Building Composable Bridges Between the Conceptual Space and the Implementation Space

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Topics

• Problem
• Back To Basics
• Need for Bridging
  – Aspects of Composability
  – Aspects of Process
  – Aspects of Standards
• Definitions
  – Bridge
  – Conceptual models
• Bridges Built for Reuse
  – Patterns
  – Interfaces
  – Components
  – Discovery Metadata
• Enabling Technology Standard for Composable Bridges
• Using BOM as a Bridge to Achieve Interoperability
• Summary
Problem

• Building interoperable C2 systems and simulations is arduous
• Difficulty is in understanding what is intended
• Consider
  – Why Projects Fail?
  – Why They Succeed?

Findings
• Lack of communication among teams
• Not correlating intentions with what is being built or used (e.g. components) in the effort to realize an implementation

What is needed is a means to assist in bridging well defined concepts with what is ultimately being implemented.
Back To Basics

• Composability
  – A Common Desire!
  – A Significant Need

• Process
  – Best Practices are Tried and True
  – Why Ignore it?

• Standards
  – Can’t build quality products w/ out them!

“the ability to rapidly select and assemble components to construct meaningful simulation systems to satisfy specific user requirements.”
- DoD M&S Master Plan

Think of Legos®

Image courtesy Nathan Sawaya
Need for Bridging

Aspects of Composability
1. Selection and use of components
2. Construction of something meaningful
3. Satisfaction of specific user requirements

Aspects of Process
1. Requirements
2. Analysis
3. Design
4. Development
5. Test
6. Product Deployment

Aspects of Standards
1. Beneficial in achieving interoperability
2. Ensuring products meet certain
   - Requirements
   - Commonality
   - Reliability
   - TCO
   - Compatibility

what we create truly isn’t satisfying unless it has met our requirements

Images courtesy Nathan Sawaya
Building Composable Bridges

- “a structure spanning and providing passage over a gap or barrier.”
- “a transitional passage connecting two subjects or movements.”
- a means to span and provide a way to connect an idea (i.e., initial concept) to something implementable.

What we all want for any project is to be able to bridge quickly and easily from initial concept to implementation.

bridges should be represented and supported by well-defined conceptual models, providing an effective way to communicate among stakeholders.
conceptual models -

- A means to understand what is to be represented
- Provides a quick way to look at what that product might be like
- Like a blueprint
- Implementation neutral

- C2 systems and simulations can share the same (or similar) conceptual models
- C2 systems may embed (i.e. compose) simulations to support its objectives.
  - C2/Simulation used for training.
  - Composable bridges supported through well-defined conceptual models can be of great assistance.

**Conceptual Model** - describes “what the [system or simulation] will represent, the assumptions limiting those representations, and other capabilities needed to satisfy the user’s requirements.”

- IEEE 1516.3 - FEDEP

**Building Composable Bridges**

composable bridges, like a blueprint, need to be reflected structurally as a means to communicate a concept for all stakeholders
Bridges Built for Reuse –
Patterns

• What should we look for when trying to identify and define conceptual models?

pattern is “an idea that has been useful in one practical context and will probably be useful in others.”
- Martin Fowler

Pattern “… describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice.”
- Christopher Alexander

“The best way to discover a pattern is to perform a conceptual analysis on the problem space.”
Weapon’s Effect Pattern

“It’s often said that patterns are discovered rather than invented”*
- Martin Fowler

Weapon Effects is a frequent “Pattern of Interplay”


Pattern of Interplay
Jamming / Detection Pattern

We could conceivably use the “Detection” pattern for other purposes besides just “Jamming” such as “Vectoring Interceptors”

“It’s often said that patterns are discovered rather than invented”*
- Martin Fowler

Bridges Built for Reuse – Interfaces

• What should we look for when trying to identify and define conceptual models?

• We should identify mappable interfaces
• interfaces identify
  – what will be provided
  – what should be supported by an implementation (hardware, software, or a system component)

“…it is essential for the software industry's health that key interfaces be well-specified and publicly available.” - Bjarne Stroustrup

• Often described in terms of class structures
• Reflects a contract of what is available and accessible

Interfaces provide a framework to resulting implementations (i.e., software, simulation or system components) that support what’s described by a pattern
Bridges Built for Reuse – Interfaces to Components

• What should we look for when trying to identify and define conceptual models?

• Components provides a means to satisfy a composable bridge
• Look for available components that support the conceptual model.
• Examples
  – Lego® Brick (simple)
  – Electronic Chips
  – Simulation Models
  – Software Components
  – System Components

Components - “Reusable building blocks which have a known set of inputs and provide expected output behavior, but the implementation details may be hidden. Such components are useful for constructing simulations and/or providing functionality for simulation systems.” – COI M&S Metadata Focus Group
Bridges Built for Reuse – Discovery Metadata

- **What should we look for when trying to identify and define conceptual models?**

- Need to ensure the discovery of useful components, interfaces and patterns
- Discovery metadata provides way to catalog / tag reusable assets
- Helps optimize composability and reuse

**Metadata** is “structured, encoded data that de-scribe characteristics of information-bearing entities to aid in the identification, discovery, assessment, and management of the described entities [2].”

We want and need to use metadata to catalog patterns, interfaces and components.
What common structure allows us to represent composable bridges for supporting C2 system and simulation interoperability?
Enabling Technology Standard for Composable Bridges

Desired Characteristics:

- Identifies and names the common problems in a field of interest,
- Describes the key characteristics of effective solutions for meeting some stated goal,
- Helps the designer move from problem to problem in a logical way, and
- Allows for many different paths through the design process.

- Based on ideas from Christopher Alexander

**BOM** is “a piece part of a conceptual model, simulation object model, or federation object model, which can be used as a building block in the development and/or extension of a simulation or federation.”[3]
Using the BOM as a Bridge to Achieve Interoperability

Model Composability

System Composability

Reusable Piece Parts

Plug & Play Systems

BOMs

1. Define Objectives
2. Perform Conceptual Analysis
3. Design
4. Develop
5. Plan, Integrate, and Test Federation
6. Execute Federation & Prepare Outputs
7. Analyze Data and Evaluate Results

Interoperable Space

FEDEP

Conceptual Space

Implementation Space

Interoperable

locate create compose integrate compose

Building Composable Bridges
Using the BOM as a Bridge to Achieve Interoperability

BOMs
• help to focus on:
  • what needs to be shared conceptually within an C2 / M&S environment,
  • how the intended “components” are to perform pragmatically,
  • how qualifying interfaces are semantically defined, and
  • how such components are syntactically structured
• complements the use of other interoperability standards in an independent way (e.g., HLA / TENA)

Achieving Level 6 Conceptual Interoperability
• Ensures greater likelihood of success for other levels of interoperability.
• Requires a “fully specified, but implementation independent model.”
  – Paul Davis
Using the BOM as a Bridge to Achieve Interoperability

- BOMs support stitching of
  - Conceptual models, and the
  - Structural elements offered by Object Models
- Results in
  - Mappings
  - BOM Assembly
- BOMs / BOM Assembly can represent different architecture implementations
- provides a powerful construct for building composable bridges and achieving interoperability

"the abstract things described in a Conceptual Model (entities and events) can be mapped to the actual types of things we are modeling (representing), which are described in the Object Model Definition of a BOM. So, if I identify that there is a firing entity at the conceptual level (in the conceptual model), my mapping tells me what system architecture classes [HLA, TENA, Navy OA or otherwise] can fulfill the entities and events associated to it."
Building Composable Bridges

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• Summary

Building interoperable C2 systems and simulations is arduous

Composability – Common Desire / Need
Process – Requirements First!
Standards – Ensuring products meet Requirements and are compatible

BRIDGE - “spans / connects an idea (i.e., concept) to something implementable”

CONCEPTUAL MODEL – A means to understand what is to be represented

COMposable BRIDGES
- Metadata
- Patterns
- Interfaces

BOM
Base Object Model
Summary

- **Interoperability** is best addressed through "composability"
- **Composability** can be understood and carried forward through the use of "bridges"
- **Bridges**
  - “span and provide a way to connect an idea (i.e., concept) to something implementable”
  - should be represented and supported by well-defined conceptual models
    - Patterns,
    - Interfaces,
    - Metadata
- **BOM** offers key standard for supporting composable bridges & achieving conceptual interoperability

The clarity provided by a conceptual model is what helps bring a concept to implementation to a potential state of interoperability.
Discussion / Questions?

• Tools
• Shared Experiences
• More Info
  – www.boms.info
  – www.sisostds.org

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Backup Slides
BOM Experiences

- To date BOMs developed for the Army, Navy, Air Force, Missile Defense Agency, and general simulation community
- Example: Real-time Platform Reference (RPR) BOMs - SISO
- Example: Airborne Electronic Attack (AEA) BOMs - JHU/APL
  - BOMs developed from the collection of DoDAF views that were originally formulated by the JHU/APL architecture team.
  - BOMs have helped to solidify mission objectives and capabilities.
  - A mapping of the AEA conceptual space provided by such BOMs is being made to software constructs representing JHU/APL's simulation environment.
  - Allows for effective communication and traceability in the composition of AEA models.
- Example: Mid-Range Ballistic Attack Munitions (MR-BAM) BOMs - Navy
  - BOMs used to rapidly prototype and explore potential Mid-Range Ballistic Attack Munitions (MR-BAM) concepts.
  - BOMs served as the framework for a resulting prototype software model and simulation developed and demonstrated within a very short period of time.
Levels of Interoperability

- **Level 6** – achieved when the anticipated capability that is to be provided by the models and simulations to be used are fully understood and agreed upon by all the stakeholders. At this level of interoperability there is no ambiguity in what is expected to be shared.

- **Level 5** – achieved when systems are able to come “on-line” and begin to exchange and reflect data with other systems. Such systems are “able to comprehend the state changes that occur in the assumptions and constraints that each is making over time, and they are able to take advantage of those changes.”[7]

- **Level 4** - achieved when the systems, simulations or applications involved in the exchange of data are aware of the specific methods and/or procedures that a calling system is requesting.

- **Level 3** - achieved when a common reference model (i.e., definition set) is used to perpetuate the understanding of the level 2 data being shared.

- **Level 2** - achieved using technology such as XML, which offers a means to define and use a common data structure among the systems established in a network.

- **Level 1** - requires an agreed upon communication technology infrastructure and protocols such as UDP or TCP/IP to support the handshaking among networked systems.

Achieving Level 6 Conceptual Interoperability

- Ensures greater likelihood of success for other levels of interoperability.
- Requires a “fully specified, but implementation independent model.”

– Paul Davis
Background - BOM Early Adopters

BOMs
Base Object Models

210+ users representing 18+ countries

& Others…
Available Tool - BOMworks

- Create BOMs
- Edit BOMs
  - Grid/XML/UML
  - Cut/Copy/Paste
- Validate BOMs
- Source Code Generation
- Import FOMs
- Built on Galileo Framework - extensible and customizable

Free download is available
BOM Conceptual Model

CONCEPTUAL MODEL – Describes what is to be represented, the assumptions limiting those representations, and other capabilities needed to satisfy the user’s requirements.”

PATTERN OF INTERPLAY – a behavior pattern characterized by a sequence of pattern actions involving one or more conceptual entities.

PATTERN ACTION - A single step in a pattern of interplay. Can be supported by a defined event or by another BOM. May result in a state change of a conceptual entity.

STATE MACHINE - A description of the various states or conditions of a conceptual entity, and how the pattern actions associated with one or more patterns of interplay may affect these conditions over the conceptual entity’s life.

CONCEPTUAL ENTITY - An abstract representation of a real world entity, phenomenon, process, or system.

CONCEPTUAL EVENT - A representation of a transient action that occurs among conceptual entities that may affect the state of one or more of the conceptual entities.
**Key Concepts**

- **Composability** – *Ability to assemble things from components*

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**UNDERSTANDING COMPOSABILITY**

- Creating a simulation requires **breaking the problem into parts** that can be addressed separately
  - To reduce the effects of interruption
  - To permit specialization
  - To facilitate computing alternative ways of handling a given component
  - To maintain the software over time
  - To reduce risk by relying upon previously proven components where possible
- **Understanding** complex systems requires decomposition.
  - No one can comprehend the whole’s details
- **Testing systems** is **simplified** if done module by module then at the system level
- **Controlling costs / economic incentives**
  - Costs are correlated with the amount of new code writing
- **Maintaining and modifying** is **easier / safer**
  - Individual modules can be substantively modified or updated as software as necessary, without endangering the overall system.

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“Modularity is necessary when dealing with complex systems, and some degree of composability is surely possible and desirable.”
- Paul Davis (RAND)