A Comparison of Ship Self Defense Analysis Simulations

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Agenda

- Study Objectives
- Overview of Models
  - SSD
  - SADM
- Evaluation Process
- Evaluation Results
- System Life Cycle Utilization
- Next Steps
- Summary/Conclusions

Study Objectives (1)

- Compare capability of SADM model with the Raytheon Ship Self Defense (SSD) model
  - Find out what it can do that we currently can't do but would if we could
  - Compare model inputs/outputs/fidelity
  - Establish common scenarios for "apples to apples" comparison
  - Create test cases that we can directly compare with the same test case run in the Raytheon Ship Self Defense model, to build confidence that we get the results we expect to get
  - Model features
    - Identify missions which each model works best for, and why
    - Identify discriminating features of each model

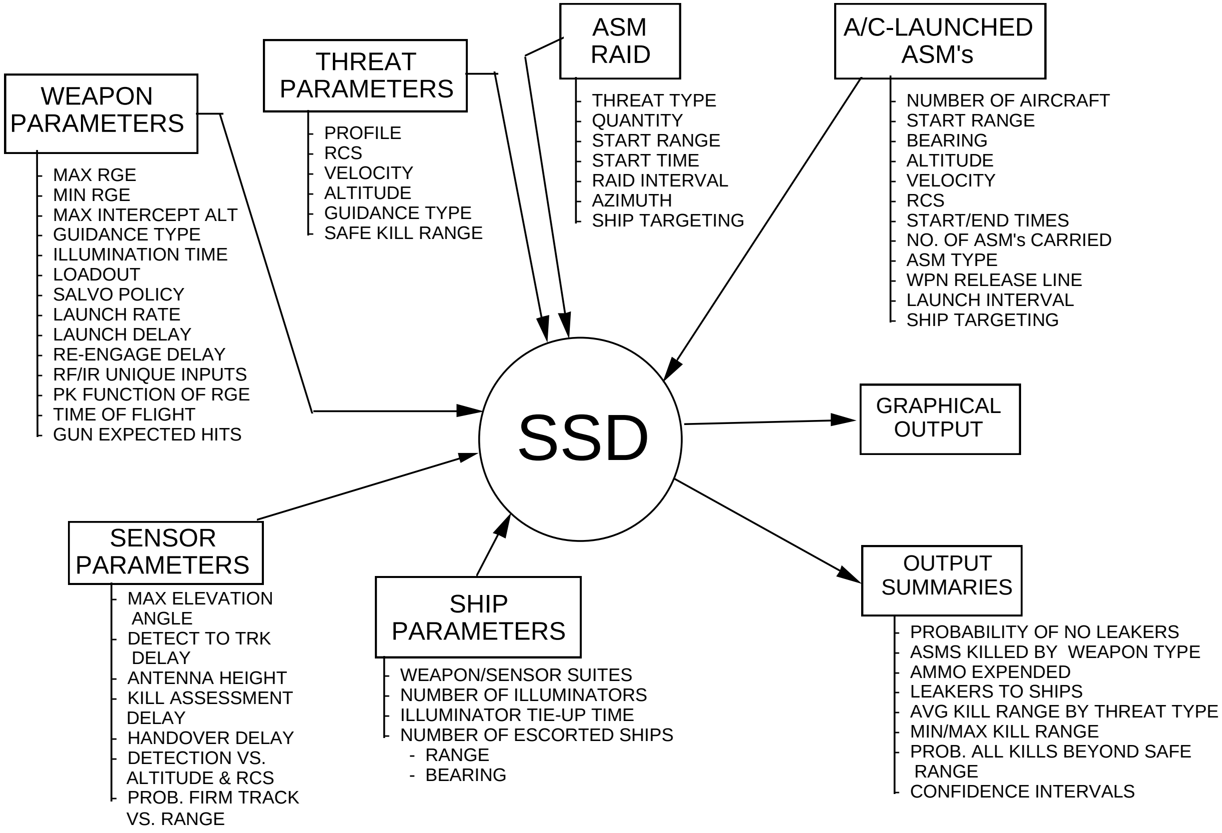
Study Objectives (2)

- Investigate capability of SADM model for usage in Raytheon
  - Get to know how to set it up, exercise it, understand what it can and can’t do for the types of analysis we typically do
  - Document what is immediately useful with the tool
  - Document its naval weapons analysis issues
    - Identify what is required to build new models for use in SADM
    - Identify additional features that are required
  - Build some scenarios with multiple firing platforms and related weapons coordination to understand what capability is there

SSD Overview

- Developed by Raytheon
- First-order effectiveness model of short range air defense against multiple antiship missiles by a single firing ship
- Measures of Effectiveness
  - Probability of killing all incoming ASMs
  - Number of Leakers
  - Kill statistics
  - Number of weapons expended
- Monte Carlo events
  - Probability of kill at intercept
  - ASM launch times and azimuth spacing
  - Sensor detection range
- User created/modified ship configuration files, threat scenario files, and weapon/sensor database

SSD Model Architecture



SSD Video Clips

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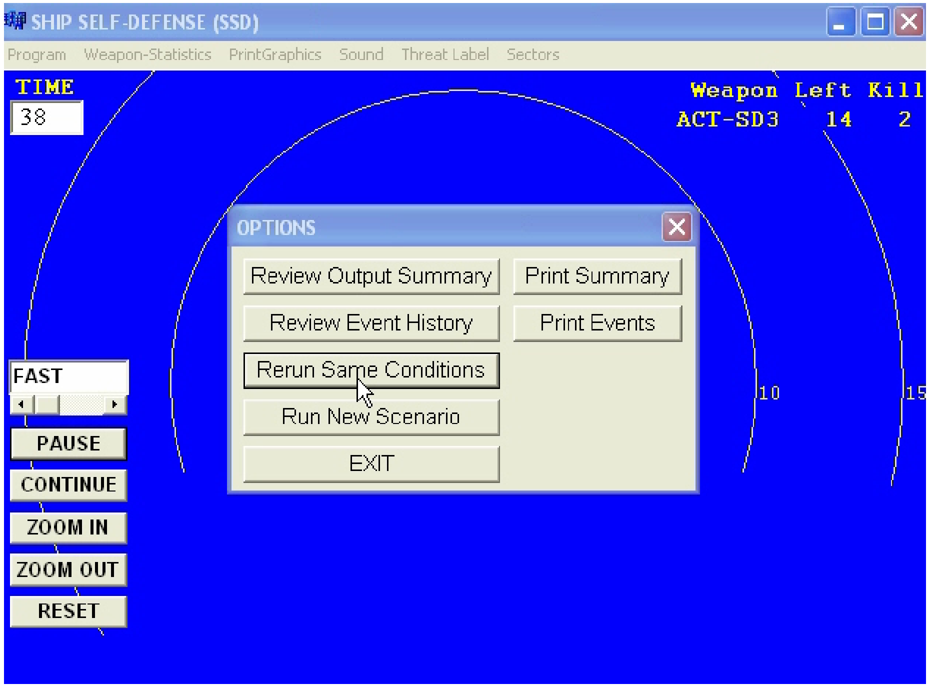

SSD Sample Measures of Effectiveness

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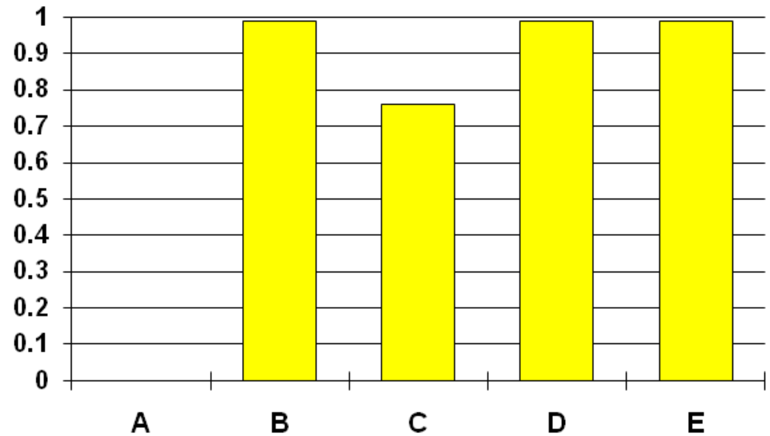
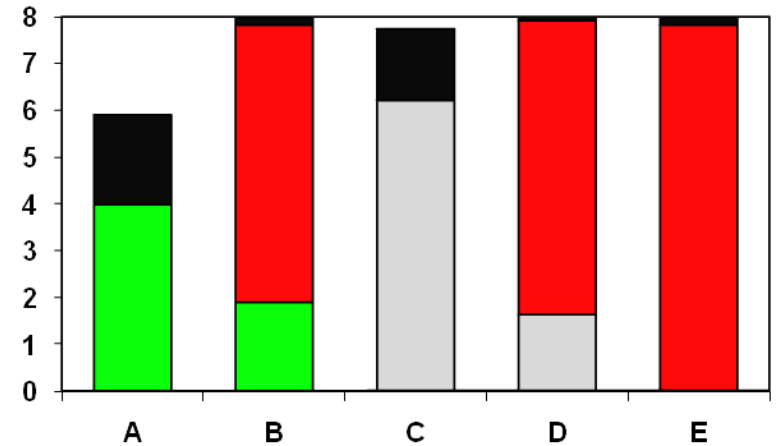
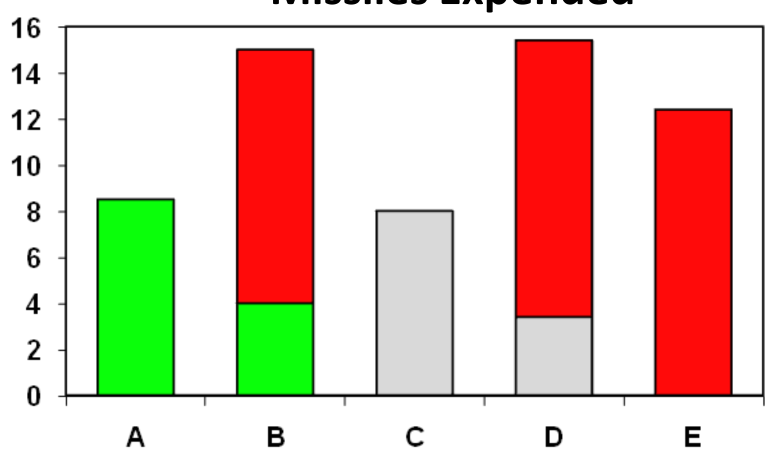
Prob of No Leakers



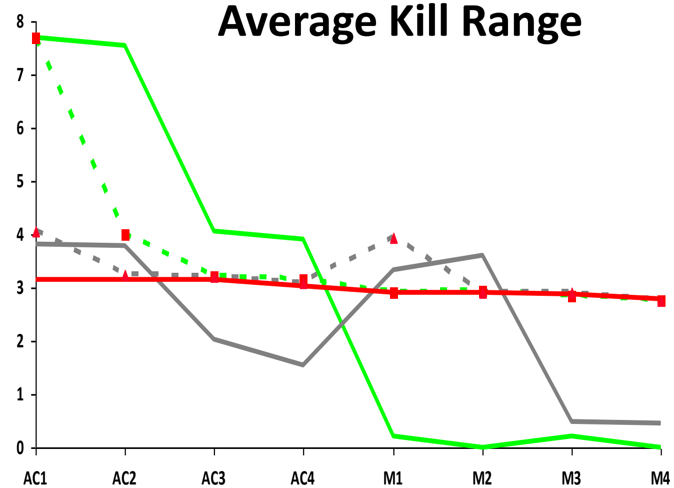
Total Kills



Missiles Expended



Average Kill Range



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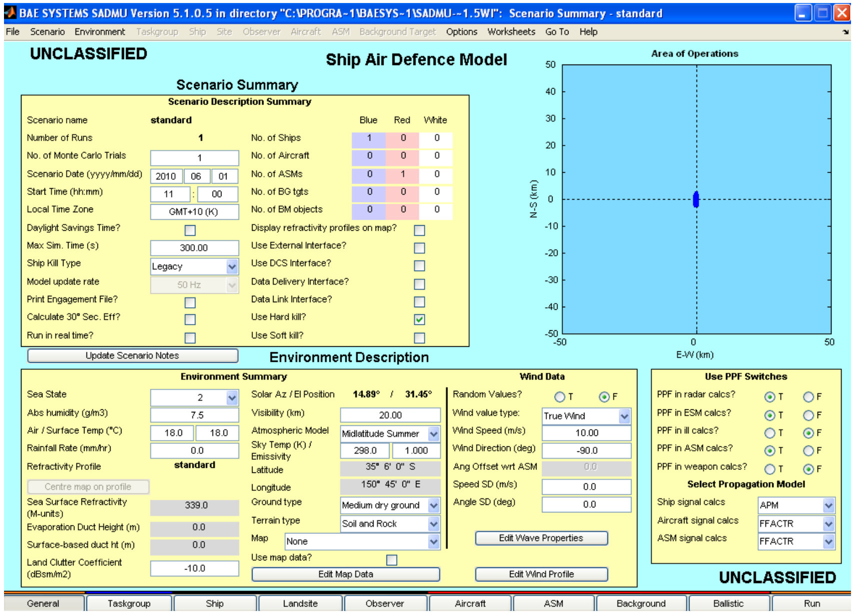
SADM Overview

- Developed by BAE Systems
- SADM is a software simulation tool directed at the Maritime Self Defence problem (air and surface threats)
- Simulates the defence of a task group against other ships, aircraft, ASMs, and background targets
- Includes littoral effects
- Consists of detailed models of
  - Platforms (ships, aircraft, land-based weapon sites etc)
  - Sensors (many types of radars, IRST, ESM)
  - Trackers and track management systems
  - Command and control, weapons control systems
  - Weapons (hard kill and soft kill)
  - Anti-ship missiles (seekers, body and electronic environment)
  - Environment (atmosphere, terrain, propagation)
  - Interactions between subsystems



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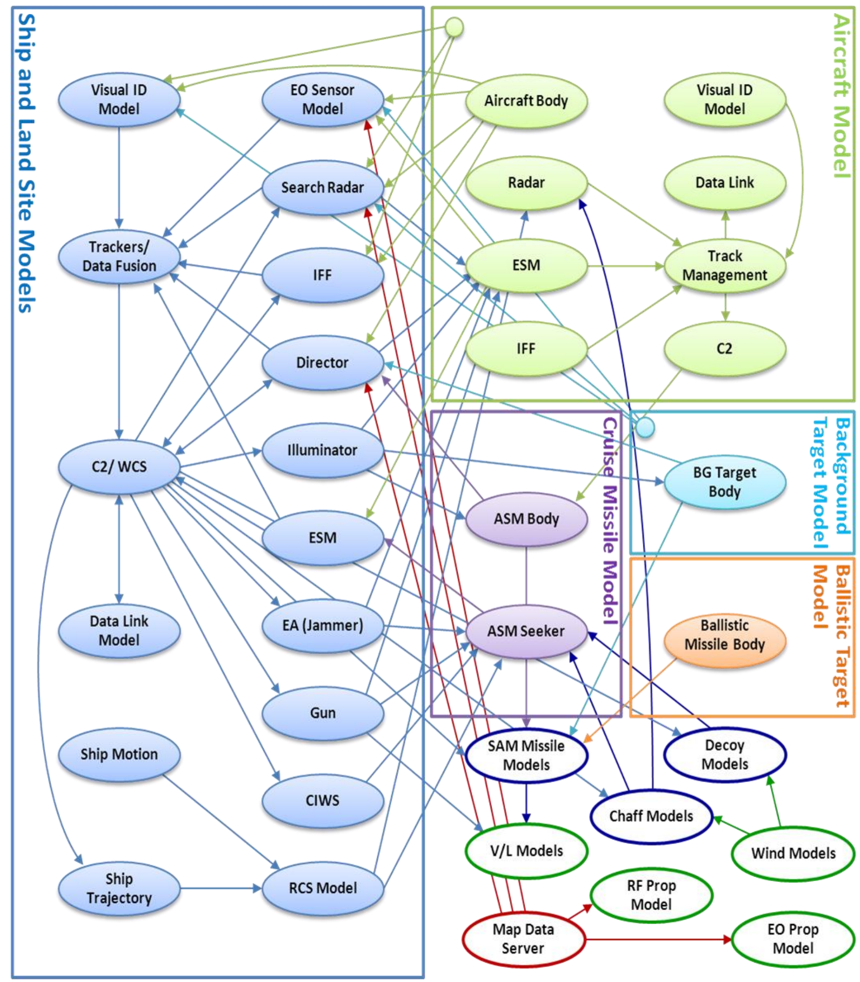
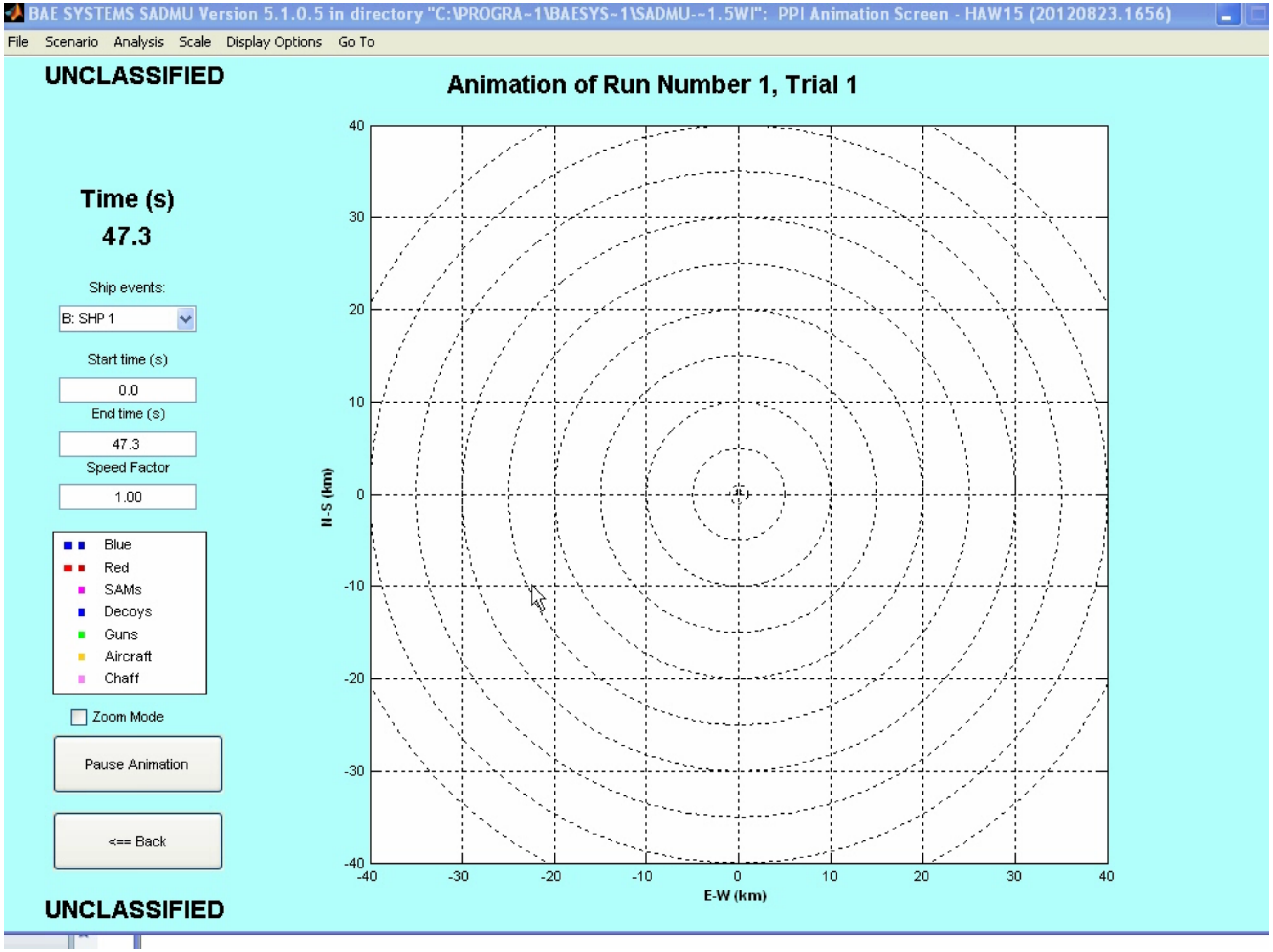
SADM Model Architecture

- Composed of interacting objects
  - Environment, propagation, and signature models
  - Sensors
  - Trackers, track management, data fusion, and hostility classification models
  - C2/WCS system(s)
  - Hard-Kill Weapons
  - Soft-Kill Weapons
- This architecture is
  - Useful to the user (add-ins)
  - Useful for code maintenance



SADM is designed as a series of interacting objects, with well-defined boundaries and interactions between them. This structure provides for easy maintenance and upgrades. It is implemented in structured Fortran 95 for increased execution speed.

SADM Video Clip



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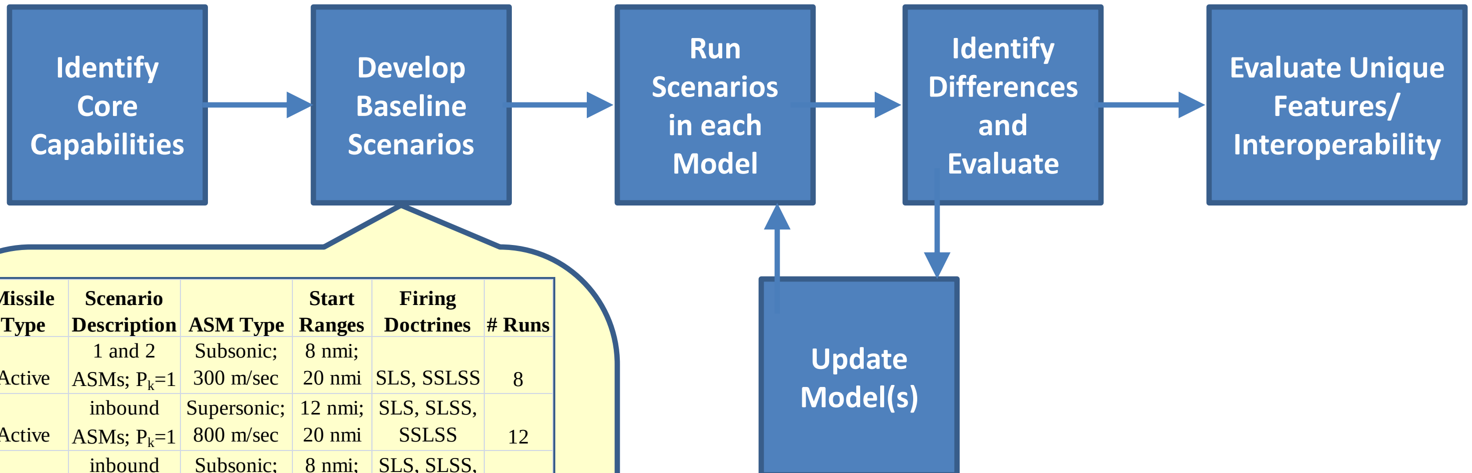
Evaluation Process



Missile Type	Scenario Description	ASM Type	Start Ranges	Firing Doctrines	# Runs
Active	1 and 2 ASMs; P_k=1	Subsonic; 300 m/sec	8 nmi; 20 nmi	SLS, SSLSS	8
Active	inbound ASMs; P_k=1	Supersonic; 800 m/sec	12 nmi; 20 nmi	SLS, SLSS, SSLSS	12
Active	inbound ASMs; P_k=0	Subsonic; 300 m/sec	8 nmi; 20 nmi	SLS, SLSS, SSLSS	12
Active	inbound ASMs; P_k=0	Supersonic; 800 m/sec	12 nmi; 20 nmi	SLS, SLSS, SSLSS	12
HAW	inbound ASMs; P_k=1	Subsonic; 300 m/sec	8 nmi; 20 nmi	SLS, SSLSS	8
HAW	inbound ASMs; P_k=1	Supersonic; 800 m/sec	12 nmi; 20 nmi	SLS, SSLSS	8
HAW	inbound ASMs; P_k=1	Subsonic; 300 m/sec	8 nmi; 20 nmi	SLS, SSLSS	8
HAW	inbound ASMs; P_k=1	Supersonic; 800 m/sec	12 nmi; 20 nmi	SLS, SSLSS	8
SATH	inbound ASMs; P_k=1	Subsonic; 300 m/sec	8 nmi; 20 nmi	SLS, SSLSS	8
SATH	inbound ASMs; P_k=1	Supersonic; 800 m/sec	12 nmi; 20 nmi	SLS, SSLSS	8
SATH	inbound ASMs; P_k=1	Subsonic; 300 m/sec	8 nmi; 20 nmi	SLS, SSLSS	8
SATH	inbound ASMs; P_k=1	Supersonic; 800 m/sec	12 nmi; 20 nmi	SLS, SSLSS	8

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Subsonic Threat Performance

Active Missiles

- Results showed excellent agreement for subsonic threats with active missiles.
- Generally, times for intercept are within 2 seconds and intercept ranges are within 0.2 nautical mile.
- Some of the initial detection ranges were a little further out for SSD, but that difference can be attributed to the fact that SSD assumes "perfect" radar detection and SADM models actual radar performance.

	Blue Ship		Threats	Notes														
	Ship	Ship			SADM Data							SSD Data						
Test #	Search Radar	Firing Doctrine	ASMs		Initial Detect		Launch		Intercept			Initial Detect		Launch		Intercept		
					R (nm)	T (s)	R (nm)	T (s)	R (nm)	H/M?	T (s)	R (nm)	T (s)	R (nm)	T (s)	R (nm)	H/M?	T (s)
1	Phased Array	SLS	1 SBS @ 20 nm	Set PK = 1	14.8	31.0	12.8	43.0	7.8	HIT	73.0	16.3	22.3	13.0	41.7	8.0	HIT	71.7
2	Phased Array	SLS	1 SBS @ 8 nm	Set PK = 1	7.9	1.0	6.3	11.0	4.0	HIT	24.5	8.0	0.1	6.3	10.1	4.2	HIT	22.7
3	Phased Array	SSLSS	1 SBS @ 20 nm	Set Pk = 1. SAM1	14.8	31.0	12.8	43.0	7.8	HIT	73.0	16.3	22.3	13.0	41.7	8.0	HIT	71.7
				SAM2			12.4	45.0		Overkill					43.7		Overkill	
4	Phased Array	SSLSS	1 SBS @ 8 nm	Set Pk = 1. SAM1	7.9	1.0	6.3	11.0	4.0	HIT	24.5	8.0	0.1	6.3	10.1	4.2	HIT	22.7
				SAM2			5.9	13.0		Overkill					12.1		Overkill	
5	Phased Array	SLS	2 SBS @ 20 nm; 1 second apart	Set Pk = 1. ASM1/SAM2	15.0	30.0	12.7	43.5	7.8	HIT	73.3	16.3	22.3	13.0	41.7	8.0	HIT	71.7
				ASM2/SAM1	15.0	30.0	12.6	45.5	7.7	HIT	74.8	16.3	23.3	12.8	43.7	7.9	HIT	73.2
6	Phased Array	SLS	2 SBS @ 8 nm; 1 second apart	Set Pk = 1. ASM1/SAM1	7.9	1.0	6.3	11.0	4.0	HIT	24.5	8.0	0.1	6.3	10.1	4.2	HIT	22.7
				ASM2/SAM1	8.1	1.0	6.1	13.0	3.9	HIT	26.2	8.0	1	6.1	12.1	4.1	HIT	24.3
7	Phased Array	SSLSS	2 SBS @ 20 nm; 1 second apart	Set Pk = 1. ASM1/SAM1	14.8	31.0	13.0	42.5	7.8	HIT	73.0	16.3	22.3	13.0	41.7	8.0	HIT	71.7
				ASM1/SAM2			12.6	44.5		Overkill					43.7		Overkill	73.7
				ASM2/SAM1	15.0	31.0	12.4	46.5	7.6	HIT	75.3	16.3	23.3	12.5	45.7	7.7	HIT	74.3
				ASM2/SAM2			12.0	48.5		Overkill					47.7		Overkill	
8	Phased Array	SSLSS	2 SBS @ 8 nm; 1 second apart	Set Pk = 1. ASM1/SAM1	7.9	1.0	6.3	11.0	4.0	HIT	24.5	8.0	0.1	6.3	10.1	4.2	HIT	22.7
				ASM1/SAM2			5.9	13.0		Overkill					12.1		Overkill	24.6
				ASM2/SAM1	8.1	1.0	5.7	15.0	3.7	HIT	27.6	8.0	1	5.8	14.1	3.8	HIT	25.8
				ASM2/SAM2			5.4	17.0		Overkill					16.1		Overkill	

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Supersonic Threat Performance

Active Missiles

	Blue Ship		Threats	Notes														
	Ship	Ship			SADM Data							SSD Data						
Test #	Search Radar	Firing Doctrine	ASMs		Initial Detect		Launch		Intercept			Initial Detect		Launch		Intercept		
					R (nm)	T (s)	R (nm)	T (s)	R (nm)	H/M?	T (s)	R (nm)	T (s)	R (nm)	T (s)	R (nm)	H/M?	T (s)
9	Phased Array	SLS	1 SSS @ 20 nm	Set Pk = 1. SAM1	19.1	2.0	14.0	14.0	5.7	HIT	33.0	19.1	2.1	14.7	12.1	6.1	HIT	32.0
10	Phased Array	SLS	1 SSS @ 12 nm	Set PK = 1	11.4	1.0	7.1	11.0	2.7	HIT	21.3	11.9	0.1	7.6	10.1	3.1	HIT	20.4
11	Phased Array	SLSS	1 SSS @ 20 nm	Set Pk = 1. SAM1	19.1	2.0	14.4	13.0	5.8	HIT	33.0	19.1	2.1	14.7	12.1	6.1	HIT	32.0
				SAM2											14.1		Overkill	
12	Phased Array	SLSS	1 SSS @ 12 nm	Set Pk = 1. SAM1	11.4	1.0	7.1	11.0	2.7	HIT	21.3	11.9	0.1	7.6	10.1	3.1	HIT	20.4
				SAM2											12.1		Overkill	
13	Phased Array	SSLSS	1 SSS @ 20 nm	Set Pk = 1. SAM1	18.7	3.0	14.4	13.0	5.8	HIT	33.0	19.1	2.1	14.7	12.1	6.1	HIT	32.0
				SAM2			13.5	15.0		Overkill					14.1		Overkill	
14	Phased Array	SSLSS	1 SSS @ 12 nm	Set Pk = 1. SAM1	11.4	1.0	7.1	11.0	2.7	HIT	21.3	11.9	0.1	7.6	10.1	3.1	HIT	20.4
				SAM2			6.3	13.0		Overkill					12.1		Overkill	

- Results showed excellent agreement for supersonic threats
- Generally, times for intercept are within 2 seconds and intercept ranges are within 0.5 nautical miles.

Subsonic Threat Performance

Active Missiles, Pk=0

- In this case, the probability of kill (P_k) was set to 0 to compare engagement ranges and timelines, with a special focus on quantifying the “depth of fire” and reengagement timelines in both models
- Initial results found significant differences in each model’s reengagement timelines; with additional analysis of the parameters used to model engagement timelines in both models, we were able to reconfigure each model to produce similar results.
- Generally, times for intercept are within 2 seconds and intercept ranges are within 0.2 nautical mile.

	Blue Ship		Threats	Notes														
	Ship	Ship			SADM Data							SSD Data						
Test #	Search Radar	Firing Doctrine	ASMs		Initial Detect		Launch		Intercept			Initial Detect		Launch		Intercept		
					R (nm)	T (s)	R (nm)	T (s)	R (nm)	H/M?	T (s)	R (nm)	T (s)	R (nm)	T (s)	R (nm)	H/M?	T (s)
21	Phased Array	SLS	1 SBS @ 20 nm	Set Pk = 0. SAM1	15.0	30.0	13.1	41.5	7.9	MISS	72.3	16.3	22.3	13.0	41.7	8.0	MISS	71.7
				SAM2			6.7	80.0	4.3	MISS	94.3			6.6	79.8	4.4	MISS	93.1
				SAM3			3.0	102.0	1.7	MISS	110.1			3.1	101.2	1.9	MISS	108.4
22	Phased Array	SLS	1 SBS @ 8 nm	Set Pk = 0. SAM1	7.9	1.0	6.3	11.0	4.0	MISS	24.5	8.0	0.1	6.3	10.1	4.2	MISS	22.7
				SAM2			2.8	32.0	1.5	MISS	39.8			2.8	30.7	1.7	MISS	37.6
23	Phased Array	SLSS	1 SBS @ 20 nm	Set Pk = 0. SAM1	16.2	23.0	13.0	42.0	7.9	MISS	72.6	16.3	22.3	13.0	41.7	8.0	MISS	71.7
				SAM2			6.7	80.0	4.3	MISS	94.3			6.3	81.8	4.2	MISS	94.4
				SAM3			6.3	82.0	4.1	MISS	95.7			2.5	104.5	1.4	MISS	110.9
				SAM4			2.8	103.0	1.5	MISS	110.9				106.5	1.2	MISS	112.4
				SAM5			2.5	105.0	1.3	MISS	112.4							
24	Phased Array	SLSS	1 SBS @ 8 nm	Set Pk = 0. SAM1	7.9	1.0	6.3	11.0	4.0	MISS	24.5	8.0	0.1	6.3	10.1	4.2	MISS	22.7
				SAM2			2.8	32.0	1.5	MISS	39.8			2.5	32.7	1.4	MISS	39.1
				SAM3			2.4	34.0	1.2	MISS	41.3				34.7	1.2	MISS	40.6
25	Phased Array	SSLSS	1 SBS @ 20 nm	Set Pk = 0. SAM1	16.2	23.0	12.8	43.0	7.8	MISS	73.0	16.3	22.3	13.0	41.7	8.0	MISS	71.7
				SAM2			12.5	45.0	7.7	MISS	74.1				43.7	7.8	MISS	72.8
				SAM3			6.3	82.0	4.1	MISS	95.7			6.5	80.9	4.3	MISS	93.8
				SAM4			6.0	84.0	3.8	MISS	97.1				82.9	4.1	MISS	95.2
				SAM5			2.5	105.0	1.3	MISS	112.4			2.7	103.3	1.6	MISS	110.0
				SAM6			2.2	107.0	1.0	MISS	113.8				105.3	1.3	MISS	111.5
26	Phased Array	SSLSS	1 SBS @ 8 nm	Set Pk = 0. SAM1	7.9	1.0	6.3	11.0	4.0	MISS	24.5	8.0	0.1	6.3	10.1	4.2	MISS	22.7
				SAM2			5.9	13.0	3.8	MISS	25.9				12.1	4.0	MISS	24.0
				SAM3			2.6	33.0	1.4	MISS	40.5			2.6	32	1.5	MISS	38.6
				SAM4			2.3	35.0	1.1	MISS	42.0				34	1.3	MISS	40.1

Supersonic Threat Performance

Active Missiles, Pk=0

- Both models were able to generate results with good agreement after some reconfiguration of their reengagement parameters.
- Generally, times for intercept were within 2 seconds and intercept ranges within 0.5 nautical mile.
- The biggest finding in this set of data was that SADM had a different SLSS firing policy than SSD. SADM would shoot one shot the first engagement, and 2 shots for subsequent engagements. The SSD model employed an adaptive algorithm which would shoot 2 shots on the first round if it was the only engagement opportunity.

	Blue Ship		Threats	Notes														
	Ship	Ship			SADM Data							SSD Data						
Test #	Search Radar	Firing Doctrine	ASMs		Initial Detect		Launch		Intercept			Initial Detect		Launch		Intercept		
					R (nm)	T (s)	R (nm)	T (s)	R (nm)	H/M?	T (s)	R (nm)	T (s)	R (nm)	T (s)	R (nm)	H/M?	T (s)
39	Phased Array	SLS	2 SSS @ 20 nm; 1 second apart	Set Pk = 0. ASM1/SAM1	18.7	3.0	14.4	13.0	5.8	MISS	32.9	19.1	2.1	14.7	12.1	6.1	HIT	32.0
				ASM1/SAM2			2.8	40.0	0.4	MISS	45.5							
				ASM2/SAM1	19.6	2.0	13.9	15.0	5.7	MISS	34.2	19.1	3.1	14.3	14.1	6.0	HIT	33.3
				ASM2/SAM2														
40	Phased Array	SLS	2 SSS @ 12 nm; 1 second apart	Set Pk = 0. ASM1	11.5	1.0	6.3	13.0	2.3	MISS	22.4	11.9	0.1	7.6	10.1	3.1	MISS	20.4
				ASM2	11.9	1.1	7.6	11.0	2.9	MISS	21.9	12.0	1	7.2	12.1	2.9	MISS	21.9
41	Phased Array	SLSS	2 SSS @ 20 nm; 1 second apart	Set Pk = 0. ASM1/SAM1	18.7	3.0	14.4	13.0	5.8	MISS	32.9	19.1	2.1	14.7	12.1	6.1	MISS	32.0
				ASM1/SAM2			2.8	40.0	0.4	MISS	45.5				14.1	5.9	MISS	32.6
				ASM2/SAM1	19.1	3.0	13.9	15.0	5.7	MISS	34.2	19.1	3.1	13.4	16.1	5.7	MISS	34.0
				ASM2/SAM2											18.1	5.4	MISS	34.7
42	Phased Array	SLSS	2 SSS @ 12 nm; 1 second apart	Set Pk = 0. ASM1/SAM1	11.5	1.0	6.3	13.0	2.3	MISS	22.4	11.9	0.1	7.6	10.1	3.1	MISS	20.4
				ASM1/SAM3											12.1	2.7	MISS	21.4
				ASM2/SAM1	11.9	1.1	7.6	11.0	2.9	MISS	21.8	12.0	1	6.3	14.1	2.5	MISS	22.9
				ASM2/SAM2											16.1	2.1	MISS	23.8
43	Phased Array	SSLSS	2 SSS @ 20 nm; 1 second apart	Set Pk = 0. ASM1/SAM1	18.7	3.0	12.7	17.0	5.2	MISS	34.3	19.1	2.1	14.7	12.1	6.1	MISS	32.0
				ASM1/SAM2			11.8	19.0	4.8	MISS	35.2				14.1	5.9	MISS	32.6
				ASM2/SAM1	19.1	3.0	14.8	13.0	6.0	MISS	33.5	19.1	3.1	13.4	16.1	5.7	MISS	34.0
				ASM2/SAM2			13.9	15.0	5.7	MISS	34.2				18.1	5.4	MISS	34.7
44	Phased Array	SSLSS	2 SSS @ 12 nm; 1 second apart	Set Pk = 0. ASM1/SAM1	11.5	1.0	5.4	15.0	1.8	MISS	23.4	11.9	0.1	7.6	10.1	3.1	MISS	20.4
				ASM1/SAM2			4.6	17.0	1.3	MISS	24.5				12.1	2.7	MISS	21.4
				ASM2/SAM1	11.9	1.1	7.6	11.0	2.9	MISS	21.9	12.0	1	6.3	14.1	2.5	MISS	22.9
				ASM2/SAM2			6.7	13.0	2.5	MISS	22.8				16.1	2.1	MISS	23.8

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Threat Performance

"Home All the Way" Missiles, SLS Firing Doctrine

	Blue Ship		Threats	Notes														
	Ship	Ship			SADM Data							SSD Data						
Test #	Search Radar	Firing Doctrine	ASMs		Initial Detect		Launch		Intercept			Initial Detect		Launch		Intercept		
					R (nm)	T (s)	R (nm)	T (s)	R (nm)	H/M?	T (s)	R (nm)	T (s)	R (nm)	T (s)	R (nm)	H/M?	T (s)
45	Default_Radar	SLS	1 SBS @ 20 nm		12.5	44.8	9.5	63.1	6.1	HIT	83.4	12.5	44.8	10.8	54.9	6.8	HIT	78.6
46	Default_Radar	SLS	1 SBS @ 8 nm		7.9	1.5	6.1	12.0	3.9	HIT	25.2	8.0	0.1	6.3	10.1	4.2	HIT	22.7
47	Default_Radar	SLS	2 SBS @ 20 nm; 1 second apart	ASM1/SAM1	12.3	47.2	4.6	93.8	2.8	HIT	104.4	12.5	44.8	10.8	54.9	6.8	HIT	78.6
	Default_Radar			ASM2/SAM1	12.0	45.7	9.8	58.9	6.3	HIT	80.1	12.5	45.8	5.0	90.6	3.2	HIT	101.1
48	Default_Radar	SLS	2 SBS @ 8 nm; 1 second apart	ASM1/SAM1	7.9	1.0	6.1	12.0	3.9	HIT	25.2	8.0	0.1	6.3	10.1	4.2	HIT	22.7
	Default_Radar			ASM2/SAM1	8.1	1.0	1.9	38.0	0.9	HIT	44.5	8.0	1	2.3	34.7	1.3	HIT	40.9
49	Default_Radar	SLS	1 SSS @ 20 nm		16.1	8.9	10.8	21.4	4.4	HIT	36.2	16.0	9.2	11.7	19.2	5.1	HIT	34.5
50	Default_Radar	SLS	1 SSS @ 12 nm		11.8	0.2	7.1	11.1	2.7	HIT	21.4	11.9	0.1	7.6	10.1	3.1	HIT	20.4
51	Default_Radar	SLS	2 SSS @ 20 nm; 1 second apart	ASM1/SAM1	16.0	9.2	11.4	20.0	4.7	HIT	35.6	16.0	9.2	11.7	19.2	5.1	HIT	34.5
				ASM2/SAM1	15.1	12.2	No launch - HIT SHIP					16.0	10.2	No launch - HIT SHIP				
52	Default_Radar	SLS	2 SSS @ 12 nm; 1 second apart	ASM1/SAM1	11.6	0.8	6.4	12.8	2.3	HIT	22.2	11.9	0.1	7.6	10.1	3.1	HIT	20.4
				ASM2/SAM1	11.3	2.3	No launch - HIT SHIP					12.0	1	No launch - HIT SHIP				

- Results for subsonic and supersonic cruise missiles engaging the ship, ship employs "Home All the Way" (HAW) missiles using a Shoot-Look-Shoot (SLS) firing doctrine.
- Both models were able to generate results with quite good agreement. Generally, times for intercept are within 2 seconds and intercept ranges are within 0.2 nautical miles for subsonic threats and 0.5 nautical mile for supersonic threats.
- Similarly, we had good agreement while employing a SSLSS firing doctrine as well.

Threat Performance

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Semi-Active Terminal Homing Missiles, SSLSS Firing Doctrine

- Results for cruise missiles engaging the ship, ship employs missiles with semi-active terminal homing (SATH) capability using a Shoot-Shoot-Look-Shoot-Shoot (SSLSS) firing doctrine.
- Both models were able to generate results with quite good agreement. Generally, times for intercept are within 2 seconds and intercept ranges are within 0.2 nautical miles for subsonic threats and 0.5 nautical mile for supersonic threats.
- Similarly, the SATH results for cruise missile threats employing a SLS firing doctrine also showed good agreement.

	Blue Ship		Threats	Notes														
	Ship	Ship			SADM Data							SSD Data						
Test #	Search Radar	Firing Doctrine	ASMs		Initial Detect		Launch		Intercept			Initial Detect		Launch		Intercept		
					R (nm)	T (s)	R (nm)	T (s)	R (nm)	H/M?	T (s)	R (nm)	T (s)	R (nm)	T (s)	R (nm)	H/M?	T (s)
69	Default_Radar	SSLSS	1 SBS @ 20 nm	ASM1/SAM1	12.4	45.7	10.5	57.0	6.6	HIT	80.3	12.5	44.8	10.8	54.9	6.8	HIT	78.6
	Default_Radar			ASM1/SAM2			10.2	59.0		Overkill					56.9		Overkill	
70	Default_Radar	SSLSS	1 SBS @ 8 nm	ASM1/SAM1	8.0	0.4	6.3	11.0	4.0	HIT	24.5	8.0	0.1	6.3	10.1	4.2	HIT	22.7
	Default_Radar			ASM1/SAM2			5.9	13.0		Overkill					12.1		Overkill	
71	Default_Radar	SSLSS	2 SBS @ 20 nm; 1 second apart	ASM1/SAM1	12.2	46.6	9.3	64.0	6.0	HIT	84.2	12.5	44.8	10.8	54.9	6.8	HIT	78.6
				ASM1/SAM2			9.0	66.0		Overkill					56.9		Overkill	80.5
				ASM2/SAM1	12.6	45.1	4.3	95.0	2.7	HIT	105.2	12.5	45.8	6.5	81.7	4.3	HIT	94.7
				ASM2/SAM2			4.0	97.0		Overkill					83.7		Overkill	
72	Default_Radar	SSLSS	2 SBS @ 8 nm; 1 second apart	ASM1/SAM1	7.9	1.3	6.1	12.0	3.9	HIT	25.2	8.0	0.1	6.3	10.1	4.2	HIT	22.7
				ASM1/SAM2			5.8	14.0		Overkill					12.1		Overkill	24.6
				ASM2/SAM1	8.0	1.3	2.2	36.5	1.0	HIT	43.3	8.0	1	2.9	31.1	1.8	HIT	38.2
				ASM2/SAM2			1.9	38.5		Overkill					33.1		Overkill	
73	Default_Radar	SSLSS	1 SSS @ 20 nm	ASM1/SAM1	15.9	9.5	11.4	20.0	4.7	HIT	35.6	16.0	9.2	11.7	19.2	5.1	HIT	34.5
				ASM1/SAM2			10.5	22.0		Overkill					21.2		Overkill	
74	Default_Radar	SSLSS	1 SSS @ 12 nm	ASM1/SAM1	11.4	1.1	6.7	12.0	2.5	HIT	21.8	11.9	0.1	7.6	10.1	3.1	HIT	20.4
				ASM1/SAM2			5.9	14.0		Overkill					12.1		Overkill	
75	Default_Radar	SSLSS	2 SSS @ 20 nm; 1 second apart	ASM1/SAM1	15.6	10.3	No launch - HIT SHIP					16.0	9.2	11.7	19.2	5.1	HIT	34.5
				ASM1/SAM2											21.2		Overkil	36.4
				ASM2/SAM1	16.0	10.3	10.5	23.0	4.3		37.5	16.0	10.2	No launch - HIT SHIP				
				ASM2/SAM2			9.6	25.0		Overkill								
76	Default_Radar	SSLSS	2 SSS @ 12 nm; 1 second apart	ASM1/SAM1	11.3	1.4	No launch - HIT SHIP					11.9	0.1	7.6	10.1	3.1	HIT	20.4
				ASM1/SAM2											12.1		Overkil	22.3
				ASM2/SAM1	11.7	1.4	7.1	12.0	2.7	HIT	22.4	12.0	1	No launch - HIT SHIP				
				ASM2/SAM2			6.3	14.0		Overkill								

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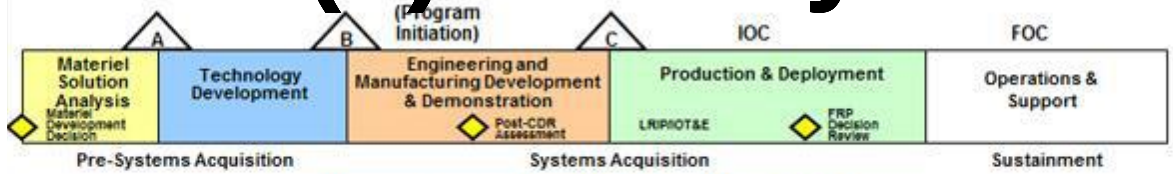
SSD/SADM Comparison

Criteria	SSD	SADM
Ease of use	Easy to set up and use – low learning curve. Easy to set up exact conditions (detect, launch, intercept, etc.) you wish to study.	Significant learning curve for new users. Large set of default values available, but analyst must validate them for his study. Requires many more inputs to run a scenario
Execution Speed	Runs fast and provides many Monte Carlo runs to analyze in minutes.	Runs fairly quickly, though it can take hours to complete large numbers of Monte Carlo runs.
Modeling approach	Uses look up tables to characterize most performance. Validity depends on source of data; excellent if from high fidelity sims.	Uses physics based models more than look up tables (models sensor detections / flies missile at physics level).
Sensor models	Sensor models are very basic, providing low fidelity. Analyst will use sensor as “black box” using SSD.	Sensor models are medium fidelity, allowing an analyst to configure a realistic sensor model for their study with a sensor as key component.
Weapon models	Models exist for a large variety of weapons, and model can be readily adapted for new weapon models using look up tables.	Medium fidelity physics based models. No capability to model dual mode missiles like RAM or future ESSM Block 2 today, though in development.
Target audience	Provides results tuned to missile analyst’s needs.	Provide results tuned to ship system designer’s needs with enhanced trade-offs for sensors, weapons, and threats available. Utilized in Navy for hard kill / soft kill interaction analysis.

Fidelity Differences between Models Drive Data Requirements and Learning Curve

Model(s) Life Cycle View



DoD 5000 Lifecycle Phase	Goals	SSD Data Produced	SADM Data Produced
Material Solution Analysis	Assess potential materiel solutions, Develop ICD, Conduct AoA	Ship Self Defense combat survivability data for projected ship systems and threats.	Ship Self Defense combat survivability data for projected ship systems and threats.
Technology Development	Reduce technology risk, determine and mature the appropriate set of technologies to be integrated into a full system, demonstrate on prototypes.	Ship Self Defense combat survivability data for projected ship systems and threats. This will include updated sensor and weapon performance data from this phase.	Ship Self Defense combat survivability data for projected ship systems and threats. This will include updated sensor, C2, and weapon models using updated design and performance data during this phase.
Engineering and Manufacturing Development	Develop a system or an increment of capability; complete full system integration (technology risk reduction occurs during Technology Development); develop manufacturing process; ensure operational systems integration (HSI); design for producibility; ensure affordability; minimizing the logistics footprint; and demonstrate system integration, interoperability, safety, and utility.	Ship Self Defense combat survivability data for developed ship systems and projected threats. This will include updated sensor and weapon performance data from this phase.	Ship Self Defense combat survivability data for developed ship systems and projected threats. This will include updated sensor, C2, and weapon models using updated design and performance data during this phase.
Production and Deployment	Achieve an operational capability that satisfies mission needs. Operational test and evaluation shall determine the effectiveness and suitability of the system.	Ship Self Defense combat survivability data for existing ship systems and projected threats.	Ship Self Defense combat survivability data for existing ship systems and projected threats. This will include updated sensor, C2, and weapon models using updated design and performance data during this phase.
Operations and Support	Execute a support program that meets materiel readiness and operational support performance requirements, and sustains the system in the most cost-effective manner over its total life cycle.	Ship Self Defense combat survivability data for existing ship systems and projected threats.	Ship Self Defense combat survivability data for existing ship systems and projected threats. This will include updated sensor, C2, and weapon models using updated design and performance data during this phase.

- This illustrates how SSD and SADM might be utilized over the acquisition life cycle
- SSD will utilize updated performance data as the weapon system design matures
- SADM will incorporate updated models for the sensors, C2, and weapons
- The higher fidelity of the SADM model is expected to increase its utility later in the lifecycle, while SSD shines in the early stages of the lifecycle
- We plan to update this initial assessment after we completed our next phase of the study.

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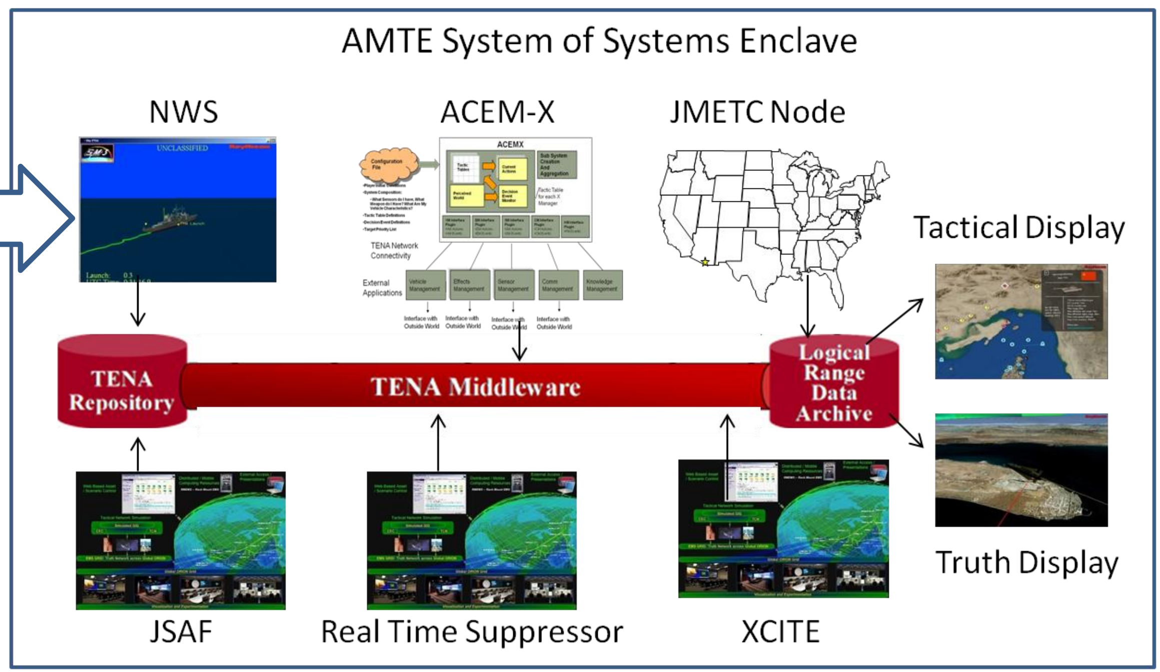
Extended SADM Applications

SADM can be extended to include higher fidelity missile models for stand alone analysis, or……..

SADM can be embedded into LVC experiments for Advanced Mission Test Environments (AMTEs).



Link AMTE into JMETC Exercises

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Summary/Conclusions

- This study identified a strong correlation between fidelity, data requirements, and learning curve for the models evaluated
- Our initial results indicate that both SSD and SADM, while similar models in many ways, provide unique capabilities
  - SSD provides an important "quick look" capability that is important early in the lifecycle
  - SADM provides a more "in depth" look at relationships between system components that will increase in importance as the lifecycle advances
- We are currently looking at a mixed use strategy where both SSD and SADM will be used at different points in the system lifecycle to support weapon system analysis

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About the Author

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- **TIM JAHREN** has been with the Raytheon family of companies for 30 years. Tim has been a leader in the Simulation Interoperability Standards Organization (SISO) for 15 years. He is the current chair for SISO's System Life Cycle (SLC) forum. He has supported a wide variety of M&S and Simulation Based Acquisition (SBA) programs, including the Joint Simulation System (JSIMS) Enterprise, the Navy's DD-21 and DD(X) programs, and the Army's Future Combat System. Tim holds a bachelors degree in electrical engineering from Northwestern University and a masters degree in electrical engineering with a focus on communication systems from the University of Southern California.