Low Size, Weight, and Power (SWaP) Sensor Analyses Plan

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Agenda

- Overview
- Analysis objectives
- Analysis assumptions
- Dataset assumptions
- Analysis methodology
- Schedule

Overview

- RTCA SC-228 WG1 is creating a new class of air-to-air radar (ATAR) in DO-366 Phase 2 MOPS development for low size, weight, and power (SWaP) UAS

- RTCA SC-228 WG1 may also create a class of low SWaP EO/IR sensor equipment

- Analyses will be performed to understand trade space for Field of Regard (FoR) and Radar Declaration Range (RDR) requirements for low SWaP sensors

Overview

- Phase 1 analyses will be repeated for the low SWaP radar and EO/IR sensor parameters
  - **DO-366 Appendix C** investigates cases where field of regard (FOR) limits the timely detection of targets according to alerting requirements for DAA.
  - **DO-366 Appendix D** verifies that the radar declaration range (RDR) provides enough time margin, from detection to loss of well clear (LoWC), to meet DAA alerting requirements.
- Since the surveillance volume requirements have not been established, multiple values of RDR and FoR will be used as independent variables

Analysis Objectives

- Explore implications of low SWaP sensor FoR and RDR on ability to detect intruders and maintain DAA well clear definitions

- Requirements addressed for low SWaP in DO-366
  - 2.2.6 Radar Field of Regard
    - Azimuth (026) /Elevation Coverage (027)
  - 2.2.7 Radar Tracks
    - Intruder track acquisition time (022)
    - RDR for Small (039), Medium (040), and Large (041) intruders

Analysis Objectives

- Perform fast time, unmitigated simulation of a large number of encounters using candidate Low SWaP Radar and EO/IR sensor parameters

- Analyze data to
  - estimate the probability of an intruder entering the sensor field of regard within the sensor declaration range (Appendix C)
  - validate the radar declaration volume against DAA alerting requirements (Appendix D)

Radar Requirements

Symbol	Parameter	Phase 1	Phase 2, Non-cooperative, Low SWaP
FOR	Field of Regard, Azimuth	+/- 110°	+/- 110°, +/- 135° preferred
FOR	Field of Regard, Elevation	+/- 15°	+/- 15°
RDR	Radar Declaration Range, at Azimuth = 0°	5.4, 6, 6.7 NMi	2, 2.5, 3, 3.5 NMi (TBD)
RDR	Radar Declaration Range, Correction Factor	(See next slide)	? – From AAG
$RCPR$	Radar Closest Performance Range	4000 ft	? – From Honeywell
	"Track Acquisition Time" from DO-366 requirement 2.2.7.22. †	15 s	? – From Honeywell

†: For intruders that enter the FOR within **95%** of the RDR, in **90%** of these encounters, tracks must meet accuracy requirements (2.2.8) within **15s** after entering FOR/RDR (DO-366 requirement 2.2.7.22). This was the requirement that was validated in appendix C.

Radar Requirements: RDR Correction Factor

Intruder Bearing Angle	RDR Correction Factor		
	Small	Medium	Large
$\|angle\| < 30$	1	1	1
$30 \leq \|angle\| < 60$	0.67	0.78	0.84
$60 \leq \|angle\| < 90$	0.45	0.52	0.6
$\|angle\| \geq 90$	0.35	0.43	0.55

(from phase 1, DO-366 2.2.7.14)

DAA Well Clear Alerting Requirements

Symbol	Parameter	Phase 1	Phase 2, Non-cooperative, Low SWaP
HMD^*	Horizontal Miss Distance Threshold	4000 ft	2200 ft*
h^*	Vertical Separation Threshold, Corrective & Warning	450 ft	450 ft*
h^*	Vertical Separation Threshold, Preventive	700 ft	700 ft
τ^*_{mod}	Modified Tau Threshold	35 s	0 s*
MIR	Maneuver Initiation Range		1.9 NMi*
THR_{Late}	Late Threshold, Preventive & Corrective	20 s	20 s
THR_{Late}	Late Threshold, Warning	15 s	15 s
	Minimum Average Alert Time, Preventive & Corrective	55 s	55 s
	Minimum Average Alert Time, Warning	25 s	25 s

Note: Non-Hazard alerting requirements have not been established.

*From NASA, MIT/LL, CAL Analytics DWC Joint Briefing 03/05/2019

Ownship Simulation Assumptions

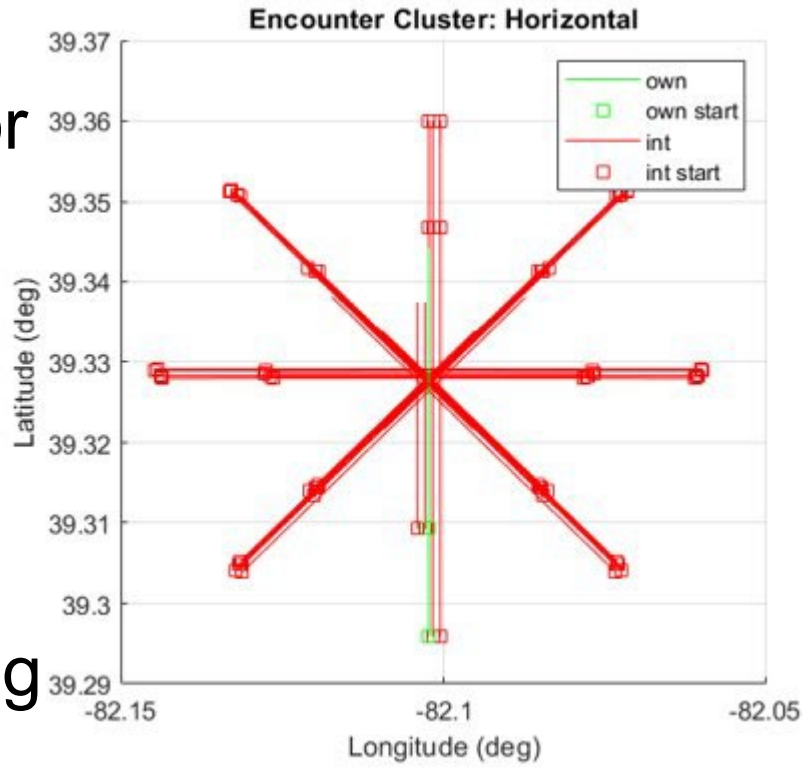
Parameter	Phase 1	Phase 2, Non-cooperative, Low SWaP
Turn Rate	3°/s	7°/s
Velocity	40 – 200 KTAS	40 – 100 KTAS
Min Altitude, AGL	1000 ft (AGL)	500 ft (AGL)
Max Altitude, MSL	10,000 ft (MSL)	10,000 ft (MSL)

- Extended operations in airspace classes D, E (non-terminal), or G (non-terminal).
- Transit operations in classes B and C.

Dataset Assumptions

- Recommend low SWaP encounter set used by MIT/LL for NASA Mitigated Well Clear Analysis dated March 5, 2019
  - See next slide for details

- Modeling & Sim tool for sweeping linear encounter parameters
  - Altitude separation, closest point of approach (CPA), heading



Encounter Set Parameters

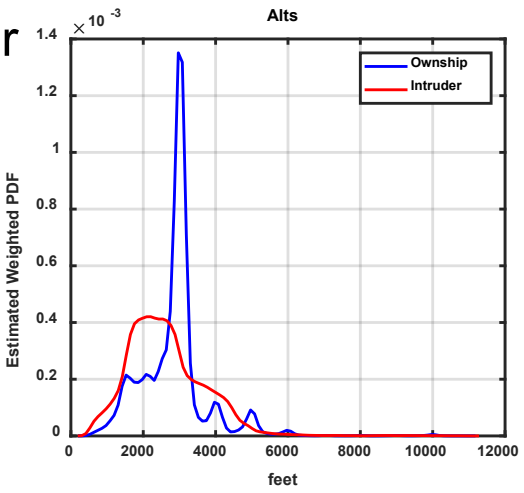
Encounter characteristics

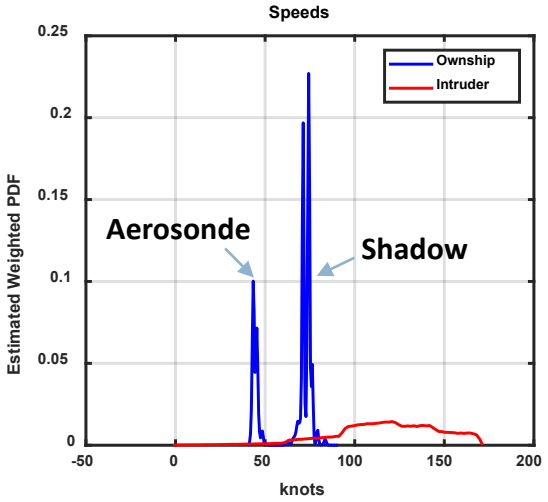
- Minimum Separation at Encounter Start: 800 ft (vertically) or 1.5 NM (horizontally)
- Max HMD: 3 NM
- Max VMD: 1500 ft
- Closest Approach: 150 sec
- Encounter duration: 180 sec
  - Extended up to 300 sec if necessary to satisfy initial minimum separation
- Airspace classes: E/G

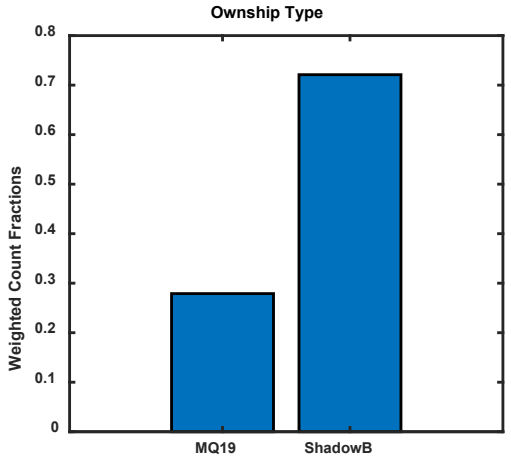
Aircraft characteristics

- Ownship speed: 40-100 kts
- Intruder speed: 0-170 kts
- Ownship/intruder altitude: 500 AGL-10000 ft MSL

Low-SWAP Encounter Characteristics







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Appendix C Analysis

- Objective: estimate the probability of an intruder entering the sensor field of regard within the radar declaration range (RDR)
  - Determine probability of those impacted by track acquisition time requirement of 15s
- Analyze multiple RDRs for FoRs to cover possible final values of RDR
- Perform micro-level analysis of encounters which enter FoR within RDR to better understand challenging encounter scenarios

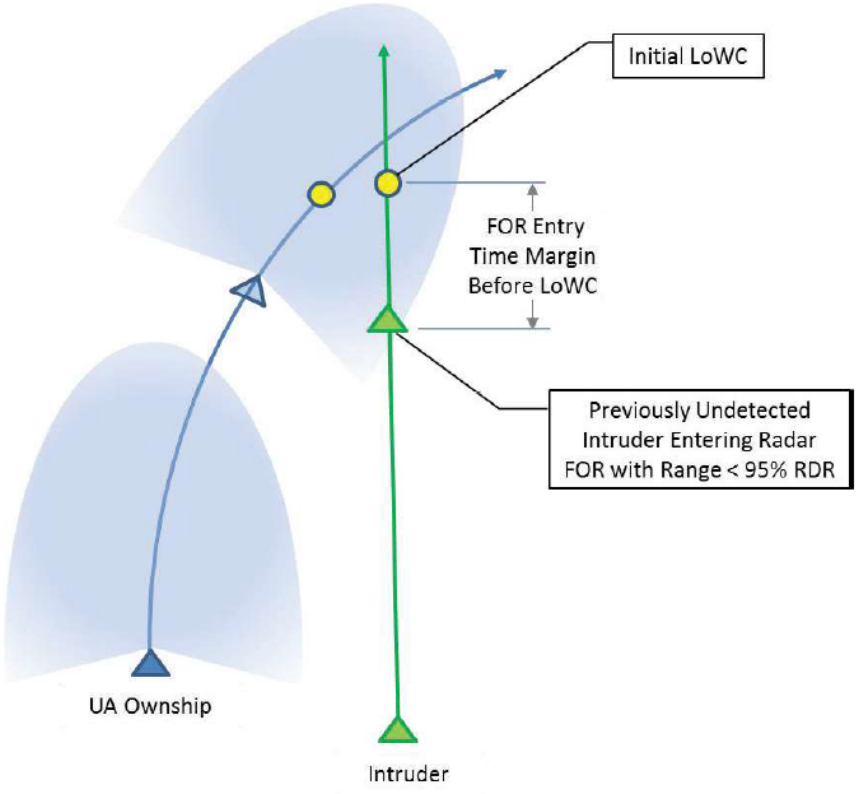
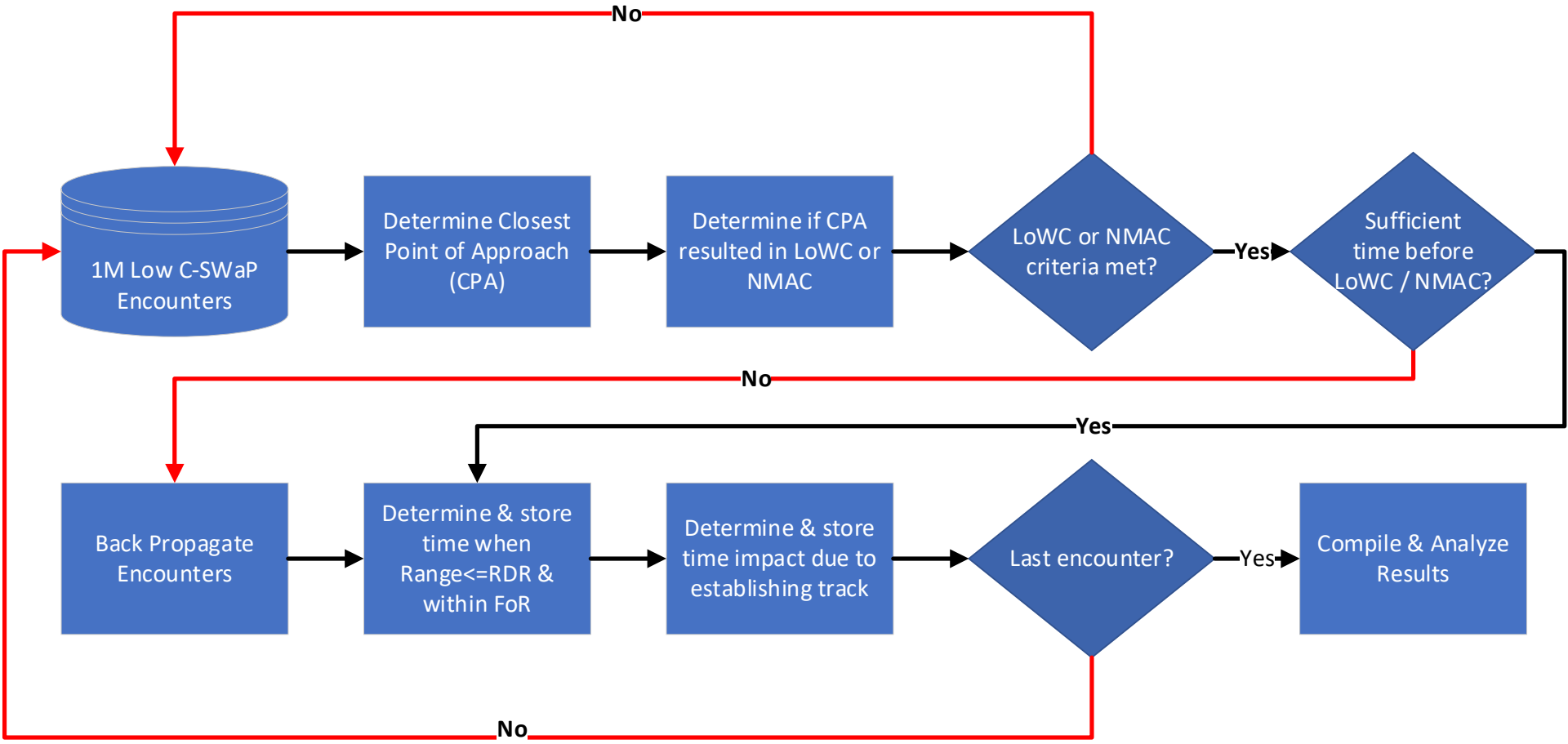


Figure C-2 **Capturing the FOR Entry Time Margin**

Taken from DO-366, Appendix C

Analysis Workflow: Appendix C



Appendix D Analysis

- Objective: Verify that radar declaration range (RDR), subject to the Field of Regard (FOR), provides enough Time Margin, from detection to loss of well clear (LoWC), for DAA alerting
  - Compare RDR Time Margin per encounter to Minimum Average Alert Times and Late Alert Thresholds
  - Compute Required RDR per encounter and compare statistics to candidate RDRs
- Time Margins resulting from various RDR candidates will be examined
- Statistics will be generated for different geometries and encounter categories

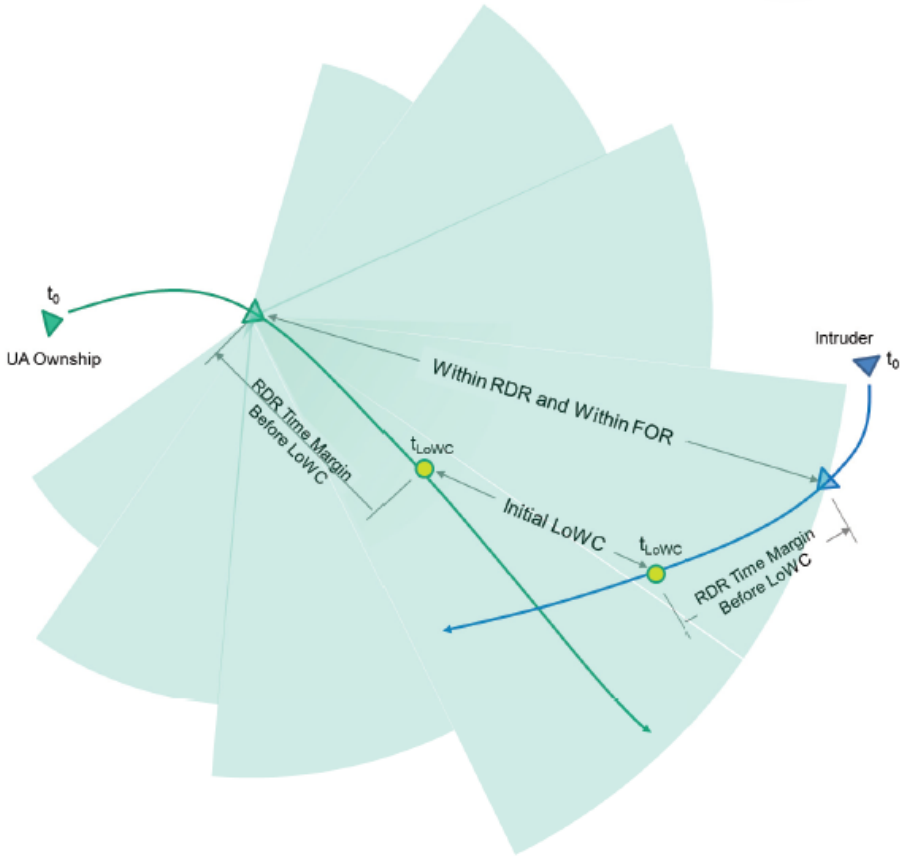
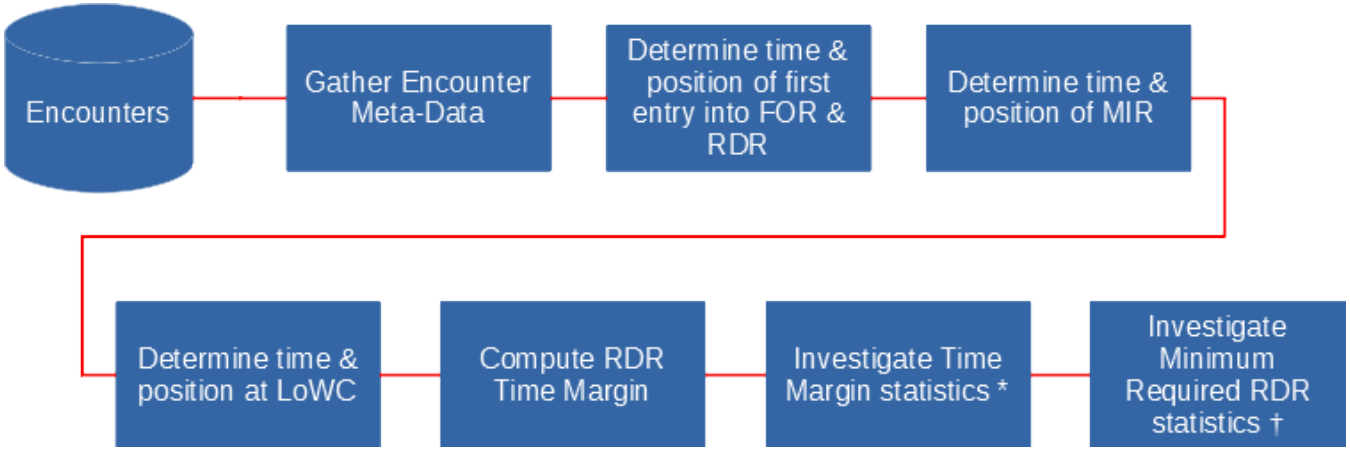


Figure D-1 RDR Time before LoWC against Corrective Alerting Requirements

Taken from DO-366, Appendix D

Analysis Workflow: Appendix D



- RDR Time Margin and Minimum Required RDR will be analyzed per encounter to generate statistics

* RDR Time Margin statistics will be compared to the time parameters from phase 1: **Minimum Average Alert Times** and **Late Alert Thresholds**.

† Minimum Required RDR statistics will be compared to current **RDR** candidates.

Schedule

Analyses of the Alerting Timeline with Low C-SWaP Sensors' Field of Regard	**4/15/2019**	**10/28/2019**
Coordination with SC-228	4/15/2019	6/15/2019
Development	4/30/2019	09/09/2019
Report Preparation	9/10/19	9/30/2019
[SP D.2.110] Delivery of Analyses results to SC-228	10/28/2019	10/28/2019

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Backup

Analysis Workflow: Appendix C

- For each encounter, determine if LoWC or NMAC occurred
- If sufficient time within the encounter does not exist, back propagate encounters
  - E.g. encounter starts within RDR/FoR
- Determine intruder times when:
  - First enter FoR
  - First enter RDR
  - First time when intruder is in FoR AND RDR
- Determine time impact due to track acquisition requirement
- Compile and analyze results to assess if intruder entered FoR within RDR
- Analysis
  - Micro analysis figures of challenging encounter geometries
  - Encounter distribution plots for time margin for entering FoR
  - Computed probabilities of intruder entering FoR within RDR for RDRs detailed above

Analysis Workflow: Appendix D

- The correlation of Time Margin and RDR to ownship / intruder speeds, and relative heading, will be investigated
- Time Margin will be computed for various RDR
- The percentage of targets detected vs. Time Margin will be computed
- Statistics will be computed from…
  - all encounters
  - non-accelerating encounters
  - accelerating encounters
  - turning encounters
  - vertically converging encounters
  - Intruder overtake encounters