A Proposed Open System Architecture for Modeling and Simulation (OSAMS)

A Service Oriented Architecture (SOA) for the M&S Community…

Jeffrey S. Steinman, Ph.D.

JPEO CBD
Software Support Activity
Integration and Test

Motivation…

- How would our lives improve if the cost of M&S was reduced by *an order of magnitude?*
  - How about *two orders of magnitude?*
- M&S provides a cost effective way (and sometimes the only way) to support many challenging applications
  - However, we believe that the true potential cost savings for M&S has not been realized!
- If we are going to reach these potential cost savings, we cannot continue doing things the same way
  - Current M&S interoperability standards are not adequate
  - Revolutionary, not evolutionary change is needed

Interoperability Standards

- Current interoperability standards allow simulations to interoperate
  - However, there are no standards for how to build models!

We should be building models, not simulations!

- OSAMS provides standards that specify how to build highly interoperable models
  - OSAMS-compliant simulation engine required to host models
  - OSAMS-compliant models must not deviate from the API
  - OSAMS is part of a bigger *Standard Simulation Architecture* (SSA) that has been carefully constructed to support interoperability with other standards such as HLA, DIS, TENA, and web-enabled SOAs

Some Basics… What is M&S

Model

A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process.

DIS Glossary of M&S Terms, DoD Directive 5000.59,
DoD Publication 5000.59-P and MSETT NAWC-TSD Glossary

Simulation

A method for implementing a model over time.

DoD Directive 5000.59 and DoD Publication 5000.59-P

Modeling & Simulation (M&S)

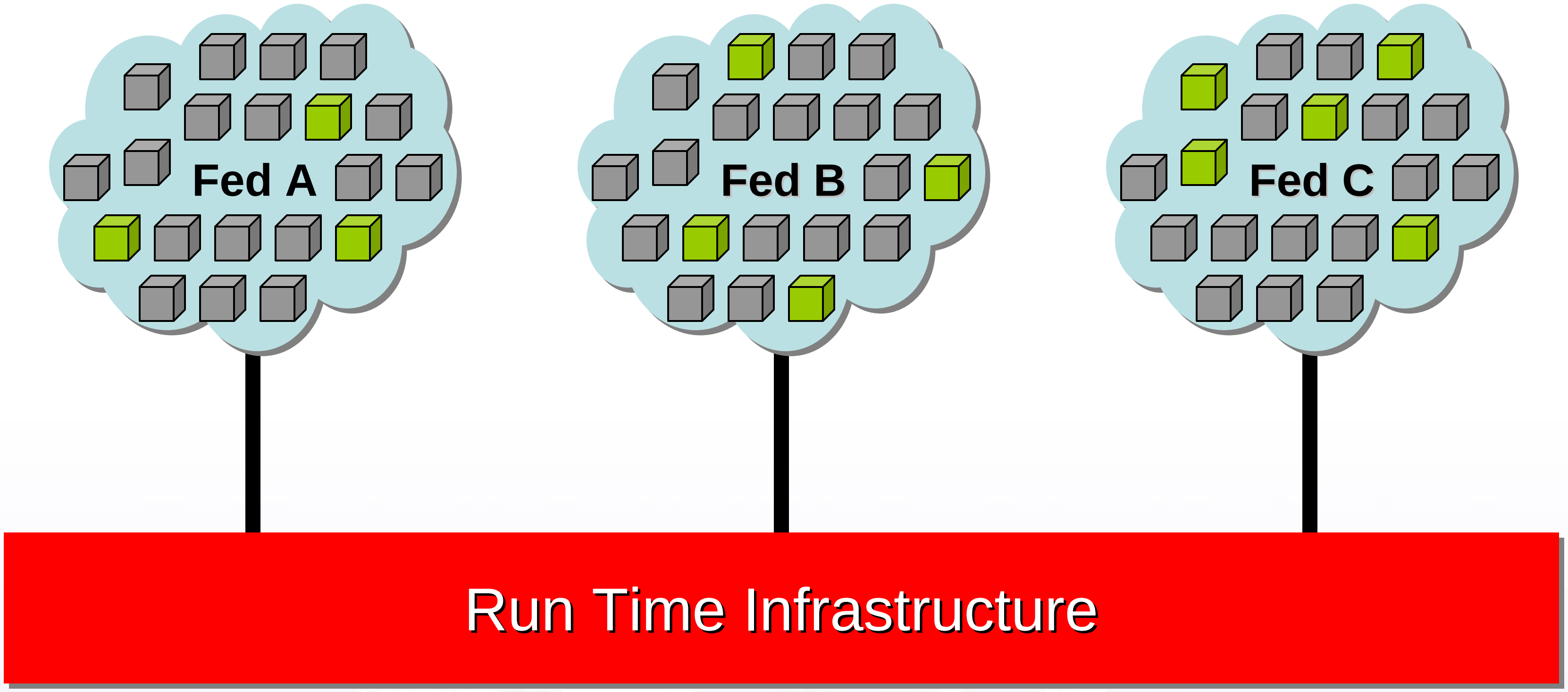
The use of models, including emulators, prototypes, simulators, and stimulators, either statically or over time, to develop data as a basis for making managerial or technical decisions. The terms "modeling" and "simulation" are often used interchangeably.

MSETT NAWC-TSD Glossary

From a Software Developer Perspective

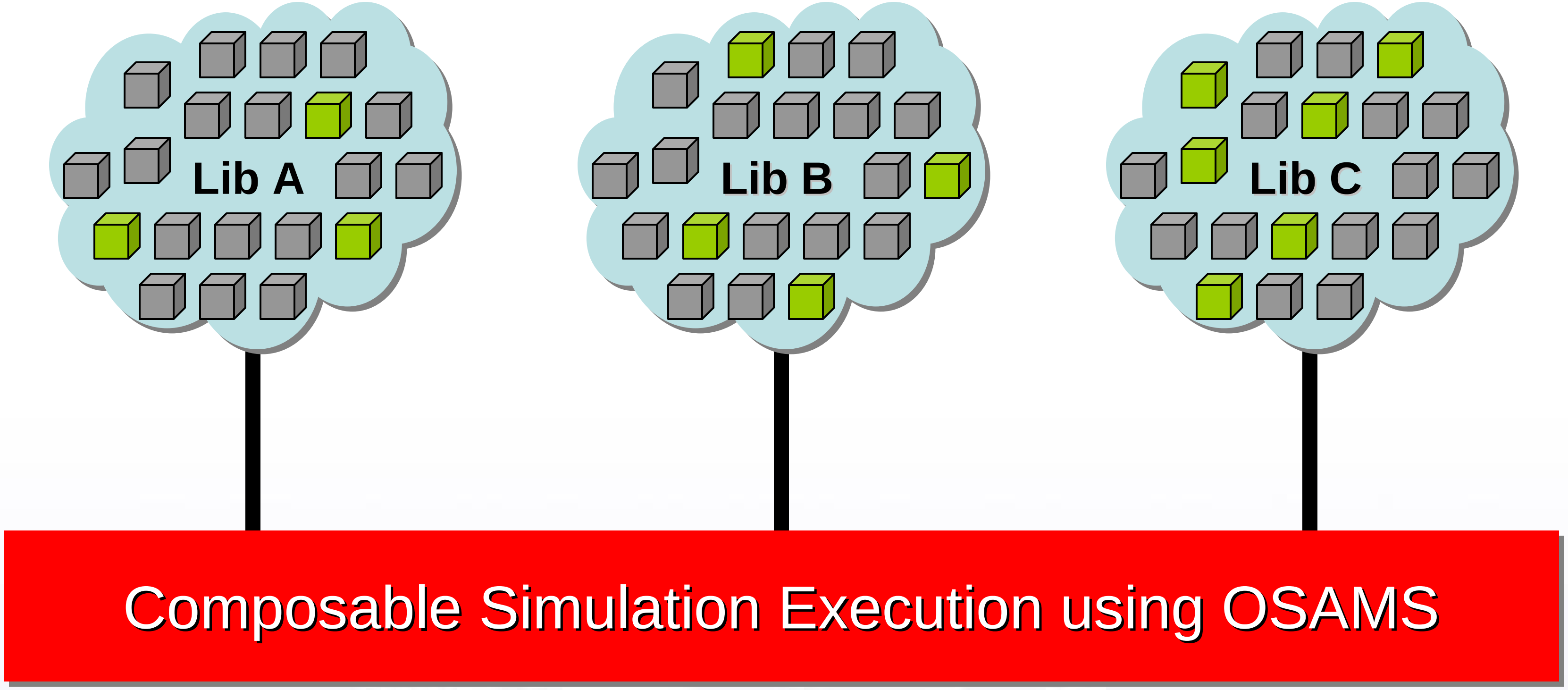
- Terminology: Simulations
  - Simulations are programs that are composed of models
  - Simulations generally require a simulation engine to provide core event-scheduling and event-processing services that allow models to advance in time
- Terminology: Models
  - Models are software representations of systems
  - Models can be self contained and therefore be reusable if…
    - Independent of the simulation engine (does not coordinate the passage of time)
    - Independent of other models (does not directly invoke methods on other models)
    - No reliance on shared global variables (encapsulation)
  - But… More likely, models are tightly coupled to the simulation engine, other models, utility services, and global variables (in other words, models are generally not reusable)

Current Interoperability Strategy Simulation-to-Simulation Interoperability



- **Integrating entire simulations when only select models from each federate are required…**
  - **High integration costs**
  - **Expensive and clumsy to operate**
  - **Unavoidable performance and fidelity tradeoffs**

The Proposed OSAMS Strategy
Model-to-Model Interoperability



Composable Simulation Execution using OSAMS

- **A better approach is to create model repositories/libraries that can be linked together to form a composable simulation…**
  - **Low integration costs**
  - **Easy to operate**
  - **High performance and fidelity**

Modern Applications of Plug-In Composability

- Many modern applications support plug in strategies to support interoperability between components developed by different vendors
  - Web services (SOA)
  - Graphics art
  - Office productivity tools
  - Video games
  - Entertainment systems
  - Wireless networks
  - Music software
  - CBD sensors in NCES environment
- So why not provide a plug-in SOA approach to provide model interoperability?

Plug and Play for M&S

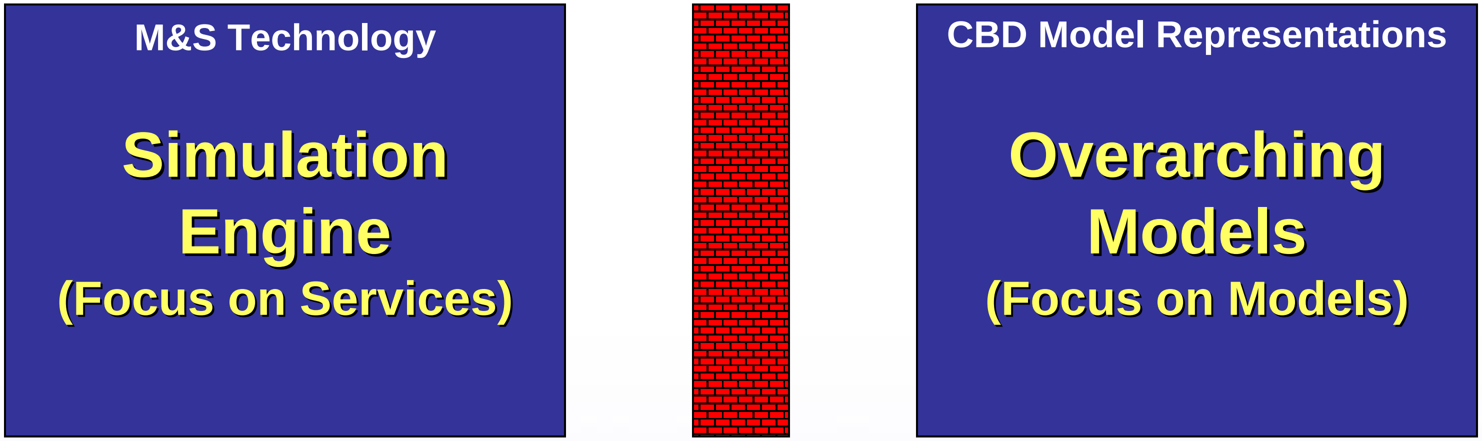
- Model interoperability is much more difficult than traditional plug in systems because different categories of models require different interfaces (and there are a lot of them…)
  - Requires standardizing common types of interfaces such as sensor detection and track data, communications, command and control, various representations of complex motion, human intelligence, rules of engagement, etc.
  - Requires a plug-in strategy that decouples highly interacting model components
  - Also requires composability tool that verifies associations with other models when they are plugged in
- Polymorphic and publish/subscribe data exchanging techniques provide decoupling between software modules while still promoting full model interoperability
- Potential timing issues between models in their interplay affects where models should reside in network environments

Simulation Engines

- **What simulation engines provide**
  - **Simulation engines provide the core event-processing infrastructure and language semantics required to enable the development and execution of complex models. Simulation engines allow applications to coordinate their processing activities in simulated time, which can be synchronized to the wall clock for real-time systems, or unconstrained for as-fast-as-possible synthesis and data analysis runs.**

Simulation Engine & Models

Wall of Separation



M&S Technology

Simulation Engine
(Focus on Services)

CBD Model Representations

Overarching Models
(Focus on Models)

- Commonly used modeling constructs and software utilities
- All network-related operations automatically provided
- Capabilities and technology advances leveraged by all models
- Simulation engine implements an Application Programming Interface

- Focus is on models, not infrastructure or bookkeeping
- Composable interoperability provided between models
- Form repository of models that can be reused
- Models plug into the simulation engine and use the API

Hardware Composability

- **Hierarchically Composing a Federation onto Hardware**
  - Federations are composed of networked federates
    - *Milliseconds*
  - Federates are composed of one or more machines
    - *Less than a millisecond on local area networks*
  - Machines are composed of processing nodes
    - *Microseconds if using shared memory*
  - Nodes are composed of threads
    - *Nanoseconds for context switching between threads*
  - Threads are composed of functions
    - *Much less than a nanosecond for function or method calls*

☛ **Performance spans more than six orders of magnitude**

☛ **Must apply reasonable hardware composition strategy**

Model Composability

- **Hierarchically Composing a Federation from Models**
  - Federations are composed of federates
    - *Communication through RTI*
  - Federates are composed of entities
    - *Entities may reside on different processors*
  - Entities are composed of components and Federation Objects
    - *Components within an entity are on same processor*
  - Components are composed of subcomponents and Federation Objects
    - *Hierarchical composition is recursive*

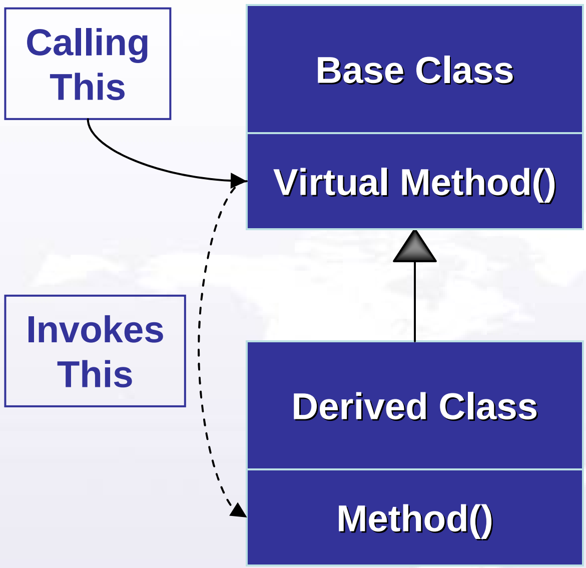
OSAMS provides the required APIs that support…

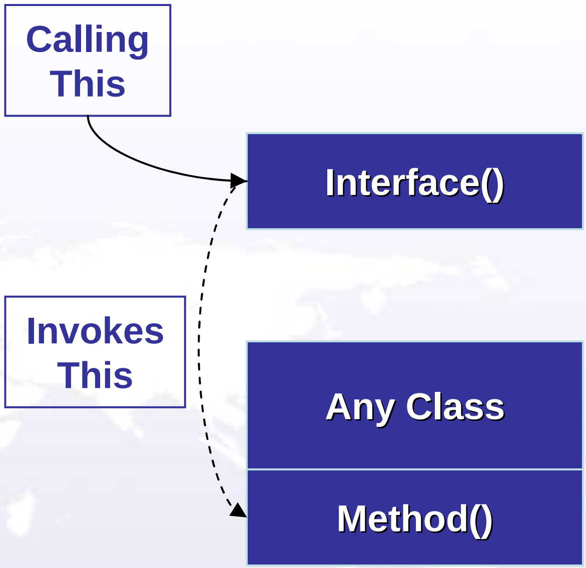
- ☛ **Flexible hierarchical model component construction**
- ☛ **Modeling framework for scheduling events**
- ☛ **Abstract interfaces to support component interactions**
- ☛ **Distributed object abstractions to support network operation**
- ☛ **Data logging and trace file generation for debugging, analysis, and VV&A**

Polymorphism Conceptualized

- *Old school* polymorphism was accomplished through class inheritance and virtual functions that are implemented by the derived classes. This approach is supported by all object oriented languages.
  - Inheritance required
  - Method names must match

- A more *modern* way to accomplish polymorphism is to define abstract interfaces that can be dynamically registered by class methods during run time. This is similar to the SOA methodology.
  - No inheritance required
  - Methods can be named anything

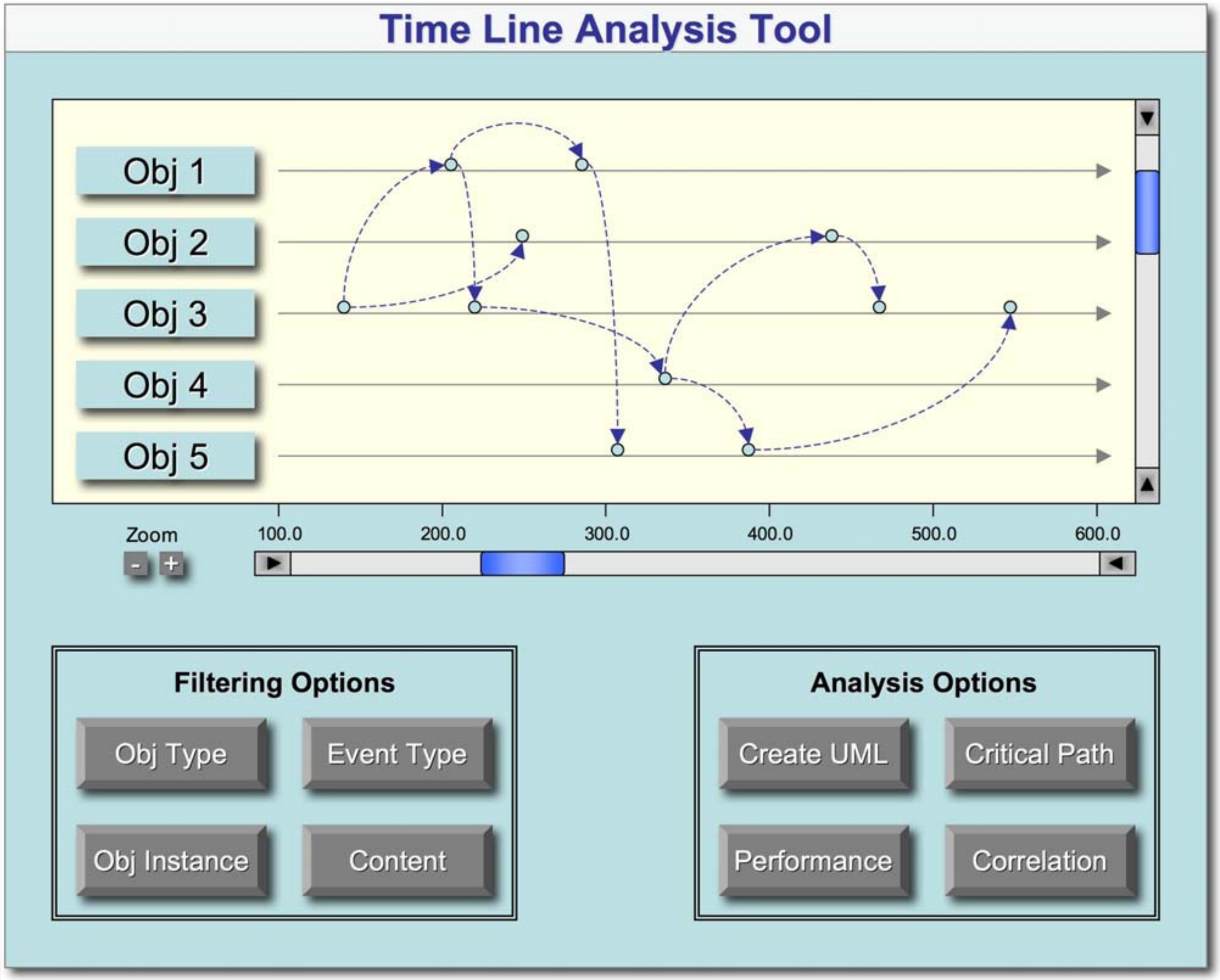




Architecture Rules for Model Interoperability

- **Must preserve the abstraction that an entity may reside on any node when running in parallel, or within any federate when executing in an HLA federation**
  - **Entity state exchanged with other entities must be provided exclusively through Federation Objects**
  - **Entities interact with other entities exclusively through HLA-style Interactions**
- **Key to automating interoperability with HLA… Entities behave like miniature federates!**
  - **Entities are special SimObjs that are distributed to different nodes or federates when executing in parallel and/or distributed environments**
  - **Distributed object capabilities support HLA-like functionality between entities**
  - **Operator overloading in C++ can automate distribution of attributes**
  - **Interest management automatically operates on attributes**

Trace File Generation and Time Line Analysis Tools



Summary of Composability Architecture Rules and Properties

- **Completely passive and encapsulated models with no relationships to other objects are automatically reusable**
  - **However, these kinds of models are rarely developed or openly shared**
- **To promote interoperability and reuse, all other models…**
  - **Must support a flexible *hierarchical composition structure* with the ability to define, compose, and construct simulation objects at run time**
  - **Must be allowed to advance time through services that are provided by a *standardized modeling framework* and compliant simulation engine**
  - **Must rely on *abstract polymorphic interfaces* to decouple interacting models**
  - **Must support *distributed object capabilities* to automate interoperability with legacy systems in a federated publish/subscribe environment and to support high performance computing**
  - **Must support *data logging interfaces and trace file* generation to support testing, debugging, analysis, and VV&A**

An Open Standard Architecture for Modeling and Simulation (OSAMS) is required to promote model-based interoperability and reuse

How to Proceed with OSAMS

- **Phase I - OSAMS specifies all interfaces invoked by models**
  - Developers are required to implement the interfaces themselves within their own simulation engines (dependence on standalone utility libraries are ok)
  - Could support interface subsets as long as there exists at least one available simulation engine that supports all interfaces
- **Phase II - OSAMS provides common middleware software infrastructure with the right programming hooks to allow any simulation engine to implement the mapping**
  - Can significantly reduce costs of making a simulation engine OSAMS compliant
  - Requires development of the middleware capability
  - Potential technical issues involving the mapping
- **Phase III - OSAMS encourages the development of freely available open source compliant simulation engines**
  - Consolidates development costs, but has potential problems involving software rights, CM, industry buy-in, life cycle support, etc.

Summary & Conclusions

- **Open Standard Architecture for Modeling & Simulation (OSAMS) is needed to lower the cost of M&S for CBD Overarching Models**
  - ✓ Strategy is not to just do things better… we must do things differently

In particular, reuse must begin at the model level

- **This will lower costs of model development, VV&A, scenario generation, operation of simulation, post processing**
- **Better performance without compromising fidelity can be achieved by composing tightly interacting models together into a single executing process**
- **Next-generation capabilities can be achieved without throwing away investments in legacy simulations or M&S technology efforts**

Final Thoughts

- OSAMS is a proposed SOA for the M&S Community and is based on proven technology and freely available open source software that could be used today

- OSAMS Specifically Addresses:
  - Plug and Play interoperability/composability of Models
  - Interoperability of Simulations