

Storage and Reuse

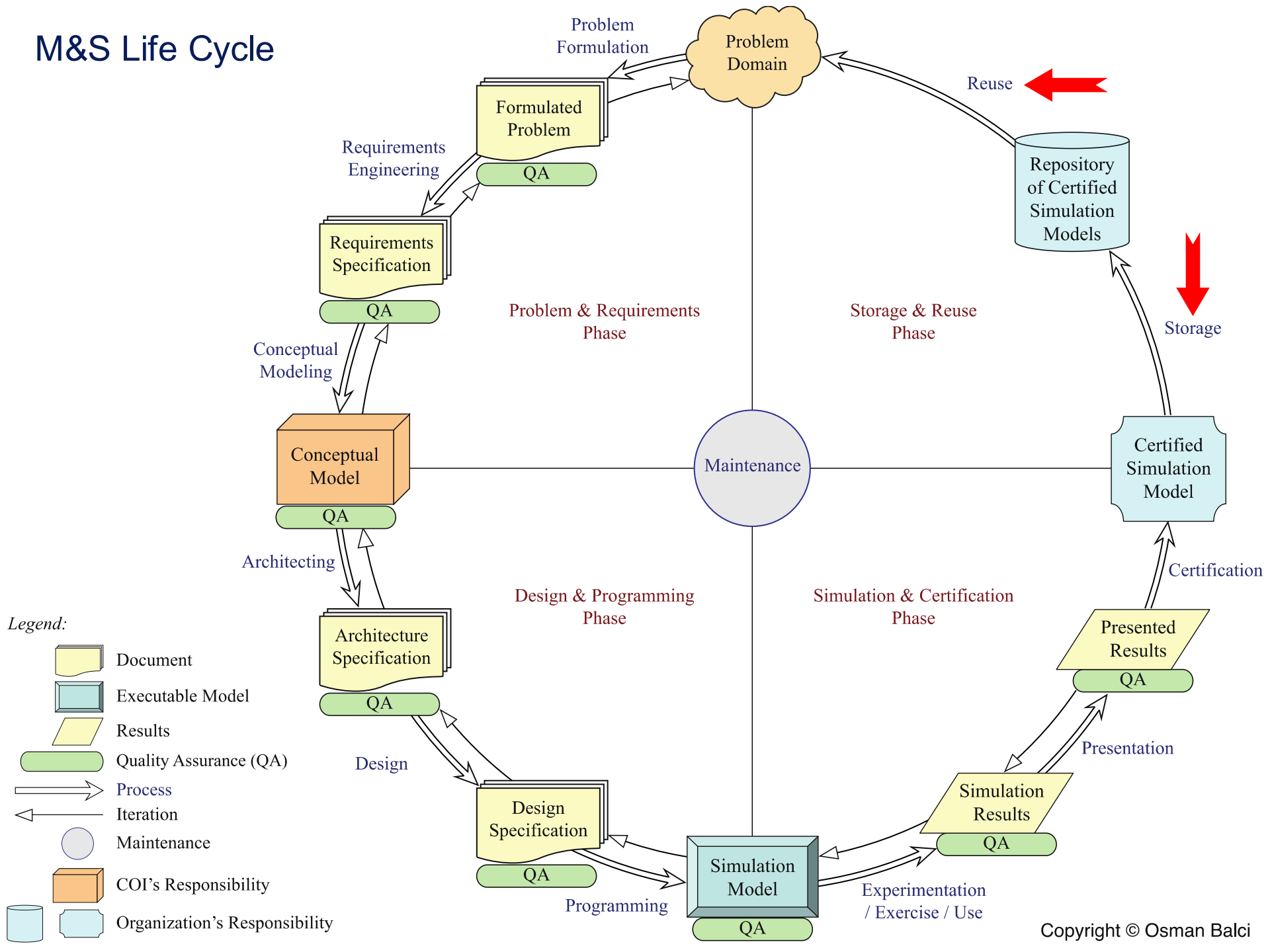
OSMAN BALCI

Professor

Department of Computer Science
Virginia Polytechnic Institute and State University (Virginia Tech)
Blacksburg, VA 24061, USA

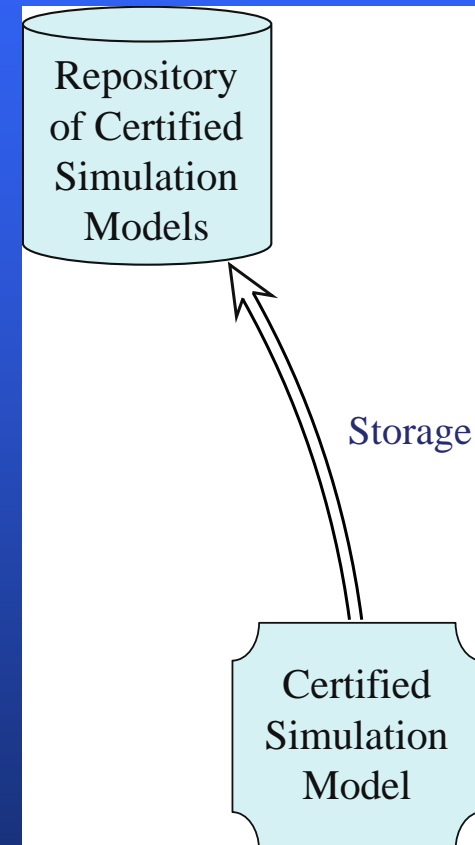
<https://manta.cs.vt.edu/balci>

M&S Life Cycle

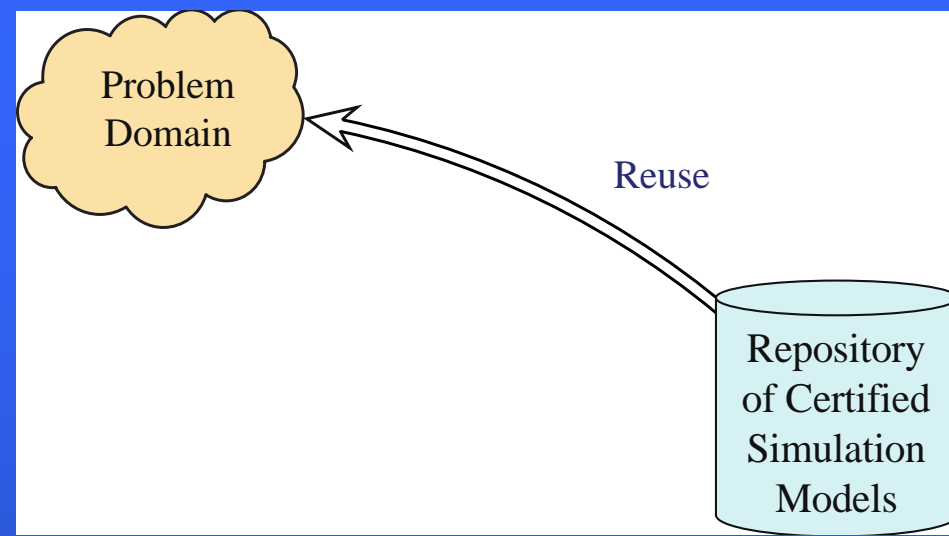


Storage

- Creation of an organization-wide **Repository of Certified Simulation Models** is the responsibility of any organization that develops and uses M&S applications on a regular basis.
- A certified Simulation Model becomes an asset for an organization (e.g., FAA, FEMA, MDA, NASA) and must be preserved and reused.
- The **process of storage** places the certified Simulation Model with its full documentation into an organization-wide repository for reuse.
- **Storage of models, submodels, documentation, and data should be done using metadata in such a way that the search and retrieval operations are greatly facilitated.**



Reuse



- **Repository of Certified Simulation Models** is the responsibility of any organization that develops and uses M&S applications on a regular basis.
- For example, DoD maintains and provides a **Modeling and Simulation Resource Repository (MSRR)**
- MSRR provides retrieval of metadata descriptions of M&S resources.
- M&S resource providers include Air Force, Army, C4ISR DSC, Defense Intelligence, DMSO, MDA, and NMSO.

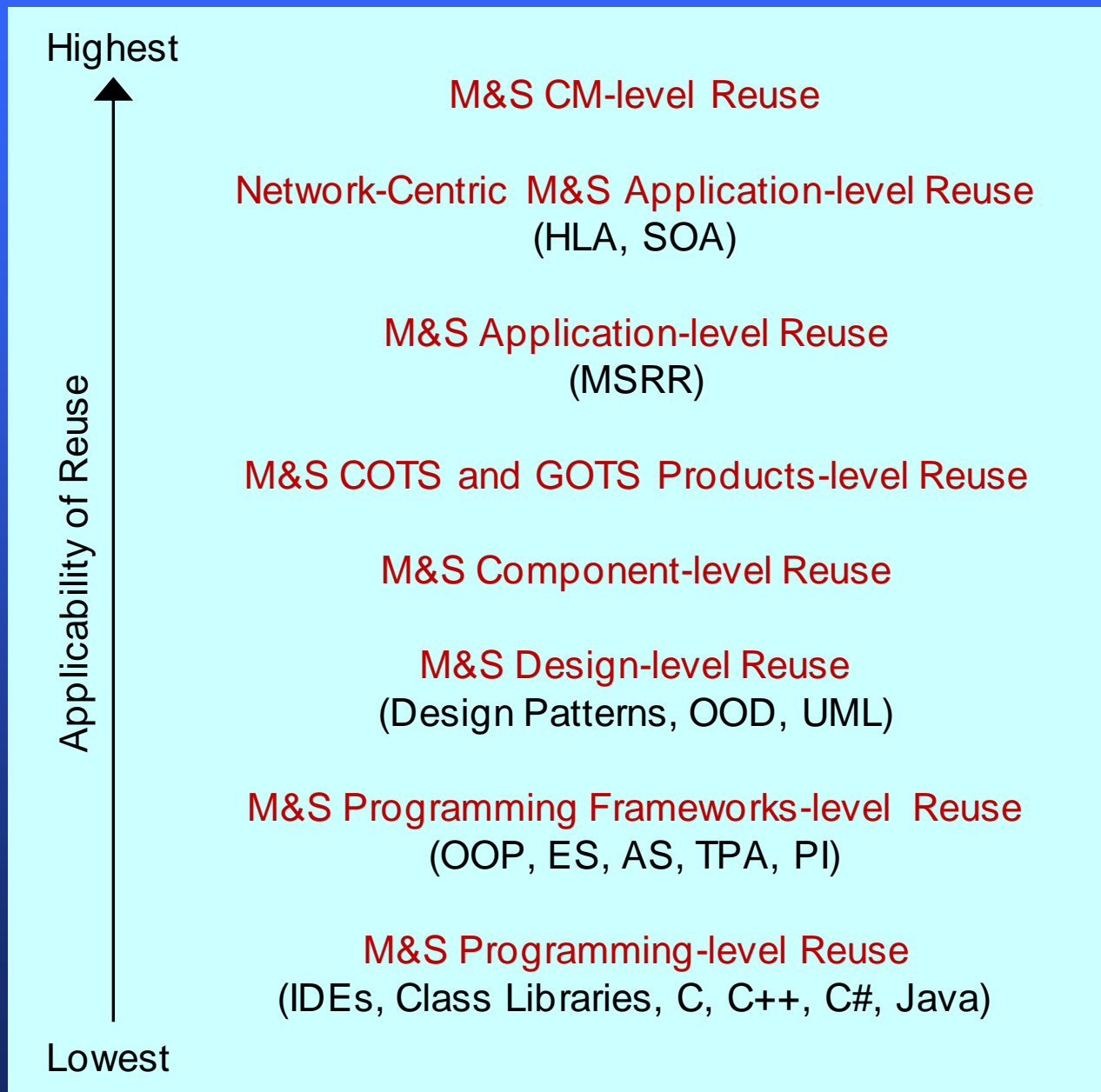
Guidelines for Reuse of Earlier Developed (Sub)Models

1. An earlier developed M&S application can be reused without any change if and only if its credibility is substantiated to be sufficient for the Intended Uses for which it is created. **The M&S application can be reused only for the prescribed Intended Uses for which it is created.**
2. An earlier developed submodel (model component) can be reused without any change if and only if (a) its credibility is substantiated to be sufficient for the Intended Uses for which it is created, and (b) its Intended Uses match the Intended Uses of the simulation model into which it will be integrated.
3. Any change to the earlier developed M&S application will require it to be verified, validated, and certified again.
4. **Any change to the earlier developed submodel will require not only the submodel, but also the entire simulation model to be verified, validated, and certified again.**

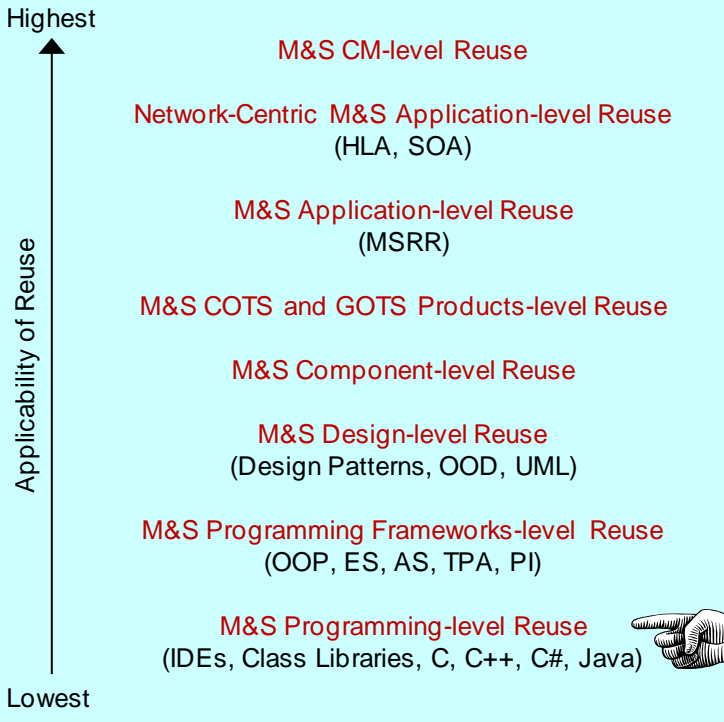
Guidelines for Reuse of Earlier Developed (Sub)Models

- 5. The programming language, operating system, and hardware platform must be taken into consideration in attempting to reuse for a standalone M&S application.**
- 6. An earlier developed (sub)model can be converted into a web service and can be reused for a web-based (network-centric) M&S application under the Service-Oriented Architecture (SOA).**

Levels of Reuse in M&S Application Development



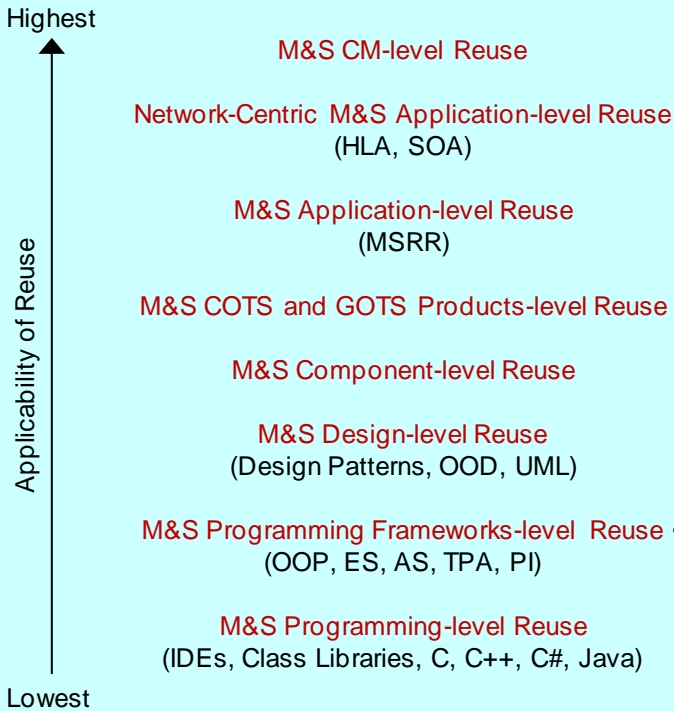
M&S Programming-level Reuse



- **Classes** (under the object-oriented paradigm - OOP) and **subroutines/functions** (under the procedural paradigm - PP) are **reused** from a library under an Integrated Development Environment (IDE) such as Microsoft Visual Studio.

- However, **reuse at this level is extremely difficult** due to
 - ❖ many options in programming languages (e.g., C, C++, Objective C, C#, Java),
 - ❖ differences in operating systems (e.g., Unix, Windows), and
 - ❖ variations among hardware platforms (e.g., Intel, Sparc) supporting language translators.

M&S Programming Frameworks-level Reuse



- M&S programming frameworks: OOP and PP
- PP conceptual frameworks:
 - event scheduling (ES)
 - activity scanning (AS)
 - three-phase approach (TPA)
 - process interaction (PI)

- A simulation programmer is guided under one of these frameworks by reusing the concepts underlying that conceptual framework.
- However, a simulation (sub)model programmed under one framework cannot be easily reused under another.

Highest

Applicability of Reuse

Lowest

M&S CM-level Reuse

Network-Centric M&S Application-level Reuse
(HLA, SOA)

M&S Application-level Reuse
(MSRR)

M&S COTS and GOTS Products-level Reuse

M&S Component-level Reuse

M&S Design-level Reuse
(Design Patterns, OOD, UML)



M&S Programming Frameworks-level Reuse
(OOP, ES, AS, TPA, PI)

M&S Programming-level Reuse
(IDEs, Class Libraries, C, C++, C#, Java)

M&S Design-level Reuse

- Reuse at the design level is feasible if the same **design paradigm** (e.g., OOP, PP) is employed.
- The reuse is also affected by the **design patterns** employed.
- Unified Modeling Language (**UML**) **diagrams** are useful only for object-oriented design (OOD).

- Reuse at the design level is extremely difficult or impossible due to the types of M&S applications:
 - ❖ e.g., discrete, continuous, Monte Carlo, system dynamics, agent-based, and gaming-based.

M&S Design-level Reuse

- Simulation model representation is completely different for each M&S application type/area.
- For example:
 - A **discrete simulation** model consists of logic.
 - A **continuous simulation** model consists of differential equations.
 - **Monte Carlo simulation** is based on statistical random sampling.
 - A **system dynamics simulation** model represents cause-and-effect relationships in terms of causal-loop diagrams, flow diagrams with levels and rates, and equations.
 - An **agent-based simulation** model represents agents and their interactions. An agent is “intelligent”, adaptive, autonomous, goal/self-directed, has the ability to learn, and can change its behaviors based on experience.

Highest

Applicability of Reuse

Lowest

M&S CM-level Reuse

Network-Centric M&S Application-level Reuse
(HLA, SOA)

M&S Application-level Reuse
(MSRR)

M&S COTS and GOTS Products-level Reuse

M&S Component-level Reuse



M&S Design-level Reuse
(Design Patterns, OOD, UML)

M&S Programming Frameworks-level Reuse
(OOP, ES, AS, TPA, PI)

M&S Programming-level Reuse
(IDEs, Class Libraries, C, C++, C#, Java)

M&S Component-level Reuse

- M&S component level reuse is intended to enable the assembly (composition) of a simulation model by way of employing already developed model components in a similar fashion as an automobile is assembled from previously produced parts.

- However, **component level reuse is also extremely difficult** since each reusable component can be
 - ❖ implemented in a **different programming language**
 - ❖ intended to run under a particular **operating system**
 - ❖ on a specific **hardware** platform.

Highest

Applicability of Reuse

Lowest

M&S CM-level Reuse

Network-Centric M&S Application-level Reuse
(HLA, SOA)

M&S Application-level Reuse
(MSRR)

M&S COTS and GOTS Products-level Reuse

M&S Component-level Reuse

M&S Design-level Reuse
(Design Patterns, OOD, UML)

M&S Programming Frameworks-level Reuse
(OOP, ES, AS, TPA, PI)

M&S Programming-level Reuse
(IDEs, Class Libraries, C, C++, C#, Java)



M&S COTS and GOTS Products-level Reuse

- M&S Commercial Off-The-Shelf (COTS) and M&S Government Off-The-Shelf (GOTS) products enable reuse of components within their Integrated Development Environments (IDEs).

- Such an IDE provides a library of reusable model components.
- A user can click, drag, and drop an already developed component from the library and reuse it in building a simulation model.
- However, such reuse is specific only to that particular COTS or GOTS IDE, and portability to another IDE would become a user responsibility.

Highest

Applicability of Reuse

Lowest

M&S CM-level Reuse

Network-Centric M&S Application-level Reuse
(HLA, SOA)

M&S Application-level Reuse
(MSRR)



M&S COTS and GOTS Products-level Reuse

M&S Component-level Reuse

M&S Design-level Reuse
(Design Patterns, OOD, UML)

M&S Programming Frameworks-level Reuse
(OOP, ES, AS, TPA, PI)

M&S Programming-level Reuse
(IDEs, Class Libraries, C, C++, C#, Java)

M&S Application-level Reuse

- Reuse at the application level is feasible if the **Intended Uses** (objectives) of the reusable M&S application match the Intended Uses of the M&S application under development.
- For example, DoD provides a **M&S Resource Repository** (MSRR) containing previously developed M&S applications.

- Even if the source code is provided, understanding the code sufficiently to modify the represented complex behavior is extremely challenging.
- **Reusability of earlier developed M&S applications is dependent on the run-time environment compatibility and the match between Intended Uses.**

Highest

Applicability of Reuse

Lowest

M&S CM-level Reuse

Network-Centric M&S Application-level Reuse
(HLA, SOA)

M&S Application-level Reuse
(MSRR)

M&S COTS and GOTS Products-level Reuse

M&S Component-level Reuse

M&S Design-level Reuse
(Design Patterns, OOD, UML)

M&S Programming Frameworks-level Reuse
(OOP, ES, AS, TPA, PI)

M&S Programming-level Reuse
(IDEs, Class Libraries, C, C++, C#, Java)



Network-Centric M&S Application-level Reuse

■ A network-centric M&S application describes the case in which the M&S components interoperate with each other over a network (e.g., Internet, virtual private network, wireless network).

- **High Level Architecture (HLA)** — DoD, IEEE, and NATO standard — enables the interoperability of a federation of simulation models running on different nodes of a network.
- **If a simulation model is built in compliance with the HLA standard, then that model can be reused** by other models interconnected through the HLA protocol over a network.

Network-Centric M&S Application-level Reuse

- **Service Oriented Architecture (SOA)** can be employed for developing a network-centric M&S application by way of reuse of simulation models, submodels, components, and services over a network.
- For example, Sabah and Balci (2005) provide **a web service for random variate generation (RVG)** from 27 probability distributions. The RVG web service can be called from any M&S application that runs on a server computer over a network using XML as the vehicle for interoperability.
- **Reuse and interoperability are fully achieved regardless of the programming language, operating system, or hardware platform under SOA.**
- **However, this type of reuse is possible only for network-centric or web-based M&S application development.**

Highest

Applicability of Reuse

Lowest

M&S CM-level Reuse 

Network-Centric M&S Application-level Reuse
(HLA, SOA)

M&S Application-level Reuse
(MSRR)

M&S COTS and GOTS Products-level Reuse

M&S Component-level Reuse

M&S Design-level Reuse
(Design Patterns, OOD, UML)

M&S Programming Frameworks-level Reuse
(OOP, ES, AS, TPA, PI)

M&S Programming-level Reuse
(IDEs, Class Libraries, C, C++, C#, Java)

M&S CM-level Reuse

- We believe that the highest degree of applicability of reuse can be achieved by providing a **Community of Interest (COI)** problem domain-specific conceptual constructs and knowledge at the highest level of abstraction in an **M&S Conceptual Model**.

- The conceptual constructs and knowledge provided in a **M&S Conceptual Model** can be reused by the designer of any type of M&S application in the COI.