

# Implementing a Digital Engineering Environment for Mission Engineering

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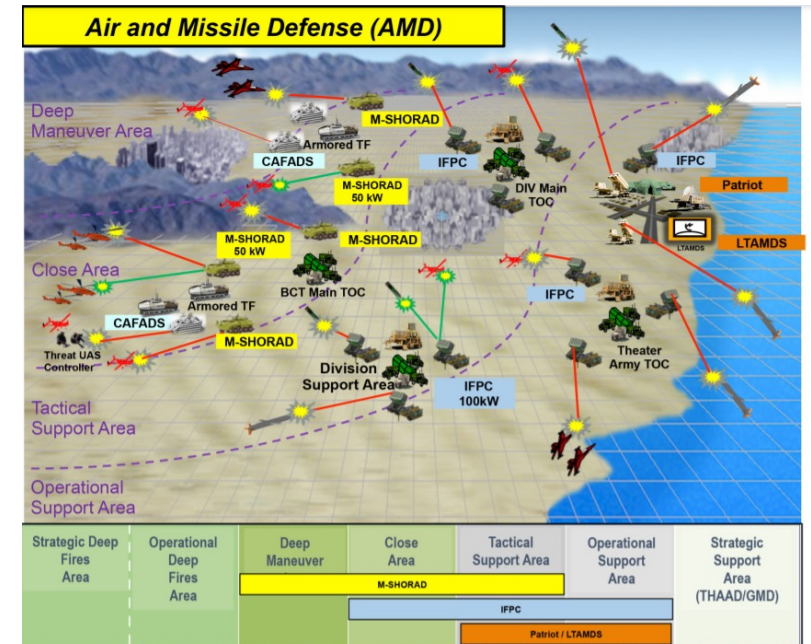
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# Introduction

- The presentation describes the broad mission context driving the development and the approach used to creating a **Digital Engineering Environment (DEE)** for the Joint Staff J8's Joint Integrated Air and Missile Defense Organization (JIAMDO).
- This includes the development of top-level mission threads for IAMD which can be specialized to address different mission sets, including **Counter Unmanned Aerial Systems (C-UAS)** as well as **Cruise Missile Defense (CMD)**.
- The presentation includes perspectives from the DEE team, MITRE, as well as the end user, JIAMDO.

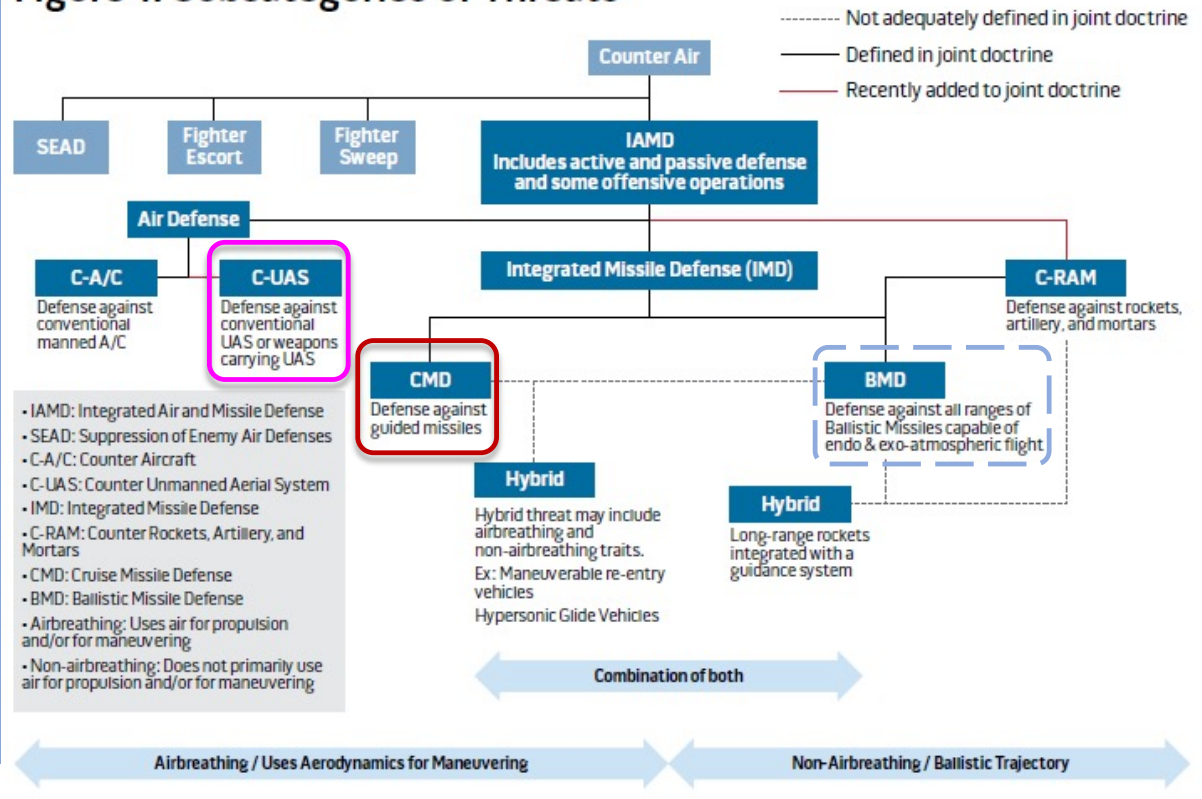


Source: Army Air and Missile Defense Vision 2028, USASMD/ARSTRAT



# IAMD Mission Space

Figure 1. Subcategories of Threats

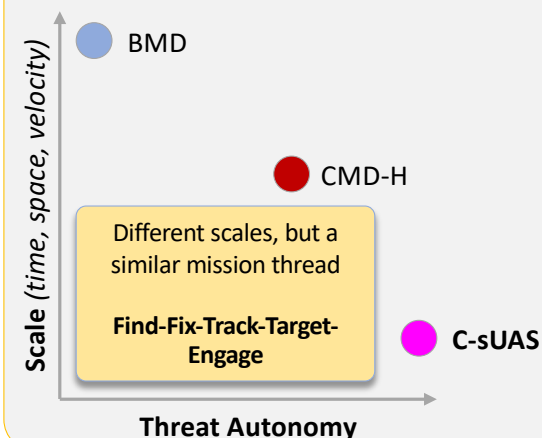


Credit: Gabriel Almodovar, Daniel P. Allmacher, Morgan P. Ames III, and Chad Davies, JFQ 88, 1<sup>st</sup> Quarter 2018

## Key Insight

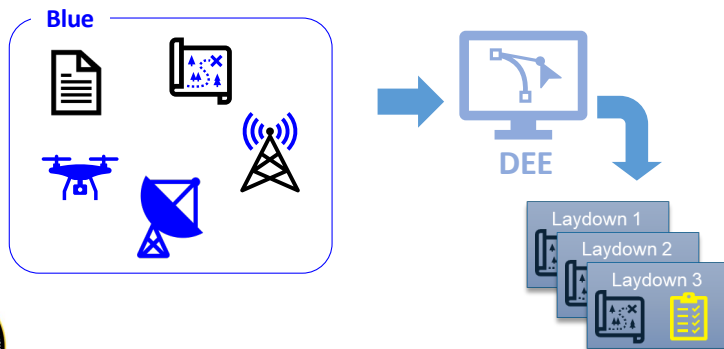
**A Digital Engineering Environment developed for any IAMD mission can be easily re-factored to address the others.**

Current work is focused on analysis of Countering Small Unmanned Aerial Systems (**C-sUAS**) – has been expanded to Cruise Missile Defense of the Homeland (**CMD-H**) in FY21, and will be expanded to support Ballistic Missile Defense (**BMD**) in FY22



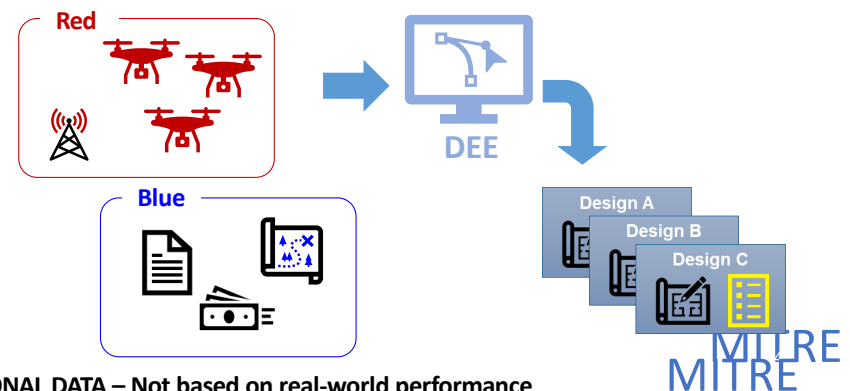
## Two Complementary Analytical Approaches

- Start with knowns – *“Make the most of what you have”*
- Given existing C-sUAS system parameters, **determine the optimal set of capabilities** for a given scenario.



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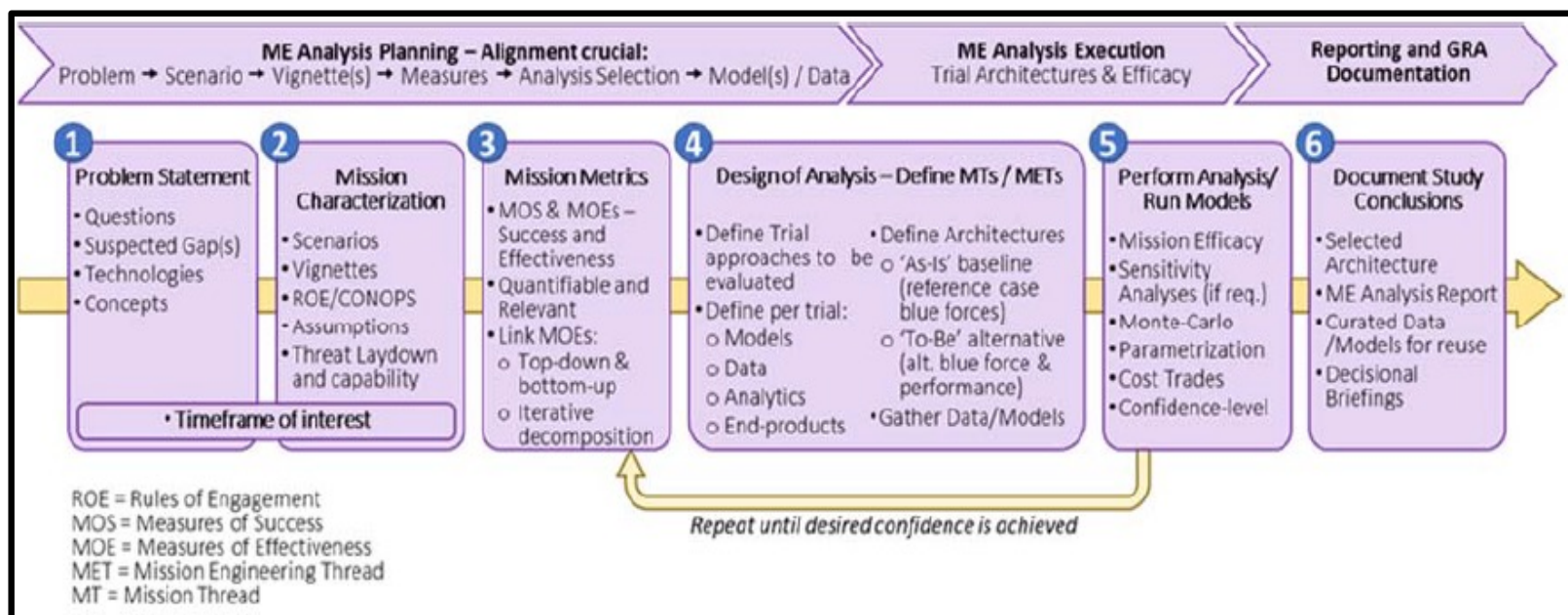
- Start with requirements – *“Buy the best of what you need”*
- Given adversary capabilities and BF CONOPs, **derive the required C-sUAS capabilities and parameters** that optimize performance for a given scenario.



NOTIONAL DATA – Not based on real-world performance



## ME Approach and Methodology



ME process begins with the end in mind, a carefully articulated problem statement, the characterization of the mission and identification of metrics, and working through the collection of data and models needed to analyze the mission and document the output results.

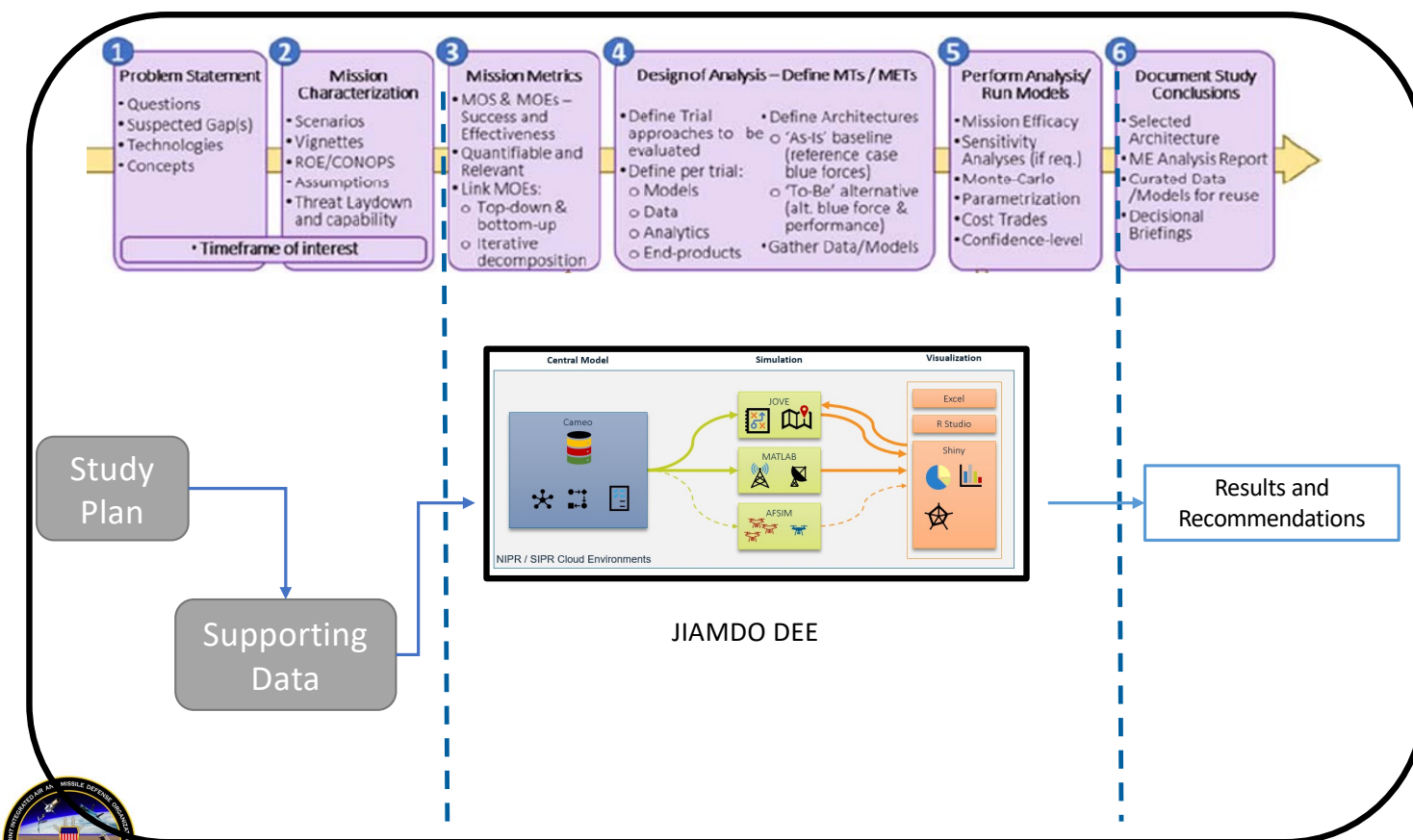


Source: OSD Mission Engineer Guide - [https://ac.cto.mil/wp-content/uploads/2020/12/MEG-v40\\_20201130\\_shm.pdf](https://ac.cto.mil/wp-content/uploads/2020/12/MEG-v40_20201130_shm.pdf)

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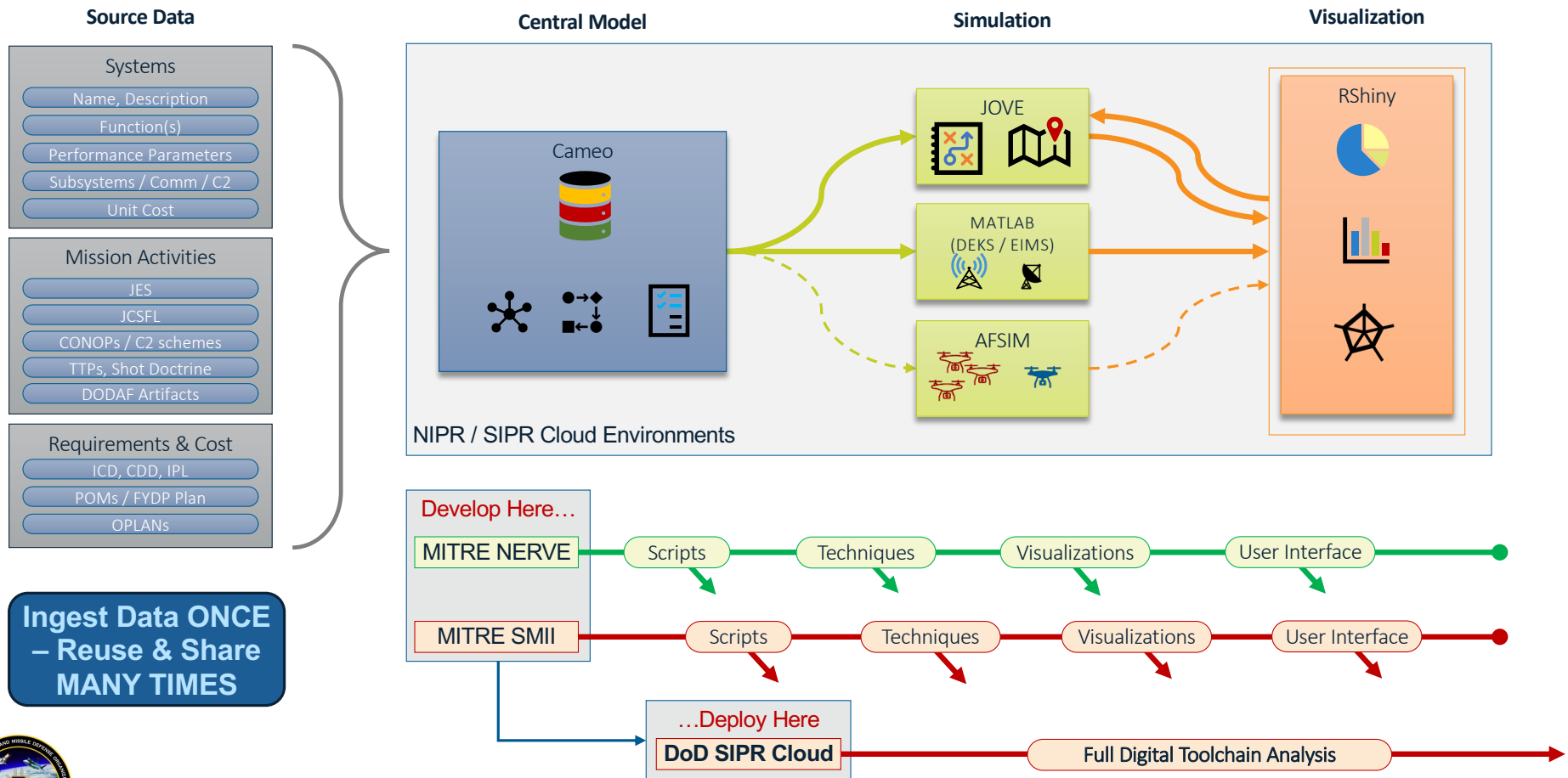
# DE Framework within Mission Engineering (ME)



Simplifying the execution of Steps #3, #4 and #5 in the ME process



# JIAMDO DE Environment – Process Flow

























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# CUAS Digital Engineering Environment

	Product Type: Scopes the viewpoint of each product			
	REQUIREMENTS	BEHAVIOR	STRUCTURE	PARAMETERS
<b>Mission Level: What problem is being modeled</b>	<b>Stakeholder Needs</b>  Fixed / Semi-Fixed Mission Overview  C-UAS CDD Requirements	<b>Use Cases</b>  Dynamic Targeting Use Case  C-UAS Dynamic Targeting	<b>System Context</b>  C-UxS Systems	<b>Measures of Effectiveness</b>  Measures of Effectiveness  Cost Items
<b>System of Systems: Describes the SoS to address the problem and verify the solutions.</b>	<b>System Requirements</b>  System Satisfy Matrix  Notional SoS	<b>System Behavior</b>  C-UAS System A  C-UAS System B	<b>System Structure</b>  C-UAS System A  C-UAS System B	<b>Measures of Performance</b>  System Sensing Performance  Kinetic Effectors Performance  Non-Kinetic Effectors Performance
<b>Model: Describes how the M&amp;S application will represent a portion of the problem space to validate the solutions</b>	<b>Simulation Requirements</b>	<b>Simulation Behavior</b>  Baseline Config  To Be Config	<b>Simulation Structure</b>  Baseline Systems  To Be Systems	<b>Test Case</b>  

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### System Context – C-UAS System List

#	Name	Attributes
1	John Cadden	groupType = GroupType = Rapid Prototype Sponsor = string = -
2	AFPS	groupType = GroupType = Discontinued Sponsor = string = USA
3	Robot	groupType = GroupType = Discontinued Sponsor = string = SOCOM
4	Red Chain	groupType = GroupType = Discontinued Sponsor = string = SOCOM
5	C-HDS	groupType = GroupType = Fixed / Semi-F Sponsor = string = USAF
6	Chadler	groupType = GroupType = Discontinued Sponsor = string = SOCOM
7	C-UAS	groupType = GroupType = Rapid Prototype Sponsor = string = -
8	CORON	groupType = GroupType = Fixed / Semi-F Sponsor = string = USA, USN
9	CORON B6 C+	groupType = GroupType = Rapid Prototype Sponsor = string = -
10	Cardridge	groupType = GroupType = Discontinued Sponsor = string = DIS
11	PAKE	groupType = GroupType = Discontinued Sponsor = string = -
12	Drone Buster v1+	groupType = GroupType = Discontinued Sponsor = string = -
13	Drone Defender v1.5+	groupType = GroupType = Discontinued Sponsor = string = -
14	SHAD v1	groupType = GroupType = USA Sponsor = string = USA
15	F-LDS	groupType = GroupType = Fixed / Semi-F Sponsor = string = USA
16	EDS	groupType = GroupType = Discontinued Sponsor = string = SOCOM
17	Enferaske	groupType = GroupType = Discontinued Sponsor = string = CTSO
18	FAAD C2	groupType = GroupType = C2 Sponsor = string = USA
19	Guardian	groupType = GroupType = Rapid Prototype Sponsor = string = -
20	L-MAOS	groupType = GroupType = Mobile / Mount / Afloat Sponsor = string = USMC
21	UPWS	groupType = GroupType = Mobile / Mount / Afloat Sponsor = string = USA
22	H-LDS	groupType = GroupType = Fixed / Semi-F Sponsor = string = CTSO
23	MAOS	groupType = GroupType = Mobile / Mount / Afloat Sponsor = string = USAF
24	MEDUSA	groupType = GroupType = Mobile / Mount / Afloat Sponsor = string = USMC
25	MEDUSA C2	groupType = GroupType = Fixed / Semi-F Sponsor = string = USAF
26	MEDUSA Mobile	groupType = GroupType = C2 Sponsor = string = -
27	MDI II	groupType = GroupType = USMC Sponsor = string = USMC
28	Morphose	groupType = GroupType = Rapid Prototype Sponsor = string = -
29	MDCA	groupType = GroupType = Fixed / Semi-F Sponsor = string = SOCOM

### Measures of Performance Sensing Performance

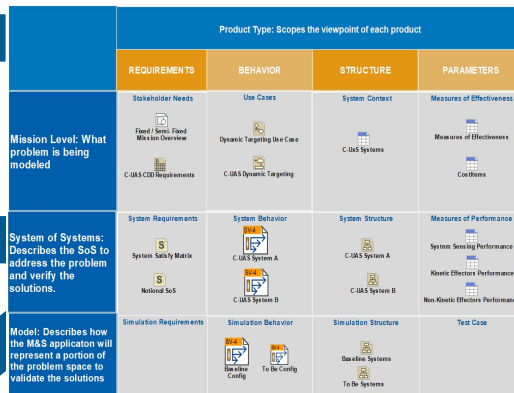
Name	Source	Target	Range KM	FO	False Alarm Rate Per Hour
2.3.2 C-UAS System Building Blocks					
BLUE					
C-UAS System A	C-UAS System A Se...	OII	5	1	
C-UAS System B					
Subsystems					
Radar B	Radar B	OII	25	0.75	
Radar A	Radar A	OII	15	0.75	10
Dismount Sensor	Dismount Sensor	OII	1.82	0.7	
RED					
Sensors	EO/IS Camera	HYT	1.852	1	
2.3.4 Placeholder Systems					

### System Costs

Name	UnitCost	Expenditures
C-UAS System A	150	<undefined>
C2	50	<undefined>
Dismount Effector	30	<undefined>
Dismount Sensor	10	<undefined>
EW Effector	100	<undefined>
Interceptor	20	<undefined>
Interceptor Launcher	1000	<undefined>
Radar A	3416	<undefined>
Radar B	5000	<undefined>



# Analytic Elements



## Measures of Effectiveness

#	Name	Documentation	Specification
1	JSR Mission		
2	Spider Chart MDEA		
3	(1) % of Red threats killed before Threshold requirement Range from BSC	Of the total # of red threats flown, how many are killed before they get to 80km - 4.3 nm	# Just
4	(1) % of Red threats killed before BSC detection	The BSC "Ground Truth" test events will be good for this. If threat is not killed, use 0	# of red that make at least 1 sense of BSC / # of total red (5)
5	(1) % of Red Collects Prevented	Of the total # of red threats flown in, how many can detect the BSC at all, (do they get close enough to use their sensor?)	# average detects for architecture in single replication / # detects in baseline
6	(1) % of Red threats killed	In comparison to the baseline - how many collects does the blue defense prevent - good normalized metric	# killed / # of total red (5)
7	Cost Metrics	Of the total # of red threats flown in, what % are neutralized	
8	(1) % of Non-Kinetic vs Kinetic kills		# of kills logged by a weapon that starts with EW / total kills
9	(1) Average Cost of Config		Average total cost of config (use # of expended coyote for Coyote costs)
10	(1) RQ Collected	How long can the red platforms detect blue assets?	For each red use -> T_start_detect - T_end_detect
11	(1) RQ Shared	How long can the red platforms share detections of blue assets back to their controller?	For each red use -> T_start_report - T_end_report
12	(1) R# Collected	How many detects does the red platform have on the BSC	For any red platform, total # of detects

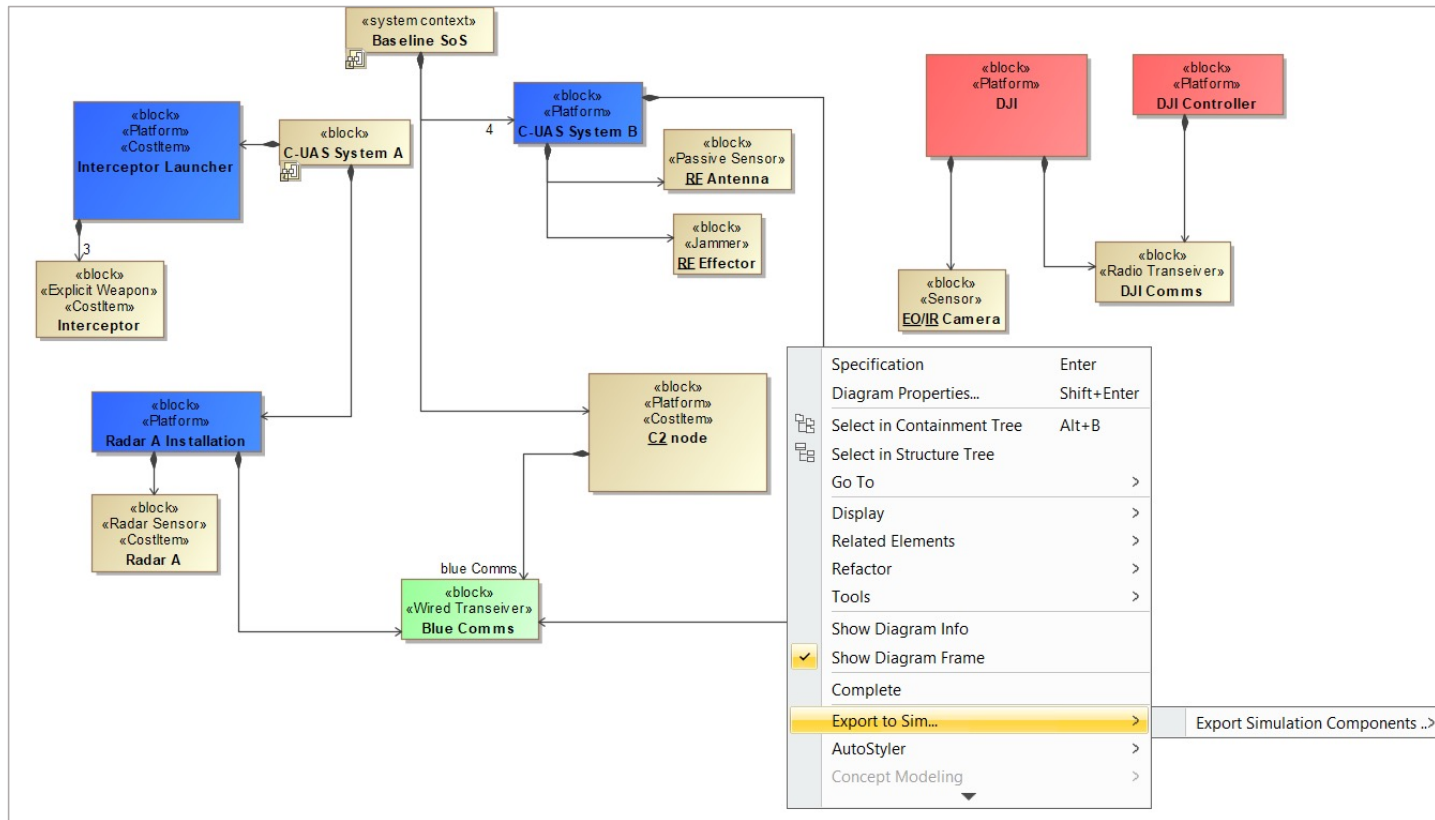
## Operational Requirements from JCO CDD

Name	Test
1.1 Detect and Track	(U) The Joint C-UAS capability shall detect and track multiple threat type / agent / multi-agent/term UASs simultaneously (Group 1, 2 & 3) with 360 degree coverage in an operational electromagnetic environment prior to their effective range to support C-UAS operations.
1.1.1 Detect and Track Size	(U) [EQ00] Must detect and track UAS to include the Unmanned Aerial Vehicle (UAV) weighing less than or equal to X lbs. (Group 1-2) which may include a ground control station (GCS), X km on the ground and UAS weighing > X lbs. (Group 3), (Ames A)
1.1.2 Detect and Track Altitude	(U) [EQ00] Must detect and track UAS operating at an altitude of ≤ X ft. Mean Sea Level (MSL) (Groups 1-2) and UAV (Group 3) at ≤ X ft. (Group 3)
1.1.3 Detect and Track Speed	(U) [EQ00] Must detect and track UAS hovering and traveling ≤ X knots indicated airspeed (Groups 1-2) and UAV (Group 3) at ≤ X knots indicated airspeed.
1.1.4 Detect and Track Range	(U) [EQ00] Must detect at ranges to prevent threat UAS from performing BSC missions and attack operations
1.1.4.1 Fixed Detect and Track Range	(U) The Joint C-UAS capability shall detect group 1, 2, & 3 UASs actively and passively
1.1.4.1.1 Fixed Active Sensor Threshold	(U) The Joint C-UAS capability shall detect group 1, 2, & 3 UASs active at ranges up to > X km (Group 1), > X km (Group 2) and > X km (Group 3)
1.1.4.1.2 Fixed Active Sensor Objective	(U) The Joint C-UAS capability shall detect group 1, 2, & 3 UASs active at ranges up to > X km (Group 1), > X km (Group 2) and > X km (Group 3)
1.1.4.1.3 Fixed Passive Sensor Threshold	(U) The Joint C-UAS capability shall detect group 1, 2, & 3 UASs passive at ranges up to > X km
1.1.4.1.4 Fixed Passive Sensor Objective	(U) The Joint C-UAS capability shall detect group 1, 2, & 3 UASs passive at ranges up to > X km
1.1.4.2 Mobile Detect and Track Range	(U) Mobile C-UAS capability shall detect group 1 & 2 UAS while on the move or at halt
1.1.4.2.1 Mobile Active Sensor Threshold	(U) Mobile C-UAS capability shall detect group 1 & 2 UAS active at > X km
1.1.4.2.2 Mobile Active Sensor Objective	(U) Mobile C-UAS capability shall detect group 1 & 2 UAS active at > X km
1.1.4.2.3 Mobile Passive Sensor Threshold	(U) Mobile C-UAS capability shall detect group 1 & 2 UAS passive at > X km
1.1.4.2.4 Mobile Passive Sensor Objective	(U) Mobile C-UAS capability shall detect group 1 & 2 UAS passive at > X km
1.1.5 Detect and Track Probability	(U) Joint C-UAS Capability shall track with > X probability of error for tracking based on method used for tracking/geo-location

## System Requirements – C-UAS System to CDD Requirements Matrix

Legend	System Requirements	Operational Requirements	Test
□ Safety	□ Safety (Implied)	□ Safety (Implied)	□ Safety (Implied)
□ C-UAS System A	□ C-UAS System A	□ C-UAS System A	□ C-UAS System A
□ C-UAS System B	□ C-UAS System B	□ C-UAS System B	□ C-UAS System B
□ Radar A	□ Radar A	□ Radar A	□ Radar A
□ Radar B	□ Radar B	□ Radar B	□ Radar B
□ Dismount Sensor	□ Dismount Sensor	□ Dismount Sensor	□ Dismount Sensor
□ EW Effector	□ EW Effector	□ EW Effector	□ EW Effector
□ Interceptor	□ Interceptor	□ Interceptor	□ Interceptor
□ Interceptor Launcher	□ Interceptor Launcher	□ Interceptor Launcher	□ Interceptor Launcher
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□ Radar B	□ Radar B	□ Radar B	□ Radar B
□ EO/IS Camera	□ EO/IS Camera	□ EO/IS Camera	□ EO/IS Camera
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□ Radar B	□ Radar B	□ Radar B	□ Radar B
□ EO/IS Camera	□ EO/IS Camera	□ EO/IS Camera	□ EO/IS Camera
□ C-UAS System A	□ C-UAS System A	□ C-UAS System A	□ C-UAS System A
□ C-UAS System B	□ C-UAS System B	□ C-UAS System B	□ C-UAS System B
□ Radar A	□ Radar A	□ Radar A	□ Radar A
□ Radar B	□ Radar B	□ Radar B	□ Radar B
□ Dismount Sensor	□ Dismount Sensor	□ Dismount Sensor	□ Dismount Sensor
□ EW Effector	□ EW Effector	□ EW Effector	□ EW Effector
□ Interceptor	□ Interceptor	□ Interceptor	□ Interceptor
□ Interceptor Launcher	□ Interceptor Launcher	□ Interceptor Launcher	□ Interceptor Launcher
□ Radar A	□ Radar A	□ Radar A	□ Radar A
□ Radar B	□ Radar B	□ Radar B	□ Radar B
□ EO/IS Camera	□ EO/IS Camera	□ EO/IS Camera	□ EO/IS Camera
□ C-UAS System A	□ C-UAS System A	□ C-UAS System A	□ C-UAS System A
□ C-UAS System B	□ C-UAS System B	□ C-UAS System B	□ C-UAS System B
□ Radar A	□ Radar A	□ Radar A	□ Radar A
□ Radar B	□ Radar B	□ Radar B	□ Radar B
□ Dismount Sensor	□ Dismount Sensor	□ Dismount Sensor	□ Dismount Sensor
□ EW Effector	□ EW Effector	□ EW Effector	□ EW Effector
□ Interceptor	□ Interceptor	□ Interceptor	□ Interceptor
□ Interceptor Launcher	□ Interceptor Launcher	□ Interceptor Launcher	□ Interceptor Launcher
□ Radar A	□ Radar A	□ Radar A	□ Radar A
□ Radar B	□ Radar B	□ Radar B	□ Radar B
□ EO/IS Camera	□ EO/IS Camera	□ EO/IS Camera	□ EO/IS Camera
□ C-UAS System A	□ C-UAS System A	□ C-UAS System A	□ C-UAS System A
□ C-UAS System B	□ C-UAS System B	□ C-UAS System B	□ C-UAS System B
□ Radar A	□ Radar A	□ Radar A	□ Radar A
□ Radar B	□ Radar B	□ Radar B	□ Radar B
□ Dismount Sensor	□ Dismount Sensor	□ Dismount Sensor	□ Dismount Sensor
□ EW Effector	□ EW Effector	□ EW Effector	□ EW Effector
□ Interceptor	□ Interceptor	□ Interceptor	□ Interceptor
□ Interceptor Launcher	□ Interceptor Launcher	□ Interceptor Launcher	□ Interceptor Launcher
□ Radar A	□ Radar A	□ Radar A	□ Radar A
□ Radar B	□ Radar B	□ Radar B	□ Radar B
□ EO/IS Camera	□ EO/IS Camera	□ EO/IS Camera	□ EO/IS Camera
□ C-UAS System A	□ C-UAS System A	□ C-UAS System A	□ C-UAS System A
□ C-UAS System B	□ C-UAS System B	□ C-UAS System B	□ C-UAS System B
□ Radar A	□ Radar A	□ Radar A	□ Radar A
□ Radar B	□ Radar B	□ Radar B	□ Radar B
□ Dismount Sensor	□ Dismount Sensor	□ Dismount Sensor	□ Dismount Sensor
□ EW Effector	□ EW Effector	□ EW Effector	□ EW Effector
□ Interceptor	□ Interceptor	□ Interceptor	□ Interceptor
□ Interceptor Launcher	□ Interceptor Launcher	□ Interceptor Launcher	□ Interceptor Launcher
□ Radar A	□ Radar A	□ Radar A	□ Radar A
□ Radar B	□ Radar B	□ Radar B	□ Radar B
□ EO/IS Camera	□ EO/IS Camera	□ EO/IS Camera	□ EO/IS Camera
□ C-UAS System A	□ C-UAS System A	□ C-UAS System A	□ C-UAS System A
□ C-UAS System B	□ C-UAS System B	□ C-UAS System B	□ C-UAS System B
□ Radar A	□ Radar A	□ Radar A	□ Radar A
□ Radar B	□ Radar B	□ Radar B	□ Radar B
□ Dismount Sensor	□ Dismount Sensor	□ Dismount Sensor	□ Dismount Sensor
□ EW Effector	□ EW Effector	□ EW Effector	□ EW Effector
□ Interceptor	□ Interceptor	□ Interceptor	□ Interceptor
□ Interceptor Launcher	□ Interceptor Launcher	□ Interceptor Launcher	□ Interceptor Launcher
□ Radar A	□ Radar A	□ Radar A	□ Radar A
□ Radar B	□ Radar B	□ Radar B	□ Radar B
□ EO/IS Camera	□ EO/IS Camera	□ EO/IS Camera	□ EO/IS Camera
□ C-UAS System A	□ C-UAS System A	□ C-UAS System A	□ C-UAS System A
□ C-UAS System B	□ C-UAS System B	□ C-UAS System B	□ C-UAS System B
□ Radar A	□ Radar A	□ Radar A	□ Radar A
□ Radar B	□ Radar B	□ Radar B	□ Radar B
□ Dismount Sensor	□ Dismount Sensor	□ Dismount Sensor	□ Dismount Sensor
□ EW Effector	□ EW Effector	□ EW Effector	□ EW Effector
□ Interceptor	□ Interceptor	□ Interceptor	□ Interceptor
□ Interceptor Launcher	□ Interceptor Launcher	□ Interceptor Launcher	□ Interceptor Launcher
□ Radar A	□ Radar A	□ Radar A	□ Radar A
□ Radar B	□ Radar B	□ Radar B	□ Radar B
□ EO/IS Camera	□ EO/IS Camera	□ EO/IS Camera	□ EO/IS Camera
□ C-UAS System A	□ C-UAS System A	□ C-UAS System A	□ C-UAS System A
□ C-UAS System B	□ C-UAS System B	□ C-UAS System B	□ C-UAS System B
□ Radar A	□ Radar A	□ Radar A	□ Radar A
□ Radar B	□ Radar B	□ Radar B	□ Radar B
□ Dismount Sensor	□ Dismount Sensor	□ Dismount Sensor	□ Dismount Sensor
□ EW Effector	□ EW Effector	□ EW Effector	□ EW Effector
□ Interceptor	□ Interceptor	□ Interceptor	□ Interceptor
□ Interceptor Launcher	□ Interceptor Launcher	□ Interceptor Launcher	□ Interceptor Launcher
□ Radar A	□ Radar A	□ Radar A	□ Radar A
□ Radar B	□ Radar B	□ Radar B	□ Radar B

# Data Exchange with Operational Simulation

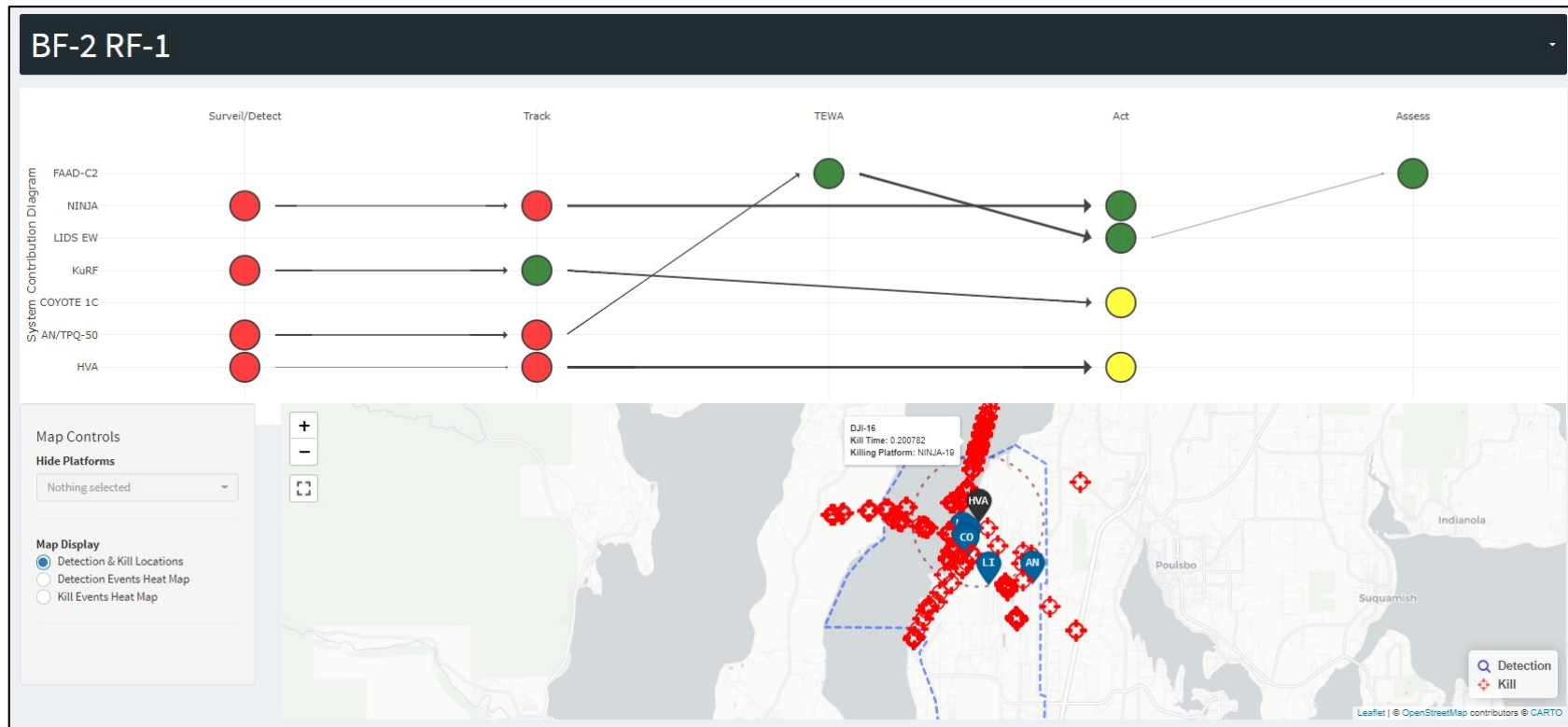


# Operational Simulations: A Comparison

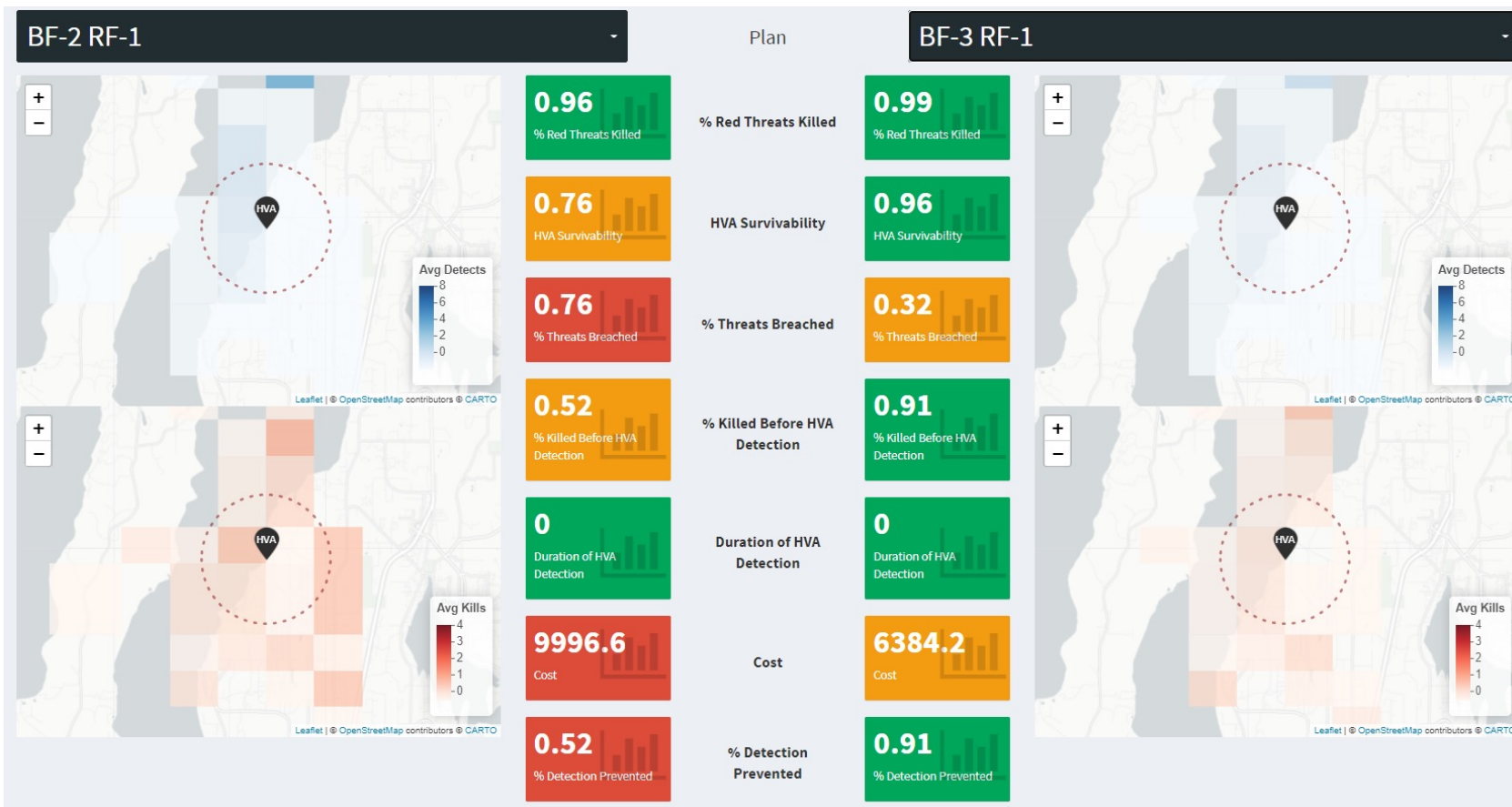
Operational Sim Feature	JOVE	DEKS	EIMS
Capable of Effects Chain Analysis	✓	✓	✓
Graphical User Interface	Yes	In Progress	No (Planned)
Simulation Type	Discrete Event	Discrete Event	Batch Monte-Carlo
Scenario Scale	Scalable	Single Base	Single Base to Theatre Level
Fidelity	Low-Med	Low	Med-High
Simulation Timeliness	Fast	Med	Slow
Real-Time Simulation View	✓	✓	
Applicable Missions	C-UAS, CMD	C-UAS	CMD, BMD
Base Laydown System		✓	
Defended Area Analysis		✓	✓
Physics-Based Behaviors		✓	✓
Blue C2 Modeling	✓		(In Progress)
Red C2 Modeling	✓	✓	
Terrain Specification	✓	✓	✓
Engagement Metrics Calculated (Out of Box)	✓	✓	✓
Surveillance Metrics Calculated (Out of Box)		✓	✓
Threat Tracking Metrics Calculated (Out of Box)			✓



# Visualization Dashboard: System Summary

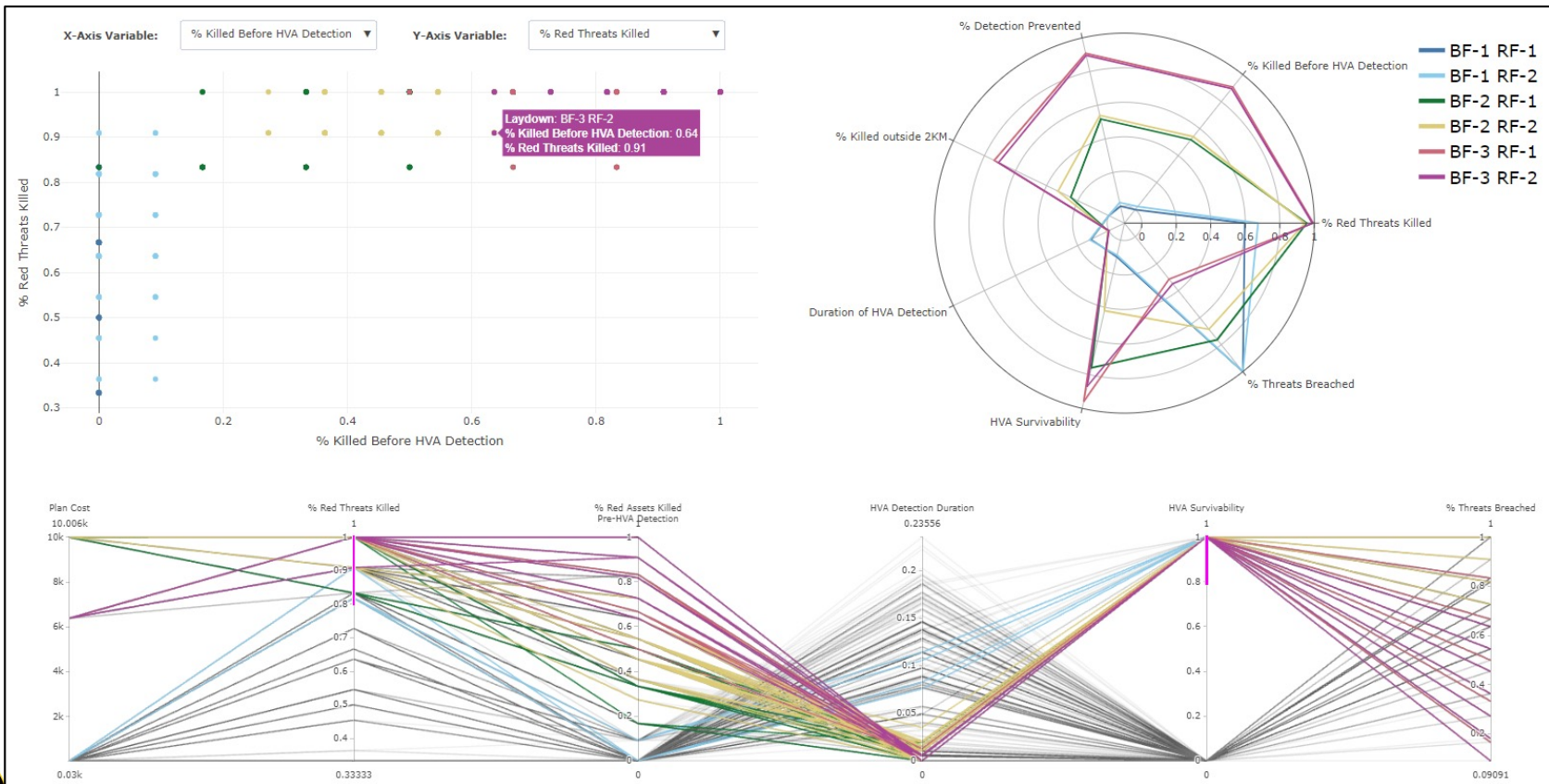


# Visualization Dashboard: Laydown Comparison



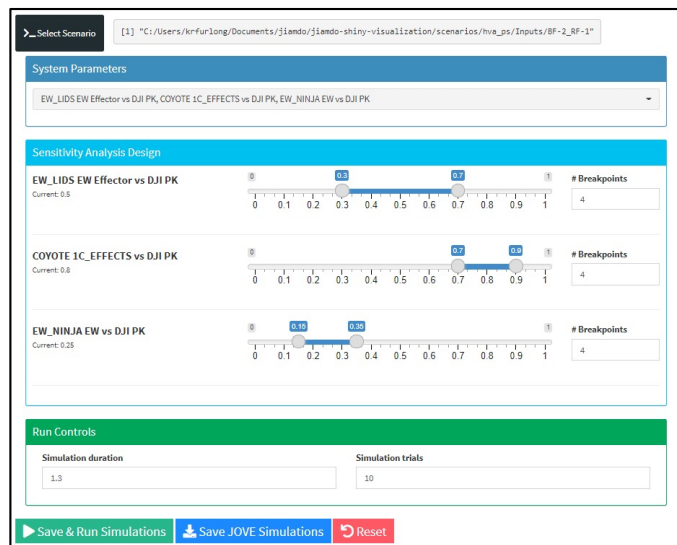


# Visualization Dashboard: MOE Analysis

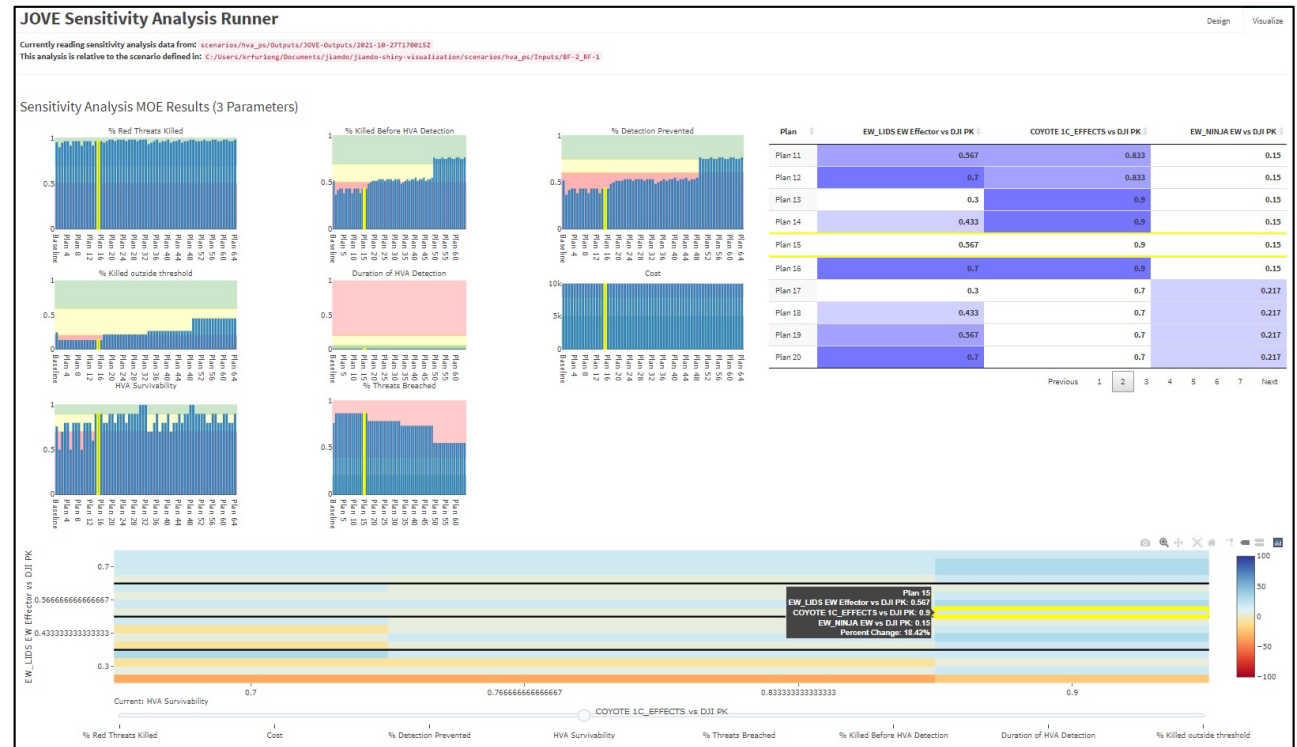




# Visualization Dashboard: Sensitivity Analysis



Real-time experimentation and  
visualization of results



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## Summary And Future Plans

- Digital Engineering Environment live and supporting C-UAS and CMD-H analytical exercises with multiple M&S tools available
  - Available at UNCLASS external to MITRE for JIAMDOD
  - Available at SECRET internal to MITRE
- FY22 Next Steps
  - SIPR Deployment
  - AFSIM Integration
  - BMD Analysis Capability

Thank-You!

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