

ANALYTICS

Aviation & Autonomous Systems Development



DO 365 Test Procedure Results and Analysis Discussion

Task 1: MOPS Test Procedures Robustness Analysis

CAL will leverage M&S tools and existing encounter data to evaluate the robustness of the DAA MOPS Test Procedures. Recently, the SC-147 ACAS-Xu team performed an analysis evaluating the Xu implementation against the DAA MOPS test procedures. Several areas of non-compliance were raised, some indicating shortfalls in our DAA test procedures and/or requirements. The ACAS-Xu team is expected to put out a report highlighting these exemptions. This work will build off that ACAS-Xu analysis/report and perform a full characterization of the statistical test procedures and document the findings. Additionally, CAL will provide recommendations for addressing these findings, potentially resulting in changes to test procedures and/or requirements.

Detailed Task Activities:

- Align system configuration with M&S group (Tracker, DAIDALUS versions, etc...)
- Prepare latest version of Test Vectors (Aligned with M&S group)
- Setup M&S Environment
- Perform data runs and analysis (iterative approach possible)
- Document results and findings

- Analysis Environment
- Tracking Analysis
- Alerting Results
 - Process
 - Truth Analysis
 - Sensor Analysis
 - Difficult Encounters
 - Test Procedure Discussion
 - Recommendations

- Environment
 - AFSIM with DAIDALUS 2.0.1
 - FAA Tracker Version 7.2 (TCAS results were re-executed with version 7.4)
 - ACAS Xu5 Tracker and Guidance
- Vector Sets
 - Test Vectors version 2.8 (LL181-270 revised to correct errors in v2.10)
 - Alerting:
 - Single Intruder, non-terminal vectors only
 - C, D, LL, H, S, M, O, P
 - Tracking Analysis: LL1-180 (omitted 181-270 due to significant tracking issues in v2.8)

Tracking Analysis

- Utilized truth test vectors and passed through CAL sensor models and subsequently through the FAA Tech Center Tracker and the Xu STM
- Evaluated the original 180 LL dynamic encounters
- Ran each set of 180 LL vectors 100 times, computing the r95 statistics for each set of 100 as a function of range.

Table 2-21 Single-Source Integrated Track Performance

Surveillance Sensor	Performance Metric	Metric Threshold (95%)
ADS-B	Horizontal Position	900'
	Vertical Position	300'
	Horizontal Velocity	30 kts
	Vertical Rate	400 fpm
Airborne Radar	Horizontal Position	$125 \cdot (x - 1 \text{ NM}) + 250'$ (1 NM, 6.7 NM)
	Vertical Position	$100 \cdot (x - 1 \text{ NM}) + 150'$ (1 NM, 6.7 NM)
	Horizontal Velocity	$10 \cdot (x - 1 \text{ NM}) + 50$ kts (1 NM, 6.7 NM)
	Vertical Rate	$380 \cdot (x - 1 \text{ NM}) + 800$ fpm (1 NM, 6.7 NM)
Active Surveillance	Horizontal Position	$1000 \cdot (x - 0.5 \text{ NM}) + 1250'$ (0.5 NM, 14 NM)
	Vertical Position	300'
	Horizontal Velocity	$33 \cdot (x - 0.5 \text{ NM}) + 85$ kts (0.5 NM, 14 NM)
	Vertical Rate	400 fpm
Ground Based Surveillance	Horizontal Position	650'
	Vertical Position	450'
	Horizontal Velocity	14 kts
	Vertical Rate	1100 fpm

Sensor Model Assumptions

Table Q-4 Ownship Navigation (NAV) Model Parameters

	State	Absolute Error (per AC) 1-sig	Bias	Time Correlation	Notes
NACp = 8	Horizontal Position	37.8m	0	300 sec	NACp = 92.6m (95%) / 2.45 = 37.8m
	Baro Altitude	0	Per TSAA model		ICAO 10 Annex Bias model. Quantization 1ft. Can apply the jitter if you models do not have aerodynamic "noise" turbulence/atmospheric effects. Pending information on whether this effect is implemented in encounter models.
NACv = 2	Horizontal Velocity	1.22m/s	0	300 sec	NACv = 2 (3 m/s 95% / 2.45 = 1.22) horizontal
	Vertical Velocity	1.707m/s (95%)			Per TSAA model. Laplacian distribution. 95_bound = 5.6ft/s Equivalent to 95% bound of 336ft/min, as determined empirically by analysis of installed Version 2 ADS-B avionics.
	Attitude	[0.2, 0.2, 0.4] degs			[Roll, Pitch, Yaw/Heading]. Note the heading error is with respect to true north. Per AHRS guidance. White Noise Model, no bias.

Table Q-3 Active Surveillance Model Parameters

State	Relative Error 1-sig	Bias	Quant	Notes
Range	15.24m (50 ft)	38.1m (125 ft)		250ft bias for Mode-C
Bearing	[-10, 10deg]: 9deg RMS, 27deg max [-15, -10] or [10, 20deg]: 15deg RMS, 45 deg max			Will assume RMS value = sigma in white noise model
Altitude	0	Per TSAA model	Quantization 25ft / 100 ft (Intruder) / 1ft (Ownship)	Can apply the jitter if you models do not have aerodynamic "noise" turbulence/atmospheric effects. Pending information on whether this effect is implemented.
State		Notes		
Update Rate	1 Hz / 0.2 Hz (Tau > 60)			
Detection Range (DR)	DR = < [20.6, 14.3, 8.0] NM (Mode C) DR = <15.6NM (Mode S)	Front: [0, +/-45deg], Side: [0, +/-45deg], Rear: [0, +/-45deg]		
Probability of Detection (PD)	PD: 0.90 (Mode C) PD: 0.95 (Mode S)	Per 1 second epoch		
Field of Regard (FOR)	360 deg Azimuth [-15, +20 deg] Elevation Angle			

Table Q-1 ADS-B Model Parameters

	State	Absolute Error (per AC) 1-sig	Bias	Time Correlation	Notes
NACp = 7	Horizontal Position	75.6m	0	300 sec	NACp = 185.2m (95%) / 2.45 = 75.6m
	Baro Altitude	0	Per TSAA model		ICAO 10 Annex Bias model used in Traffic Situation Awareness with Alerts (TSAA). Quantization 25ft / 100 ft. Can apply the jitter if you models do not have aerodynamic "noise" turbulence/atmospheric effects. Pending information on whether this effect is implemented in encounter models.
NACv = 2	Horizontal Velocity	1.22m/s	0	300 sec	NACv = 2 (3 m/s 95% / 2.45 = 1.22) horizontal
	Vertical Velocity	1.707m/s (95%)			Per TSAA model. Laplacian distribution. 95_bound = 5.6ft/s Equivalent to 95% bound of 336ft/min, as determined empirically by analysis of installed Version 2 ADS-B avionics.
State		Notes			
Update Rate	dt = 1 second				
Latency Effects (Uncompensated)	<.4sec	Bias transport delay with uniform distribution up to 400msec. This does not address the ADS-R latency effects/contributions.			
Detection Range	DR = <20NM	Will be based on Active Surveillance DR. This is due to validation requirement for ADS-B. Per SC228 meeting 14Dec2015, where it was decided we can use ADS-B w/o validation, but there is a cross-over point at which point would be required.			
Probability of Reception / Detection	PD: 0.95	Over any 3secs <= 10NM (Based on the reception of both a position and velocity) Over any 7secs > 10NM			

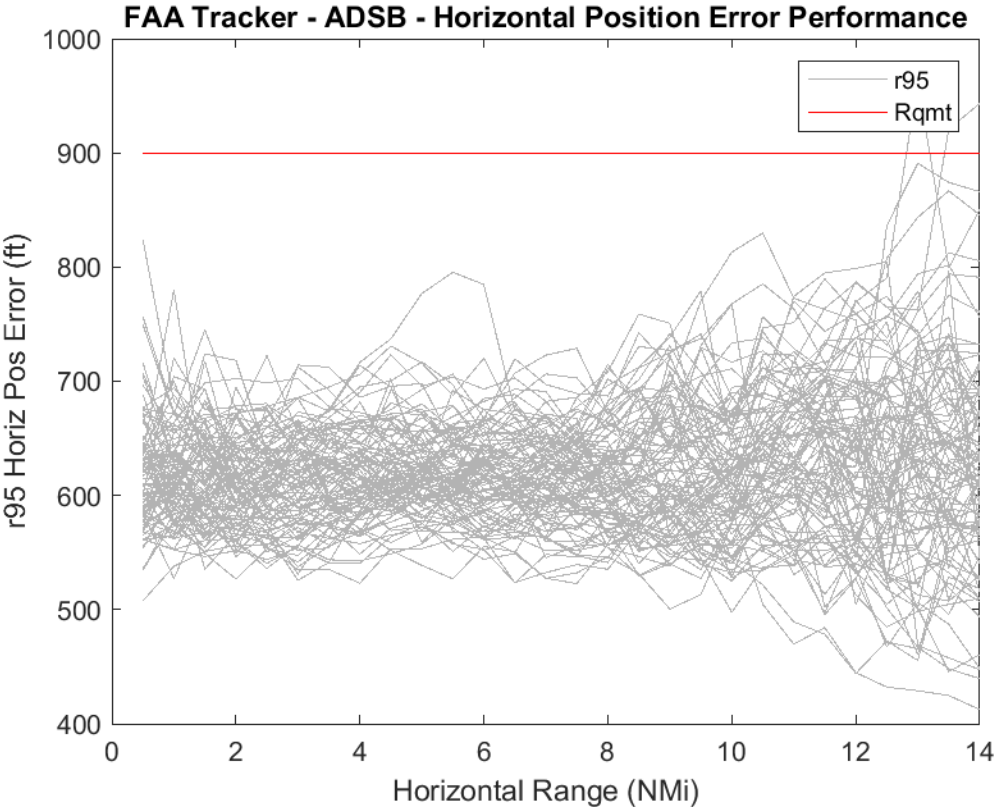
Table Q-2 ATAR Model Parameters

State	Relative Error 1-sig	Bias	Notes
Range	21.34m (70 ft)	15.24m (50 ft)	White noise model, with bias drawn from a +/- bias uniform distribution for each encounter.
Range Rate	3.0m/s (10ft/sec)	2.4m/s (8ft/sec)	White noise model, with bias drawn from a +/- bias uniform distribution for each encounter.
Angle (Az/EL)	1 deg	0.5 deg	White noise model, with bias drawn from a +/- bias uniform distribution for each encounter.

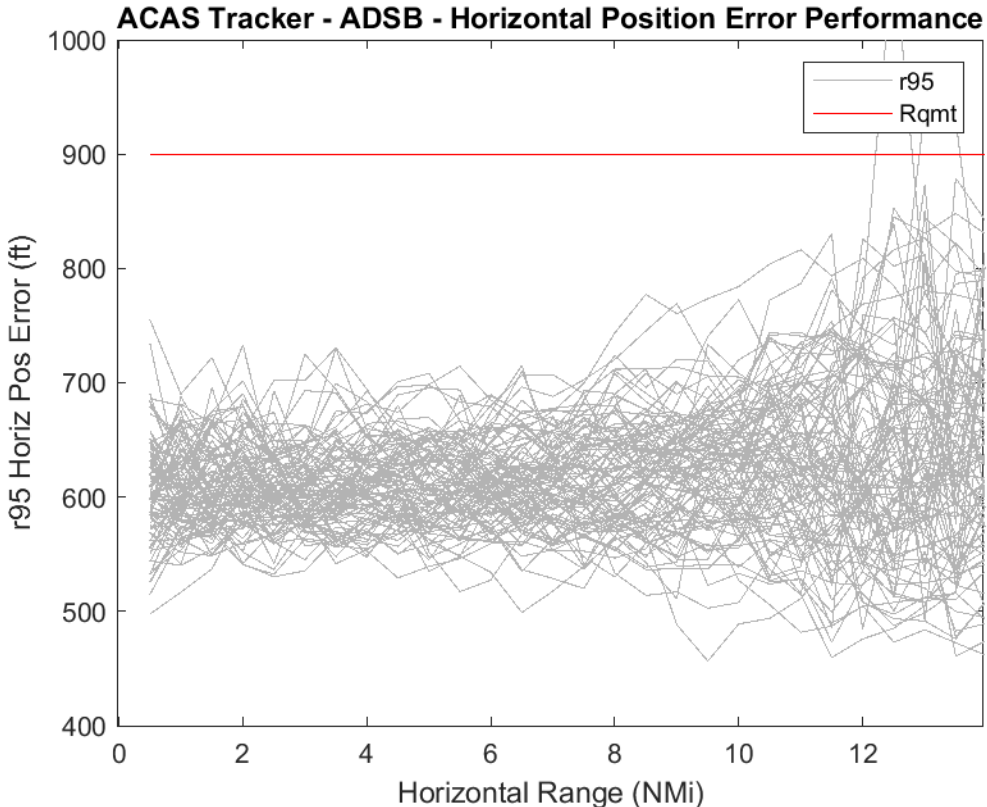
	State	Notes
Update Rate	dt = 1 second	
Tracking Range / Detection Range (DR)	DR = 5.4NM (<100kts intruder) DR = 6.0NM (100-130kts intruder) DR = 6.7NM (>130kts intruder) DR Scale Factor Az: [0 30], 1.0, 1.0, 1.0 Az: [30,60], 0.67, 0.78, 0.84 Az: [60, 90], 0.45, 0.52, 0.6 Az: [90, 110], 0.35, 0.43, 0.55	Assumption is intruder size is loosely correlated to speed, hence DR is determined by max speed in across the entire encounter. For additional detail, see the Radar MOPS. Once the track is established, do not perform the scale factor correction. DR scale factors should be linearly interpolated between levels, where the max value in each bin is given.
Field of Regard (FOR)	+/-15 Elevation (Stabilized w/ respect to velocity vector) +/-110 Azimuth	
Probability of Track	Pr(Track) = 1	Will assume perfect detection when inside the DR and FOR

ADS-B Tracking Performance

FAA Tracker

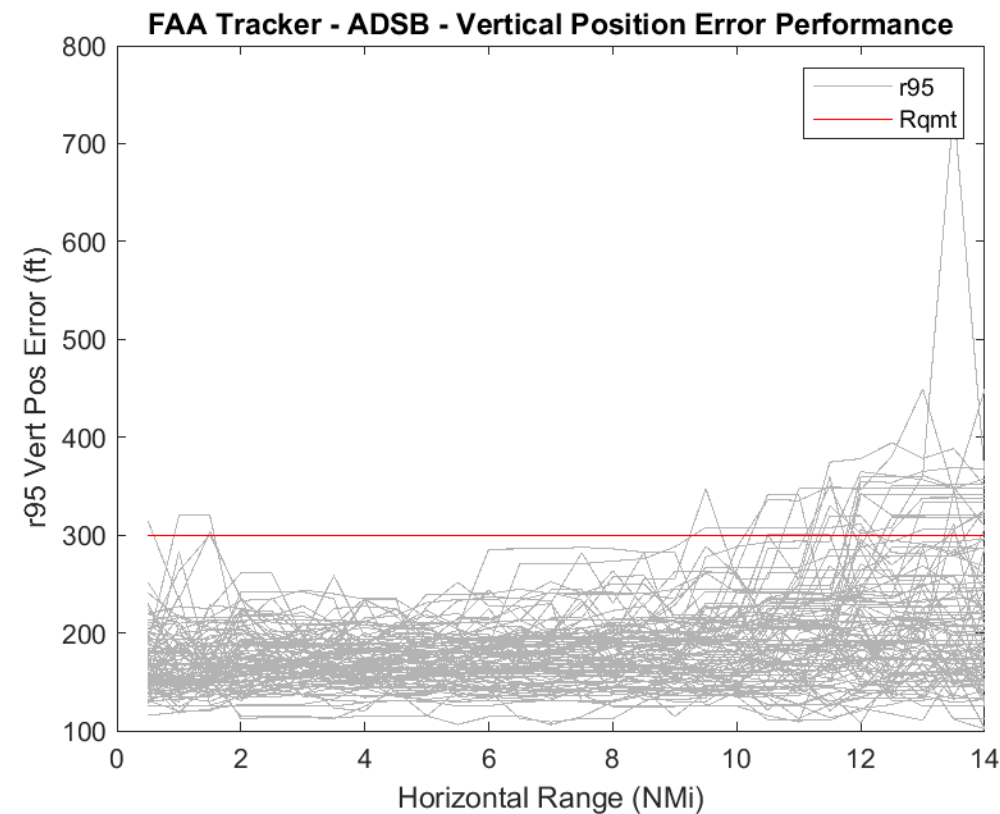


ACAS-Xu Tracker

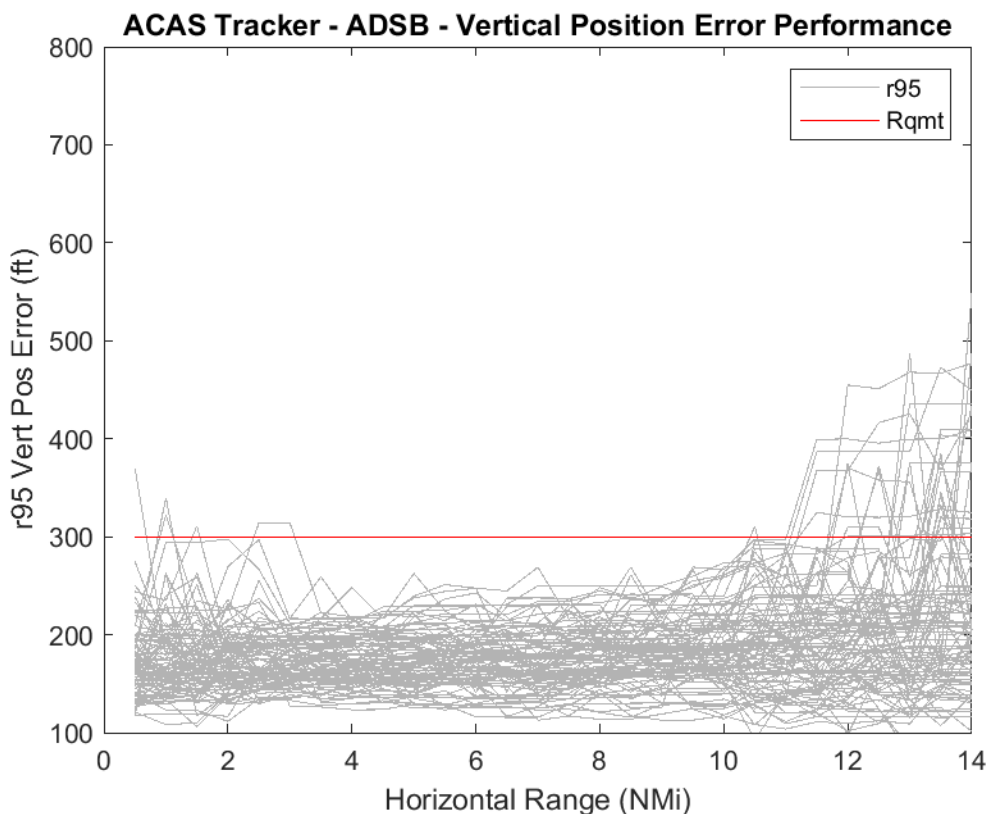


ADS-B Tracking Performance

FAA Tracker

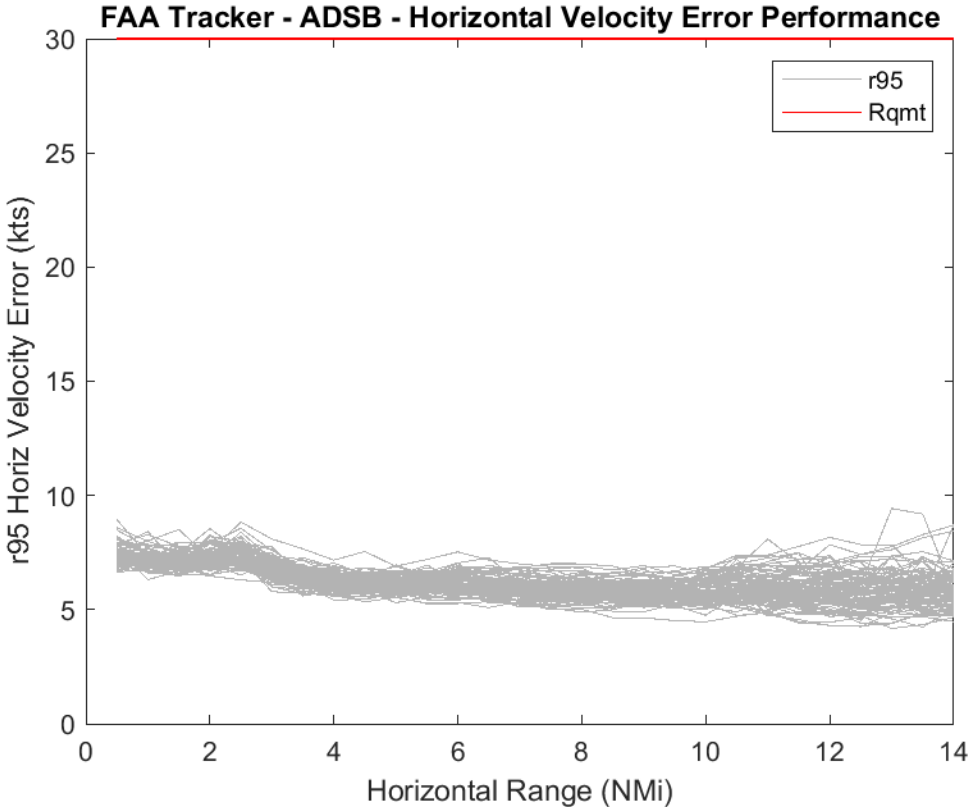


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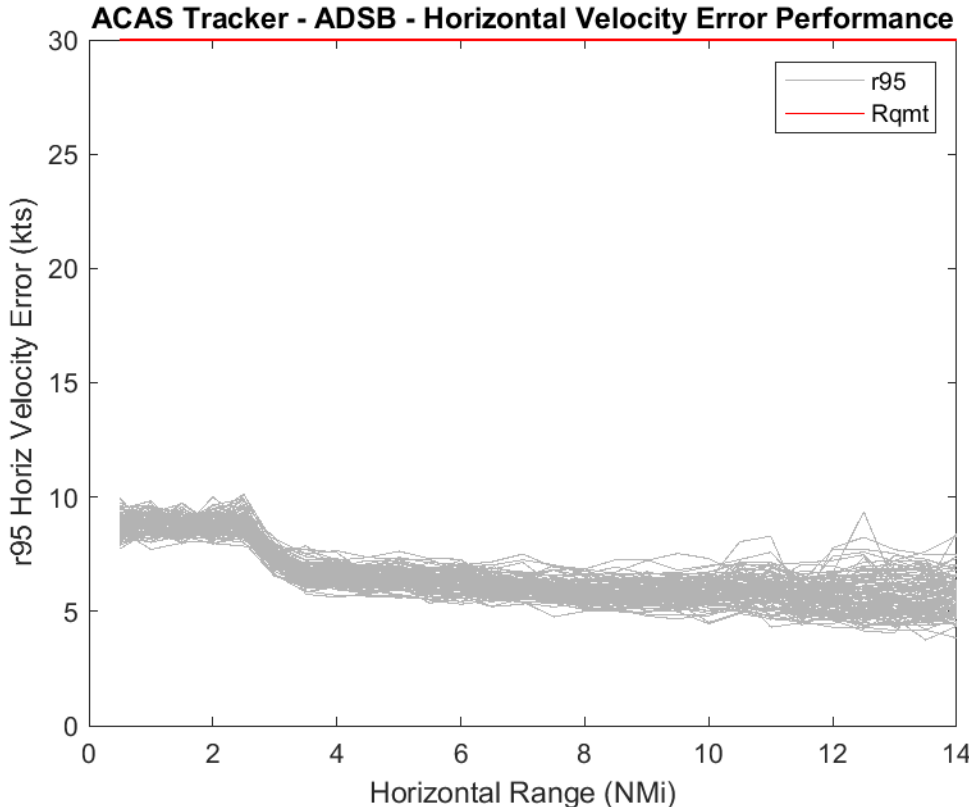


ADS-B Tracking Performance

FAA Tracker

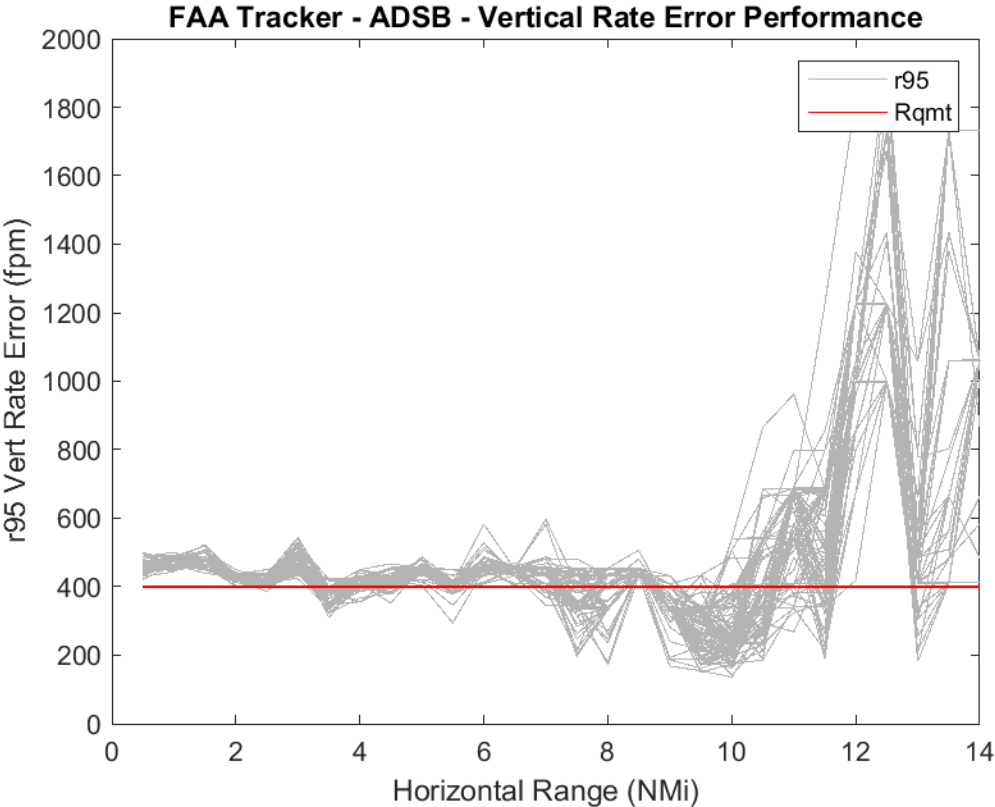


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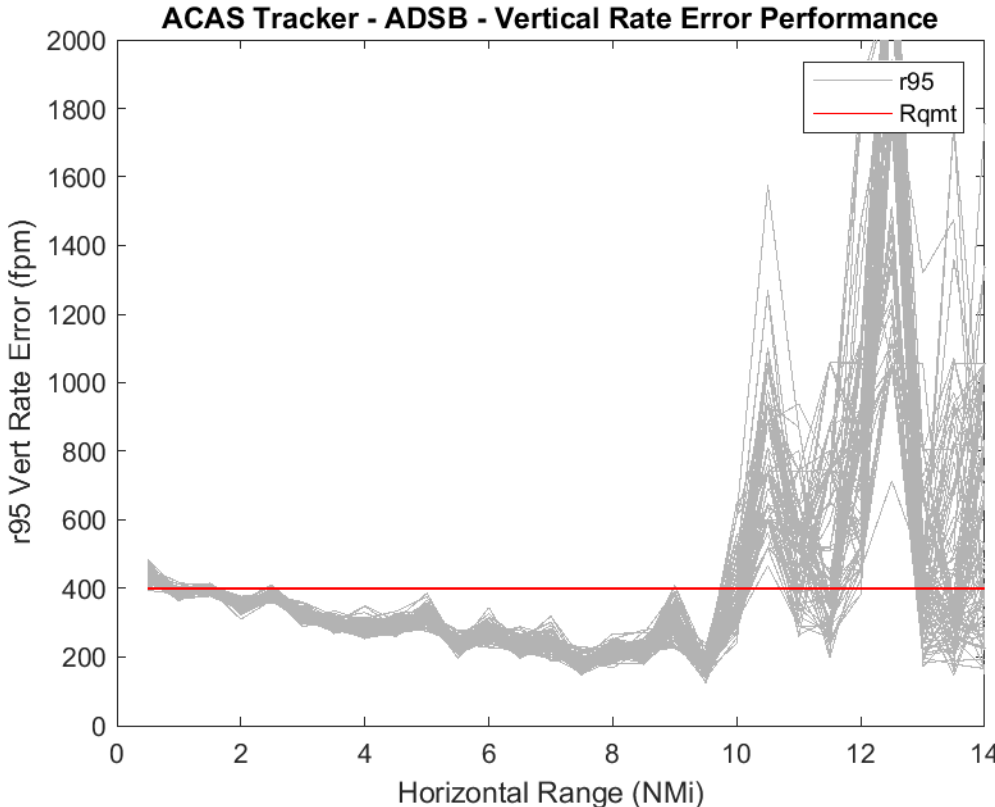


ADS-B Tracking Performance

FAA Tracker

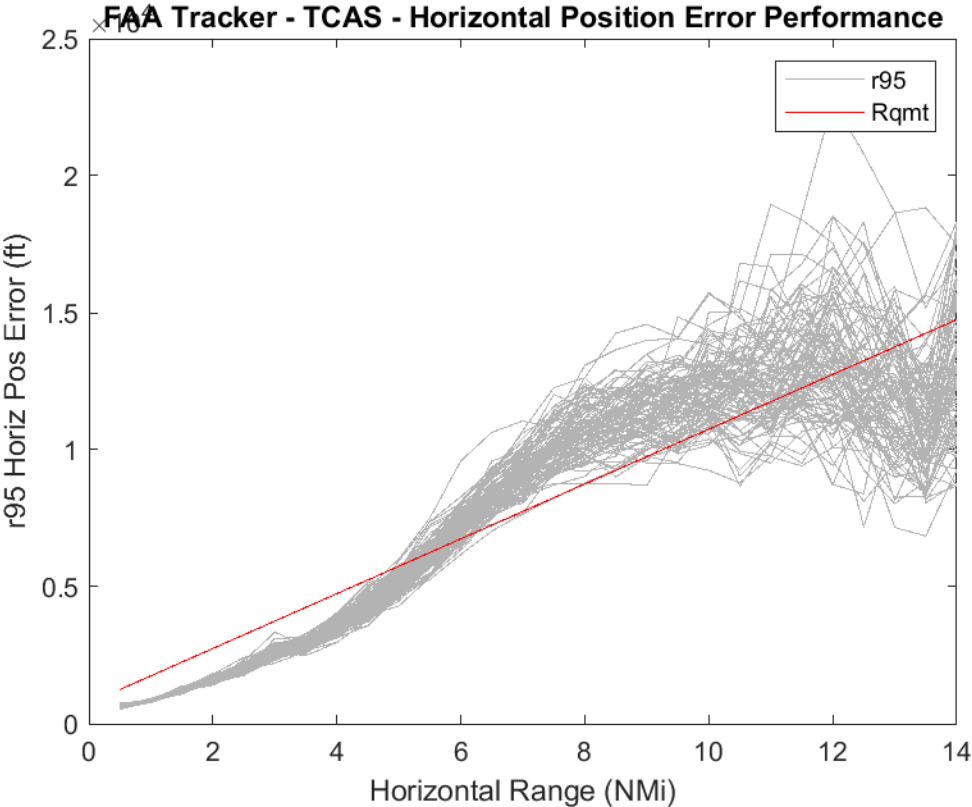


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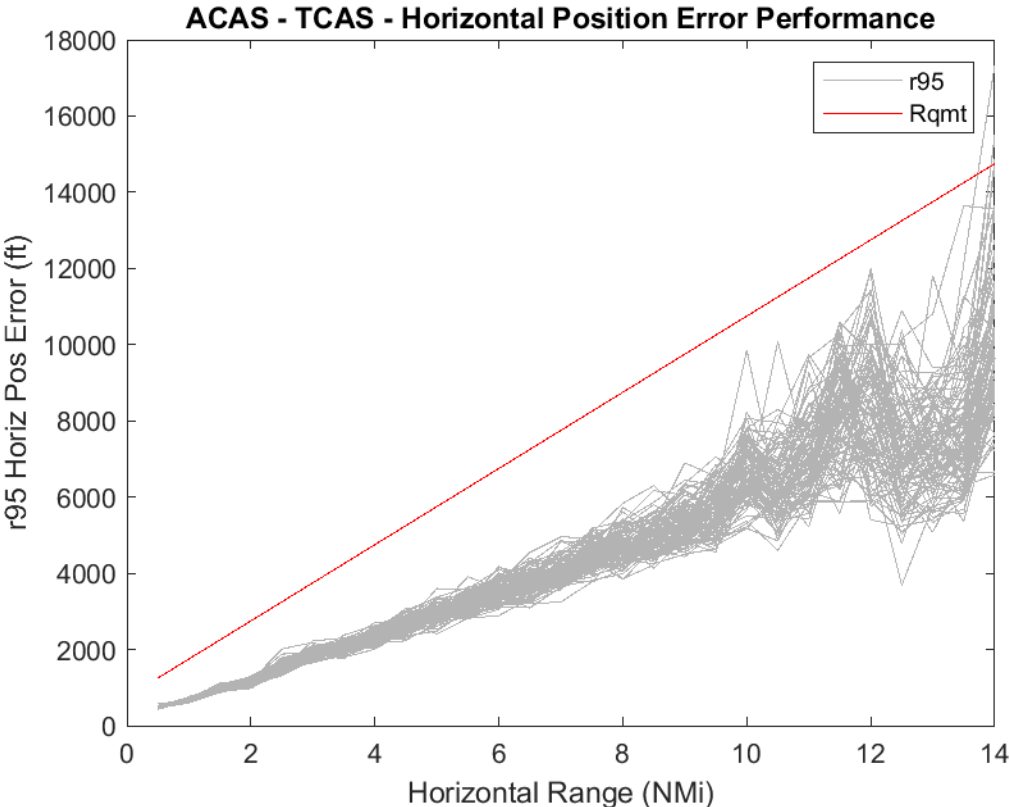


AST/TCAS Tracking Performance

FAA Tracker

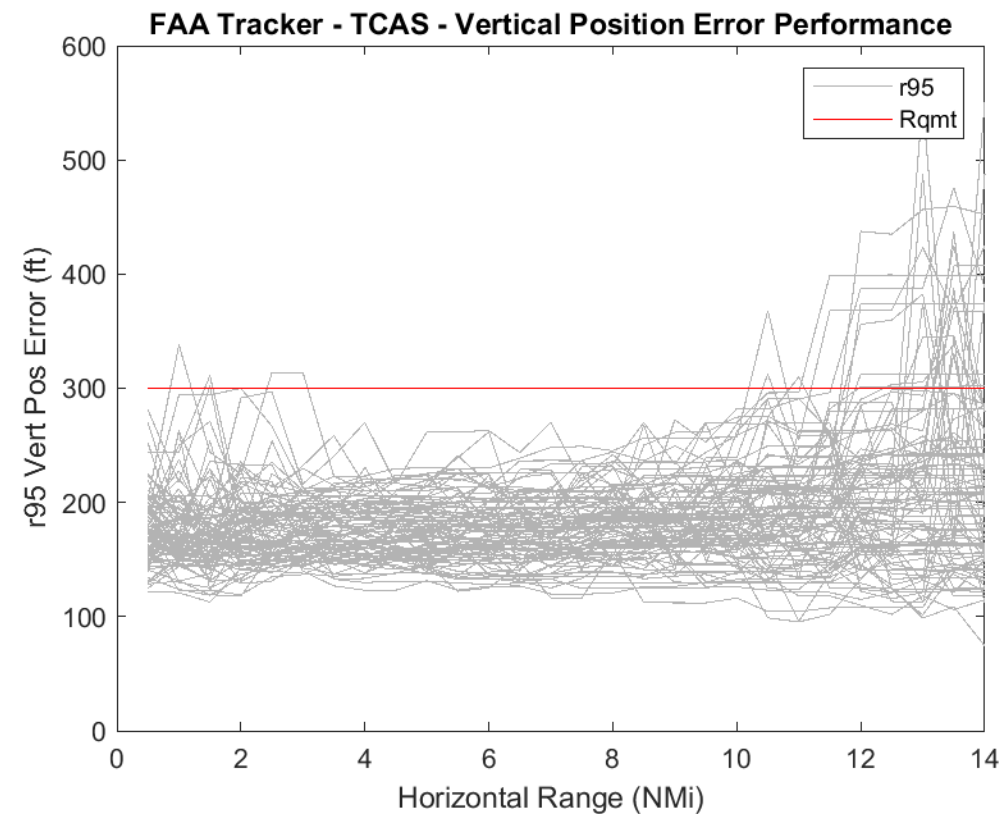


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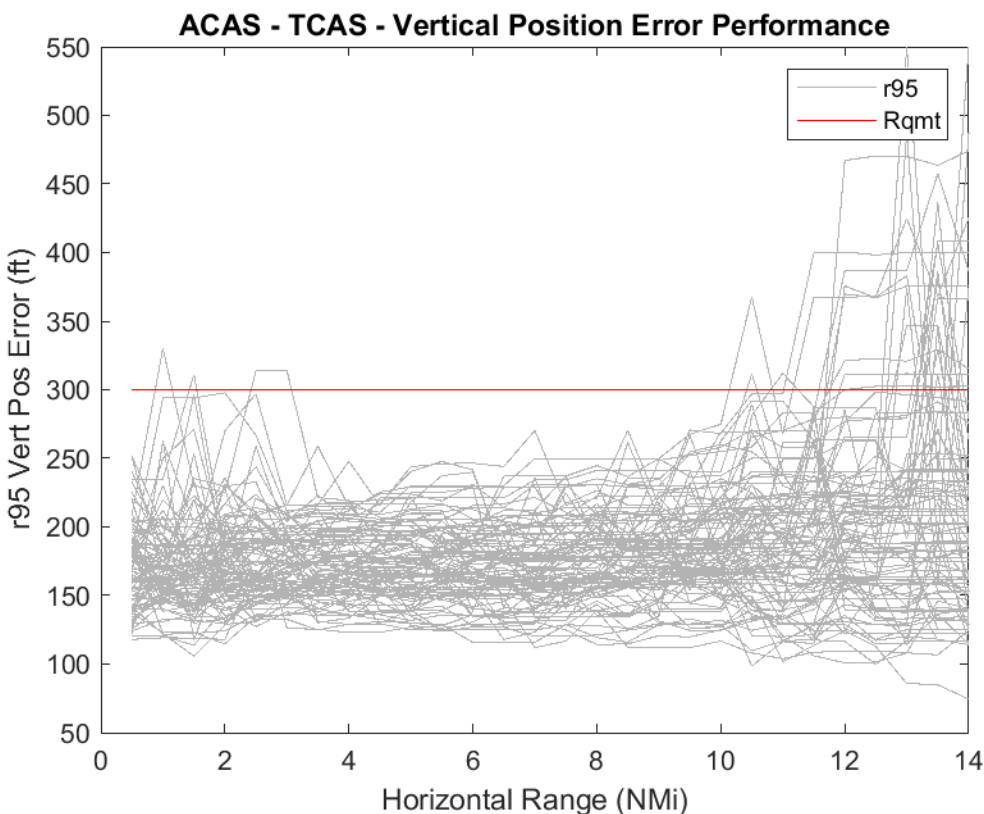


AST/TCAS Tracking Performance

FAA Tracker

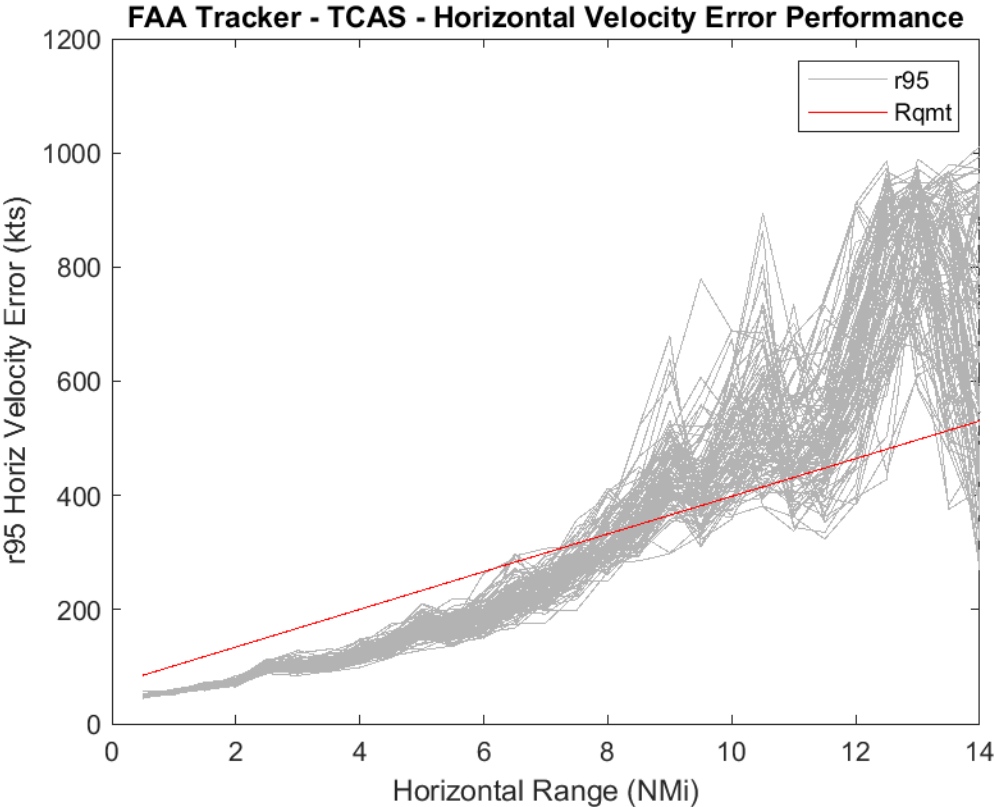


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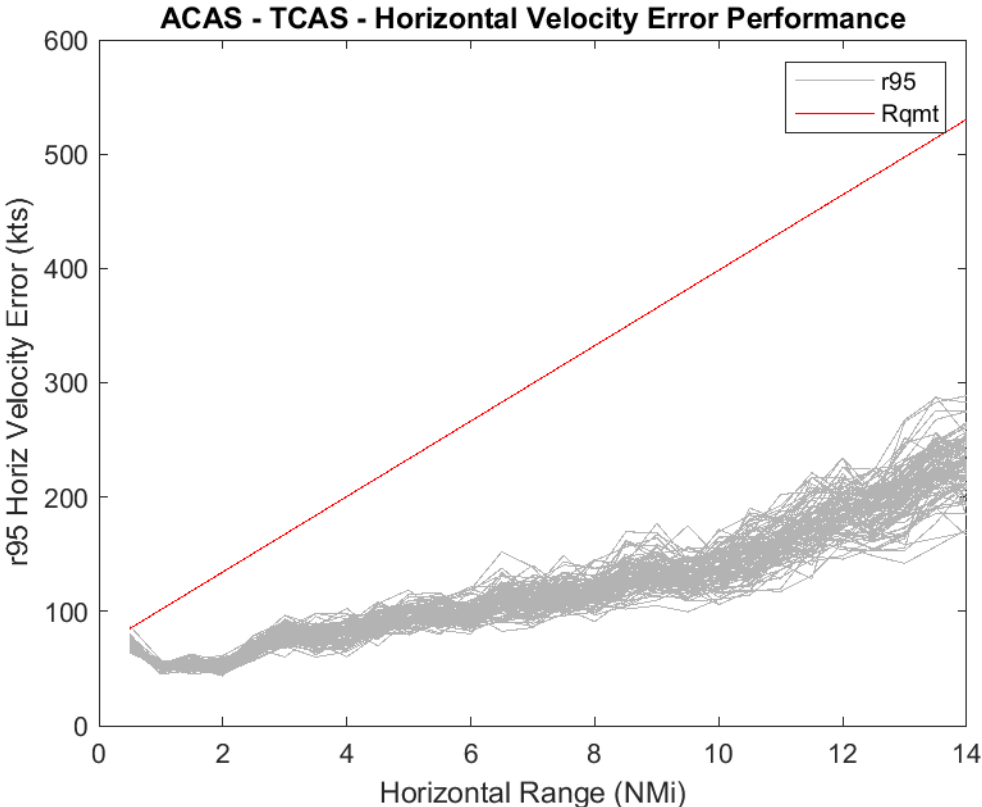


AST/TCAS Tracking Performance

FAA Tracker

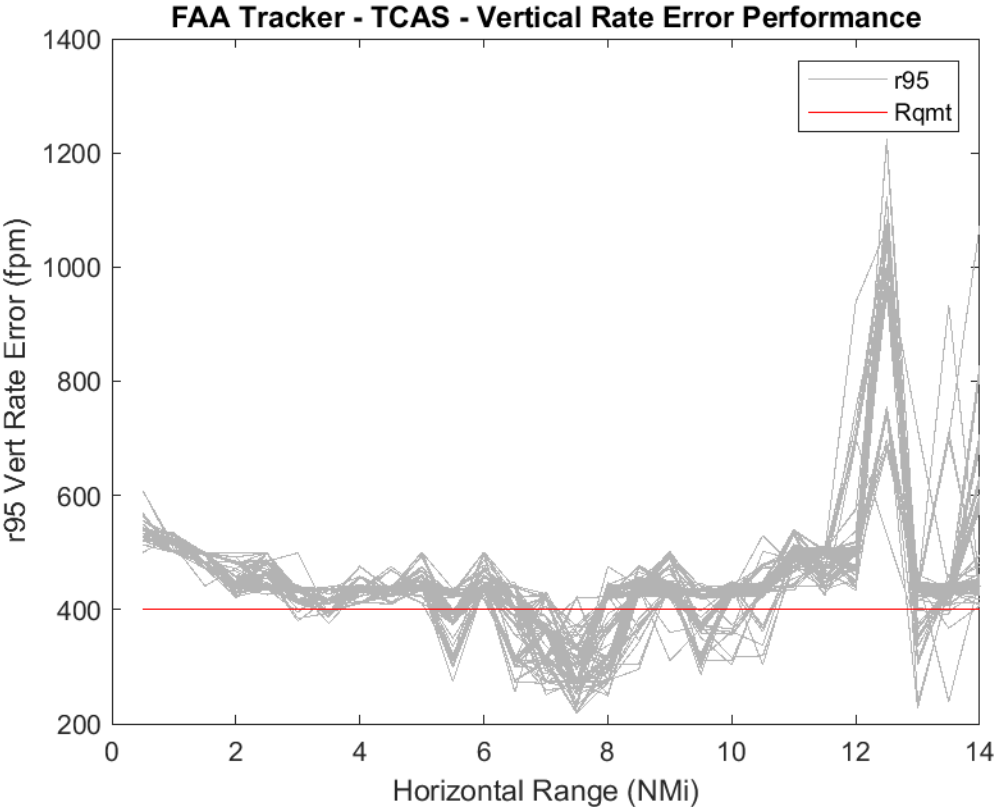


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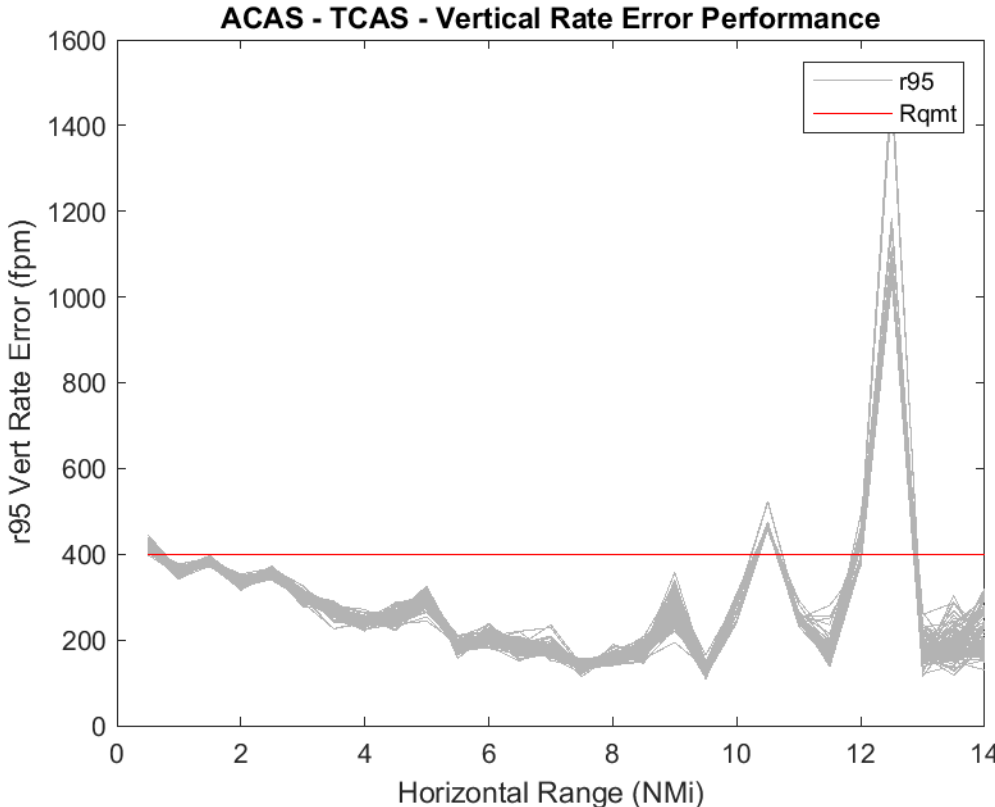


AST/TCAS Tracking Performance

FAA Tracker

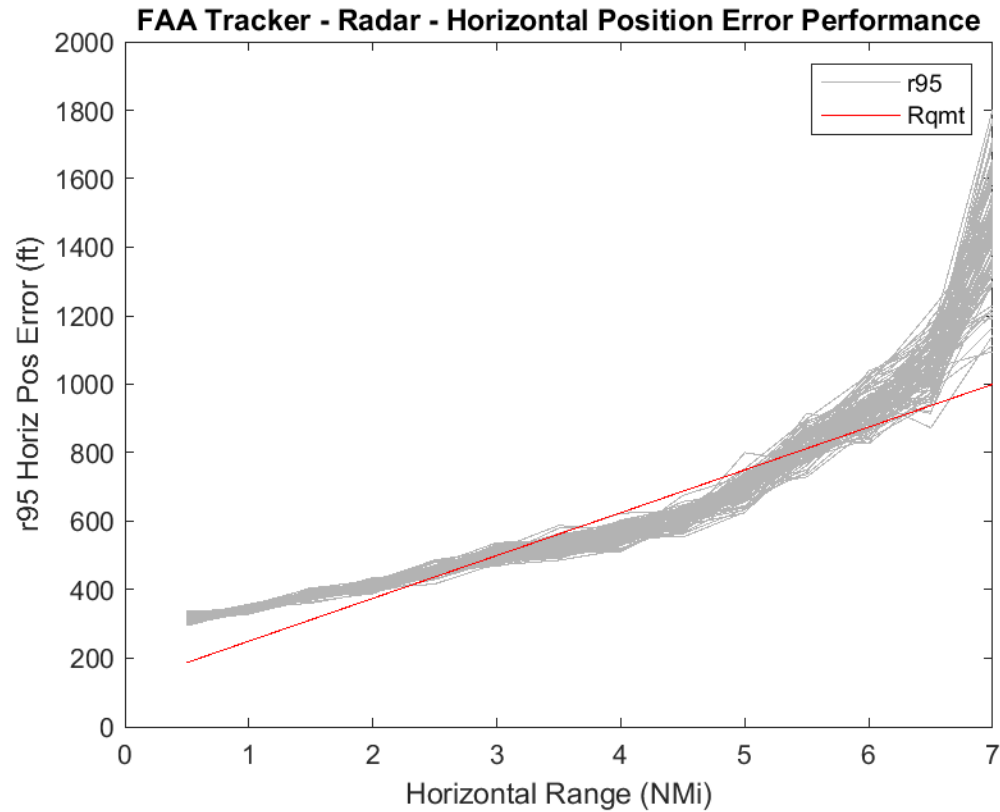


ACAS-Xu Tracker

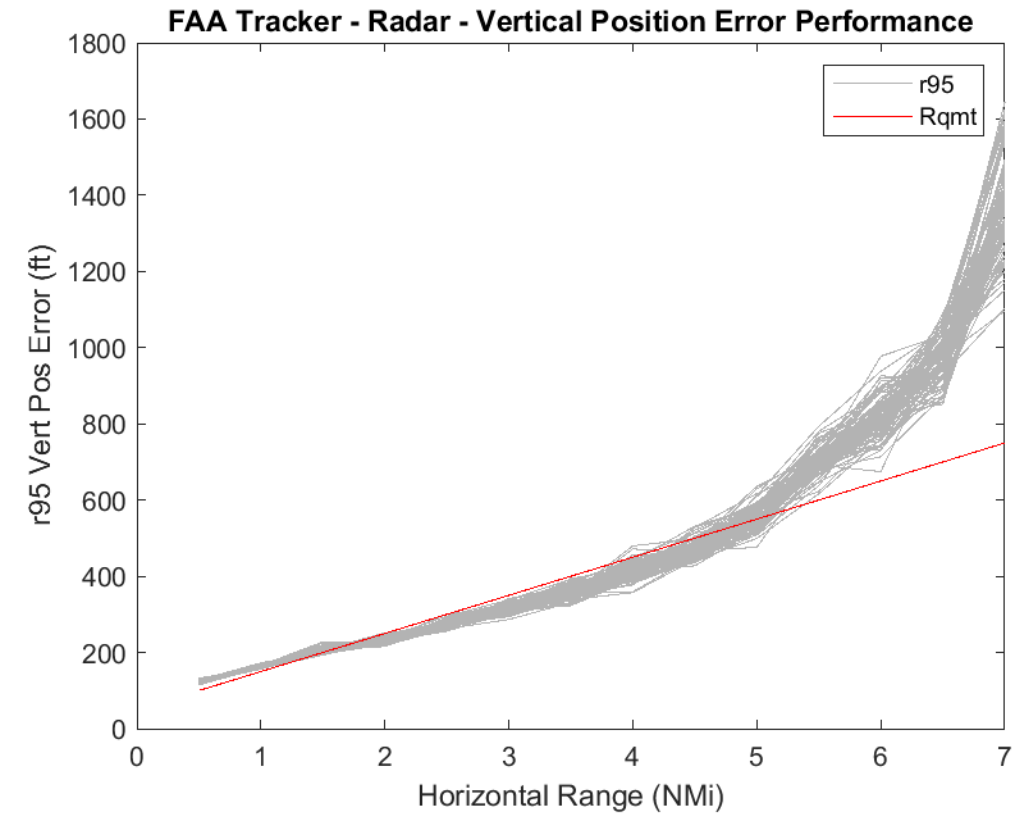


Radar Tracking Performance

FAA Tracker

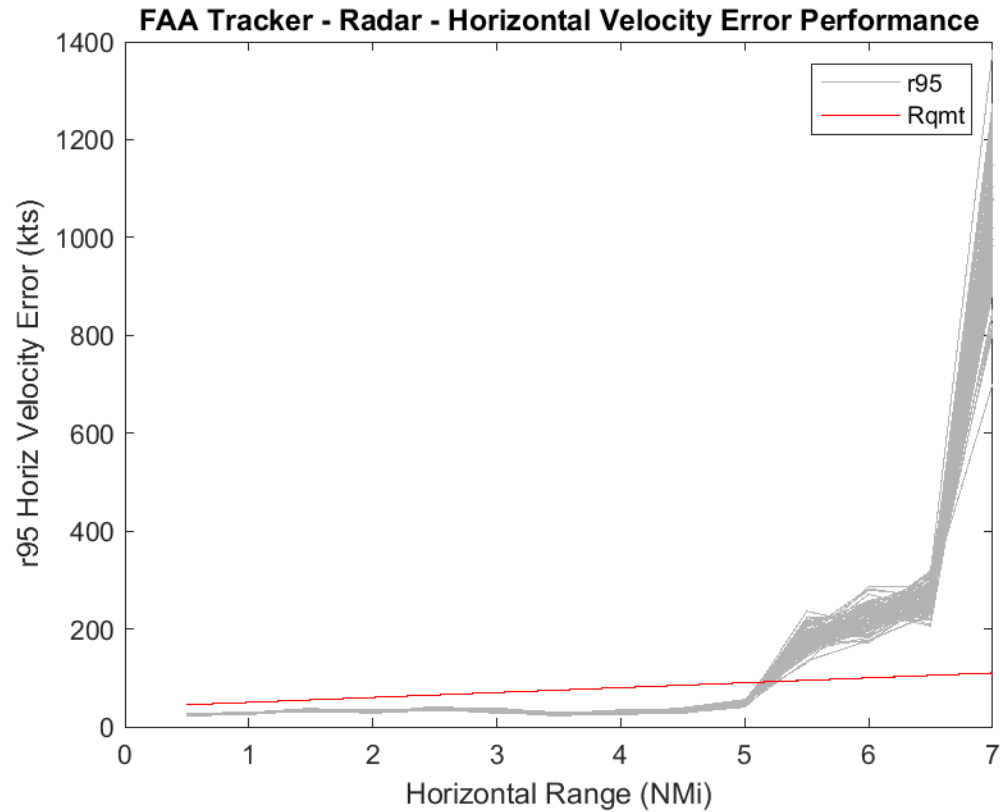


FAA Tracker

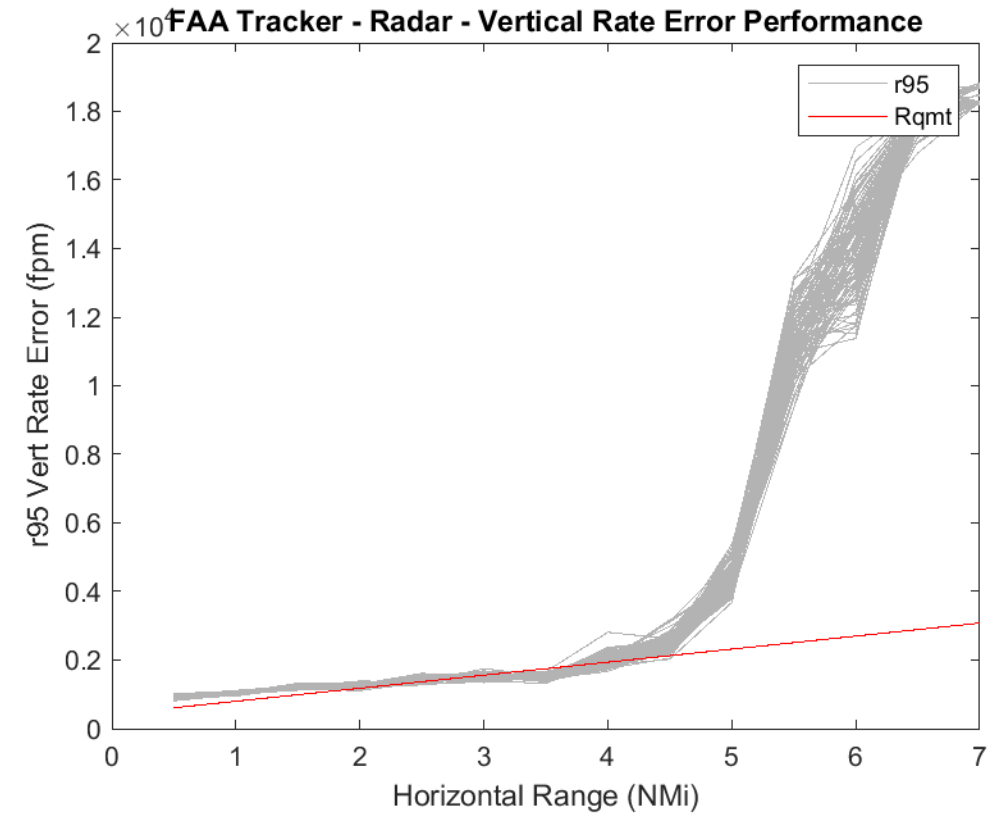


Radar Tracking Performance

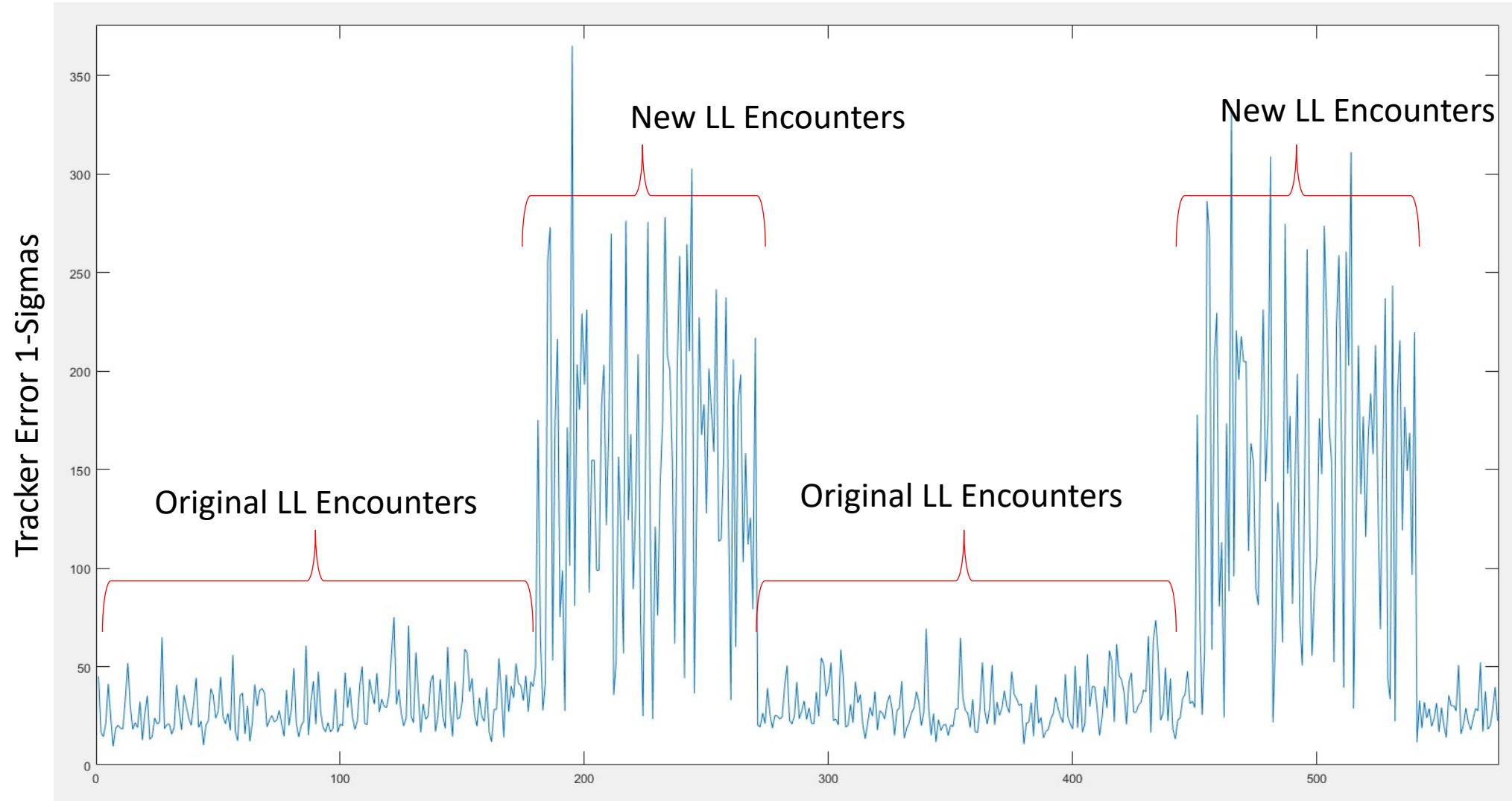
FAA Tracker



FAA Tracker



Test Vector Issue – Potentially Fixed



Alerting Analysis

Summary

- Executed each encounter with different error seeds 100 times per surveillance type
- Executed alerting analysis:
 - Direct comparison to ECF files (only executed on FAA STM tracker)
 - In accordance with appendix L
- Reviewed results against test procedures, identified “high failure” cases, cases with failures but acceptable due to 10% error threshold, and “compliant” cases

ECF File Description

Time (s)	HAZ	NHZ	Min Alert	Max Alert
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0

- Compared alerting output against min/max alerts, Omitted “extended” alerts where alerts were issued/extended outside of HAZ IAW Appendix P.3.8 paragraph 5 note.

Note: *There are no requirements for when an alert must end. For the encounter characterization files, the earliest an alert must end is at CPA; the minimum required alert will reset at this time. The maximum allowed alert level will turn off upon HAZ exit. Note that violation of this aspect of the encounter characterization files is not in direct violation of the requirements, and may be deemed acceptable.*

- Analysis was performed on truth to determine the integrity and usability of the DAA MOPS provided test package as well as confirm parameters used for surveillance analysis
- Truth analysis was performed 2 ways
 - 1) Utilizing the CAL batch analysis test suite (conforming to DAA MOPS Appendix L metrics)
 - 2) Utilizing the encounter characterization file comparison to determine if the output matched the expected performance detailed in the files

Truth Analysis – CAL Suite

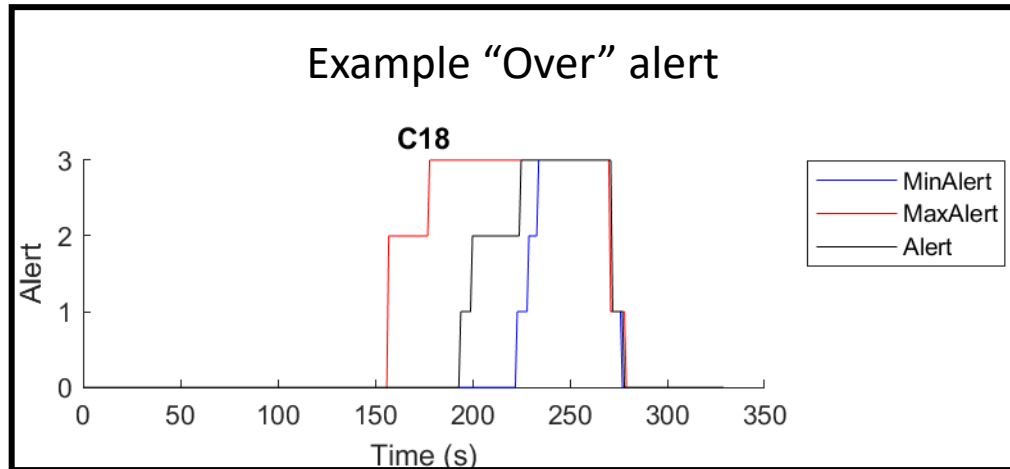
	Truth		
	P	C	W
Total Encounters	43500	43500	43500
Total Compliant	37600	38400	38600
Prob. Conformance	86%	88%	89%
Correct Alert	25100	24500	24700
Missed Alert	0	0	0
Late Alert	3300	3000	2600
Short Alert	2400	1900	2200
Early Required Alert	0	0	0
Prob. Missed Alert	0.00	0.00	0.00
Prob. Late Alert	10.65	10.14	8.78
Prob. Short Alert	7.74	6.42	7.43
Prob. Early Req. Alert	0.00	0.00	0.00
Prob. Correct Req. Alert	81.61	83.45	83.78
Average Alert Time Before HAZ	34.84	36.15	18.96
Alerting Ratio	0.99	0.99	1.00
Permissible Alert	200	600	400
Permissible Non-Alert	1900	1800	1200
Early Permissible Alert	0	0	0
Prob. Perm. Non-Alert	0.90	0.75	0.75
Prob. Early Perm Alert	0.00	0.00	0.00
Prob. Perm Alert	0.10	0.25	0.25
ANA	1.02	1.08	1.03
Correct Non-Alert	10400	11500	12300
Incorrect Alert	0	0	0
Prob. Correct Non-Alert	1.00	1.00	1.00
Prob Incorrect Alert	0.00	0.00	0.00

- Truth analysis revealed 44 non-compliant test vectors (listed here)
- These results were used as a baseline when determining the effectiveness of the surveillance tracking and alerting

	Truth		
	Preventive	Corrective	Warning
Persistence: P/C/W alerts persist for at least 4 seconds	31000/31000	30000/30000	29900/29900
Late Alert: P/C/W alerts are issued according to the late alert requirement	27700/31000	26600/29600	27000/29600
Average Alert Time: On average alerts are issued 55 seconds prior to the intruder violating the hazard zone (LL only).	31.6329	33.401	17.7624
Early Alert: P/C/W alerts are issued according to the early alert requirement	31000/31000	29600/29600	29600/29600
Must Not Alert: For all non-alerted test vectors, verify that no P/C/W alerts are issued	10400/10400	11500/11500	12300/12300
Must Alert: For all alerted test vectors verify that P/C/W alerts are issued	30800/31000	29400/29600	29500/29600
Total Test Procedure Failures:	5900/43500	5100/43500	4900/43500

Encounter	
LL122	LL220
LL127	LL32
LL132	LL41
LL133	LL46
LL138	LL52
LL16	LL53
LL171	LL61
LL180	LL7
LL184	LL79
LL187	LL83
LL2	LL89
LL204	LL9
LL205	LL92
LL207	LL99
LL208	M16
LL209	M8
LL212	P10
LL213	P13
LL214	P8
LL216	LL102
LL218	LL103
LL219	LL109

- ECF comparison of truth data revealed 102 non-compliant test vectors
- 43/44 appendix L non-compliant vectors also failed the ECF comparison, P13 was compliant with the ECF comparison
- Delta, non-compliant vectors:



Enc	Issue	Enc	Issue	Enc	Issue	Enc	Issue
C18	Over	LL55	Over	LL18	Over	M24	Over
LL126	Over	LL56	Over	LL181	Over	C8	Over
LL129	Over	LL58	Over	LL183	Late	O16	Over
LL130	Late	LL59	Over	LL197	Late	D1	Over
LL135	Late	LL6	Over	LL210	Over	C13	Over
LL141	Over	LL63	Over	LL217	Late	C14	Over
LL145	Over	LL64	Over	C3	Over	LL104	Late
LL147	Late	LL66	Over	LL25	Over	LL106	Over
LL151	Over	LL70	Over	LL29	Over	LL108	Over
LL159	Over	LL71	Over	LL30	Over	LL11	Over
LL162	Over	LL73	Over	LL40	Over	LL114	Over
LL166	Over	LL77	Over	LL44	Over		
LL167	Over	LL8	Over	LL48	Over		
LL17	Over	C4	Over	LL49	Over		
LL172	Over	LL84	Over	LL50	Over		
LL178	Late	LL95	Over	LL54	Over		

Surveillance Analysis FAA STM – CAL Suite

	Batch								
	STM Tracker								
	ADSB			TCAS			RADAR		
	P	C	W	P	C	W	P	C	W
Total Encounters	43500	43500	43500	43500	43500	43500	21200	21200	21200
Total Compliant	37192	37400	37117	30426	31716	31174	16619	16872	16953
Prob. Conformance	85%	86%	85%	70%	73%	72%	78%	80%	80%
Correct Alert	24925	23756	23415	19041	18736	17956	6043	5328	5246
Missed Alert	233	787	911	236	625	726	271	37	53
Late Alert	3280	2892	3003	5277	4929	6964	1333	776	1020
Short Alert	2398	2021	2137	6066	5016	3850	928	1074	944
Early Required Alert	0	2	0	336	250	60	40	29	4
Prob. Missed Alert	0.75	2.66	3.08	0.76	2.11	2.45	3.11	0.51	0.73
Prob. Late Alert	10.58	9.77	10.15	17.02	16.65	23.53	15.32	10.63	13.97
Prob. Short Alert	7.74	6.83	7.22	19.57	16.95	13.01	10.67	14.71	12.93
Prob. Early Req. Alert	0.00	0.01	0.00	1.08	0.84	0.20	0.46	0.40	0.05
Prob. Correct Req. Alert	80.93	80.74	79.56	61.56	63.45	60.81	70.44	73.75	72.32
Average Alert Time Before HAZ	34.94	36.17	18.76	34.77	34.50	16.59	33.21	37.28	21.62
Alerting Ratio	0.99	0.97	0.96	0.99	0.98	0.97	0.96	0.99	0.99
Permissible Alert	381	696	404	919	1300	775	748	1154	865
Permissible Non-Alert	1719	1704	1196	924	852	693	1256	1186	733
Early Permissible Alert	0	0	0	257	248	132	96	60	2
Prob. Perm. Non-Alert	0.82	0.71	0.75	0.44	0.36	0.43	0.60	0.49	0.46
Prob. Early Perm Alert	0.00	0.00	0.00	0.12	0.10	0.08	0.05	0.03	0.00
Prob. Perm Alert	0.18	0.29	0.25	0.44	0.54	0.48	0.36	0.48	0.54
ANA	1.08	1.13	1.06	1.86	1.81	1.39	1.97	2.28	1.73
Correct Non-Alert	10167	11244	12102	9285	10580	11618	8476	9144	10107
Incorrect Alert	233	256	198	1115	920	682	1924	2356	2193
Prob. Correct Non-Alert	0.98	0.98	0.98	0.89	0.92	0.94	0.82	0.80	0.82
Prob Incorrect Alert	0.02	0.02	0.02	0.11	0.08	0.06	0.19	0.20	0.18

Discussion

- Probability of correct, permissible and correct non alerts:
 - ADSB: 85%
 - TCAS: 72%
 - RADAR: 79%
- Significant late and short alerts across the board

Surveillance Analysis FAA STM – CAL Suite

- Average Alert Time anomaly – calculated for all LL vectors
- Executed separate analysis against LL encounters identified in the information file for average analysis and received similar AAT results

FAA STM									
	ADSB			TCAS			Radar		
	Preventive	Corrective	Warning	Preventive	Corrective	Warning	Preventive	Corrective	Warning
Persistence: P/C/W alerts persist for at least 4 seconds	31450/31450	30410/30410	30068/30068	33247/33247	32024/32024	31145/31145	11383/11383	10814/10814	10327/10327
Late Alert: P/C/W alerts are issued according to the late alert requirement	27720/31000	26708/29600	26597/29600	25723/31000	24671/29600	22636/29600	7367/8700	6524/7300	6280/7300
Average Alert Time: On average alerts are issued 55 seconds prior to the intruder violating the hazard zone (LL only).	32.0195	33.9616	17.7235	36.5252	35.7037	16.3119	31.9862	36.2101	21.4893
Early Alert: P/C/W alerts are issued according to the early alert requirement	31000/31000	29598/29600	29600/29600	30664/31000	29350/29600	29540/29600	8660/8700	7271/7300	7296/7300
Must Not Alert: For all non-alerted test vectors, verify that no P/C/W alerts are issued	10167/10400	11244/11500	12102/12300	9285/10400	10580/11500	11618/12300	8476/10400	9144/11500	10107/12300
Must Alert: For all alerted test vectors verify that P/C/W alerts are issued	30603/31000	28671/29600	28555/29600	30720/31000	28931/29600	28830/29600	8344/8700	7207/7300	7214/7300
Total Test Procedure Failures:	6308/43500	6100/43500	6383/43500	13074/43500	11784/43500	12326/43500	4581/21200	4328/21200	4247/21200

- ADSB: 57%
 - 276/435 total non-compliant
 - 187 with > 10% failure rate, 164 not “new” LL vectors
- TCAS: 34%
 - 311/435 total non-compliant
 - 289 with >10% failure rate, 263 not “new” LL vectors
- Radar: 30%
 - 85/212 total non-compliant
 - 81 with >10% failure rate, 71 not “new” LL vectors

Surveillance Analysis ACAS – CAL Suite

	Batch								
	Xu5 Tracker								
	ADSB			TCAS			RADAR		
	P	C	W	P	C	W	P	C	W
Total Encounters	43500	43500	43500	43500	43500	43500	21200	21200	21200
Total Compliant	34196	35452	32295	34590	35282	33928	17780	18164	17217
Prob. Conformance	79%	81%	74%	80%	81%	78%	84%	86%	81%
Correct Alert	22237	22273	18967	23634	23083	20671	6128	5683	4162
Missed Alert	3309	2549	4034	2473	1764	3409	417	103	648
Late Alert	2775	2314	3821	1988	1505	2739	525	237	1415
Short Alert	2516	2306	2724	2664	3025	2664	1550	1196	1056
Early Required Alert	0	1	0	68	56	19	4	5	1
Prob. Missed Alert	10.67	8.61	13.63	7.98	5.96	11.52	4.79	1.41	8.88
Prob. Late Alert	8.95	7.82	12.91	6.41	5.08	9.25	6.03	3.25	19.38
Prob. Short Alert	8.12	7.79	9.20	8.59	10.22	9.00	17.82	16.38	14.47
Prob. Early Req. Alert	0.00	0.00	0.00	0.22	0.19	0.06	0.05	0.07	0.01
Prob. Correct Req. Alert	72.26	75.78	64.26	76.80	78.55	70.17	71.31	78.89	57.26
Average Alert Time Before HAZ	37.10	41.81	10.15	41.53	45.89	13.21	34.72	41.29	9.24
Alerting Ratio	0.89	0.91	0.86	0.91	0.93	0.88	0.94	0.98	0.91
Permissible Alert	738	1176	438	784	1220	575	905	1380	587
Permissible Non-Alert	1360	1222	1162	1060	885	1006	1120	945	1013
Early Permissible Alert	2	2	0	256	295	19	75	75	0
Prob. Perm. Non-Alert	0.65	0.51	0.73	0.50	0.37	0.63	0.53	0.39	0.63
Prob. Early Perm Alert	0.00	0.00	0.00	0.12	0.12	0.01	0.04	0.03	0.00
Prob. Perm Alert	0.35	0.49	0.27	0.37	0.51	0.36	0.43	0.58	0.37
ANA	1.47	1.47	1.11	1.69	1.68	1.11	2.38	2.37	1.31
Correct Non-Alert	9859	10779	11728	8856	9799	11657	9552	10081	11455
Incorrect Alert	541	721	572	1544	1701	643	848	1419	845
Prob. Correct Non-Alert	0.95	0.94	0.95	0.85	0.85	0.95	0.92	0.88	0.93
Prob Incorrect Alert	0.05	0.06	0.05	0.15	0.15	0.05	0.08	0.12	0.07

Discussion

- Probability of correct, permissible and correct non alerts:
 - ADSB: 78%
 - TCAS: 80%
 - RADAR: 84%
- Significant late alerts across the board

Surveillance Analysis ACAS – CAL Suite

- Average Alert Time anomaly – calculated for all LL vectors

ACAS									
	ADSB			TCAS			Radar		
	Preventive	Corrective	Warning	Preventive	Corrective	Warning	Preventive	Corrective	Warning
Persistence: P/C/W alerts persist for at least 4 seconds	32118/32118	31342/31342	30556/30556	33411/33411	32649/32649	30739/30739	10452/10452	10098/10098	8714/8714
Late Alert: P/C/W alerts are issued according to the late alert requirement	28225/31000	27286/29600	25779/29600	29012/31000	28095/29600	26861/29600	8175/8700	7063/7300	5885/7300
Average Alert Time: On average alerts are issued 55 seconds prior to the intruder violating the hazard zone (LL only).	37.102	41.8131	10.1486	41.5331	45.8877	13.2126	34.7221	41.2876	9.2359
Early Alert: P/C/W alerts are issued according to the early alert requirement	31000/31000	29599/29600	29600/29600	30932/31000	29544/29600	29581/29600	8696/8700	7295/7300	7299/7300
Must Not Alert: For all non-alerted test vectors, verify that no P/C/W alerts are issued	9859/10400	10779/11500	11728/12300	8856/10400	9799/11500	11657/12300	9552/10400	10081/11500	11455/12300
Must Alert: For all alerted test vectors verify that P/C/W alerts are issued	27528/31000	26894/29600	25512/29600	28354/31000	27669/29600	26093/29600	8207/8700	7121/7300	6634/7300
Total Test Procedure Failures:	9304/43500	8048/43500	11205/43500	8910/43500	8218/43500	9572/43500	3420/21200	3036/21200	3983/21200

Difficult Encounters

- The following test vectors had consistent failures, across all analysis methods (STM/ACAS tracker, independent and ECF comparison)

Enc	Failures	Enc	Failures	Enc	Failures	Enc	Failures	Enc	Failures
LL46	890	O4	559	LL207	479	LL175	400	LL152	363
P13	850	LL150	557	LL7	476	LL184	400	LL166	363
LL171	784	LL103	543	LL16	473	LL68	398	LL177	362
LL102	728	C2	537	LL127	465	LL95	396	P8	362
H5	718	H8	532	LL212	441	LL108	394	LL38	360
O5	713	LL121	531	LL99	439	LL220	391	P10	360
LL138	678	LL170	530	LL114	439	LL137	389	LL126	359
LL83	671	LL167	529	LL216	433	LL163	383	LL158	359
H28	668	LL52	527	LL26	433	C3	383	C1	358
LL41	658	C7	524	LL9	432	LL155	382	LL178	357
LL141	651	LL180	518	LL89	428	LL63	382	H3	357
H6	649	LL32	518	LL219	417	LL113	379	H4	353
O6	640	LL125	516	M16	415	LL119	378	LL13	352
LL2	639	LL1	508	LL70	408	O3	378	LL40	352
D1	638	LL142	507	LL153	407	LL258	377	LL130	349
LL147	619	LL218	500	LL60	404	LL202	375	LL21	349
LL132	600	LL133	489	LL88	402	LL109	372	D7	346
LL151	594	LL87	488	LL135	401	LL61	369	LL134	344
LL79	561	LL193	480	S3	401	O2	369	LL17	341
LL92	561	D3	480	LL162	400	LL49	364	LL209	341

- Determine independent verification method or revise encounter characterization files further. Test procedures allow for independent batch analysis OR ECF comparison, analysis shows the results vary widely
- Specify batch analysis standard for test procedure execution (if applicable)
 - Error seed threshold
 - Number of encounter error seed runs required

Recommended Next Steps

- Execute CAL analysis suite against latest FAA STM tracker with v2.10 test vectors to ensure corrected LL vectors perform as expected
- Examine difficult test vectors bounds to ensure the thresholds and transitions are not so tightly coupled
- Further investigate the ECF to external analysis differences
- Determine mechanism for statistical nature requirements (AAT) to be satisfied if ECF comparison is used

Backup

v2.5 Vector Results

	Truth			Xu5 Tracker									STM Tracker								
				ADSB			TCAS			RADAR			ADSB			TCAS			RADAR		
	P	C	W	P	C	W	P	C	W	P	C	W	P	C	W	P	C	W	P	C	W
Total Encounters	344	344	344	344	344	344	344	344	344	287	287	287	344	344	344	344	344	344	287	287	287
Total Compliant	319	323	325	314	315	317	283	287	285	230	232	233	278	269	266	200	220	221	206	204	205
Prob. Conformance	94%			92%			83%			81%			79%			62%			71%		
Correct Alert	255	248	250	251	242	242	224	218	216	193	191	193	216	195	191	142	150	152	172	164	166
Missed Alert	0	0	0	0	3	3	1	3	4	2	2	2	0	4	4	2	4	7	2	2	2
Late Alert	19	15	13	17	14	14	28	21	25	33	28	25	51	60	63	90	76	82	48	40	42
Short Alert	5	4	4	11	8	8	24	24	22	17	16	17	12	8	8	45	37	26	25	32	28
Early Required Alert	0	0	0	0	0	0	3	2	1	1	0	0	0	0	1	1	1	1	0	0	0
Prob. Missed Alert	0.00	0.00	0.00	0.00	1.12	1.12	0.36	1.12	1.49	0.81	0.84	0.84	0.00	1.49	1.49	0.71	1.49	2.61	0.81	0.84	0.84
Prob. Late Alert	6.79	5.60	4.85	6.07	5.22	5.22	10.00	7.84	9.33	13.36	11.76	10.50	18.21	22.39	23.51	32.14	28.36	30.60	19.43	16.81	17.65
Prob. Short Alert	1.79	1.49	1.49	3.93	2.99	2.99	8.57	8.96	8.21	6.88	6.72	7.14	4.29	2.99	2.99	16.07	13.81	9.70	10.12	13.45	11.76
Prob. Early Req. Alert	0.00	0.00	0.00	0.00	0.00	0.00	1.07	0.75	0.37	0.40	0.00	0.00	0.00	0.00	0.37	0.36	0.37	0.37	0.00	0.00	0.00
Prob. Correct Req. Alert	91.43	92.91	93.66	90.00	90.67	90.67	80.00	81.34	80.60	78.54	80.67	81.51	77.50	73.13	71.64	50.71	55.97	56.72	69.64	68.91	69.75
Average Alert Time Before HAZ	39.84	41.48	22.23	40.45	42.37	22.95	39.79	41.74	22.23	35.68	37.99	21.74	33.04	32.80	18.08	26.37	28.00	15.15	31.89	33.74	20.44
Alerting Ratio	1.00	1.00	1.00	1.00	0.99	0.99	1.00	0.99	0.99	0.99	0.99	0.99	1.00	0.98	0.98	0.99	0.99	0.97	0.99	0.99	0.99
Permissible Alert	3	7	5	4	8	2	8	11	6	4	7	5	3	5	2	7	10	7	6	9	7
Permissible Non-Alert	11	11	6	10	10	9	6	7	5	5	5	4	11	13	9	7	8	4	3	4	2
Early Permissible Alert	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0
Prob. Perm. Non-Alert	0.79	0.61	0.55	0.71	0.56	0.82	0.43	0.39	0.45	0.50	0.38	0.44	0.79	0.72	0.82	0.50	0.44	0.36	0.30	0.31	0.22
Prob. Early Perm Alert	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00
Prob. Perm Alert	0.21	0.39	0.45	0.29	0.44	0.18	0.57	0.61	0.55	0.40	0.54	0.56	0.21	0.28	0.18	0.50	0.56	0.64	0.60	0.69	0.78
ANA	1.02	1.07	1.04	1.25	1.28	1.18	2.10	2.05	1.62	1.66	2.10	1.56	1.07	1.08	1.05	1.78	1.75	1.45	1.79	2.17	1.73
Correct Non-Alert	50	57	64	49	55	64	45	51	58	27	28	31	48	56	64	44	52	58	24	27	30
Incorrect Alert	0	1	1	1	3	1	5	7	7	3	8	9	2	2	1	6	6	7	6	9	10
Prob. Correct Non-Alert	1.00	0.98	0.98	0.98	0.95	0.98	0.90	0.88	0.89	0.90	0.78	0.78	0.96	0.97	0.98	0.88	0.90	0.89	0.80	0.75	0.75
Prob Incorrect Alert	0.00	0.02	0.02	0.02	0.05	0.02	0.10	0.12	0.11	0.10	0.22	0.23	0.04	0.03	0.02	0.12	0.10	0.11	0.20	0.25	0.25