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Suzanne M DeLong; Adam W Patterson; Adwoa K Gyekye

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14. ABSTRACT
Combat modeling can be a labor intensive, time consuming and expensive venture. SMACS was developed to analyze combat capability packages in a “back of the envelope” way through probabilistic calculations based on the functions of Blue systems stimulating, sensing, and striking Red targets. While initially developed as a spreadsheet Monte Carlo Simulation, SMACS grew into a Python simulation model that allows for the analysis of simple combat scenarios, exploring Blue system characteristics while varying Red target level of importance and engagement priority strategies. SMACS applies Monte Carlo simulation to decision trees to generate a success score based on the success of destroying the red tar

15. SUBJECT TERMS
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89th MORS Symposium

"Analytics to Enhance Decision Making"

Stochastic Model for Analyzing Combat Strategies (SMACS)

Dr. Suzanne DeLong

Mr. Adam Patterson

Ms. Adwoa Gyekye

SMACS Background

- What is SMACS?
  - A probabilistic model used to simulate blue versus red systems
  - Originally created as an Excel spreadsheet model, later expanded to a Python model
- Why we created SMACS
  - Developed to support Army Futures and Concept Center (FCC) evaluation of the Army Multi-Domain Operations (MDO) Concept (TRADOC PAM 525-3-1)
  - Assist in the selection of Blue Force capability packages
  - Developed to analyze simple scenarios as added analysis to higher fidelity scenarios being created in M&S tools
  - Allows for exploration of parameters that may be unknown

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SMACS Process

Input* blue/red systems and conditional parameters for the model

BLUE SYSTEM CHARACTERISTICS

Blue Systems	Domain	Assignment	P(S | R & A)$_1$	P(Kill | Hit)	Max. Effective Range (nm)	P(Survive)	P(S | R') = 0
UAV	Air	Stimulate	0.95		185	0.83	No
Maritime Radars	Sea	Sense	0.9		450	0.9	No
Air Platform	Air	Strike	0.8	0.8	250	0.83	No
LRPF	Land	Strike	0.85	0.95	500	0.9	Yes

RED SYSTEM CHARACTERISTICS

Red Systems	Weight	Initial Distance (nm)	Armed System?
System 1	4	1000	No
System 2	1	600	Yes
System 3	1	500	Yes

*Notional Input Data and Strategies

Design strategies* to compare success results

STRATEGIES

Volley	Strategy 1:			Priority 1	Priority 2	Priority 3
1	UAV	Stimulate	Air	System 3		
1	Maritime Radars	Sense	Sea	System 3		
1	Air Platform	Strike	Air	System 3		
1	LRPF	Strike	Land			
1						
2	UAV	Stimulate	Air	System 3	System 2	
2	Maritime Radars	Sense	Sea	System 3	System 2	
2	Air Platform	Strike	Air	System 3	System 2	
2	LRPF	Strike	Land			
2						
3	UAV	Stimulate	Air	System 1	System 3	System 2
3	Maritime Radars	Sense	Sea	System 1	System 3	System 2
3	Air Platform	Strike	Air	System 1	System 3	System 2
3	LRPF	Strike	Land			
3						

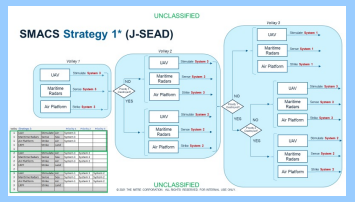
Volley	Strategy 2:			Priority 1	Priority 2	Priority 3
1	UAV	Stimulate	Air	System 3		
1	Maritime Radars	Sense	Sea	System 3		
1	Air Platform	Strike	Air	System 3		
1	LRPF	Strike	Land			
1						
2	UAV	Stimulate	Air	System 3	System 2	
2	Maritime Radars	Sense	Sea	System 3	System 2	
2	Air Platform	Strike	Air			
2	LRPF	Strike	Land	System 3	System 2	
2						
3	UAV	Stimulate	Air	System 1	System 3	System 2
3	Maritime Radars	Sense	Sea	System 1	System 3	System 2
3	Air Platform	Strike	Air			
3	LRPF	Strike	Land	System 1	System 3	System 2
3						

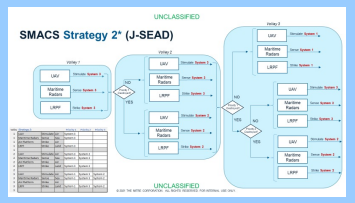
Volley	Strategy 3:			Priority 1	Priority 2	Priority 3
1	UAV	Stimulate	Air	System 3		
1	Maritime Radars	Sense	Sea	System 3		
1	Air Platform	Strike	Air	System 3		
1	LRPF	Strike	Land	System 3		
1						
2	UAV	Stimulate	Air	System 3	System 2	
2	Maritime Radars	Sense	Sea	System 3	System 2	
2	Air Platform	Strike	Air	System 3	System 2	
2	LRPF	Strike	Land	System 3	System 2	
2						
3	UAV	Stimulate	Air	System 1	System 3	System 2
3	Maritime Radars	Sense	Sea	System 1	System 3	System 2
3	Air Platform	Strike	Air	System 1	System 3	System 2
3	LRPF	Strike	Land	System 1	System 3	System 2
3						

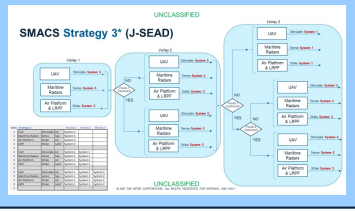
*Volley is considered "an attack"

Monte Carlo Simulation

Randomly generate success scores and statistics for each designed strategy 5,000** times

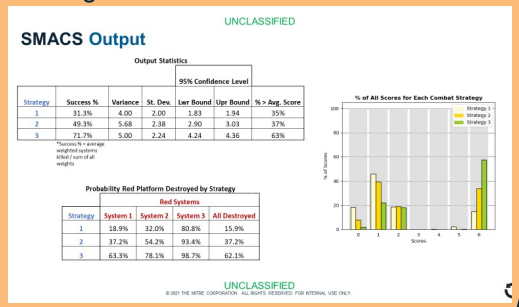




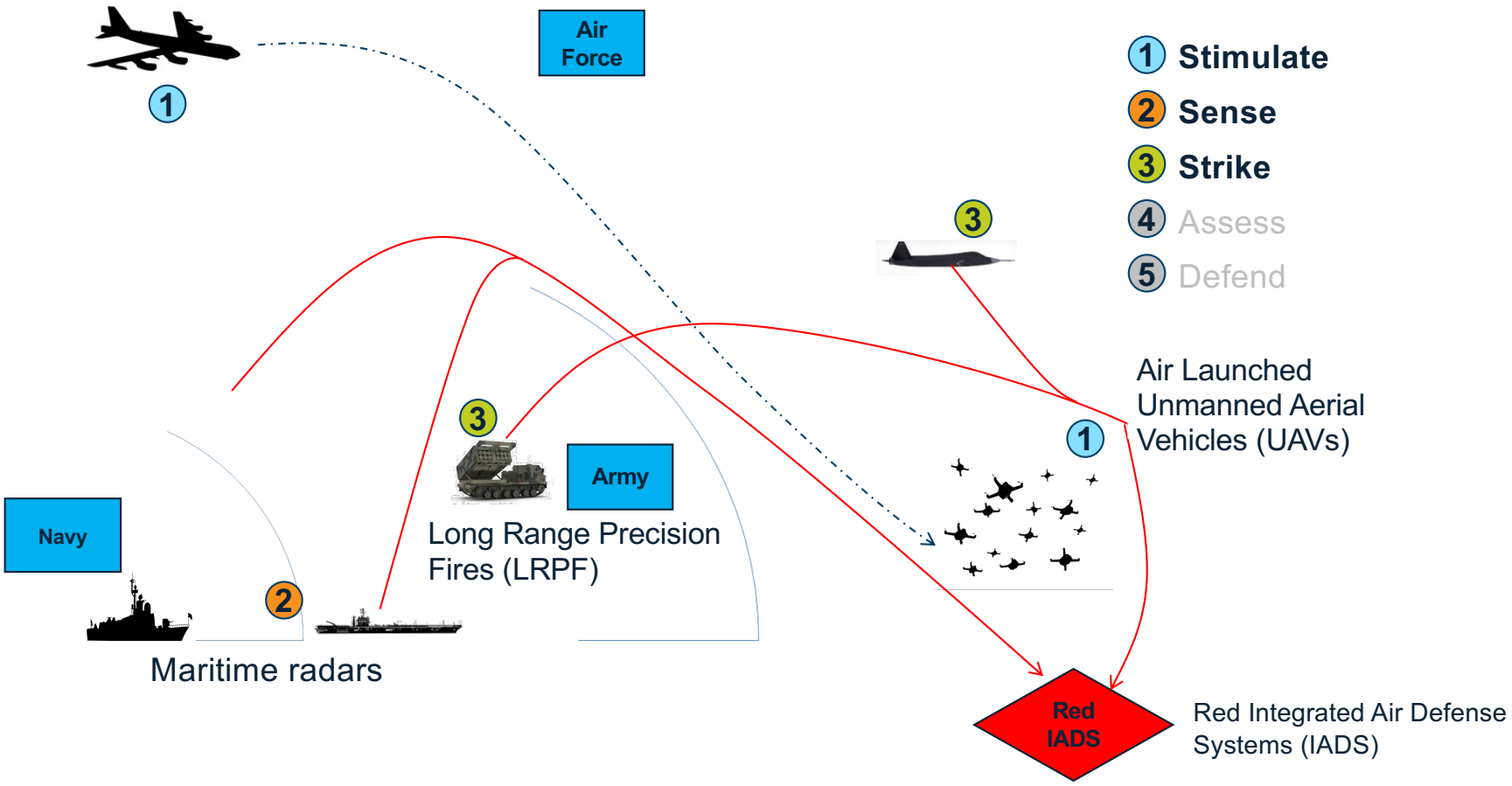


**Can be any number of simulations given feasible run-time

Display results and visuals to compare all strategies



Joint Suppression of Enemy Air Defense (J-SEAD) Play Layered Convergence



SMACS User Inputs for J-SEAD Scenario

Blue and Red System Characteristics

USER INPUTS*

*Notional Input Data

BLUE SYSTEM CHARACTERISTICS

Blue Systems	Domain	Assignment	P(S | R & A)$_1$	P(Kill | Hit)	Max. Effective Range (km)	P(Survive)	P(S | R') = 0
UAV	Air	Stimulate	0.95		185	0.83	No
Maritime Radars	Sea	Sense	0.9		450	0.9	No
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LRPF	Land	Strike	0.85	0.95	500	0.9	Yes

S = Success, R = In Range, R' = Out of Range, A = Received Message from Stimulating or Sensing Platform

1 For stimulate, probability of stimulating; for sensing, probability of detecting given stimulated; for striking, probability of hitting given stimulated & sensed. All probabilities are given the system is in range

RED SYSTEM CHARACTERISTICS

Red Systems	Weight	Initial Distance (km)	Armed System?
System 1	4	1000	No
System 2	1	600	Yes
System 3	1	500	Yes

- **P(S | R & A):** General probability the blue system will perform its assignment in a "best case" situation (assuming prior assignment was success and red system is in range) against any red system
- **P(Kill | Hit):** For blue systems striking, the probability of killing any red system given it was hit
- **Max Effective Range:** The maximum distance at which a weapon may be expected to be accurate and achieve the desired effect
- **P(Survive):** The probability of surviving given an attack
- **P(S | R') = 0:** Indicator for if the probability of success is forced to 0 given the blue system is out of range of the red target ("Yes" means probability is forced to 0 if out of range)

- **Weight:** Level of importance a red system has. Red System 1 is x times more important than Red System 2. The higher the weight, the higher the "Score" for destroying but harder to reach in the simulation
- **Initial Distance:** How far the red systems are from the blue systems from the start of the simulation. Assumes the distance is the same from all blue systems
- **Armed System:** Is the system armed? I.e. Does it have fighting/defending capabilities or is it just a stationary unarmed target?

SMACS User Inputs for J-SEAD Scenario

Conditional Probability Characteristics

USER INPUTS*

*Notional Input Data

Probability Degradation Percentages Given Failure to Stimulate and/or Sense

% less likely a blue system senses given the red system failed to be stimulated	10%
% less likely a blue system strikes/hits given the red system failed to be sensed & stimulate	40%
% less likely a blue system strikes/hits given the red system failed to be sensed but was stimulated	25%
% less likely a blue system strikes/hits given the red system was sensed but failed to be stimulated	0%

Blue Systems	Domain	Assignment	$P(S \mid R \& A)_1$
UAV	Air	Stimulate	0.95
Maritime Radars	Sea	Sense	0.9
Air Platform	Air	Strike	0.8
LRPF	Land	Strike	0.85

- **Conditional Probability Characteristics** generate conditional probabilities from the inputted **P(S | R & A)**
- Using example from above:
  - Prob(Maritime Radars sense *given* UAV stimulated) = 0.9
  - Prob(Maritime Radars sense *given* UAV **FAILED** to stimulate) = 0.9 * (1 - 0.1) = 0.81

SMACS User Input* for J-SEAD Scenario – *Strategies**

- A **strategy** is a user-designed scenario in which red system **threat priorities** are indicated for each blue system for every **volley** in the scenario
  - **Threat Priority**: Prioritizing which reds all the blues will pursue. Blue always pursues the highest "alive" threat priority
  - **Volley**: An attack where all the blues pursue their assigned red threat priorities
- The model compares probabilistic outcomes of *all created strategies* displaying which are "better" and "worse"

*Notional Input Data and Strategies

STRATEGIES

Volley	Strategy 1:			Priority 1	Priority 2	Priority 3
1	UAV	Stimulate	Air	System 3		
1	Maritime Radars	Sense	Sea	System 3		
1	Air Platform	Strike	Air	System 3		
1	LRPF	Strike	Land			
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2	Maritime Radars	Sense	Sea	System 3	System 2	
2	Air Platform	Strike	Air	System 3	System 2	
2	LRPF	Strike	Land			
2						
3	UAV	Stimulate	Air	System 1	System 3	System 2
3	Maritime Radars	Sense	Sea	System 1	System 3	System 2
3	Air Platform	Strike	Air	System 1	System 3	System 2
3	LRPF	Strike	Land			
3						

Volley	Strategy 2:			Priority 1	Priority 2	Priority 3
1	UAV	Stimulate	Air	System 3		
1	Maritime Radars	Sense	Sea	System 3		
1	Air Platform	Strike	Air	System 3		
1	LRPF	Strike	Land			
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2	Air Platform	Strike	Air			
2	LRPF	Strike	Land	System 3	System 2	
2						
3	UAV	Stimulate	Air	System 1	System 3	System 2
3	Maritime Radars	Sense	Sea	System 1	System 3	System 2
3	Air Platform	Strike	Air			
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Volley	Strategy 3:			Priority 1	Priority 2	Priority 3
1	UAV	Stimulate	Air	System 3		
1	Maritime Radars	Sense	Sea	System 3		
1	Air Platform	Strike	Air	System 3		
1	LRPF	Strike	Land	System 3		
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2	UAV	Stimulate	Air	System 3	System 2	
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2	Air Platform	Strike	Air	System 3	System 2	
2	LRPF	Strike	Land	System 3	System 2	
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3	Air Platform	Strike	Air	System 1	System 3	System 2
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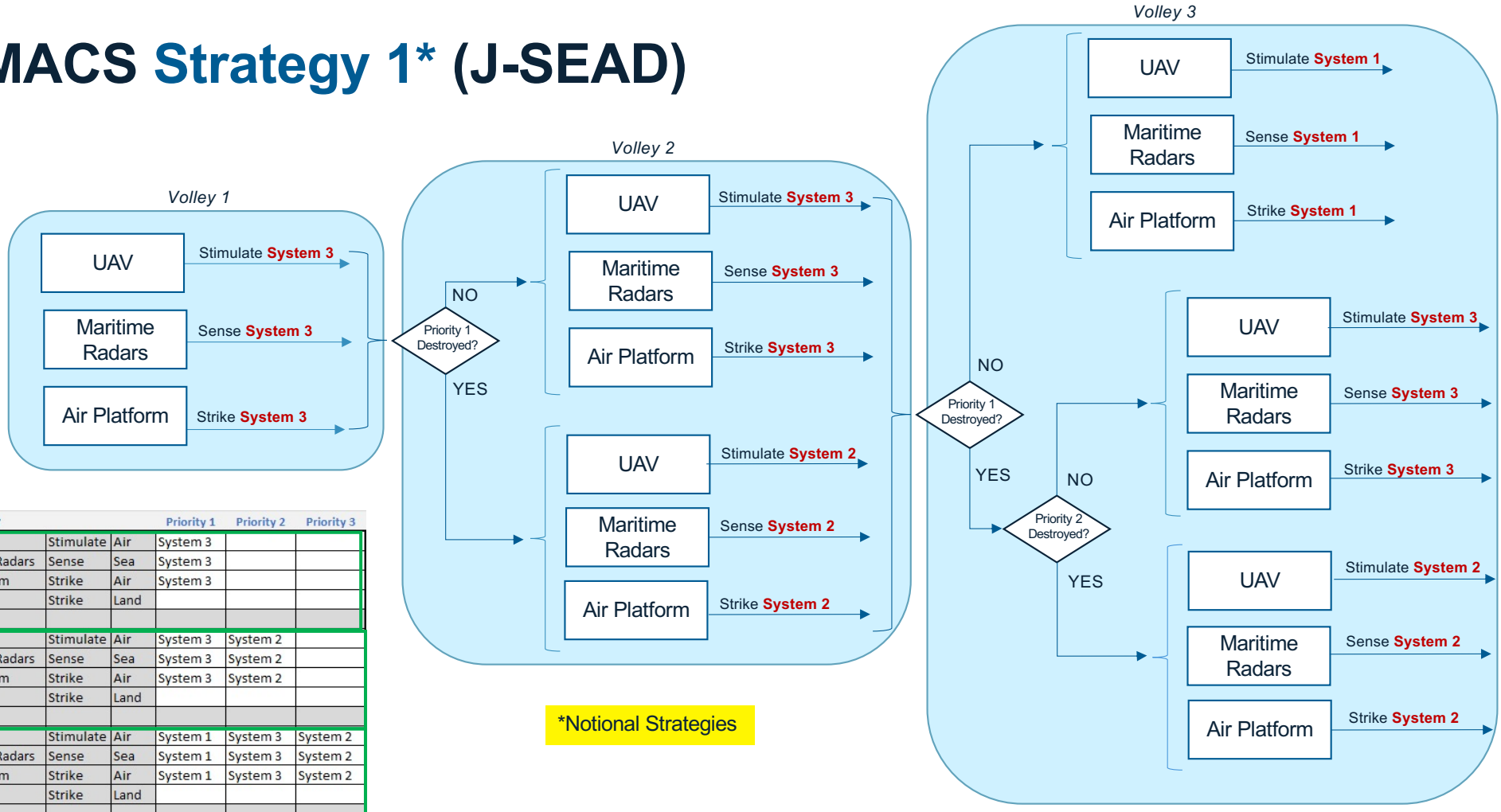
*Volley is considered "an attack"

SMACS Strategy 1* (J-SEAD)



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1	Air Platform	Strike	Air	System 3		
1	LRPF	Strike	Land			
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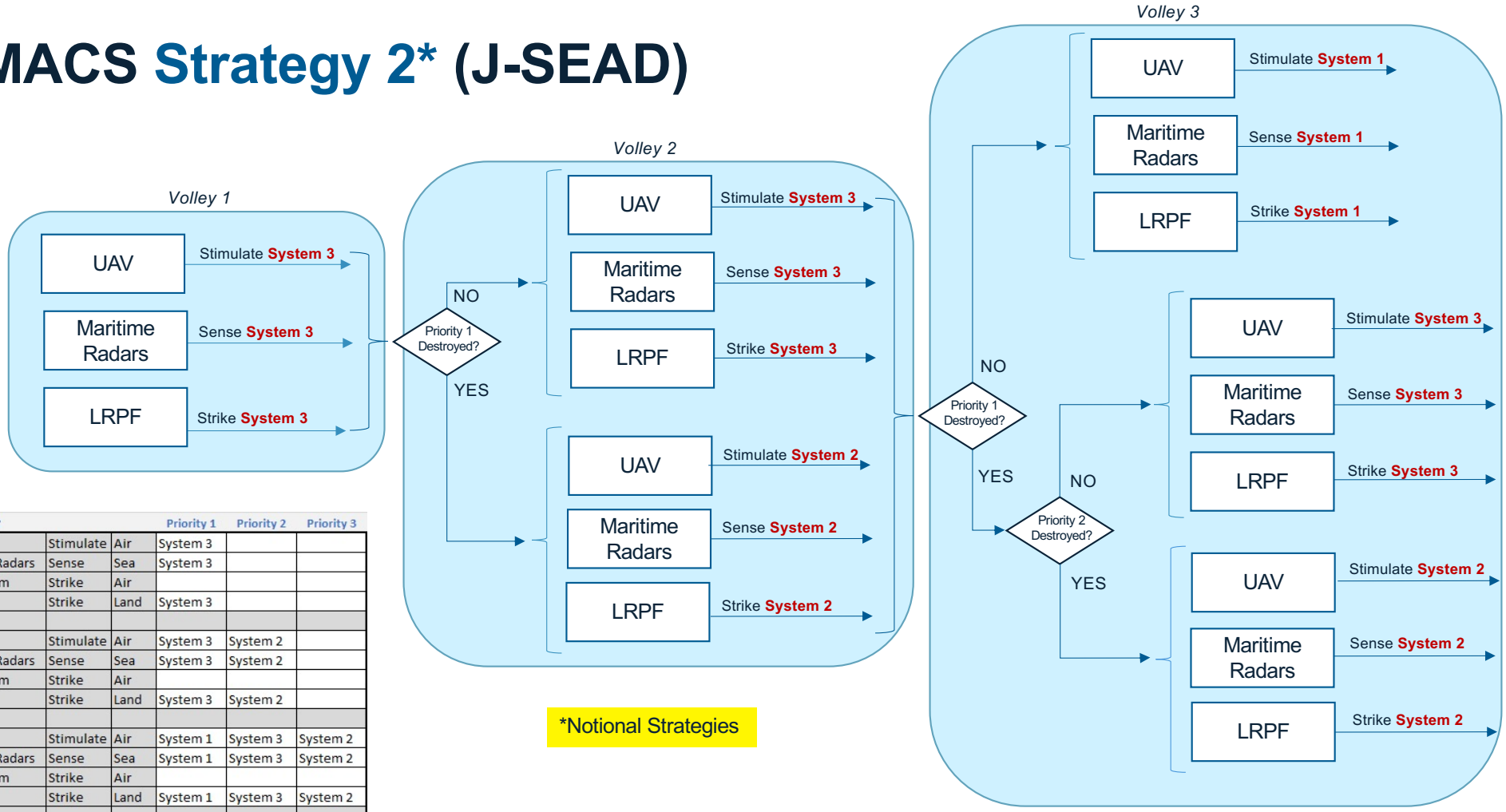
3	LRPF	Strike	Land			
3						

*Notional Strategies

SMACS Strategy 2* (J-SEAD)



Volley	Strategy 2:			Priority 1	Priority 2	Priority 3
1	UAV	Stimulate	Air	System 3		
1	Maritime Radars	Sense	Sea	System 3		
1	Air Platform	Strike	Air			
1	LRPF	Strike	Land	System 3		
1						
2	UAV	Stimulate	Air	System 3	System 2	
2	Maritime Radars	Sense	Sea	System 3	System 2	
2	Air Platform	Strike	Air			
2	LRPF	Strike	Land	System 3	System 2	
2						
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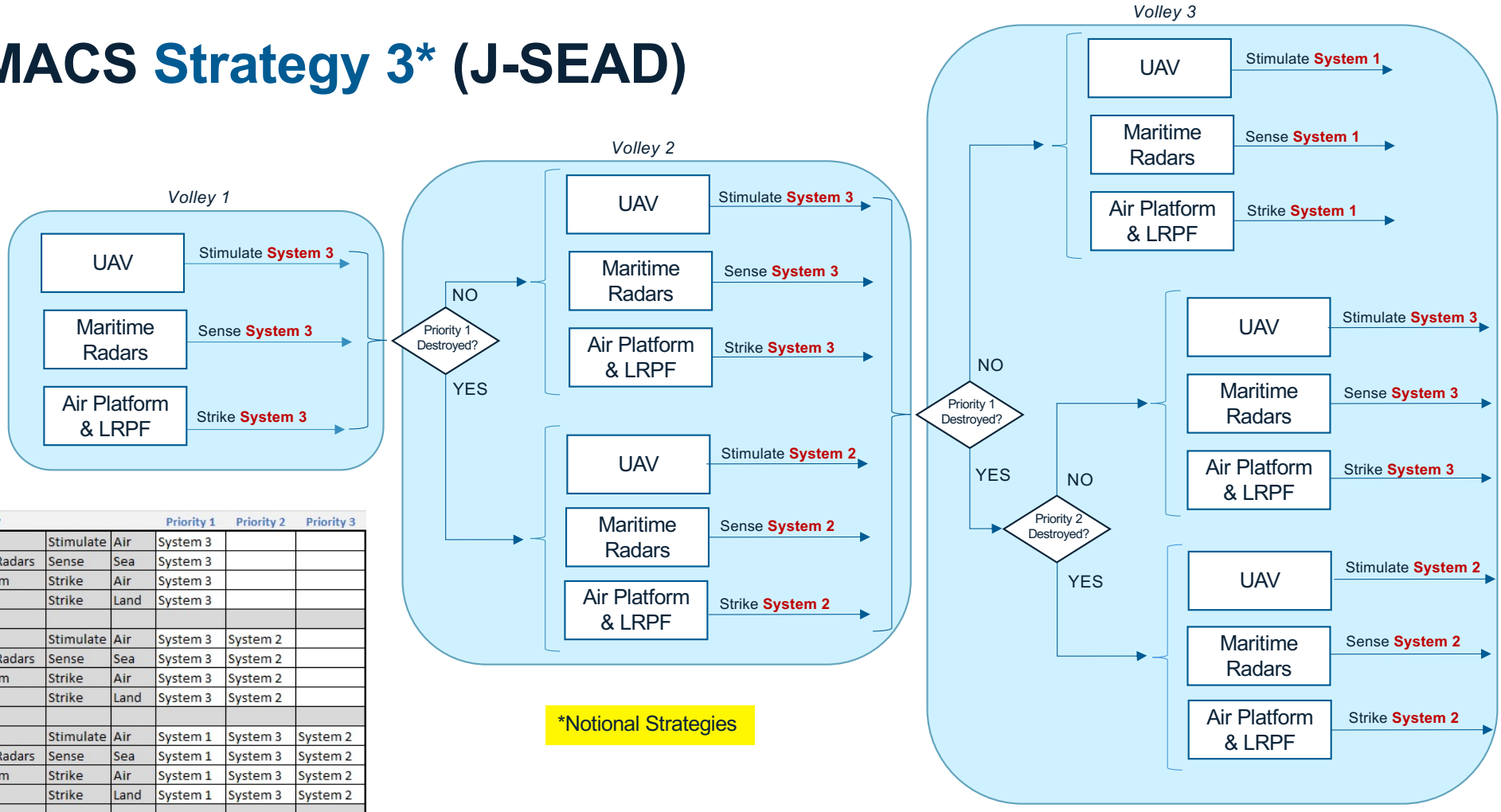
3	Maritime Radars	Sense	Sea	System 1	System 3	System 2
3	Air Platform	Strike	Air			
3	LRPF	Strike	Land	System 1	System 3	System 2
3						

*Notional Strategies

SMACS Strategy 3* (J-SEAD)



Volley	Strategy 3:			Priority 1	Priority 2	Priority 3
1	UAV	Stimulate	Air	System 3		
1	Maritime Radars	Sense	Sea	System 3		
1	Air Platform	Strike	Air	System 3		
1	LRPF	Strike	Land	System 3		
1						
2	UAV	Stimulate	Air	System 3	System 2	
2	Maritime Radars	Sense	Sea	System 3	System 2	
2	Air Platform	Strike	Air	System 3	System 2	
2	LRPF	Strike	Land	System 3	System 2	
2						
3	UAV	Stimulate	Air	System 1	System 3	System 2
3	Maritime Radars	Sense	Sea	System 1	System 3	System 2
3	Air Platform	Strike	Air	System 1	System 3	System 2
3	LRPF	Strike	Land	System 1	System 3	System 2
3						

*Notional Strategies

SMACS Assumptions

- Red platform initial distance is the same distance from each blue platform
- Initial distance of red platforms resets each volley
- Ability of each blue platform can change volley to volley. The distance a blue platform can get to a red platform can differ each volley because other factors can come into effect volley to volley
- It does not make a difference if the red platform assigned to each blue platform is armed or not. It only matters how many total armed red platforms are in the volley.
- Number of times a red platform is stimulated is not a factor. The only thing that is a factor is if it was stimulated at least once or not (this assumption is the same for sensing and striking).
- Probability of survival is fixed at the same probability each volley. i.e. probability of survival is independent volley to volley

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SMACS Output

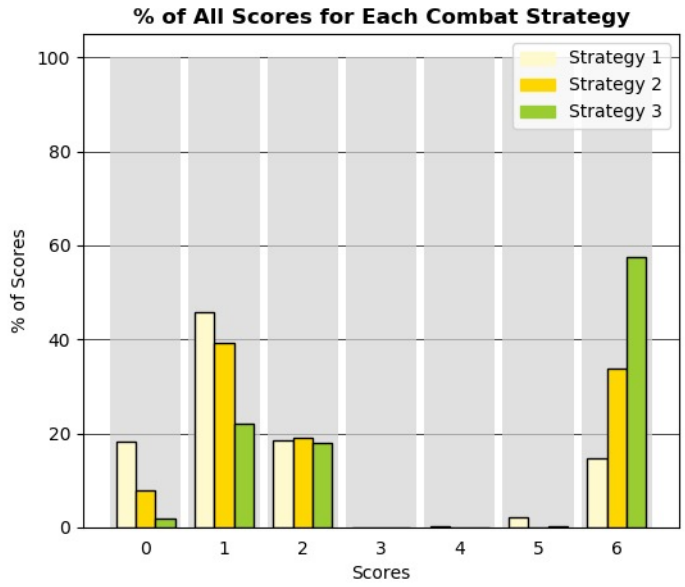
Output Statistics

Strategy	Success %	Variance	St. Dev.	95% Confidence Level		% > Avg. Score
				Lwr Bound	Upr Bound	
1	31.3%	4.00	2.00	1.83	1.94	35%
2	49.3%	5.68	2.38	2.90	3.03	37%
3	71.7%	5.00	2.24	4.24	4.36	63%

*Success % = average weighted systems killed / sum of all weights

Probability Red Platform Destroyed by Strategy

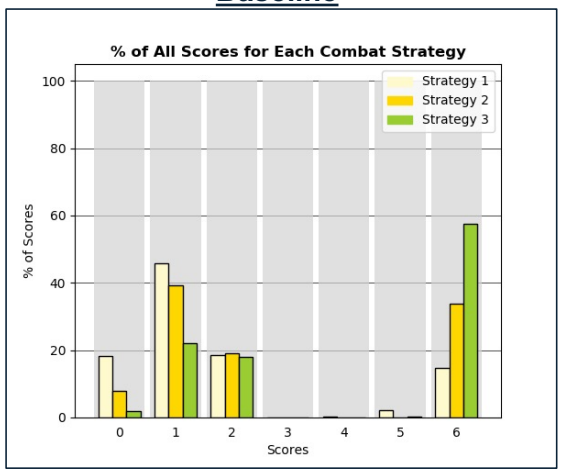
Strategy	Red Systems			
	System 1	System 2	System 3	All Destroyed
1	18.9%	32.0%	80.8%	15.9%
2	37.2%	54.2%	93.4%	37.2%
3	63.3%	78.1%	98.7%	62.1%



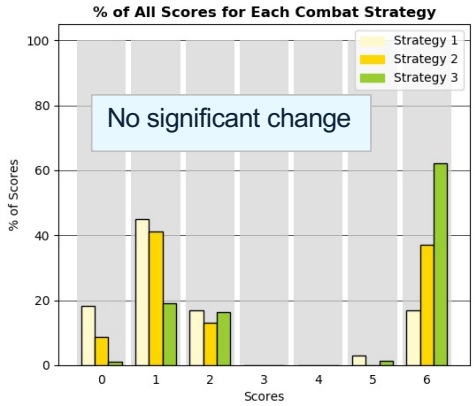
SMACS Design of Experiments

- Scenario A: Increase the maximum effective ranges of the blue platforms 10%
- Scenario B: Stimulate, sense & strike dependencies are stronger by 15%
- Scenario C: Switch the weights of System 2 and System 3 (Prioritizes higher weighted system earlier)
- Scenario D: Attack highest weighted system at the start instead of the end of the combat

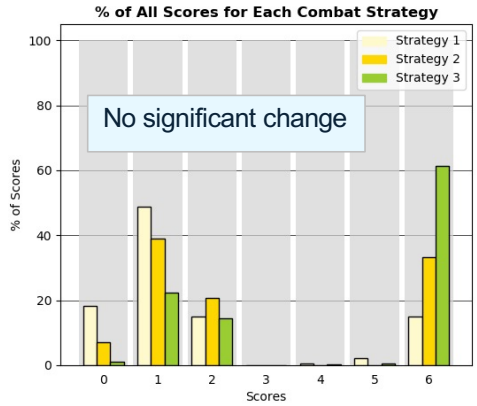
Baseline



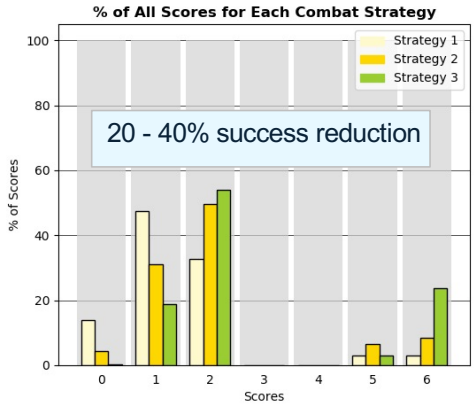
Scenario A



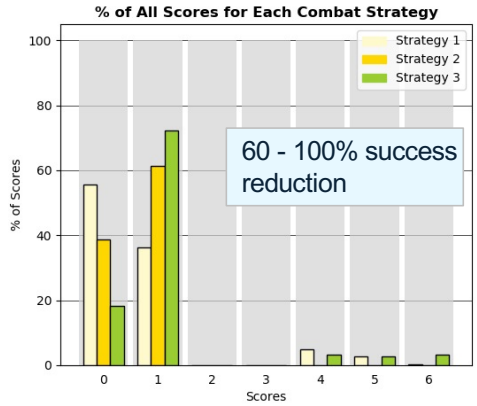
Scenario B



Scenario C



Scenario D



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Key Takeaways*

- Strategy 3 yields the greatest success
  - Air Platform and LRPF working together can provide significant impact depending on system parameters
- Results show it is better to eliminate lower weighted armed systems before prioritizing higher weighted systems
- While adjusting some parameters show some impact on results, adjusting strategies showed greater impacts

* Given this proof of concept example

Current vs Future System*
Statistically Significant Difference?

Minimum System Parameters Target for Future System Capability

Blue Systems	Assignment	Probability of Success								
		Current System	5% Improvement			7% Improvement			8% Improvement		
			Strategy 1	Strategy 2	Strategy 3	Strategy 1	Strategy 2	Strategy 3	Strategy 1	Strategy 2	Strategy 3
UAV	Stimulate	0.8	0.85			0.85			0.85		
Maritime Radars	Sense	0.78	0.819			0.819			0.819		
Air Platform	Strike	0.75	0.7875			0.7875			0.7875		

Blue Systems	Assignment	Probability of Success								
		Current System	10% Improvement			15% Improvement			20% Improvement		
			Strategy 1	Strategy 2	Strategy 3	Strategy 1	Strategy 2	Strategy 3	Strategy 1	Strategy 2	Strategy 3
UAV	Stimulate	0.8	0.88			0.92			0.96		
Maritime Radars	Sense	0.78	0.858			0.897			0.936		
Air Platform	Strike	0.75	0.825			0.8625			0.9		

8 % Improvement — Technological and Monetary Feasibility — 20+ % Improvement

Statistically Significant Difference
No Statistically Significant Difference

*Notional Input Data

Future Work

- SMACS model testing
- Conduct Design of Experiments (DOE) systematically varying input parameters
- Incorporate more Subject Matter Expert inputs when developing assumptions
- Improve the usability of SMACS tool for MITRE Platforms
- Enhanced postprocessing capability
- SMACS modeled with classified data
  - Use with other platforms and studies
  - Wargame strategy evaluation for role player enhanced decision making
- Addition of multiple entities

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