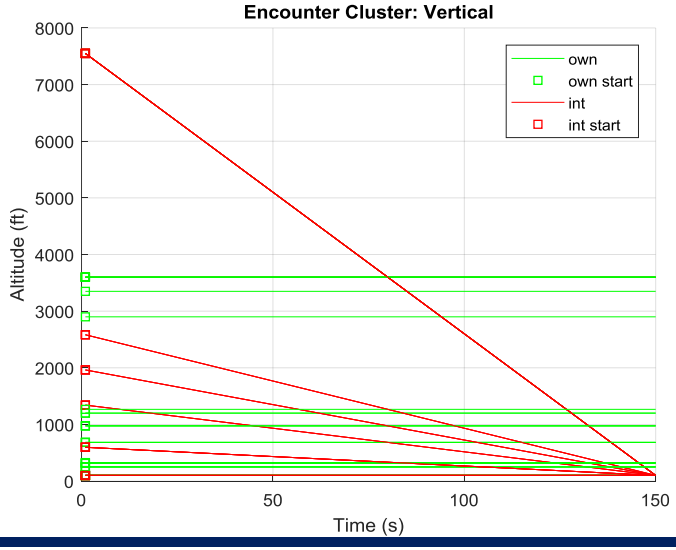


Figure U-8 Overhead View

Figure U-9 Isometric View





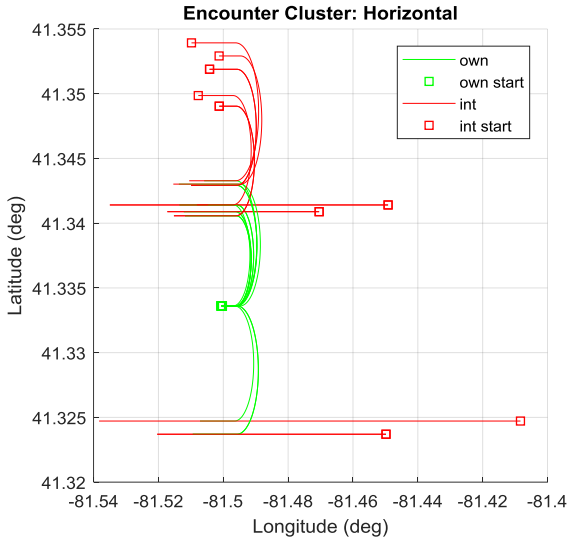
Set #4

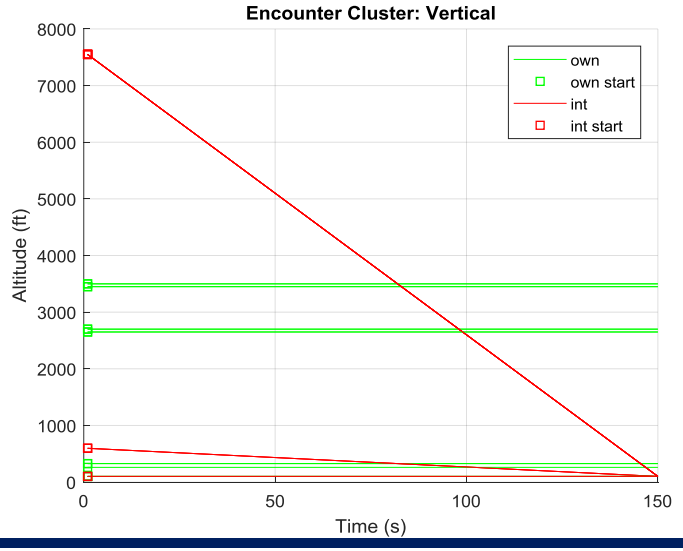
Must Alert Track Set #4: Convergence in Airport Pattern with Target Entering via Non-standard Procedure

Must Alert Track Set #4 is designed to evaluate the alerting capabilities of an ownship established in the traffic pattern that encounters a target joining the pattern via a non-standard procedure such as a direct final or opposite turn. Ownship altitude and speed are constant while following the traffic pattern base to final leg or crosswind-to-downwind leg. The ownship continually turns while the target either enters straight from above on direct final (A) or takes an opposite turn into the traffic pattern (B). The range of IAs is tested through the target and/or ownship turns. The range of RHVs is also tested through the turns with RHV decreasing to zero as the ownship and target meet. This scenario can also occur with switched target and ownship roles. Scenarios marked with (i) occur with ownship already established in the pattern. Scenarios marked with (ii) occur with ownship entering into the pattern. Figure U-10 and Figure U-11 show schematics of the encounter. Table U-11 gives the range of scenarios to be tested for this encounter.

Figure U-10 Intersect Angle (IA) and Relative Horizontal Velocity (RHV)

Figure U-11 Intersect Angle (IA) and Relative Horizontal Velocity (RHV)





Set #5

Must Alert Track Set #5: Convergence with Departing Target Jet

Must Alert Track Set #5 is designed to evaluate the alerting capabilities of a VFR ownship cruising above the traffic pattern altitude that encounters a target jet aircraft departing from a nearby airport. Ownship altitude and speed are constant. The target departs a nearby airport, ascending at 3000 ft/min. The IA can be any angle. The RHV can vary from zero to 500 knots depending on the IA.

Figure U-12 and Figure U-13 show schematics of the encounter. gives the range of scenarios to be tested for this encounter.

Figure U-12 Overhead View

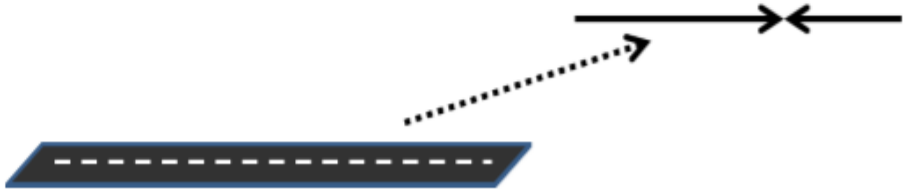
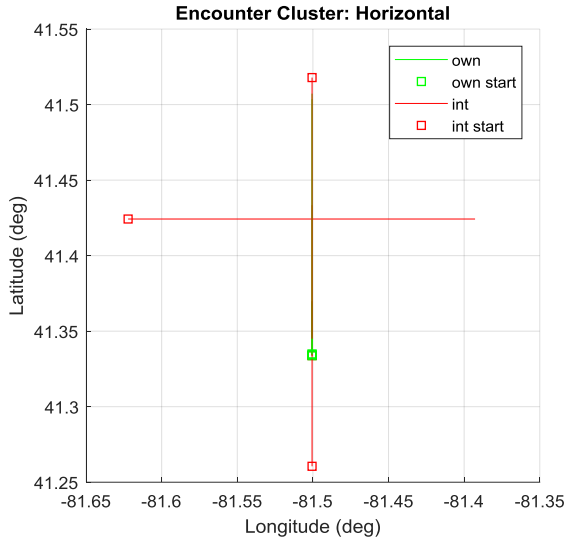
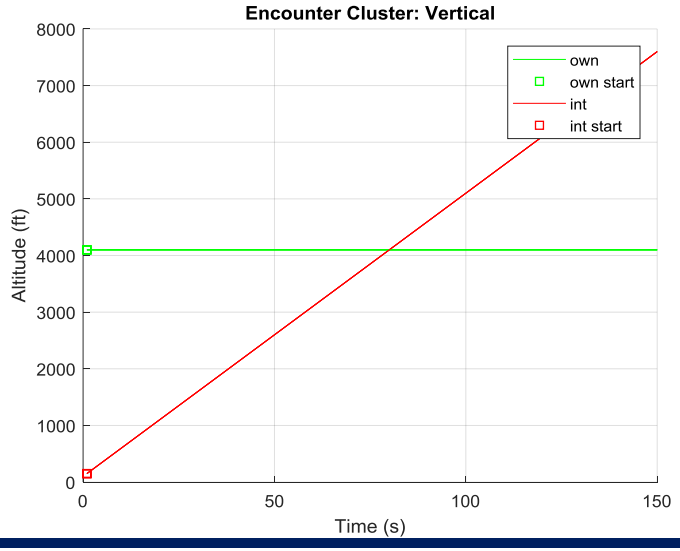


Figure U-13 Isometric View





Set #6

Must Alert Track Set #6: Convergence with Approaching Target Jet

Must Alert Track Set #6 is designed to evaluate the alerting capabilities of a departing ownship that encounters a target jet on an IFR approach to the same airport. The ownship climbs on the upwind leg while a target jet on IFR approaches a different runway. The RVV is greater than 3000 ft/min as the aircraft move quickly vertically towards each other. IA is anything but zero degrees. RHV varies from 250 to 500 knots. Figure U-14 and Figure U-15 show schematics of the encounter. Table U-13 gives the range of scenarios to be tested for this encounter.

Figure U-14 Overhead View

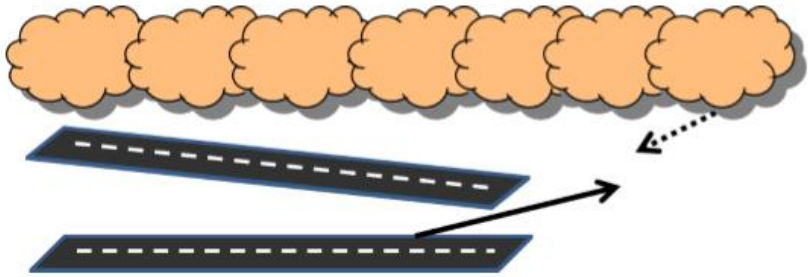


Figure U-15 Isometric View