Distributed Modeling and Simulation as a Service

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Dynamic Animation Systems
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12423 Research Parkway
Orlando, FL 32826

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Purpose/Topics

- Purpose: Provide an update on the Executable Architecture Systems Engineering Distributed Modeling Framework (EASE DMF) project

- Topics:
  - EASE DMF Overview (Recap)
  - Current State
  - Distributed Modeling Framework
  - Some Useful Theories
  - Some Useful Theories Applied
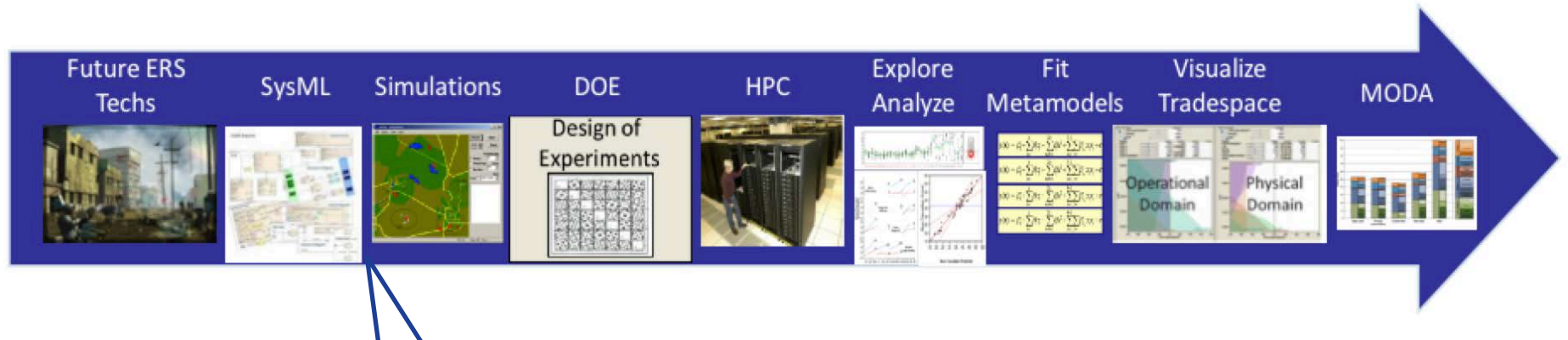 - Current Use Case
  - Final Thoughts

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Motivation/Recap

Future ERS Techs — SysML — Simulations — DOE (Design of Experiments) — HPC — Explore Analyze — Fit Metamodels — Visualize Tradespace (Operational Domain / Physical Domain) — MODA

Magic Happens Here

- Chain of tools for using M&S to develop system of systems architecture
- How to we connect the system design properties to the simulation inputs?

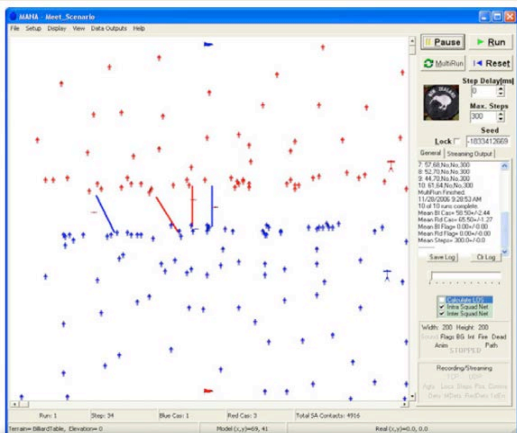Briefed M&S Subcommittee on June 16, 2015

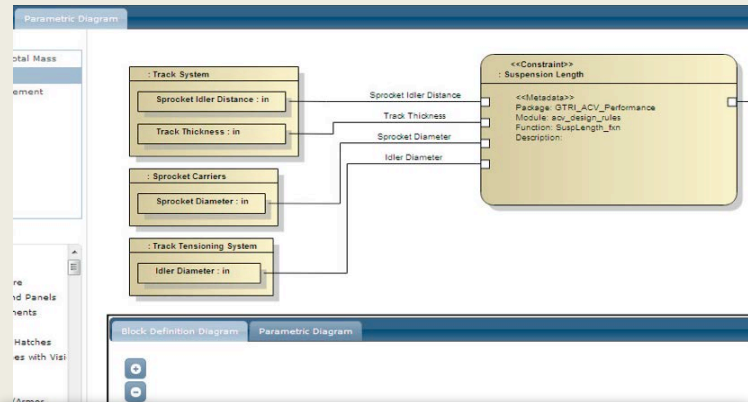*SFC Paul Ray Smith Simulation & Training Technology Center*

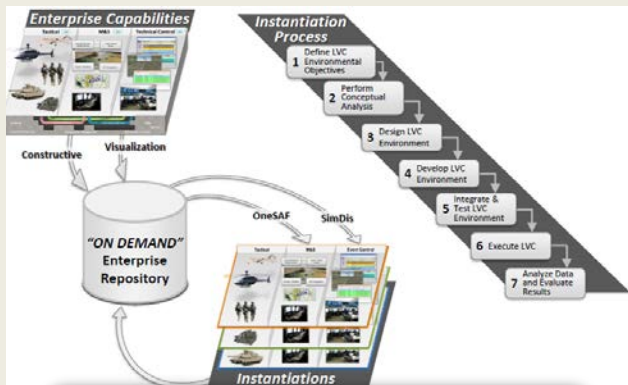**The Nation's Premier Laboratory for Land Forces**

Current Systems Arch to Executable Model Approaches

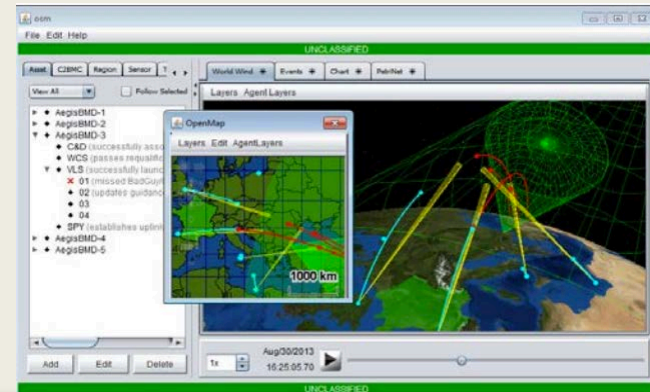**U.S. ARMY RDECOM ARL**

Agent Based Models
Engineering Resilient Systems

Link many independent models
Framework for Assessing Cost and Technology

HLA/DIS
Always On

Frameworks
Orchestrated Simulation through Modeling

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- Different information exchange protocols

- Different terrain databases

- Runs only in real time

- Complex scenario initialization must be manually coordinated across federates

- Scenario execution is manual and error-prone

- Data collection complex and causality can be impossible

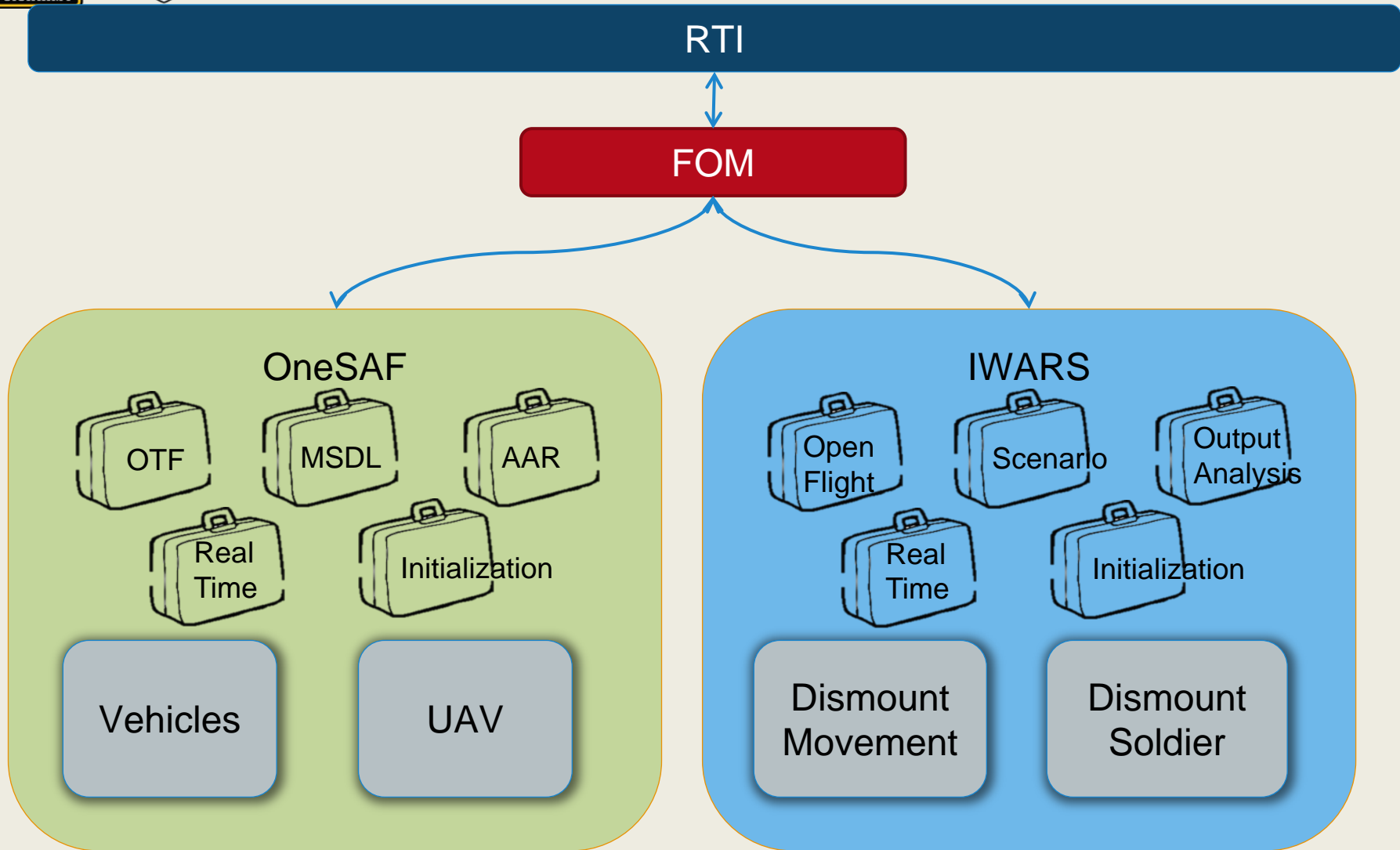- Changing the scenario is a months-long proposition

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HLA Example

Distributed Modeling Framework

Bring your models as "pure" state transition functions. Leave the baggage at home.

EASE-DMF Layers

DEVS Model (Akka Actor)

External State
This could also be and event. DEVS has a concept of transitory state, a state the has 0 duration. This is the equivalent of an HLA event
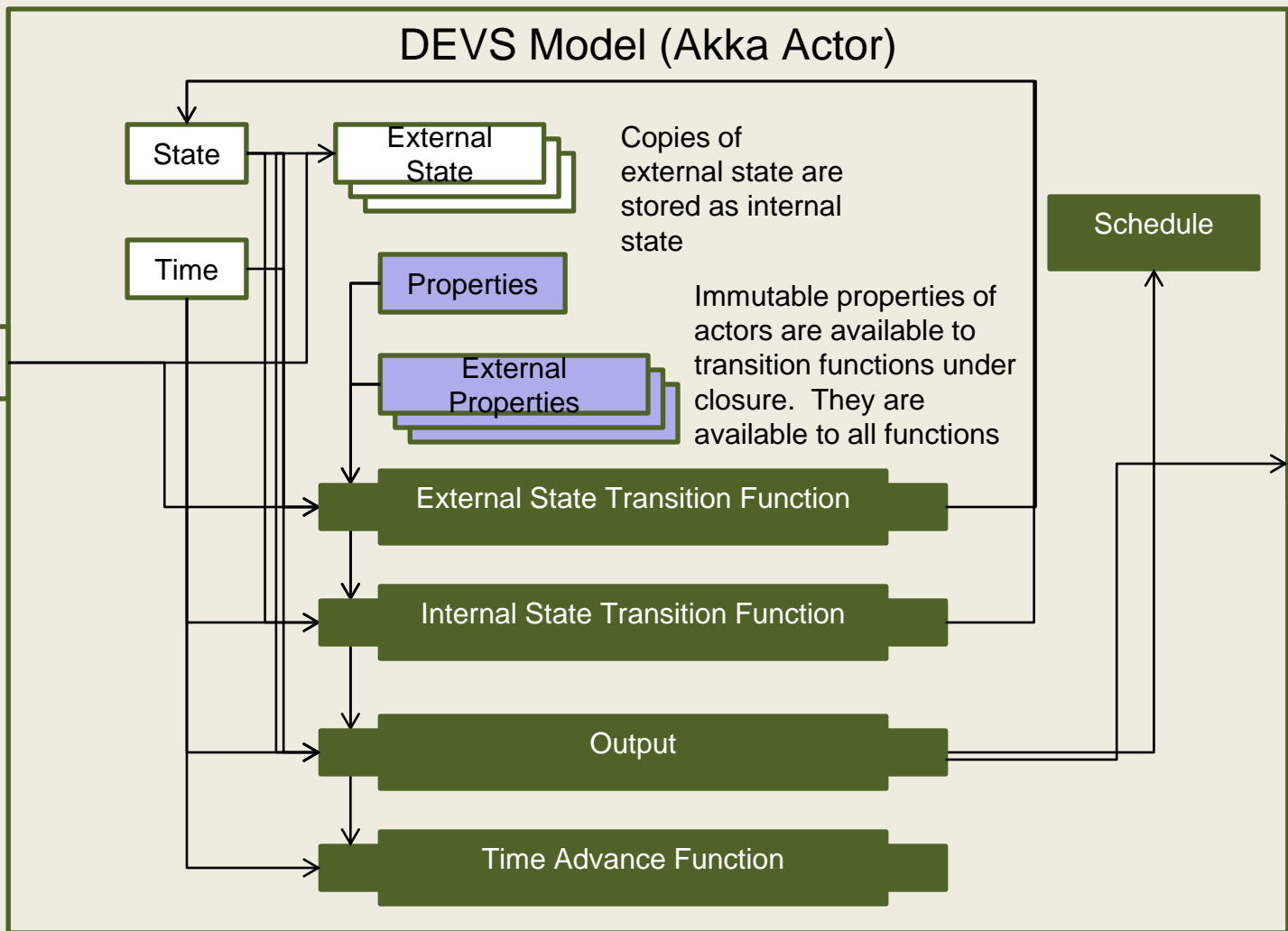
State

Time

External State

Properties

External Properties

Copies of external state are stored as internal state

Immutable properties of actors are available to transition functions under closure. They are available to all functions

Schedule

External State

External State Transition Function

Internal State Transition Function

Output

Time Advance Function

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- Must provide a valid and fully annotated XML schema to describe static properties, and must be able to initialize those properties using that schema.

- Must provide a valid and fully annotated XML schema to describe input state and output state.

- Must provide a valid and fully annotated XML schema to describe events generated as an output of the function.

- After initialization with static properties, must calculate state transitions, or events outputs, as a pure function.

  - The same input will always give the same output
  - No internal mutable state variables used in the calculation
  - For example, random variates are inputs derived from external state, they are not called during the calculation of the state transition.

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Enterprise Model Integration

Design and Analysis of Experiments

Enterprise Architecture

Simulation Execution Engine

Enterprise Data and Services

Messaging System

Enterprise Data Model
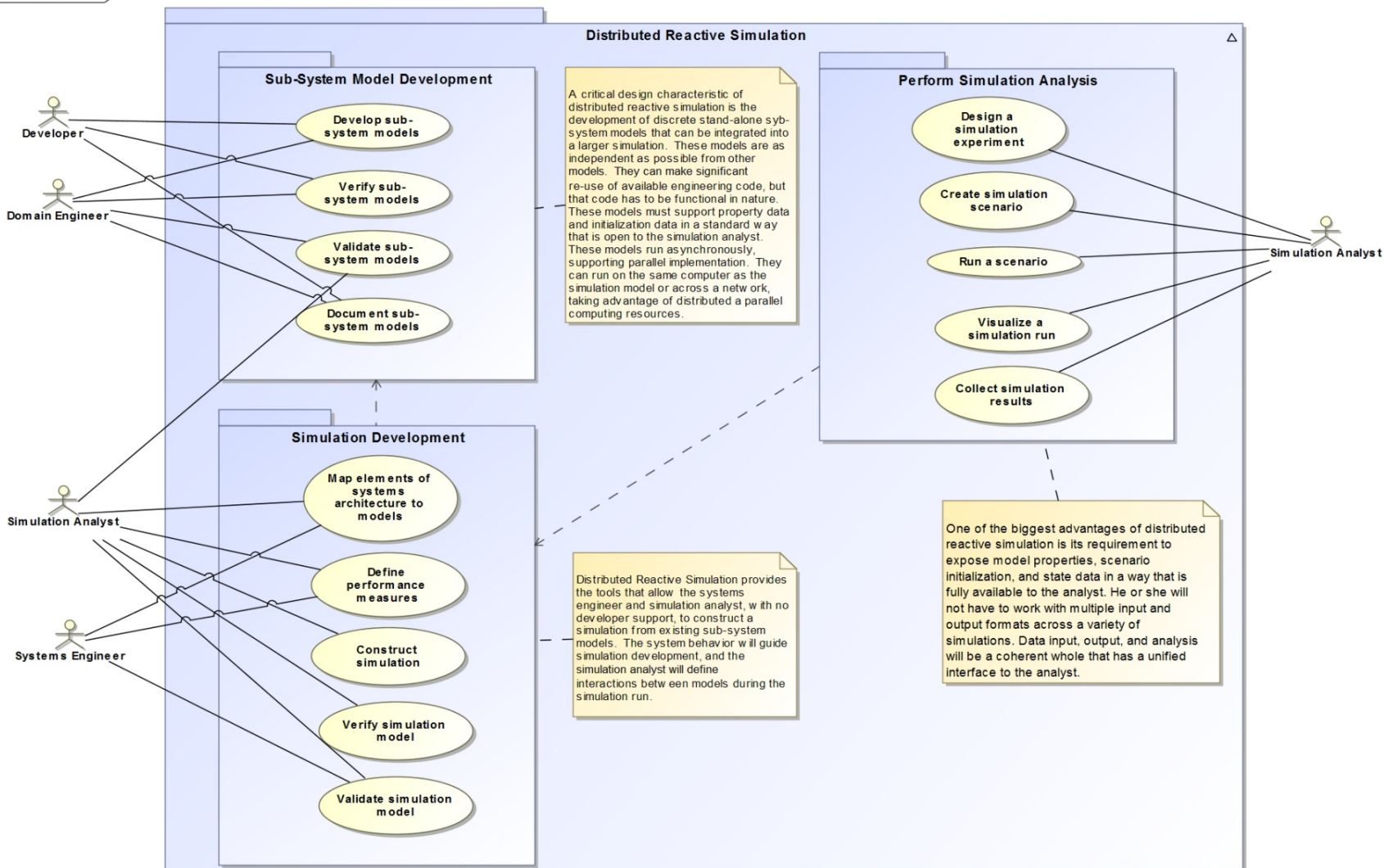
Model A

Model B

Model C

Model D

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uc [Package] UseCases [DRS Use Cases]

Distributed Reactive Simulation

Sub-System Model Development

- Develop sub-system models
- Verify sub-system models
- Validate sub-system models
- Document sub-system models

Developer

Domain Engineer

A critical design characteristic of distributed reactive simulation is the development of discrete stand-alone syb-system models that can be integrated into a larger simulation. These models are as independent as possible from other models. They can make significant re-use of available engineering code, but that code has to be functional in nature. These models must support property data and initialization data in a standard w ay that is open to the simulation analyst. These models run asynchronously, supporting parallel implementation. They can run on the same computer as the simulation model or across a netw ork, taking advantage of distributed a parallel computing resources.

Perform Simulation Analysis

- Design a simulation experiment
- Create simulation scenario
- Run a scenario
- Visualize a simulation run
- Collect simulation results

Simulation Analyst

Simulation Development

- Map elements of systems architecture to models
- Define performance measures
- Construct simulation
- Verify simulation model
- Validate simulation model

Simulation Analyst

Systems Engineer

Distributed Reactive Simulation provides the tools that allow the systems engineer and simulation analyst, w ith no developer support, to construct a simulation from existing sub-system models. The system behavior w ill guide simulation development, and the simulation analyst will define interactions betw een models during the simulation run.

One of the biggest advantages of distributed reactive simulation is its requirement to expose model properties, scenario initialization, and state data in a way that is fully available to the analyst. He or she will not have to work with multiple input and output formats across a variety of simulations. Data input, output, and analysis will be a coherent whole that has a unified interface to the analyst.

- ## Discrete Event Specification (DEVS)
  – DEVS models are modular
  – Composable hierarchies in coupled models
  – Strong track record

- ## Base Object Model (BOM)
  – Adds semantics to the models
  – Complete specification of data inputs and outputs
  – Situates models in a chain or interactions

- # Functional programming
  - Functions are composable
  - Functions have no side effects
  - Predictable behavior

- # Actor model of computation
  - Encapsulation of state
  - Responds to messages by…
    - Sending messages to other actors
    - Changing state in a way that influences future messages
    - Creating new actors
  - Reactive programming
    - Event driven
    - Responsive
    - Asynchronous
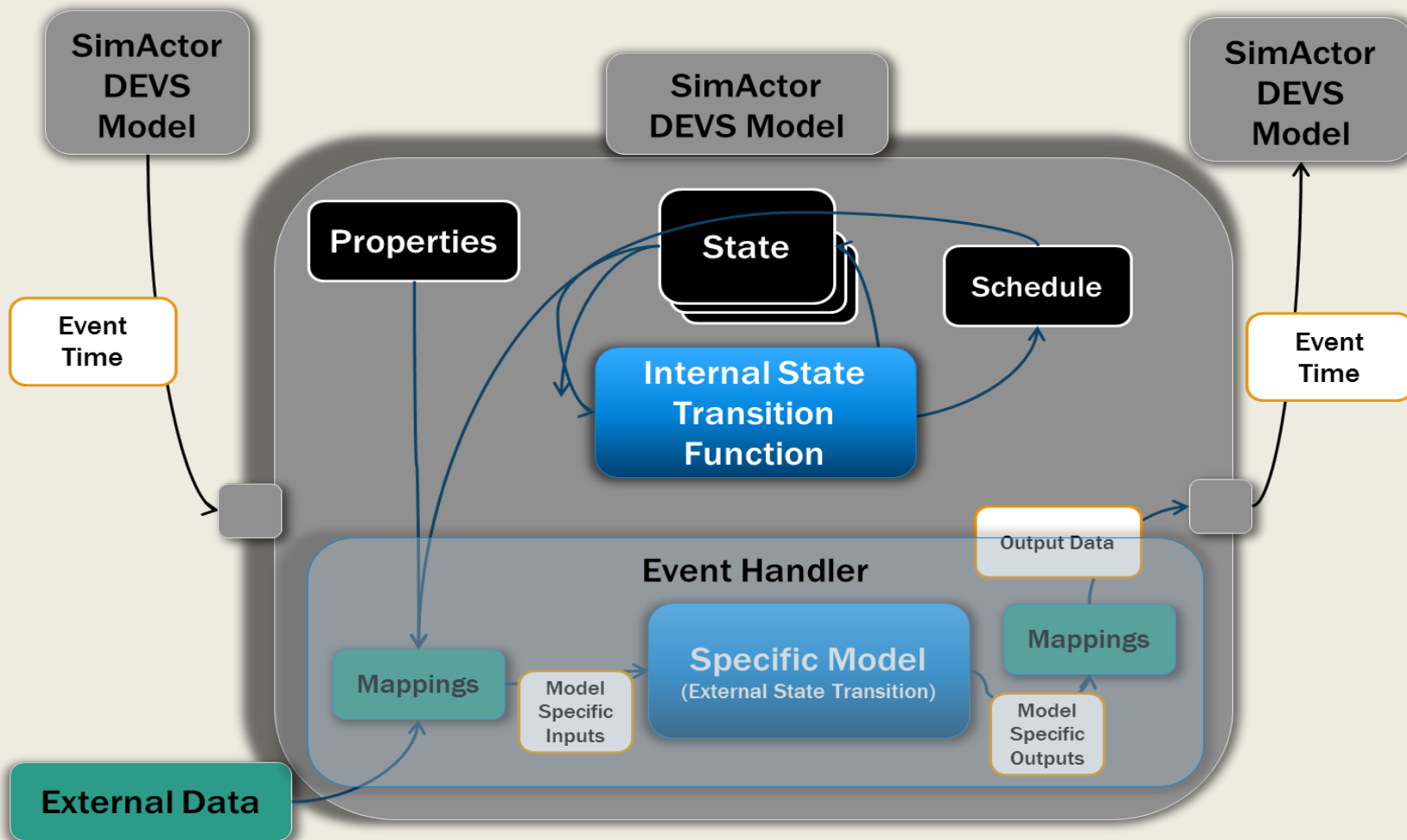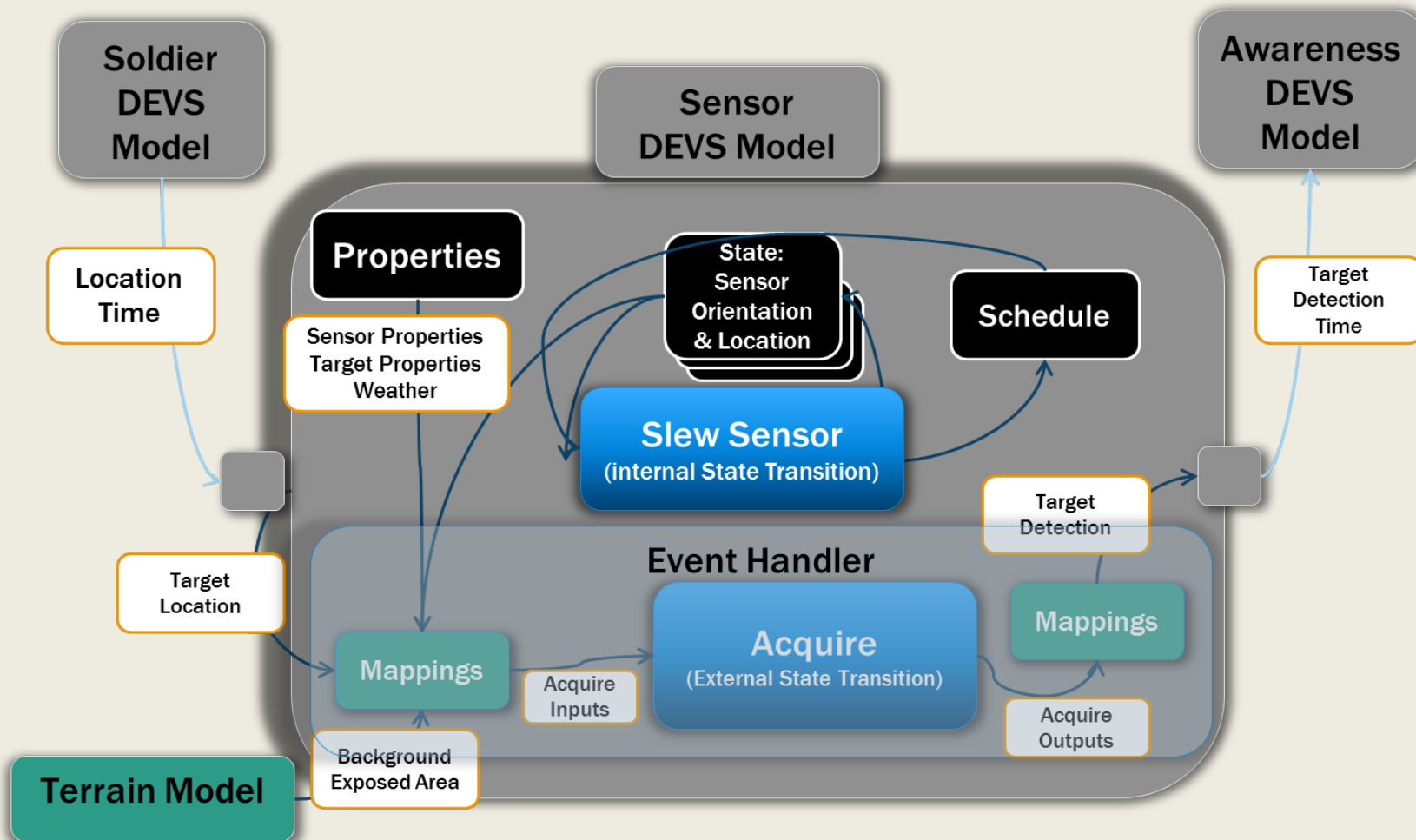   - Loosely coupled messaging
    - Fault tolerant

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Event Handler

SimActor DEVS Model

SimActor DEVS Model

SimActor DEVS Model

Event Time

Event Time

Properties

State

Schedule

Internal State Transition Function

Event Handler

Output Data

Mappings

Model Specific Inputs

Specific Model (External State Transition)

Mappings

Model Specific Outputs

External Data

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Reference Implementation

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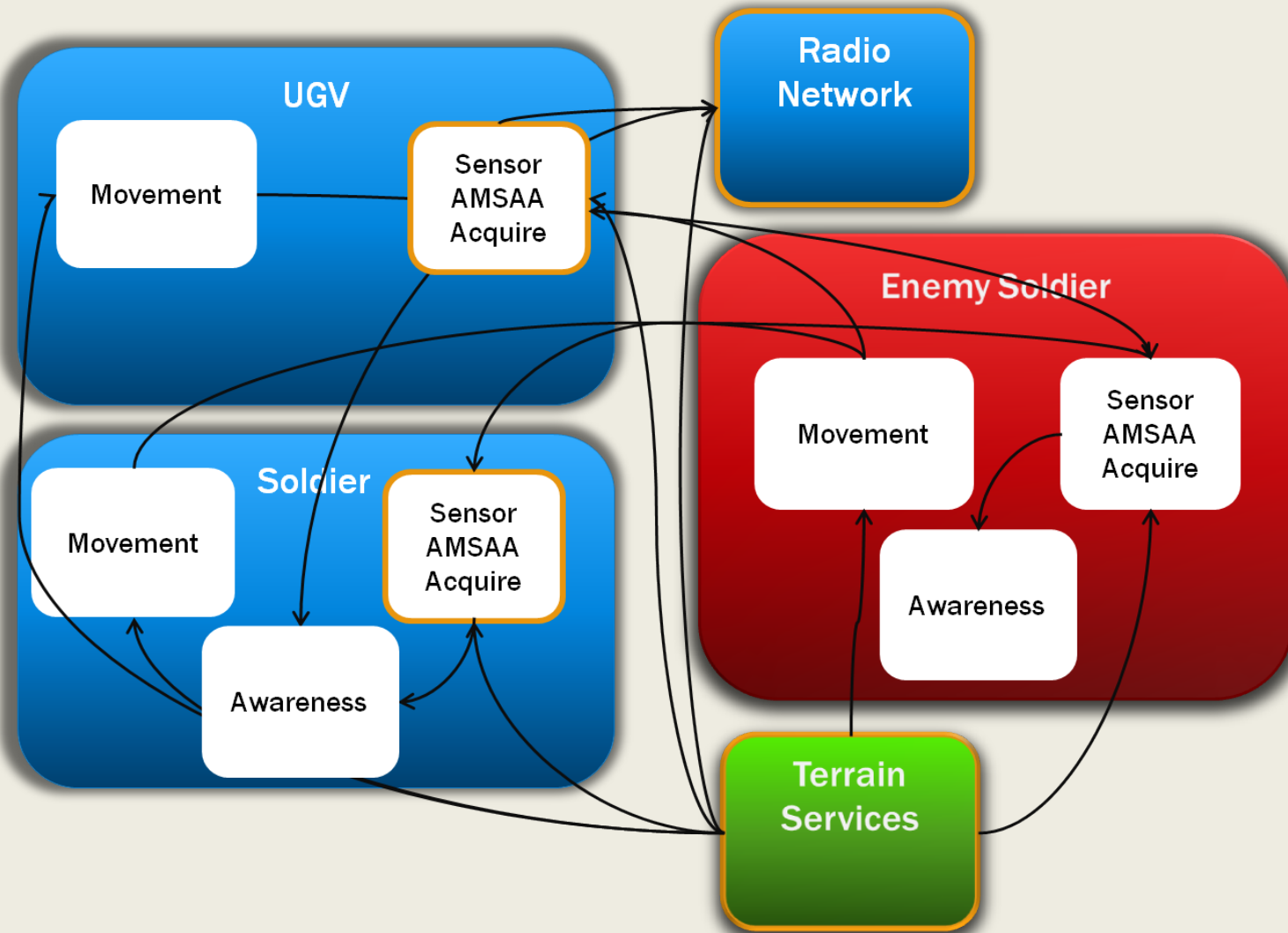
Candidate Use Case

Background

- ❏ The Small Arms Ammunition Configuration (SAAC) study is charged with determining the ammunition configuration that ensures overmatch at the lowest tactical level in 2025 and beyond.

- ❏ Weapon attributes, shooter constraints, ammunition attributes and target effect present tradeoffs that must be analyzed

- ❏ The combination of these factors present a solution space that traditional operational models can not feasibly analyze due to its size and the resource requirements associated with running operational models.

Weapon Attributes

Shooter Constraints

Ammunition Attributes

Target Effect

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AORS 2015: Cloud Based Lethality Service for Small Arms
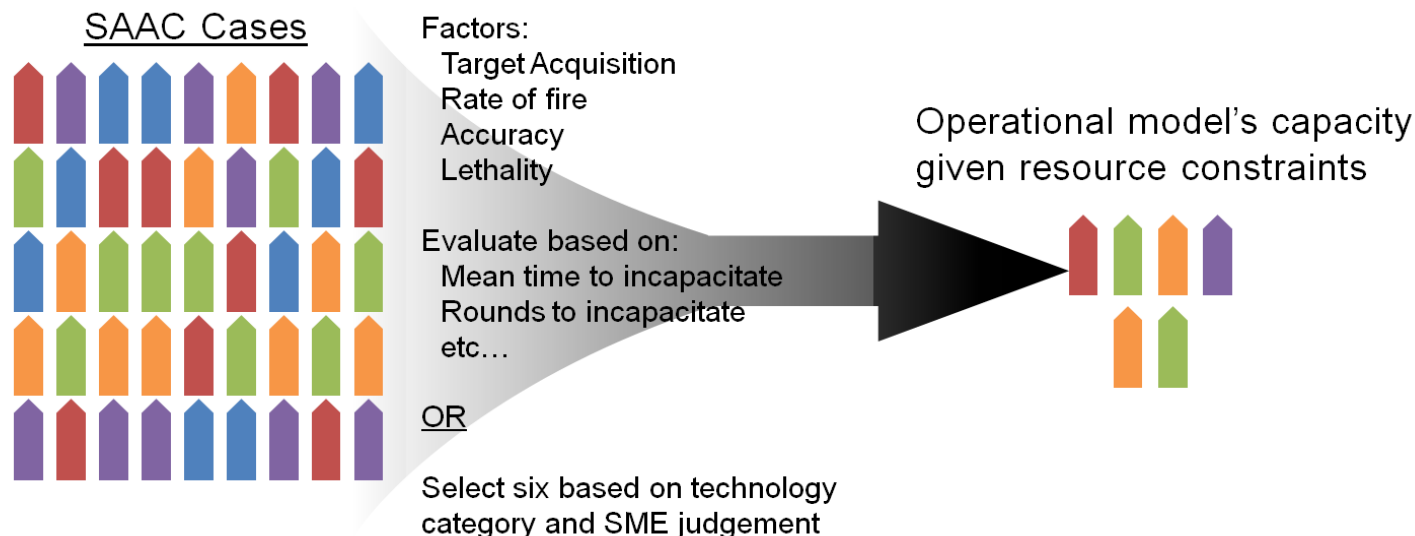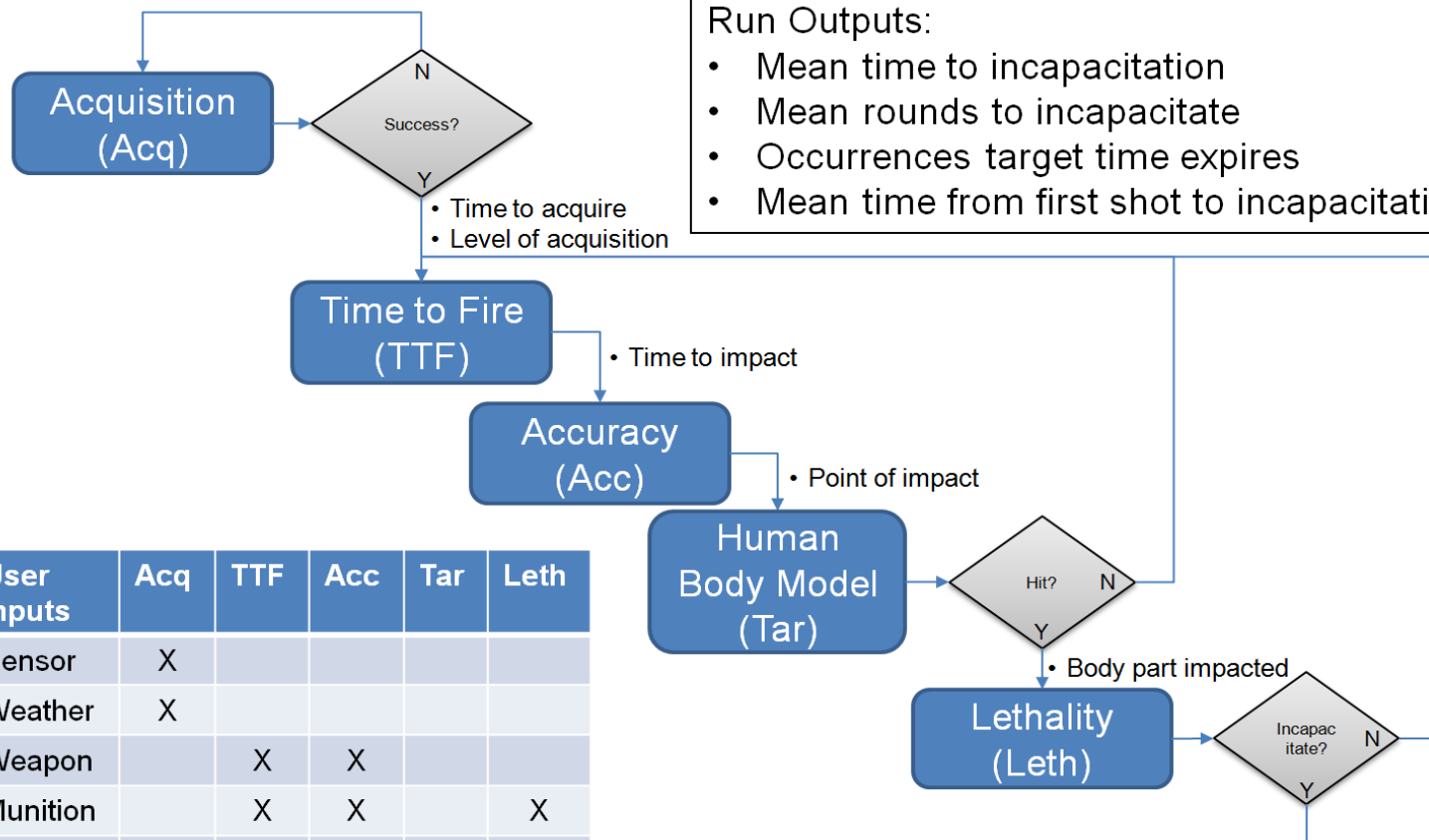CPT N. Kester, COL R. Kewley

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Candidate Use Case

SAAC Problem set

Problem: How do we screen these cases to a feasible problem set?

SAAC Cases

Factors:
Target Acquisition
Rate of fire
Accuracy
Lethality

Evaluate based on:
Mean time to incapacitate
Rounds to incapacitate
etc...

OR

Select six based on technology category and SME judgement

Operational model's capacity given resource constraints

Issues:
- These models/methodologies exist but are only integrated in operational models
- Selecting cases based on technology categories may overlook multiple solutions within a technology category

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Candidate Use Case

Network Based Execution

Run Outputs:
- Mean time to incapacitation
- Mean rounds to incapacitate
- Occurrences target time expires
- Mean time from first shot to incapacitation

Iteration Outputs:
- Time to Incapacitate
- # rounds to incapacitate

User Inputs	Acq	TTF	Acc	Tar	Leth
Sensor	X				
Weather	X				
Weapon		X	X		
Munition		X	X		X
Target	X			X	
Soldier	X	X	X		
Range	X		X		X

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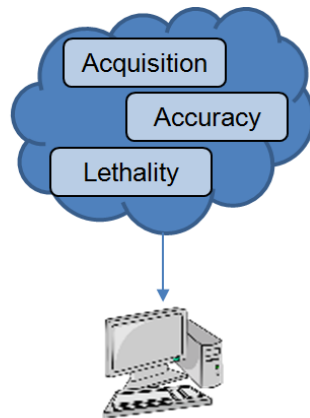**Candidate Use Case**

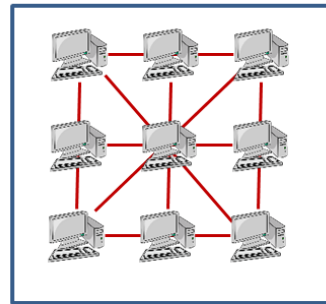## Service Deployment

- ❑ Network Based Deployment means:
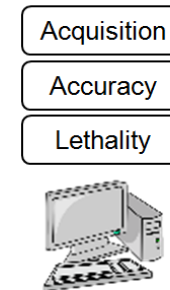

Cloud Based   OR   Local Network Based   OR   Virtual Machine Based

- ❑ Benefits:
  - – Each model operates in whatever language is appropriate for the task
  - – If inputs and outputs don't change, each micro service can be updated/changed as needed
  - – Models are integrated and accessible to more analysts

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Summary

- We want to connect the system design properties to the simulation inputs

  – Desire to link analytical data requirements to simulation elements

- Use functional programming paradigm to expose interfaces and state

- Use microservices for composability and scaling

- Created services are available to be leveraged by other programs with minimal integration

Questions/Comments?

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Back Up

Technology Stack

Data Farming, HTCondor, Statistical Software

SysML Architecture

Akka Actors/Distributed DEVS Time Warp Engine

Layered Terrain Format/Terrain Services

Akka/ZeroMQ

XML, Google Protocol Buffers

BOM — Movement Model

BOM — Target Acquisition Model

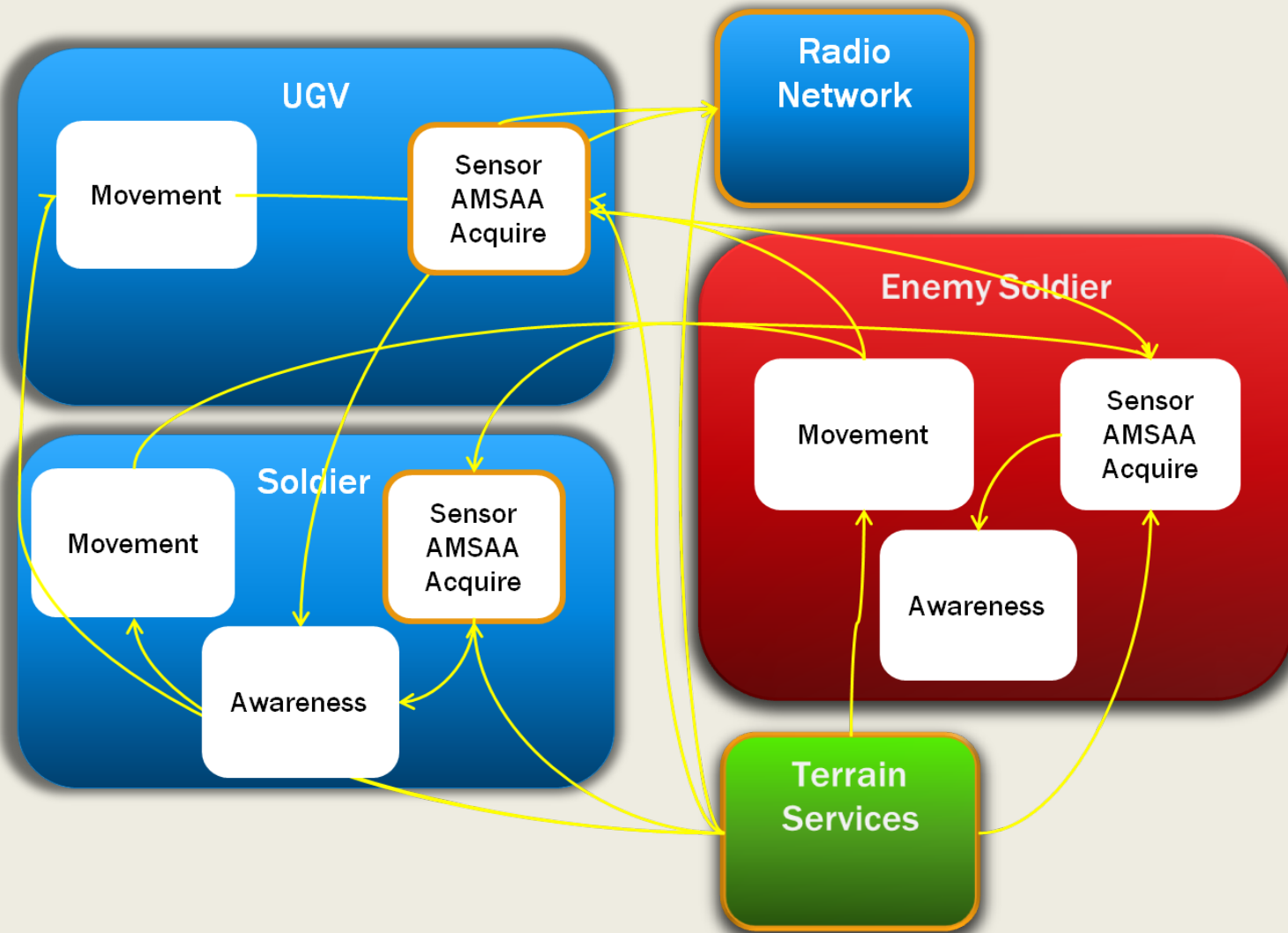BOM — Communications Model

BOM — Awareness Model

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Reference Implementation
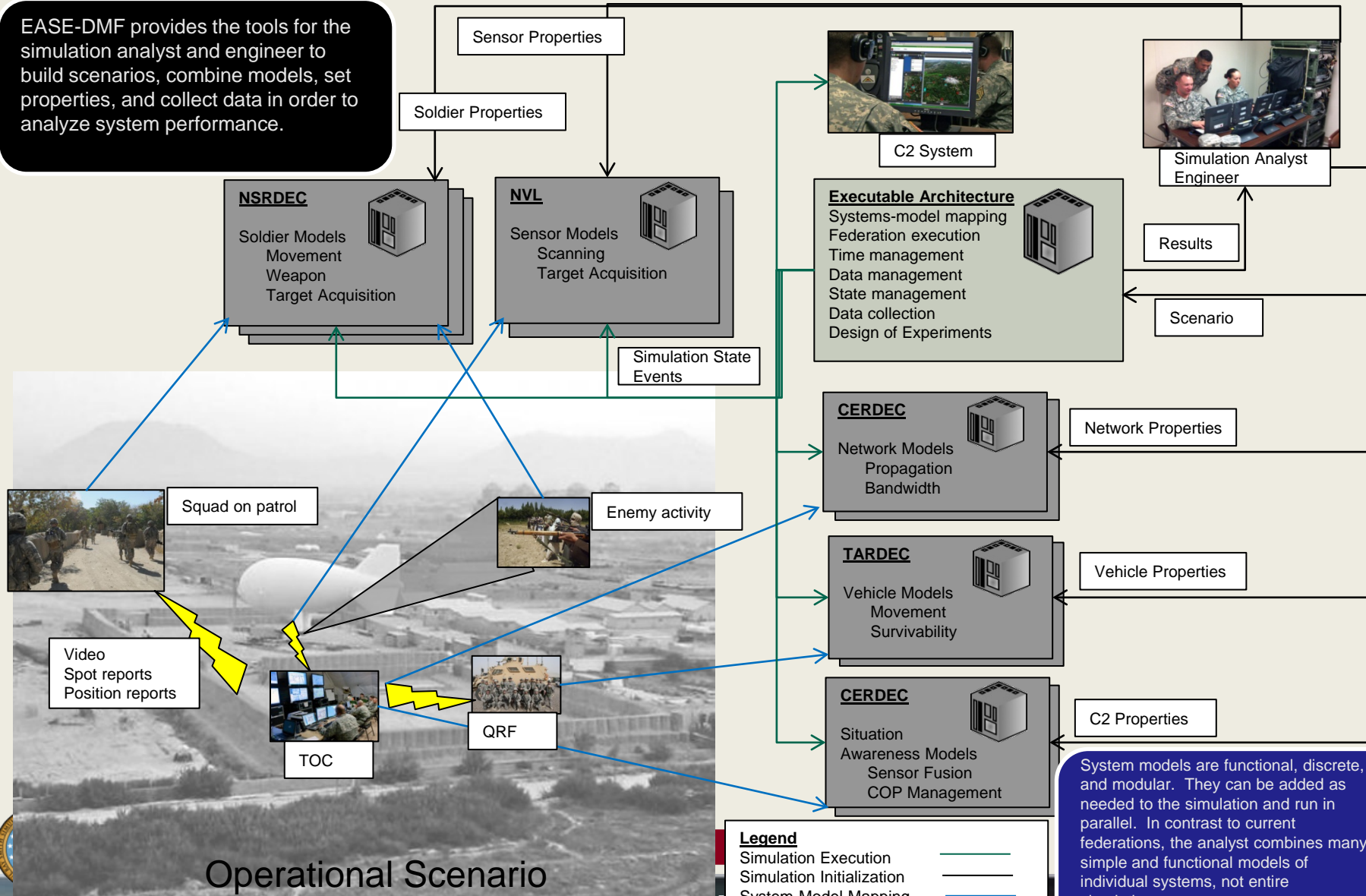
EASE-DMF

EASE-DMF provides the tools for the simulation analyst and engineer to build scenarios, combine models, set properties, and collect data in order to analyze system performance.

Sensor Properties

Soldier Properties

NSRDEC

Soldier Models
Movement
Weapon
Target Acquisition

NVL

Sensor Models
Scanning
Target Acquisition

C2 System

Simulation Analyst Engineer

Executable Architecture
Systems-model mapping
Federation execution
Time management
Data management
State management
Data collection
Design of Experiments

Results

Scenario

Simulation State Events

CERDEC

Network Models
Propagation
Bandwidth

Network Properties

TARDEC

Vehicle Models
Movement
Survivability

Vehicle Properties

CERDEC

Situation
Awareness Models
Sensor Fusion
COP Management

C2 Properties

Squad on patrol

Enemy activity

Video
Spot reports
Position reports

TOC

QRF

Operational Scenario

Legend
Simulation Execution ──────
Simulation Initialization ──────
System-Model Mapping ──────

System models are functional, discrete, and modular. They can be added as needed to the simulation and run in parallel. In contrast to current federations, the analyst combines many simple and functional models of individual systems, not entire simulations.

The Nati...   ...es