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Soo, Andy Ong Kim; Hwee, Andrew Wong Teck; Darken,
Christian J.; Buss, Arnold H.

Proceedings of the 15th International Command and Control Research and
Technology Symposium (ICCRTS) 2010 "The Evolution of C2".

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Plans Validation Using DES and Agent-Based Simulation

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15th ICCRTS



Agenda



- Introduction
- Methodology
 - Overall Design
 - Agent-based Plan Generation
 - DES-based Simulator Design
- Prototype Implementation
 - DES-based Simulator
 - Agent-based Strike Plan Generation
- Experiment & Results
- Future Work



Introduction



- Military plans validation is typically a long drawn process.
- Require planners to validate plans using
 - Anticipated scenarios
 - Military exercises

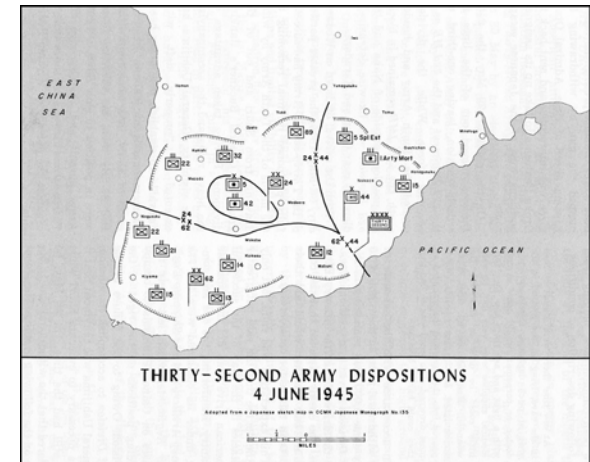
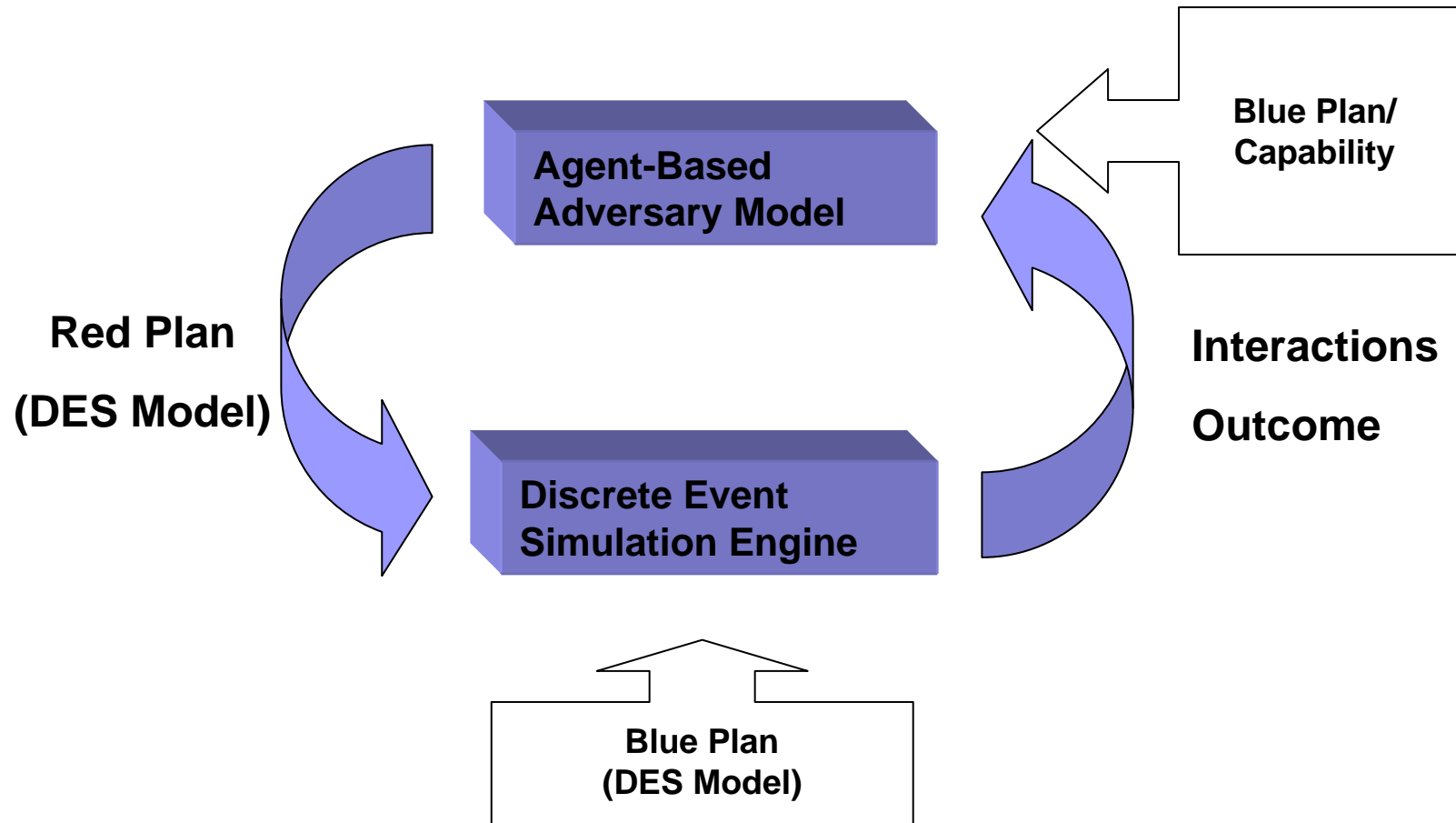


Image Source: <http://www.ibiblio.org/hyperwar/USMC/V/maps/USMC-V-16.jpg>

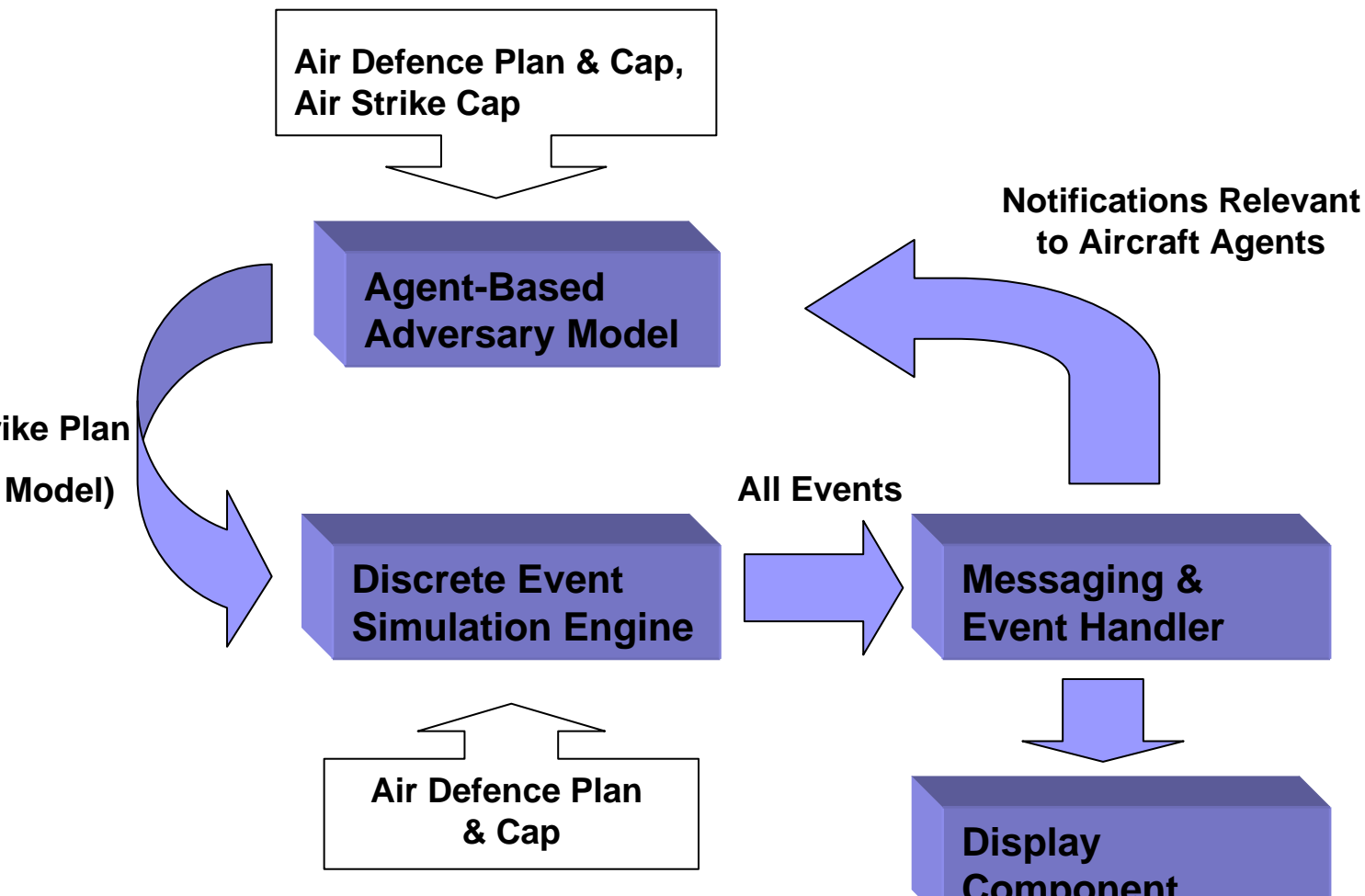


Basic Concepts

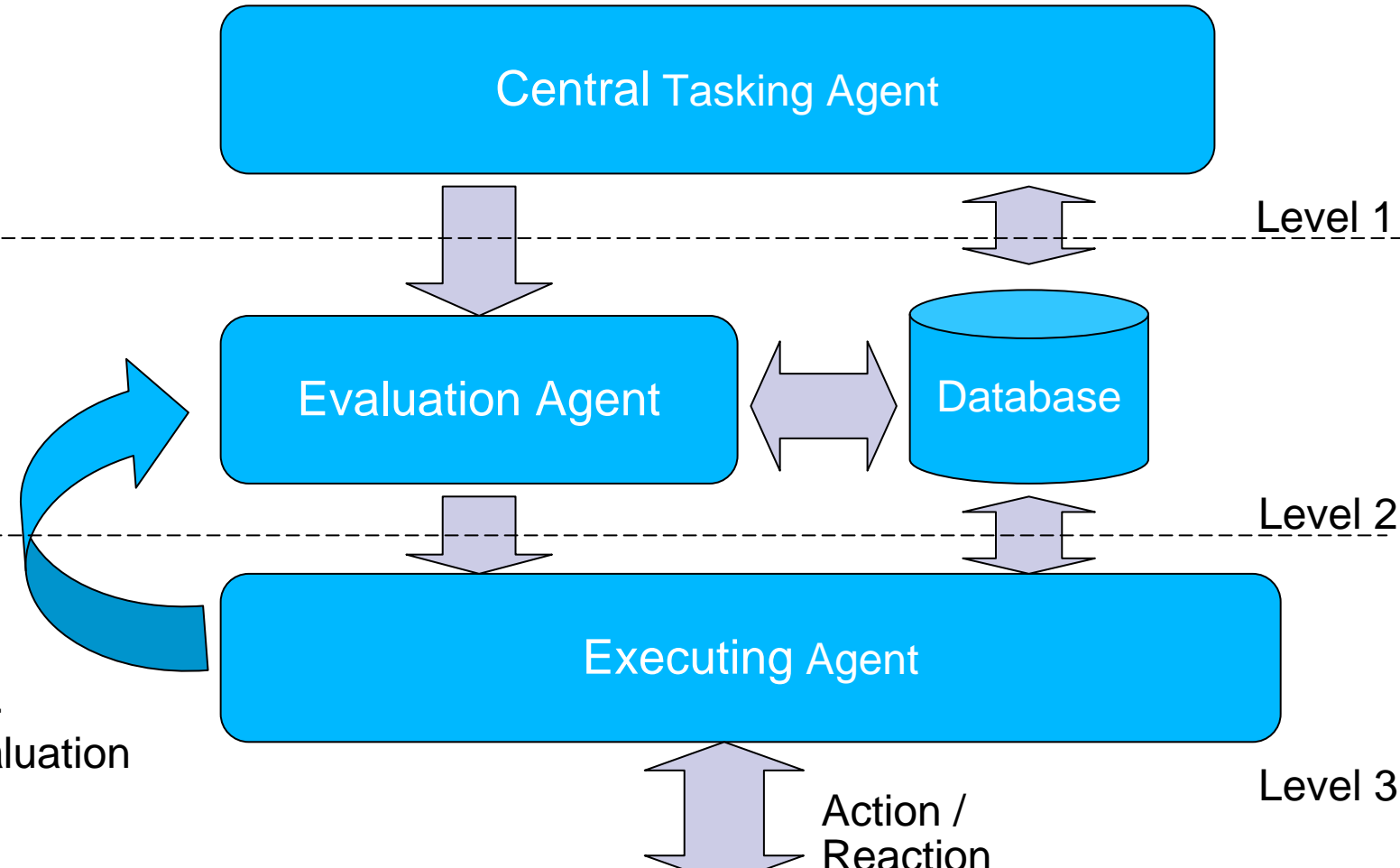


Methodology

Main Building Blocks



Agent-Based Model Architecture

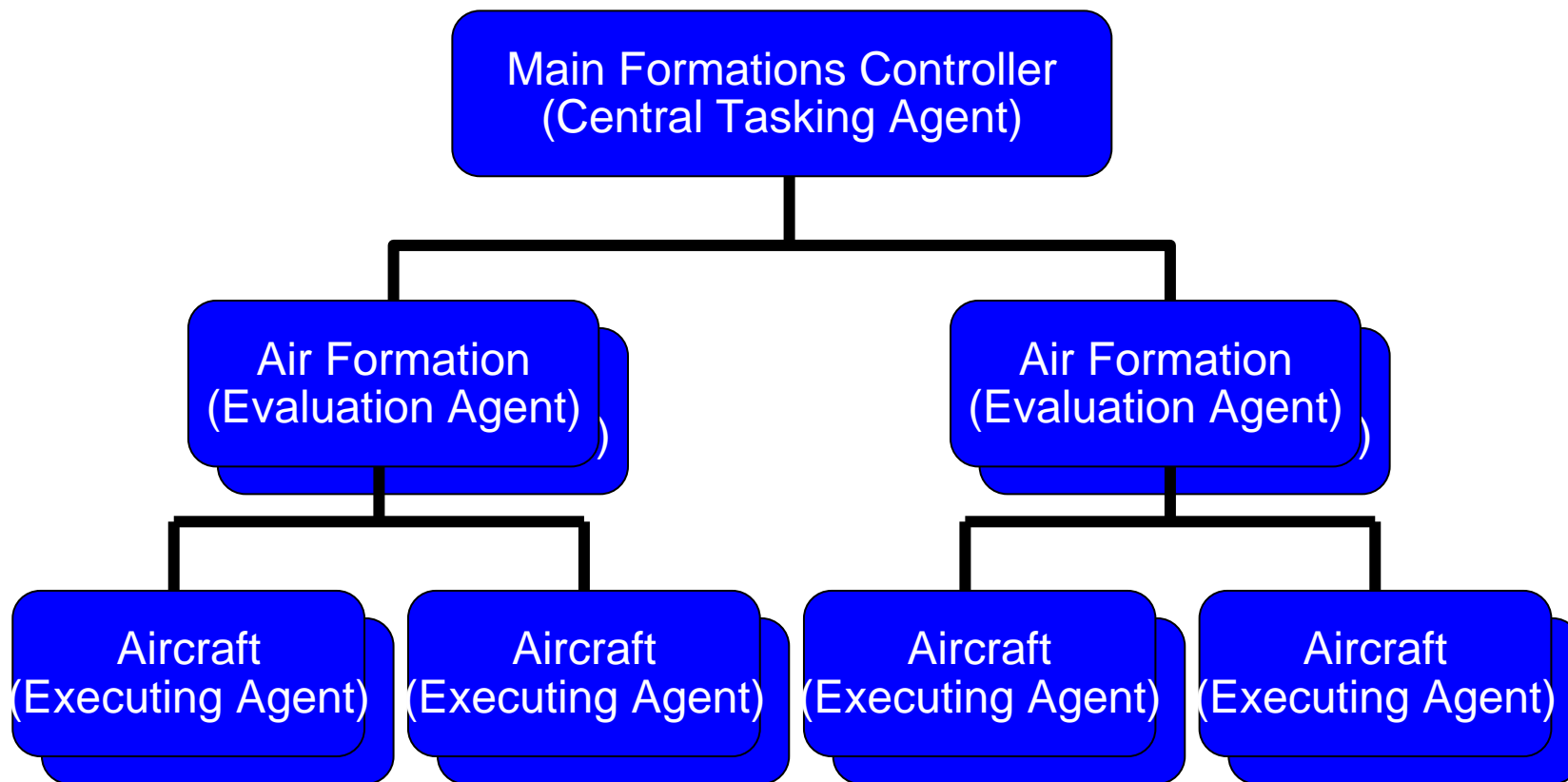


Evaluation

Level 3

Action /
Reaction

Agent Architecture



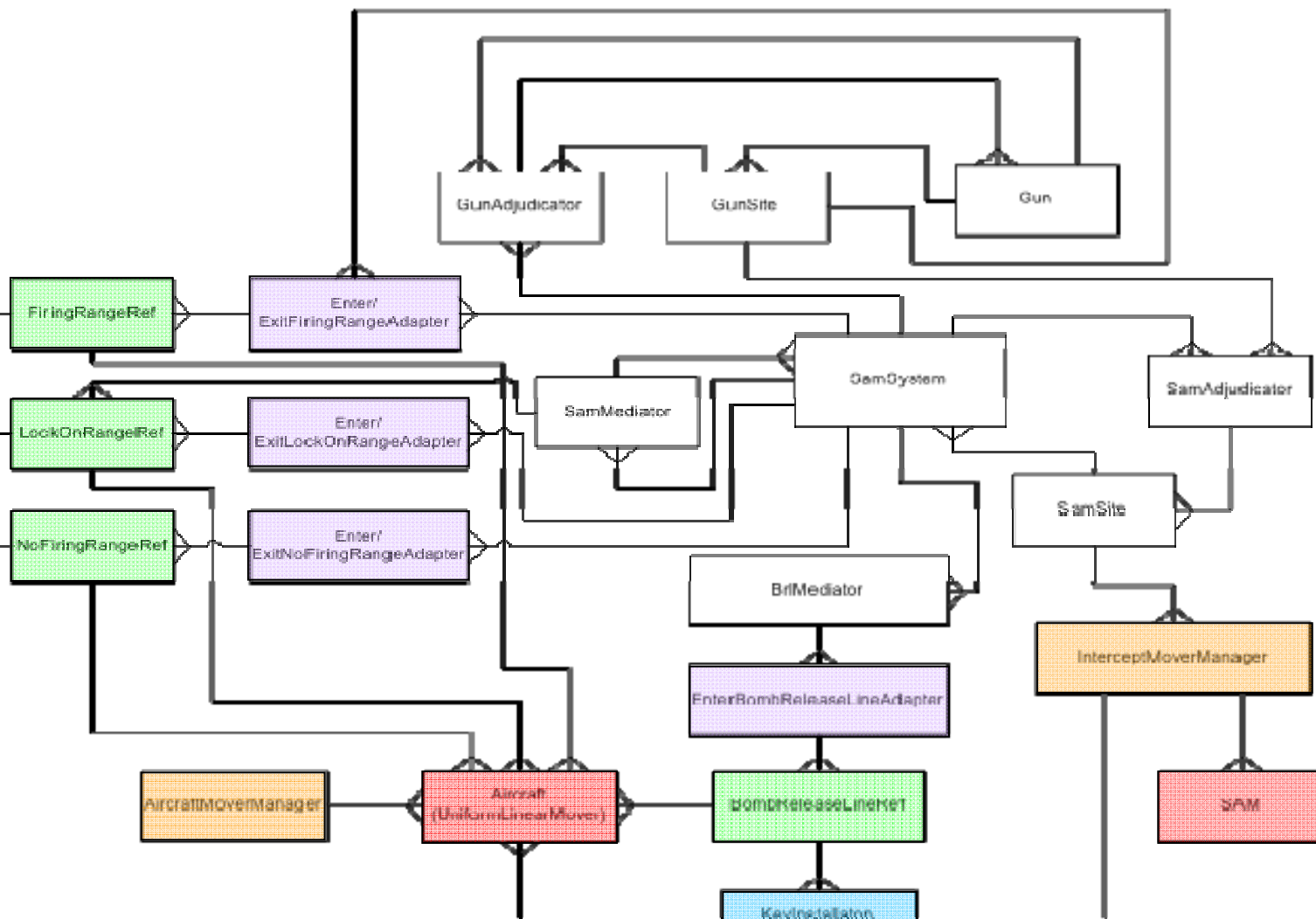
DES-Based Simulator Design

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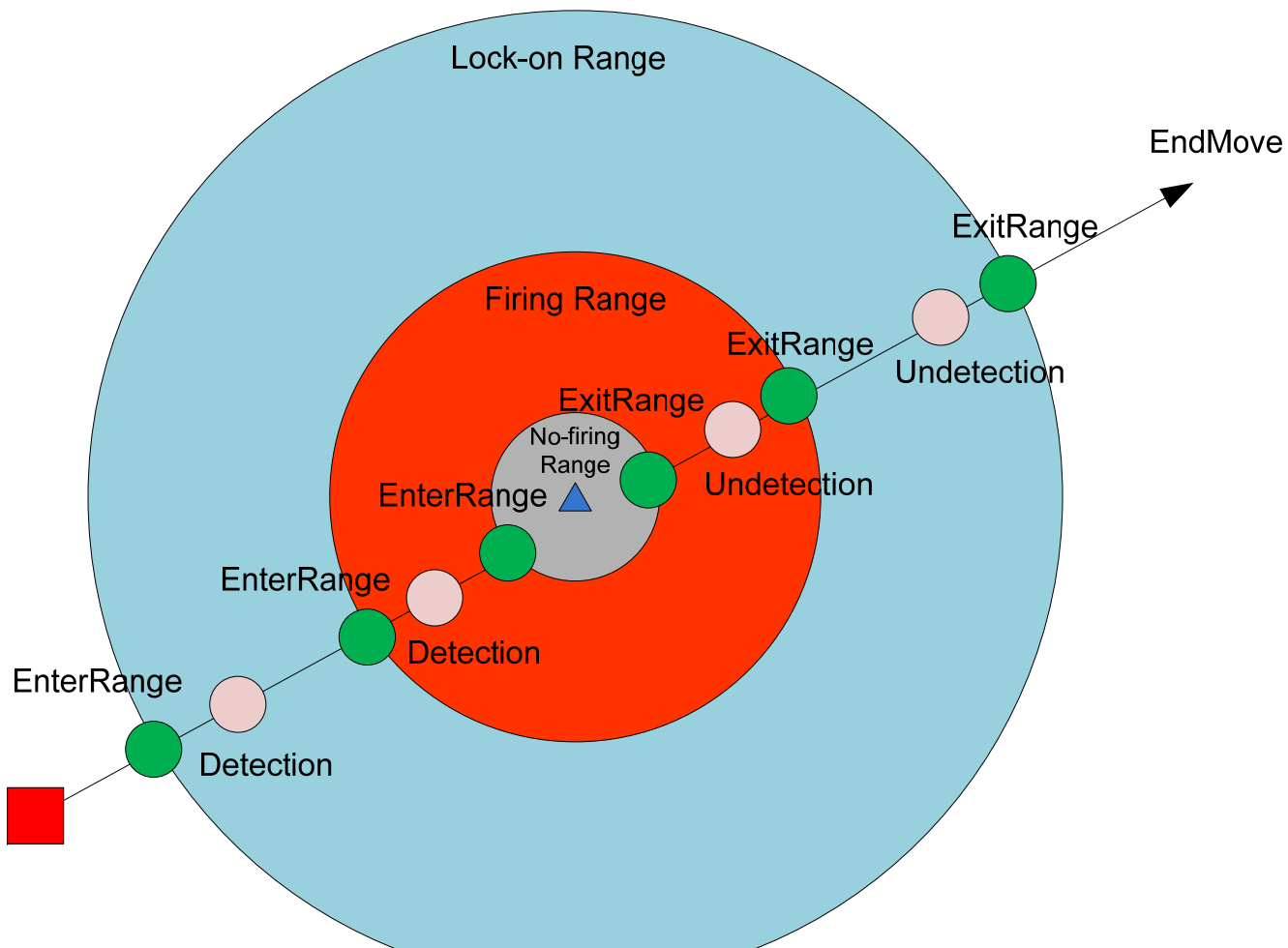
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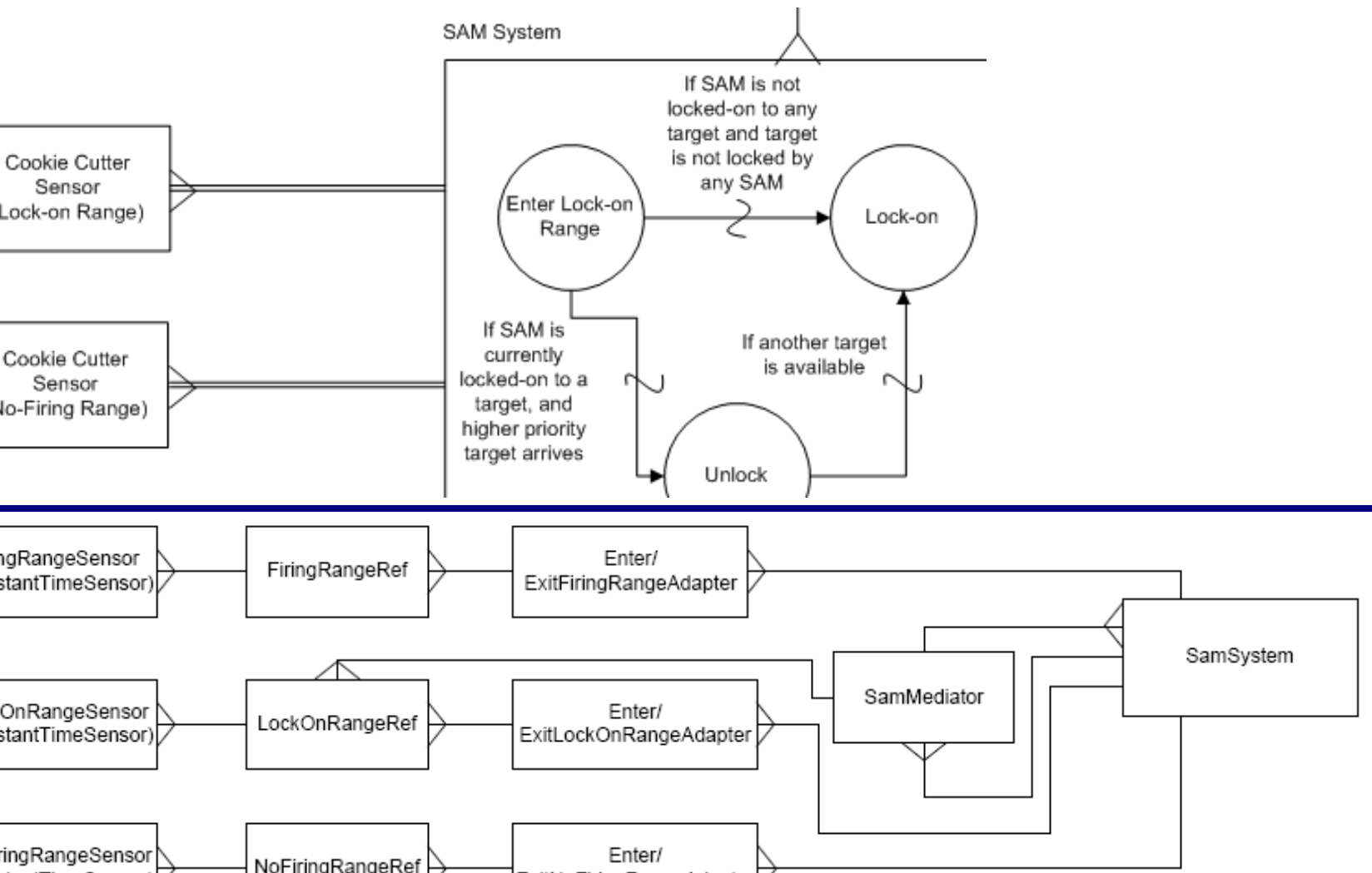
Prototype Implementation

DES Engine

Modeling SAM Sensor

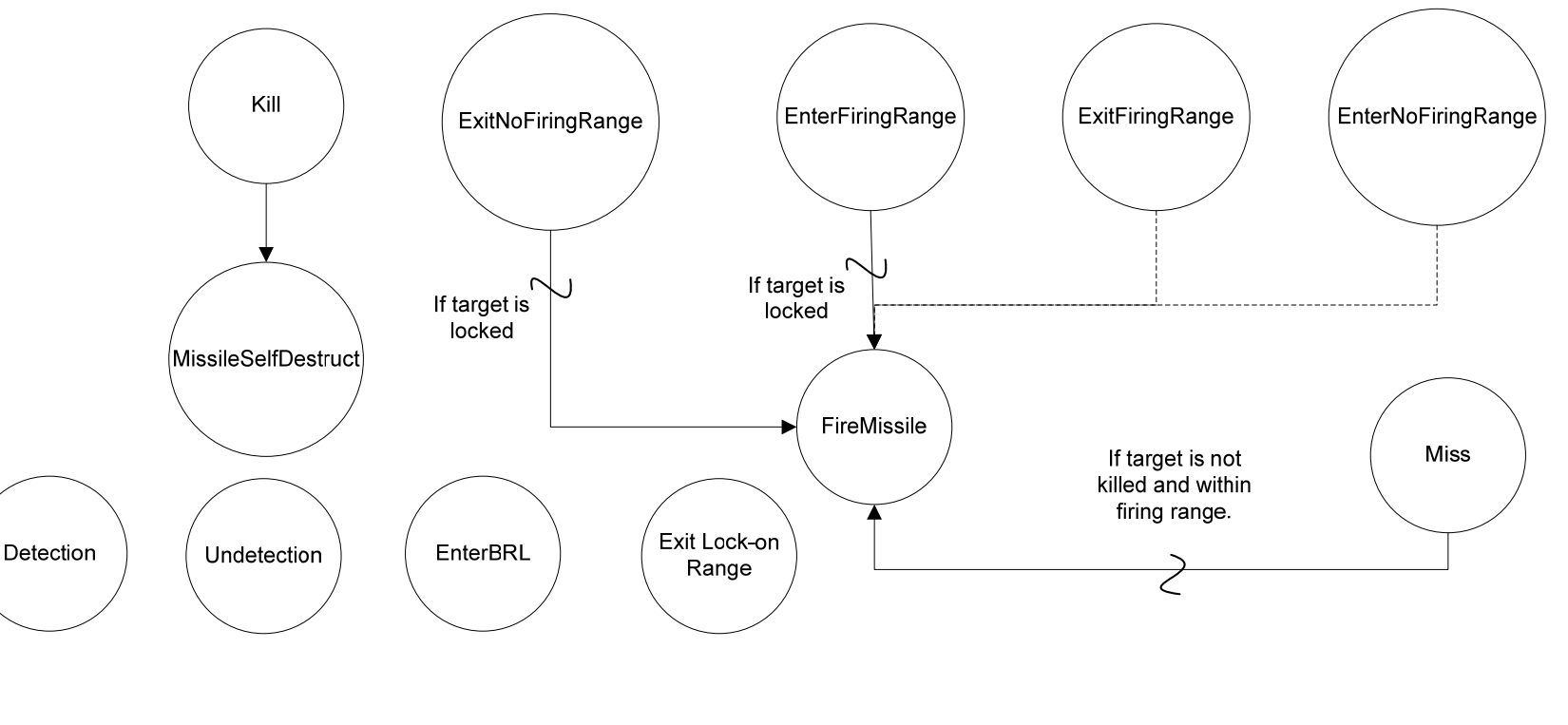


SAM Sensor Event Graph

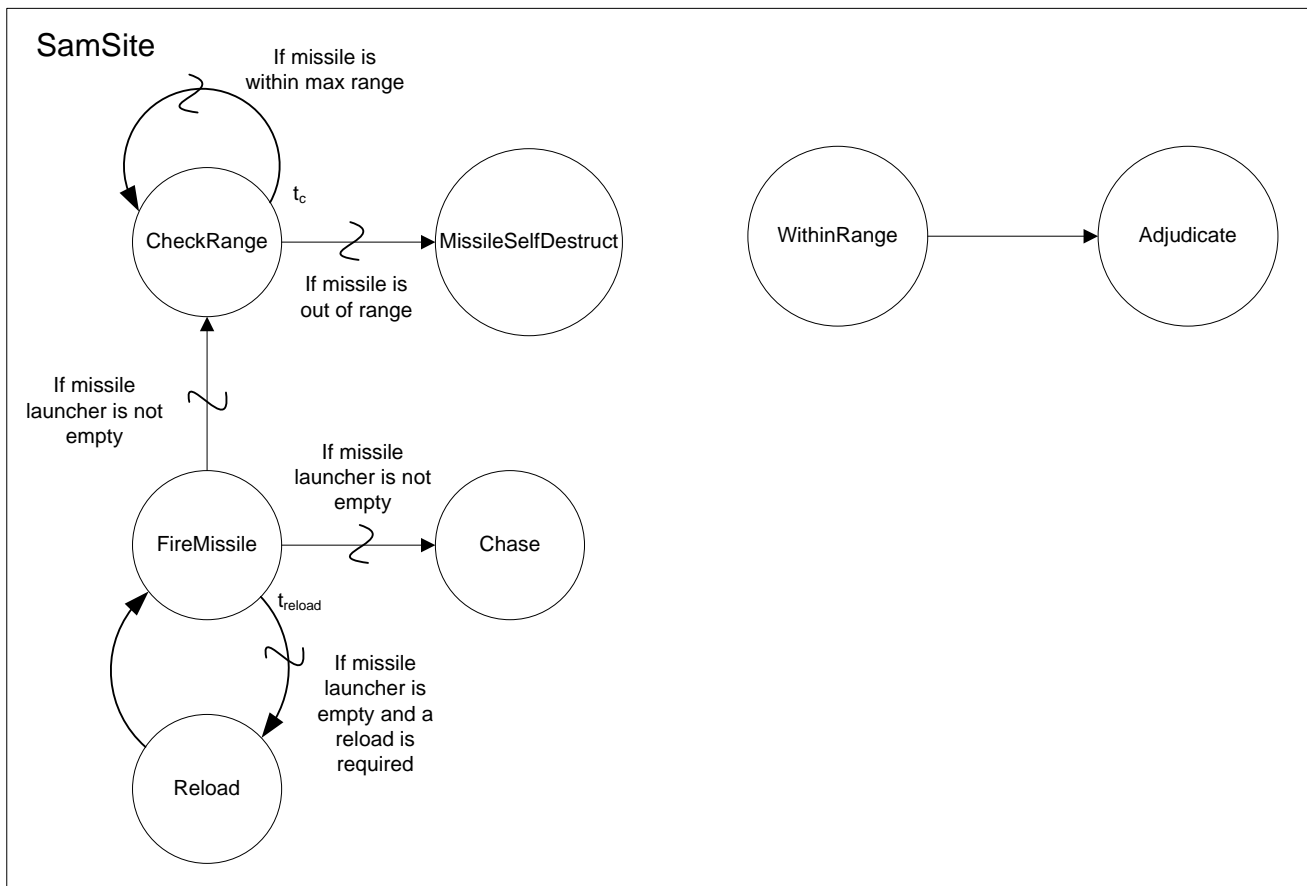


SAM System Event Graph

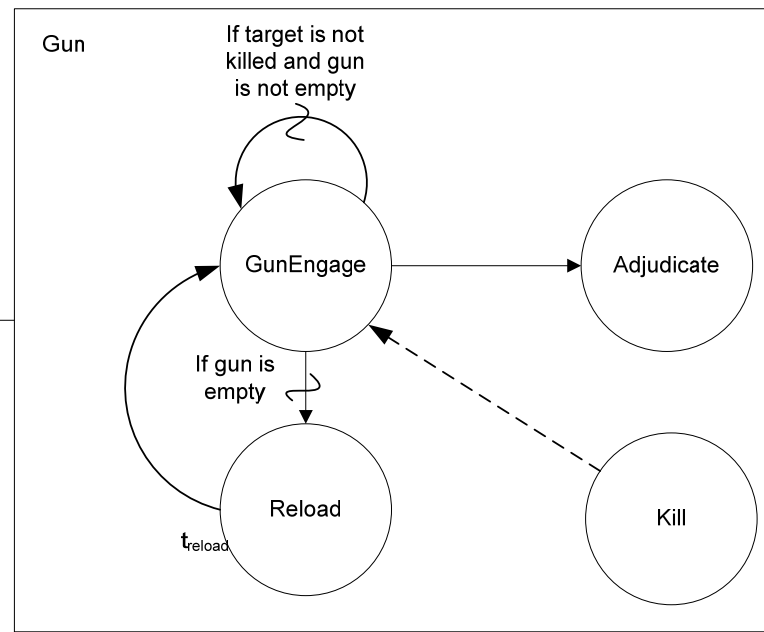
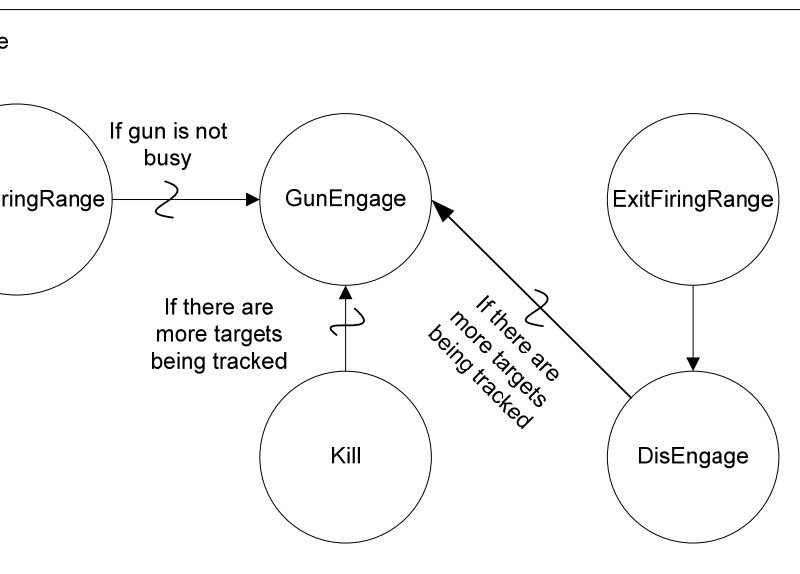
mSystem



SAM Site Event Graph



Gun Site and Gun Event Graph



Agent Model

Agent-based Model



agent model approach on air strike:

Plan Generation

- Approach vector generation
- A route generation
 - Weighted Map (Threat Map)
 - Cell Based Decomposition - Grid
 - A-Star optimize search algorithm

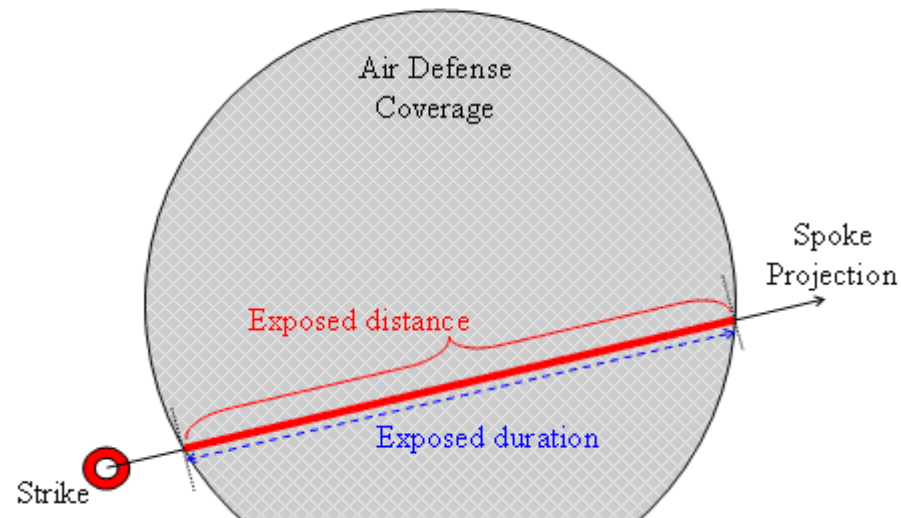
Plan Adjustment

- Individual aircraft as agent
 - Employ maneuvers

Approach Vector

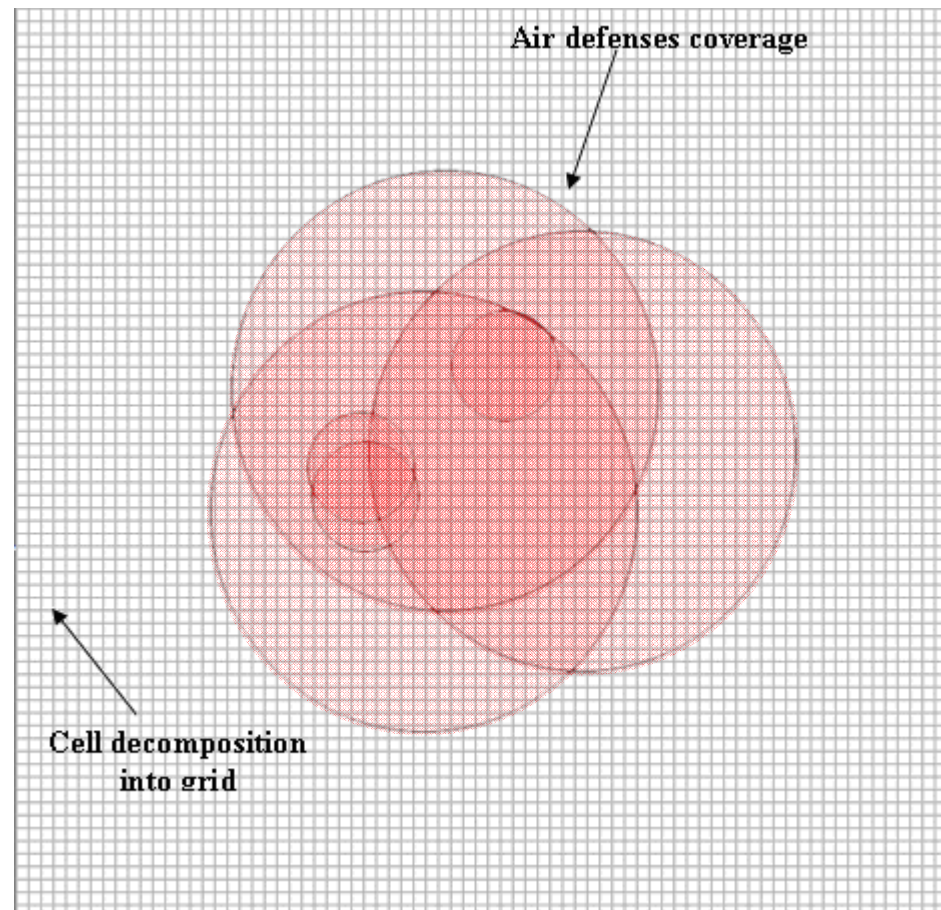
Approach Vector Computation

- Distance over the Air Defense coverages
- Expose time over the composite Air Defense Coverage's
- Speed of Aircraft
- Based on scoring



Route Generation

Cell-based decomposition
for real world abstraction
Real World area is 40km
by 40km
Each cell is represented as
a pixel = 200 meters real
world
Total cells abstraction =
10000 cells



Agent Behavior



Agent behavior mechanism

- Input messages from simulator affecting the state of the agent environment

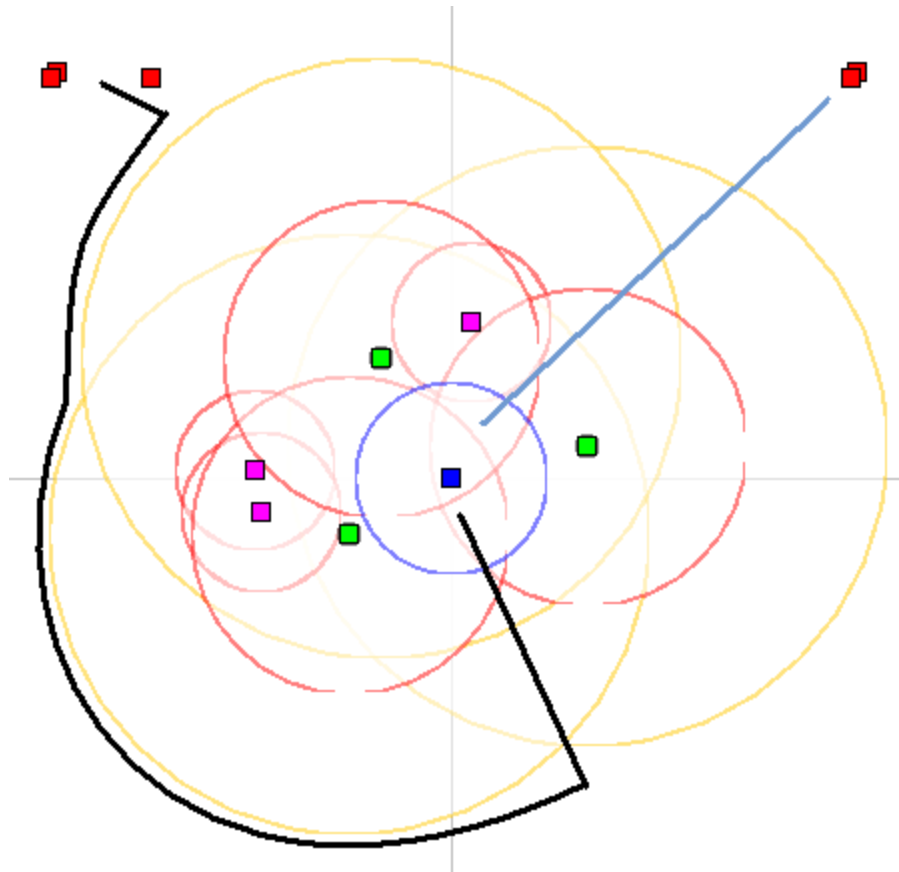
Agent responses to incoming messages from simulator

Input Messages to Strike Aircraft Agent		Agent Action Message
POSITIONAL	Positional updates of the agent in the simulation environment	■ Update Agent Status (Aircraft status & Environment changes) ■ Strike Action (Depending on Situation)
RADAR LOCK ON	Alert agent aircraft of Radar lock on	
RADAR LOCK OFF	Alert agent aircraft of Radar lock off	
INCOMING SA MISSILE	Alert agent aircraft of Incoming surface-to-air missile	■ Evasive Action
ANTI-AIR GUN FIRING	Alert agent aircraft of Anti-Airgun firing	■ Evasive Action

Experiment & Results

Scenario

- Air strike on protected site
 - Attacker has knowledge of the defence layout
 - Attack plan generated by Agent based tool
- Operational Analysis Question:
 - “How sensitive is our attack plan to variation in the weapon systems?”



Design of Experiment

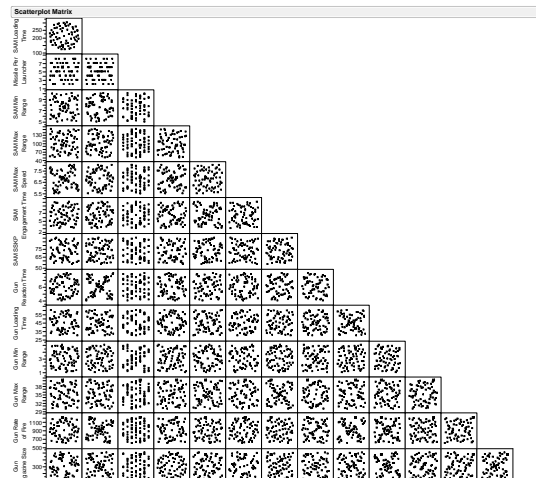


15 potential main effects
 65 design points NOLH was used
 50 replicas for each design point
 Overall 65X50 = 3250 runs

For comparison,

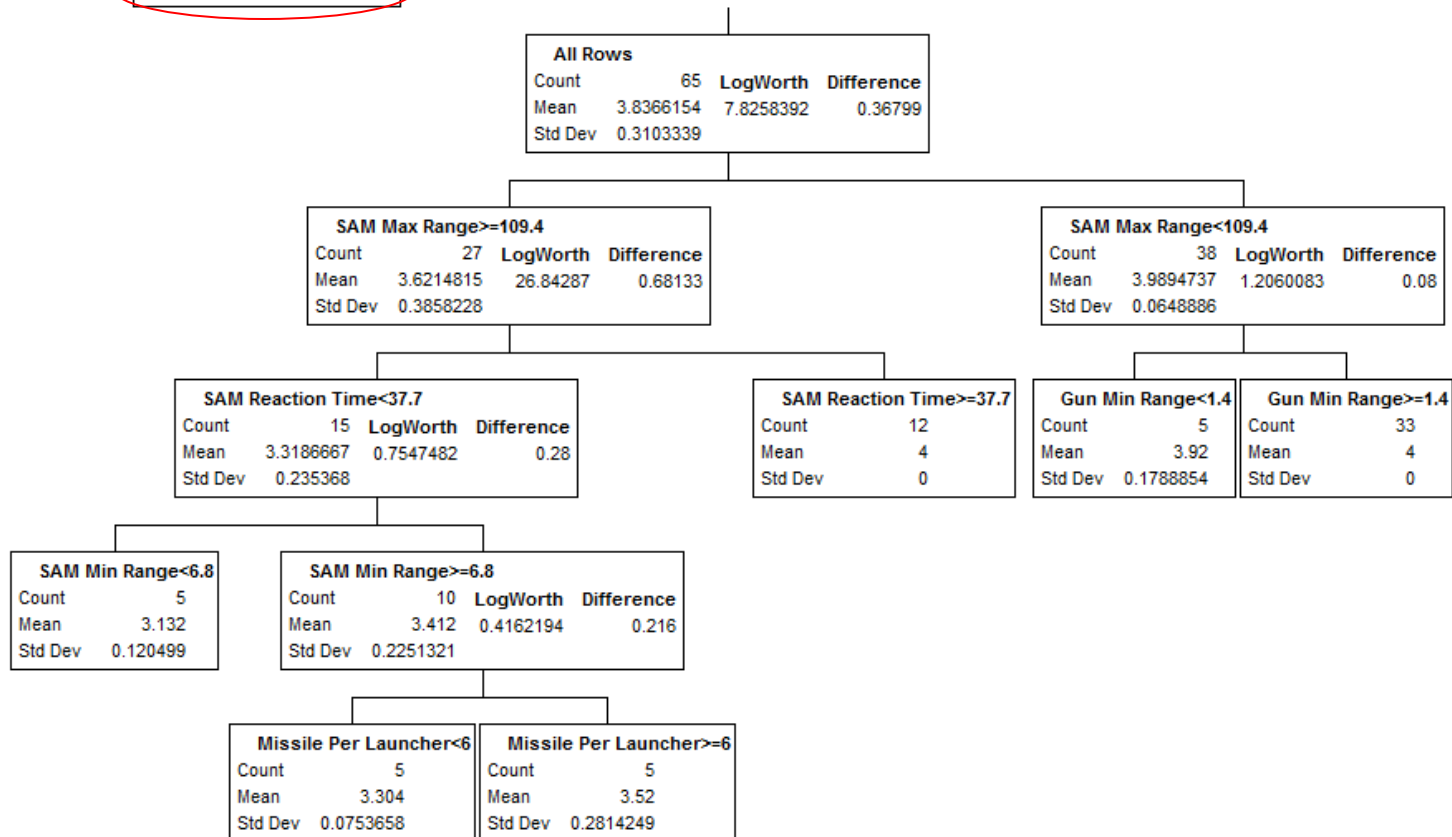
- ❑ Full factorial 2 level design
 $2^{15} = 32768$.
- ❑ Overall $32768 * 50 = 1,638,400$ runs
- ❑ Most factors are continuous, or discrete with more than 2 levels ...

Potential Effects	Min	Max	Units
SAM Reaction Time	5.0	60.0	s
SAM Loading Time	120.0	360.0	s
Miss ile Per Launcher	2	8	
SAM Min Range	5.0	10.0	'00 m
SAM Max Range	50.0	150.0	'00 m
SAM Max Speed	5.5	8.0	'00 m/s
SAM Engagement Time	3.0	10.0	s
SAM SSKP	55	90	%
Gun Reaction Time	4.0	8.0	s
Gun Loading Time	30.0	60.0	s
Gun Min Range	1.0	5.0	'00 m
Gun Max Range	30.0	40.0	'00 m
Gun Rate of Fire	600	1200	
Gun Magazine Size	200	400	
Gun SSKP	75	85	%



Partition Tree

RSquare	Number
0.915	65
	5



Regression Model



Summary of Fit

R Square	0.847953
R Square Adj	0.801408
Root Mean Square Error	0.138296
Mean of Response	3.836615
Observations (or Sum Wgts)	65

Parameter Estimates

	Estimate	Std Error	t Ratio	Prob> t
Intercept	3.9042878	0.23991	16.27	<.0001*
Reaction Time	0.0108063	0.001233	8.77	<.0001*
Max Range	-0.00523	0.000642	-8.14	<.0001*
Reaction Time-32.5015)*(SAM Max Range-100.006)	0.0003027	3.732e-5	8.11	<.0001*
Reaction Time-32.5015)*(SAM Max Speed-6.75077)*(SAM SSKP-72.5077)	-0.000286	0.000123	-2.31	0.0250*
Max Range-100.006)*(SAM Max Speed-6.75077)	0.0020898	0.000953	2.19	0.0332*

Analysis



The gun parameters has minimal affect on the outcome. It has reflected the scenario pretty well (recall that the agent generated plan avoids the AA gun).

The SAM Max Range and SAM Reaction Time are the two key main effects.

Analysis (Cont'd)



The mission should be reconsidered if the attacker is concerned about aircraft attrition and there is great uncertainty about the following:

- SAM Max Range (preferably less than 109.4)
- SAM Reaction Time (preferably greater than 37.7)

Future Work

Future Work



Discrete Event Simulator

- Sensors model can be refined to reflect more realistic characteristics
- Enhancements of sensor footprint of irregular shapes
- Modeling sensor detection/undetected time using the glimpse model
- Air defense model can be made more complex

Future Work (Cont'd)



Agent model

- Enhance Route generation by adding additional cost factors such as duration of exposure to threat
- Implementation of a dynamic area of operation for individual air formation
- Provides a realistic terrain model such as DTED map or vegetation information
- Individual agent can be enhance further to include a Neural Net or a Bayesian network

Thank You