Simulation Team

M&SNet

STRATEGOS

Continuous & Discrete M&S

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Modeling and Simulation: Basics & Classification

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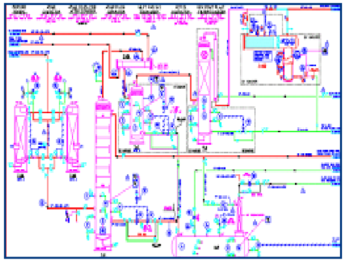
Why Modeling & Simulation?

Internal Complexity → Complex Behaviors



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Simulation:
More Efforts ←
More Capabilities
Reusable Model

Not Linear Systems
Not valid Simplification Hypotheses
Boundary Conditions are Critical
No Generalization

↑

External Complexity → Many Interaction

Simulation Origins

'50 now

Defense

Engineering

Training

Decision Support

Interoperability

Simulation based Acquisition

Industry

Manufacturing

Process Optimization

Operations Management

Decision Support

Simulation Origins

'50 → now

Defense

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Training

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Interoperability

Simulation based Acquisition

Bleriot Recruiter

Microsoft Flight Simulator ™

Static M 346 CAE

5DoF F18 Aegis

6DoF Jaguar CAE

V22 Vertical Flight Simulator NASA Ames

Industry

Manufacturing

Process Optimization

Operations Management

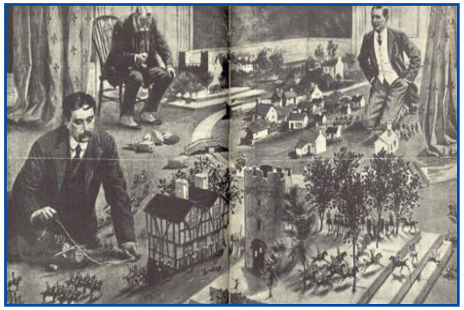
Decision Support

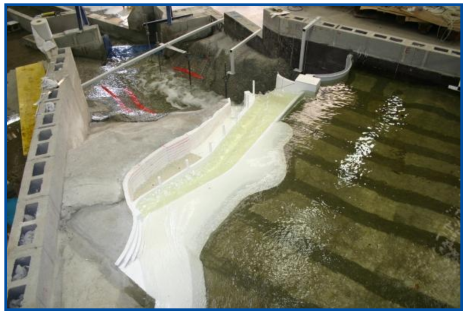
Simulation Origin?

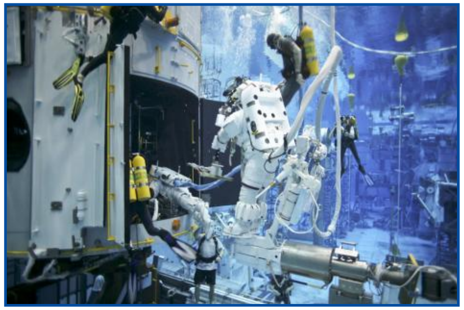
Simulator

Simulator Figurae

Ovid's Metamorphoses, 11, 634, 8 AD



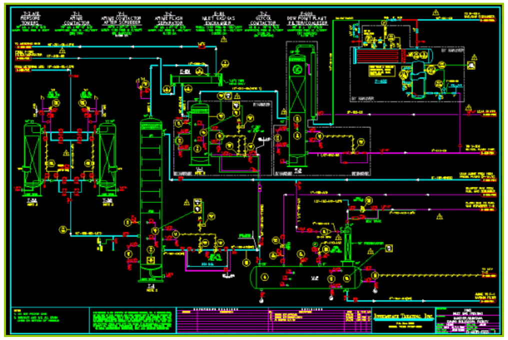




Major Questions

Simulation is able to answer to the following questions:

- **What if ? *(directly)***
- **How To ? *(indirectly)***
- **Why ? *(indirectly)***



Simulation Types

- Interoperable
- Distributed
- Parallel
- Sim. as a Service
- Deterministic
- Stochastic
- Man-in-the-Loop
- HW-in-the-Loop

SIMULATION

- Discrete Event
- Continuous
- Combined
- Hybrid
- Real-Time
- Slow-Time
- Quasi-Real Time
- Fast-Time Reality

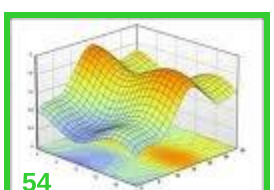
Classification Criteria for M&S in Military Applications

Classification of Simulation for Military Applications:

- **Live Simulation**
  - *A Simulation where real people are operating real systems*

- **Virtual Simulation**
  - A simulation involving real people operating simulated systems (MIL)

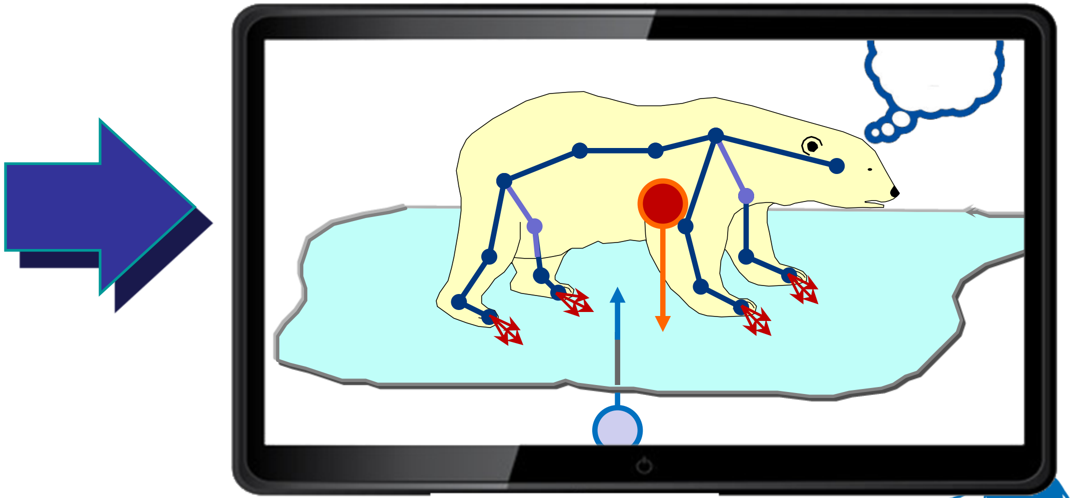
- **Constructive Simulation**
  - A simulation involving Simulated people operating simulated systems



What are M&S, SG & HBM?

Simulation is the reproduction of the reality by using computer models. The Simulation allows to build up a ***Virtual Environment*** and to run dynamic scenarios in order to analyze or optimize the real system. A **Serious Games** allows to involve players in an learning experience through user Engagement .

HBM means **Human Behavior Modeling** and/or Human Behavior Modifiers that are used for simulating the human components



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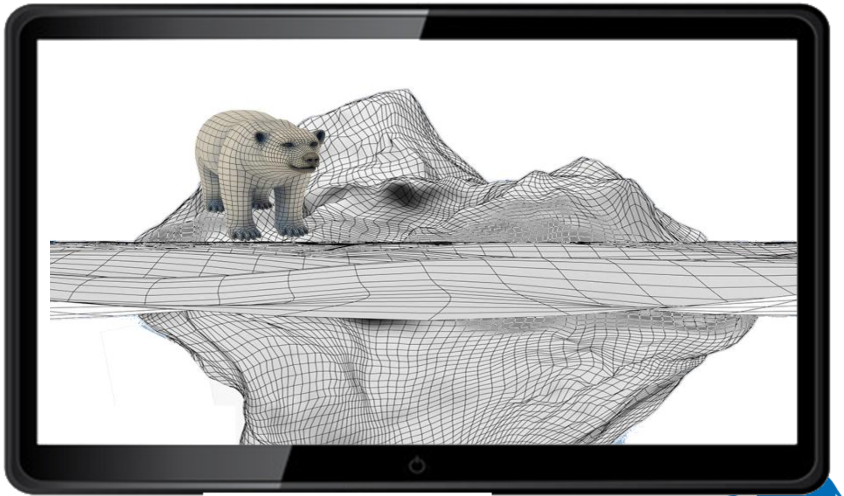

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What are M&S, SG & HBM? Hot Bear Modeling… No, but…

If we move from the technological and physical plan to operation and interaction the modeling, **Behavior** become crucial.

In case of interest into modeling Bear Activities over the ice, it emerge the fundamental need to reproduce social interactions and emotions that affect their behaviors.

In this case the fear of the Bear Cub, the Leadership of the Mother and their collective action should be model.

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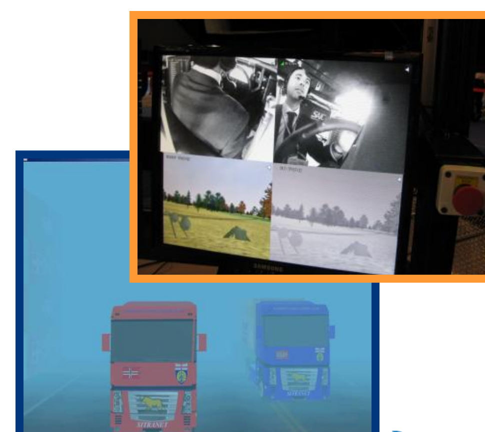
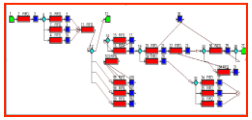
Specific Nature of Simulation Projects

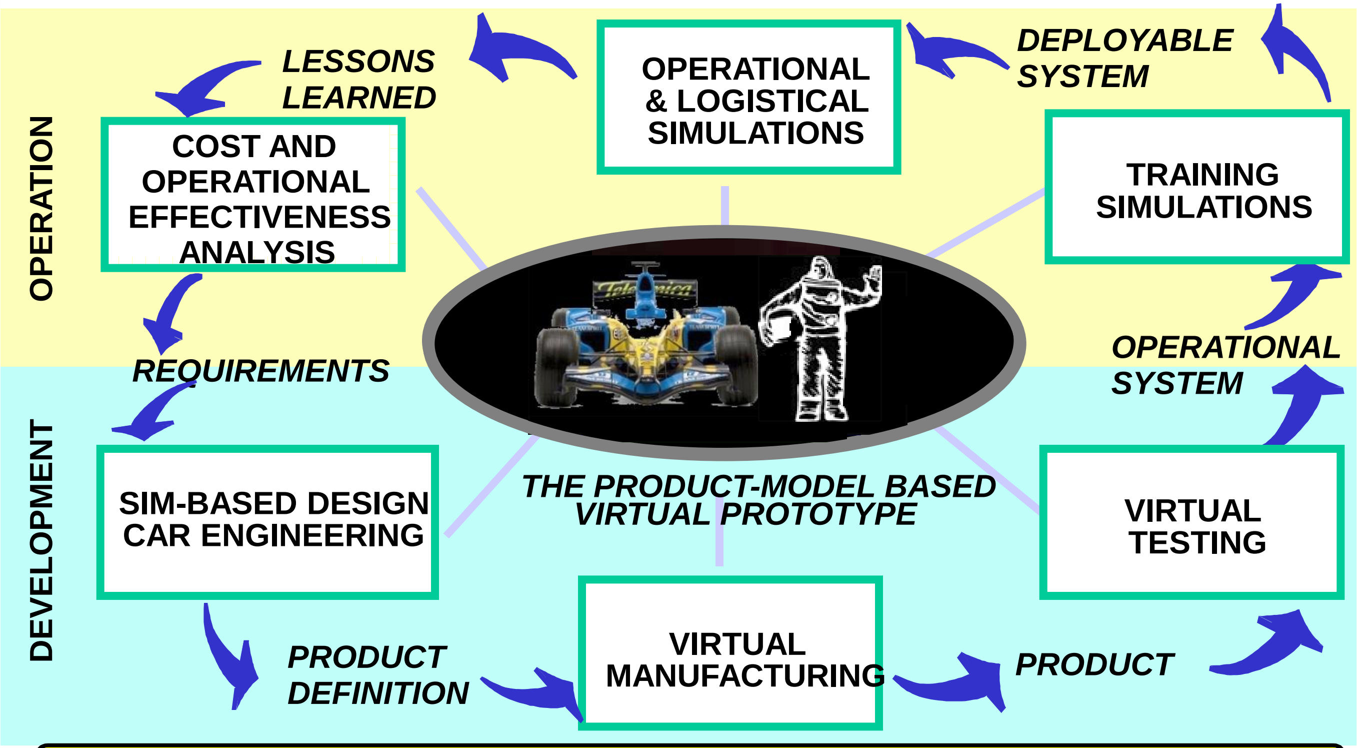
- Simulation Projects are usually a support for Larger Initiatives
- Simulation Projects deadlines and requirements are often related to other on-going Projects
- Simulation Projects are different from SW Projects because needs to face strong VV&A versus real Systems
- Simulation Knowledge needs to be used for Model Development as strong background for Implementation phase



Life Cycle: How many Models?

The Virtual Product Life Cycle

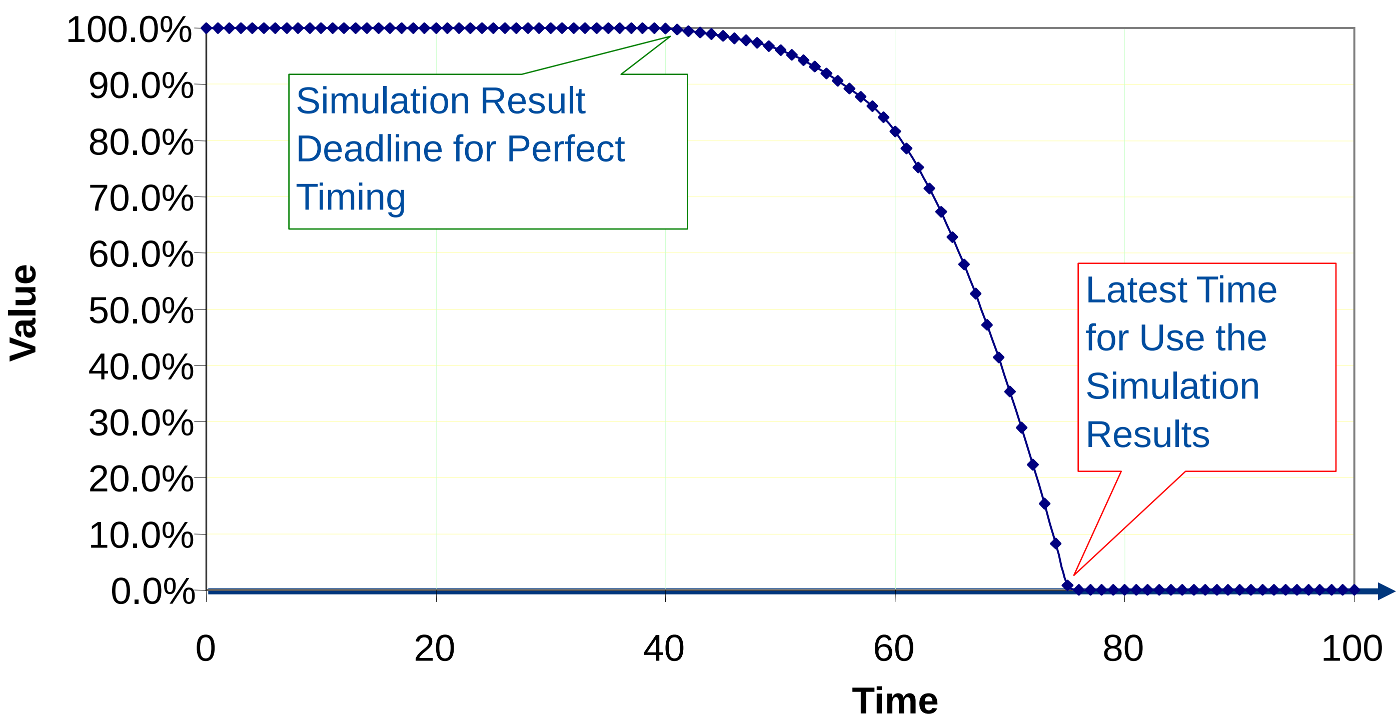




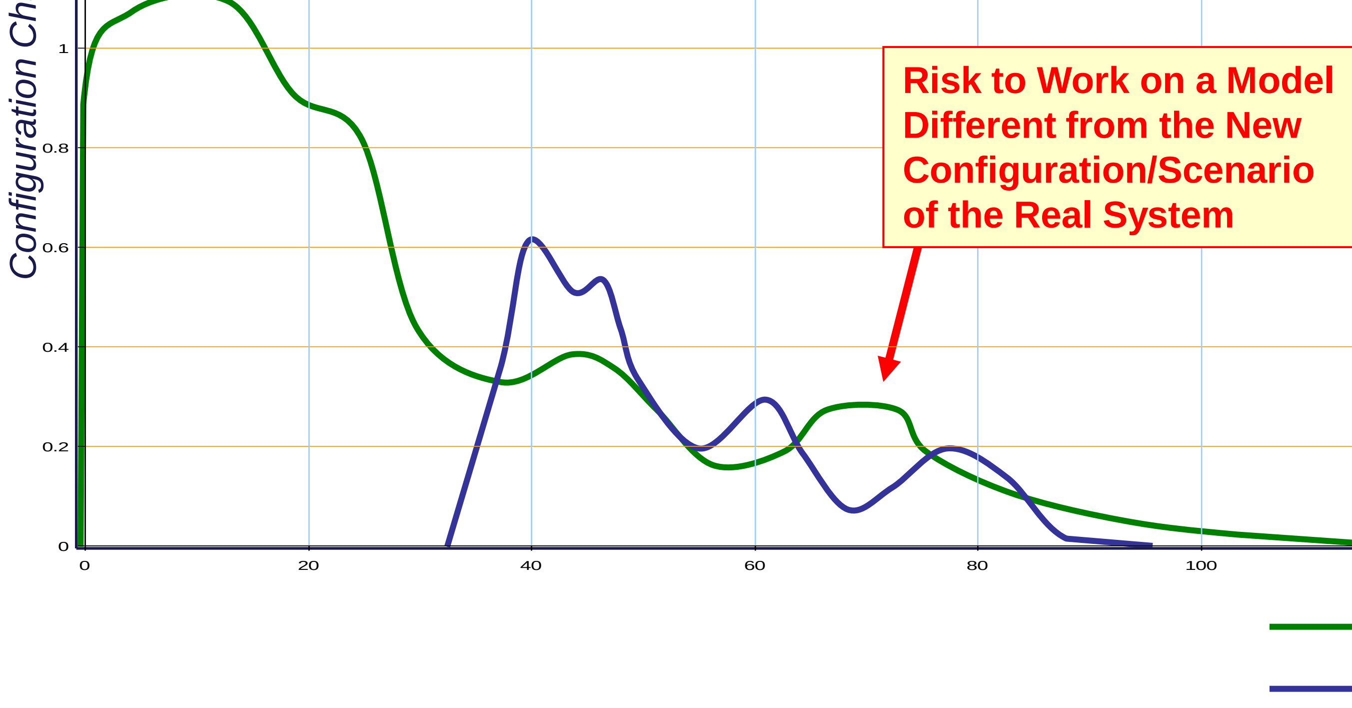
GOAL: CONCEIVE, DESIGN, BUILD, TEST, TRAIN, AND OPERATE A NEW PRODUCT IN A COMPUTER BEFORE CUTTING METAL

Just in Time on Simulator Deliverables

Simulation Result Value

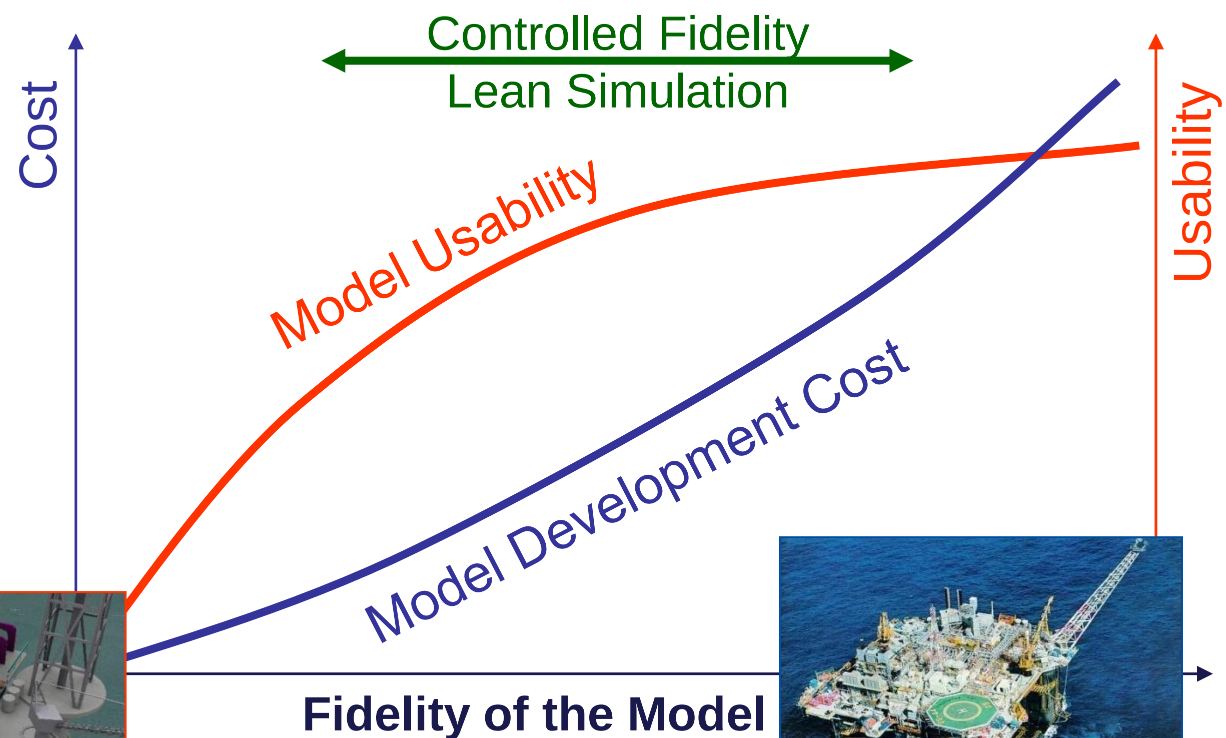


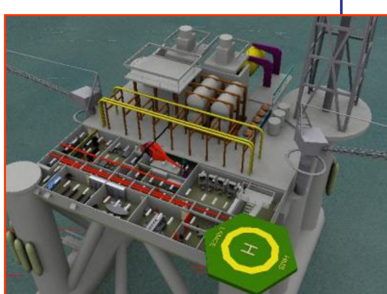
System Configuration Dynamics



Usability vs. Fidelity in M&S

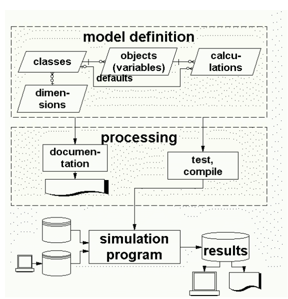
A model Output could be considered in relation to a credibility level. If correctness grows, development cost of the model grows; meanwhile usability of the model increases, but with a non-linear, and usually decreasing rate.

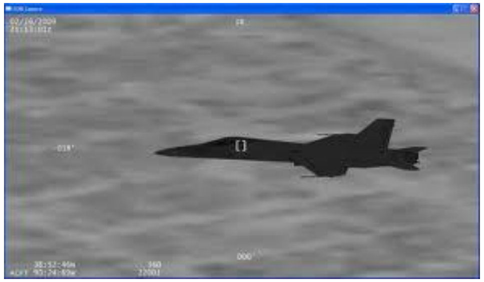




Object Oriented Simulation (OOS)

- An Object Oriented Simulation (OOS) models the behavior of interacting objects over the time.
- Object collections are called classes and can be used to create simulation models and simulation packages.
- The simulations built with these tools possess the benefits of an object-oriented design: encapsulation, inheritance, polymorphism, run-time binding, parameterized typing





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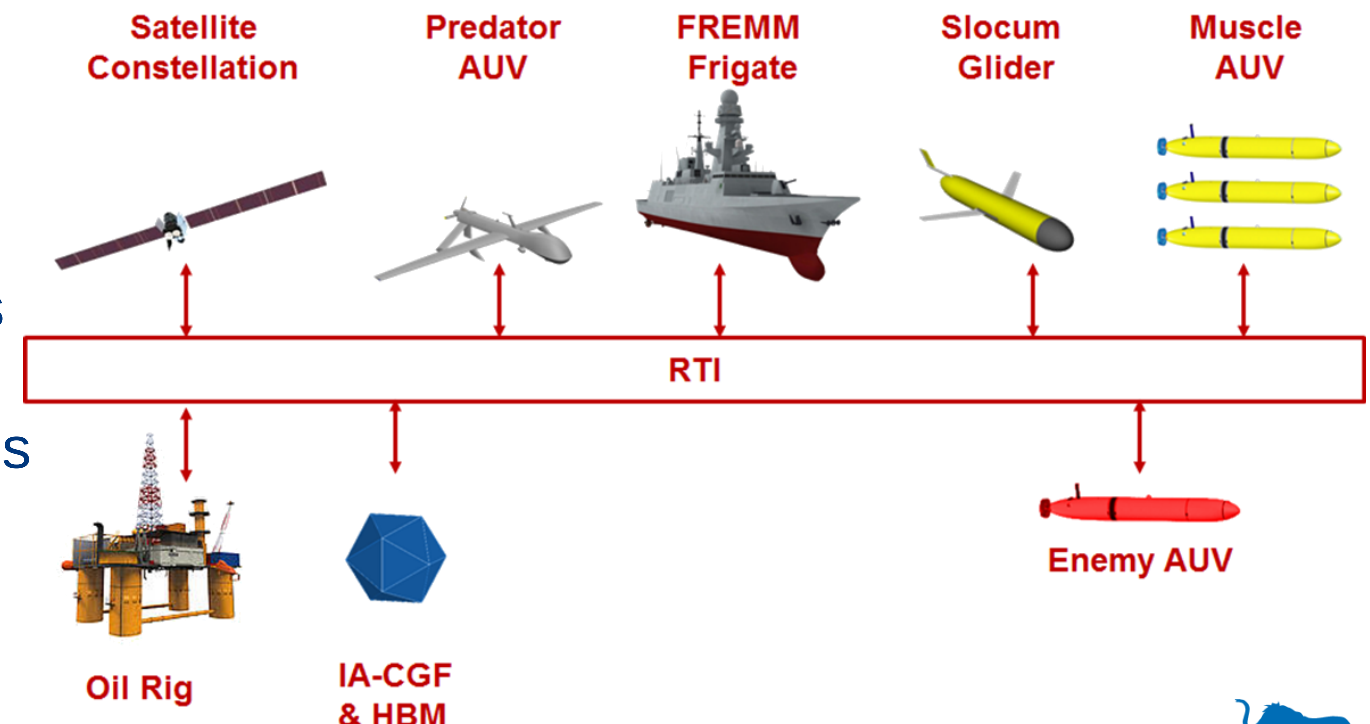
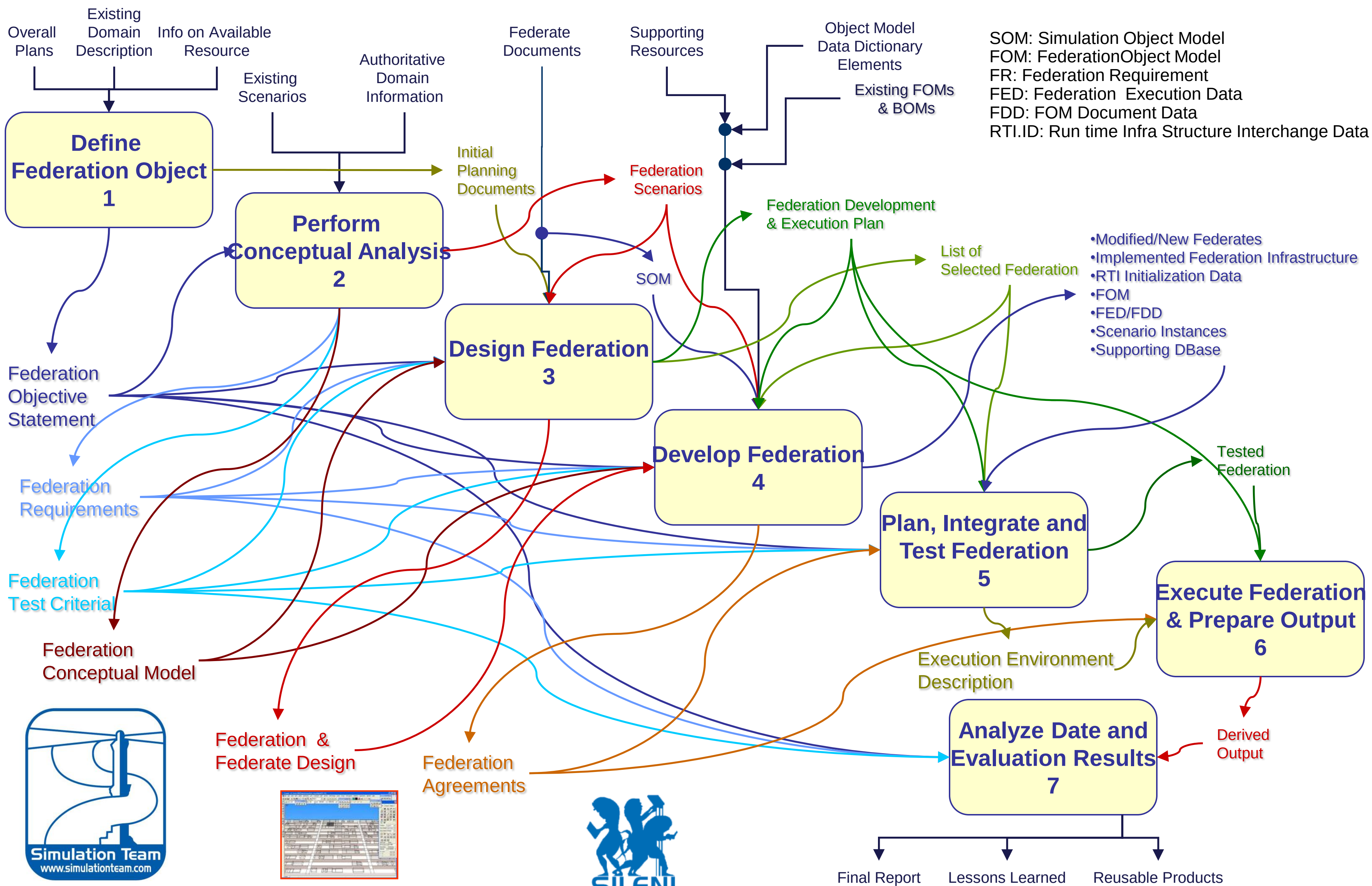
Interoperable Simulation for Extended Maritime framework

A first case for ISSEM Federation is devoted to protect an Off-Shore Platform by using AUV (Autonomous Underwater Vehicles) by adopting High Level Architecture Standard (HLA)

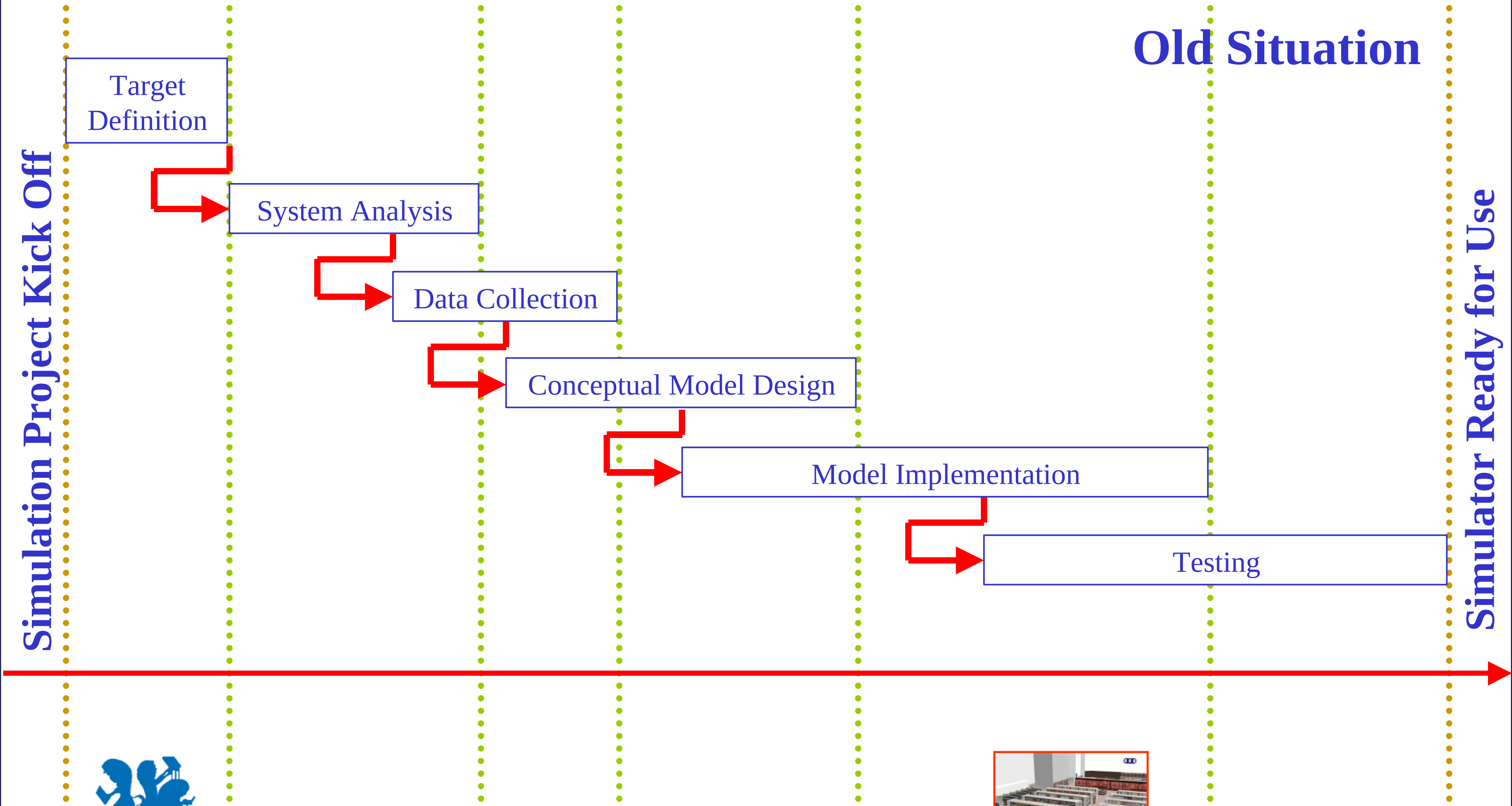
The simulation allows to model different Threats and assets.. Intelligent Agents Computer Generated Forces control the behavior of the entities



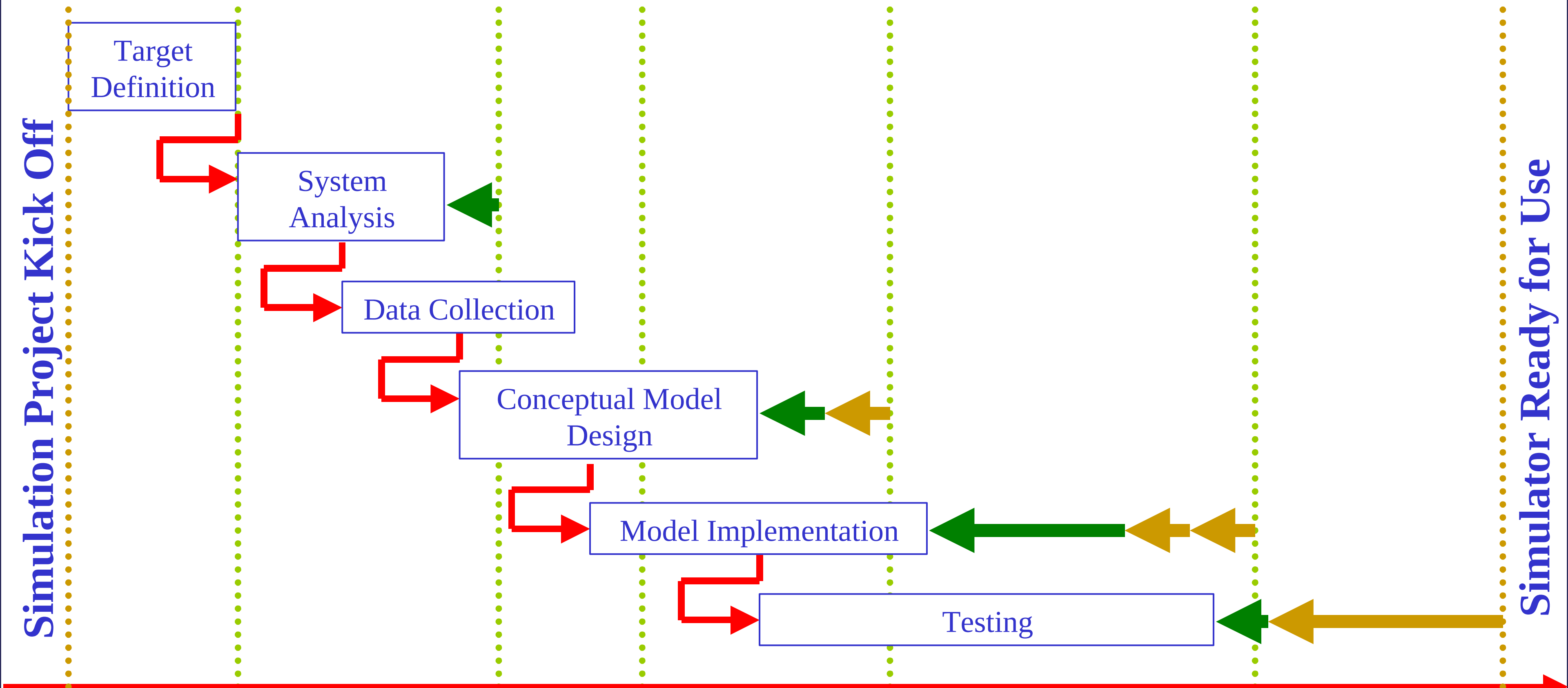
Simulation Projects vs.Fedep



Development Time: Traditional



Development Time: Now



New Situation

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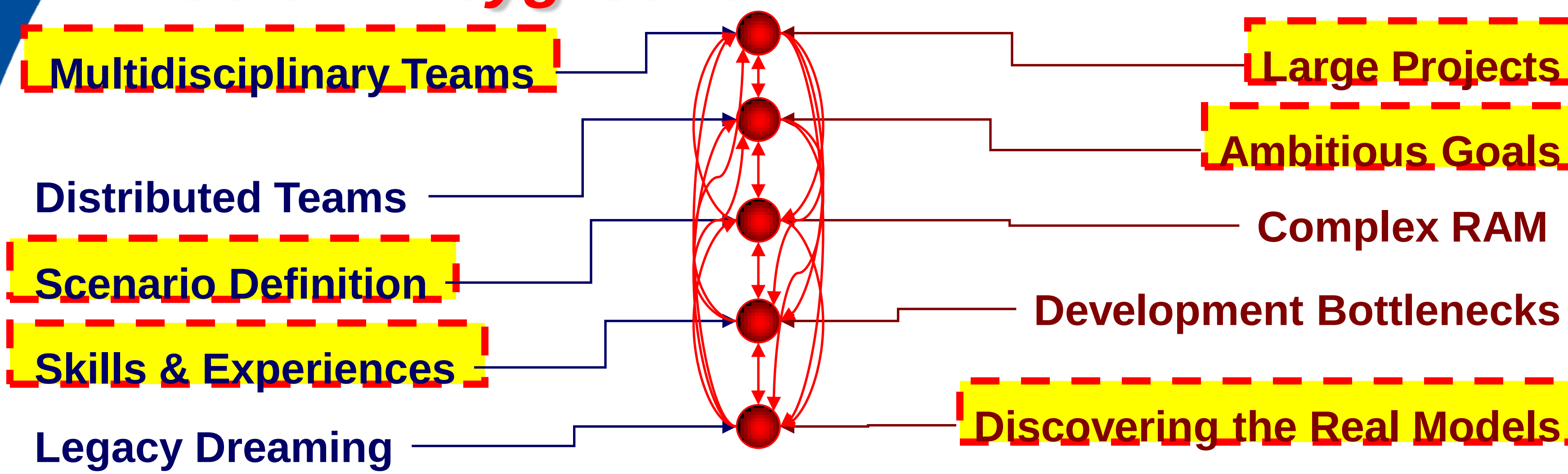
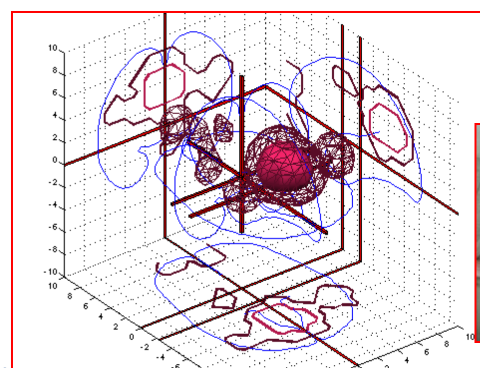
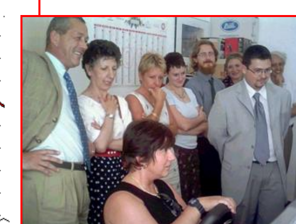
Open Issues in M&S Projects

Problem Playground

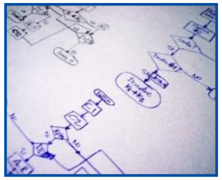






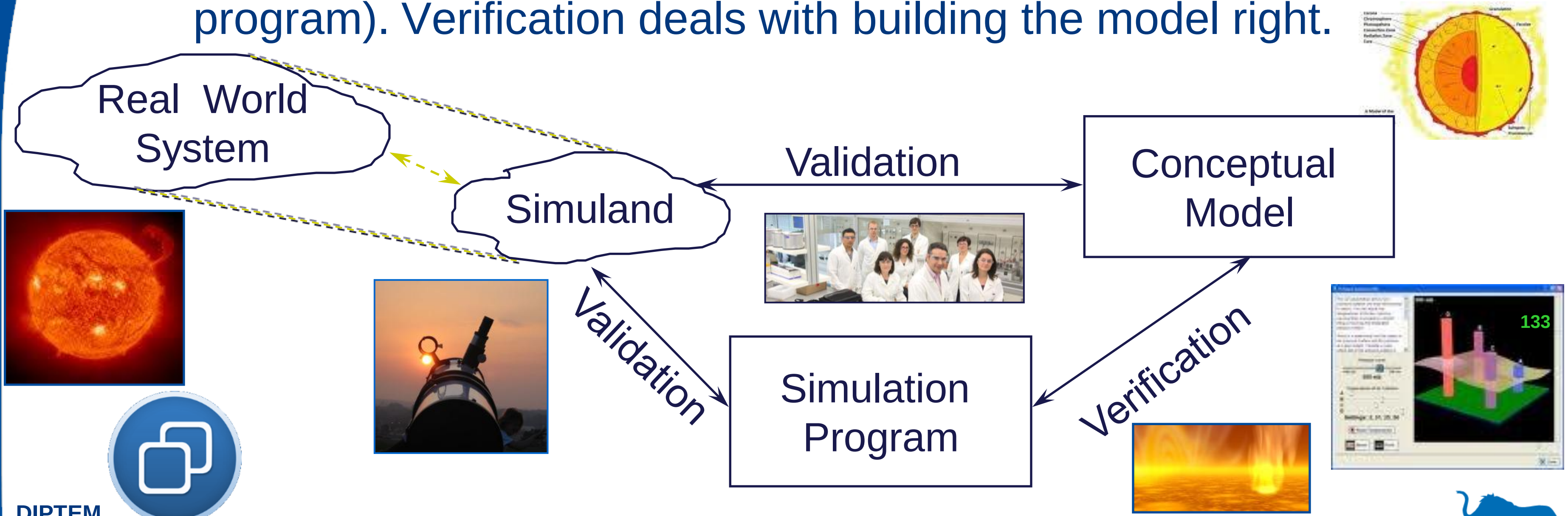
Verification and Validation in M&S… and Accreditation

- One of the most difficult problems facing the simulation analyst is determining whether a simulation model is an accurate representation of the actual system being studied (i.e., whether the model is valid).
- If the simulation model is not valid, then any conclusions derived from it is of virtually no value.
- Validation and verification are two of the most important steps in any simulation project.
- Accreditation is the crucial part of obtaining from Users the confirmation of Simulation Utility



What are Validation and Verification?

- Validation is the process of determining whether the conceptual model is an accurate representation of the actual system being analyzed. Validation deals with building the right model.
- Verification is the process of determining whether a simulation computer program works as intended (i.e., debugging the computer program). Verification deals with building the model right.



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VV&A in M&S

Verification and Validation is critical in M&S and require to be followed all along
Simulation Development Process from Objective Definition to integration tests, experimentation and data analysis

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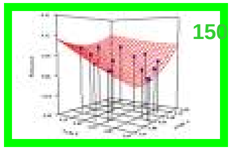
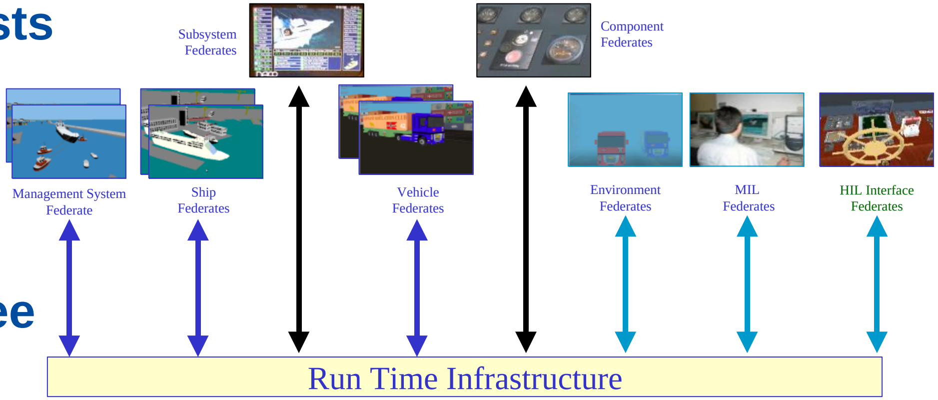
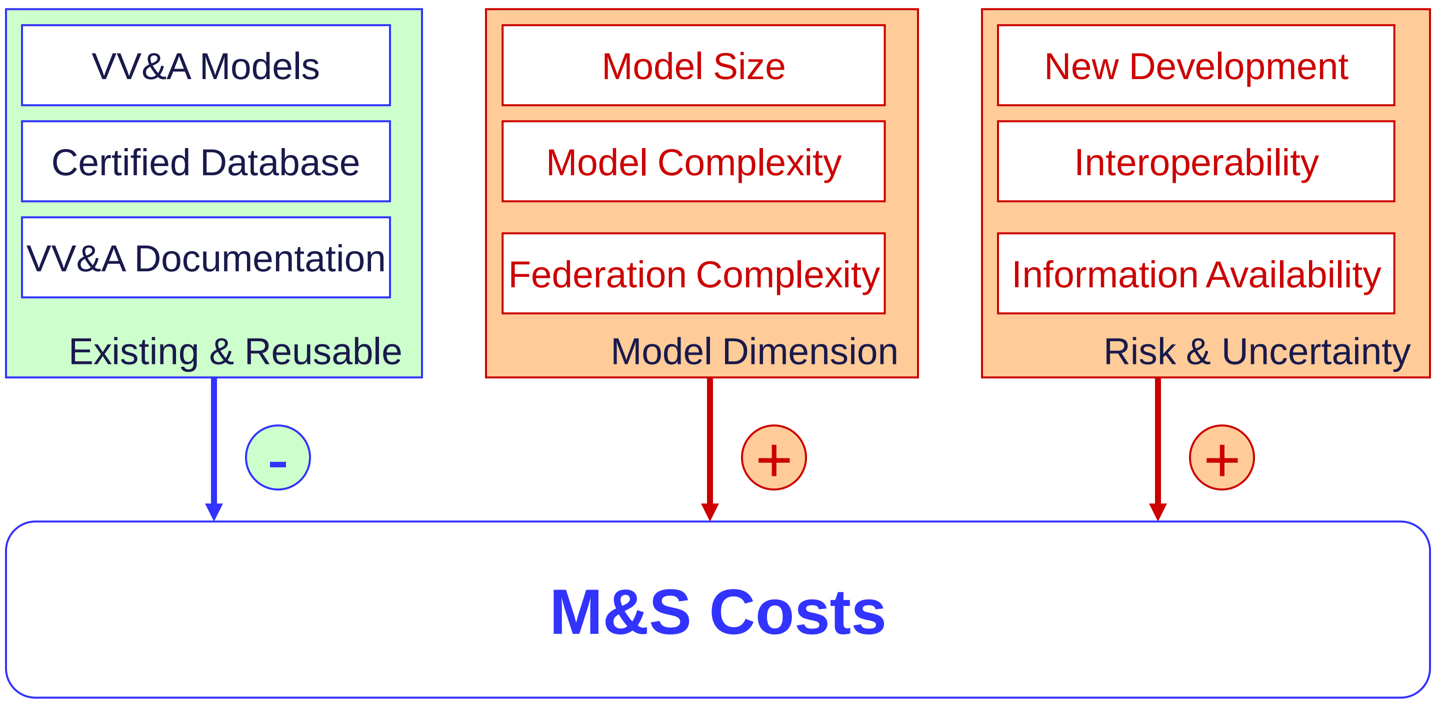
V&V for Complex Systems



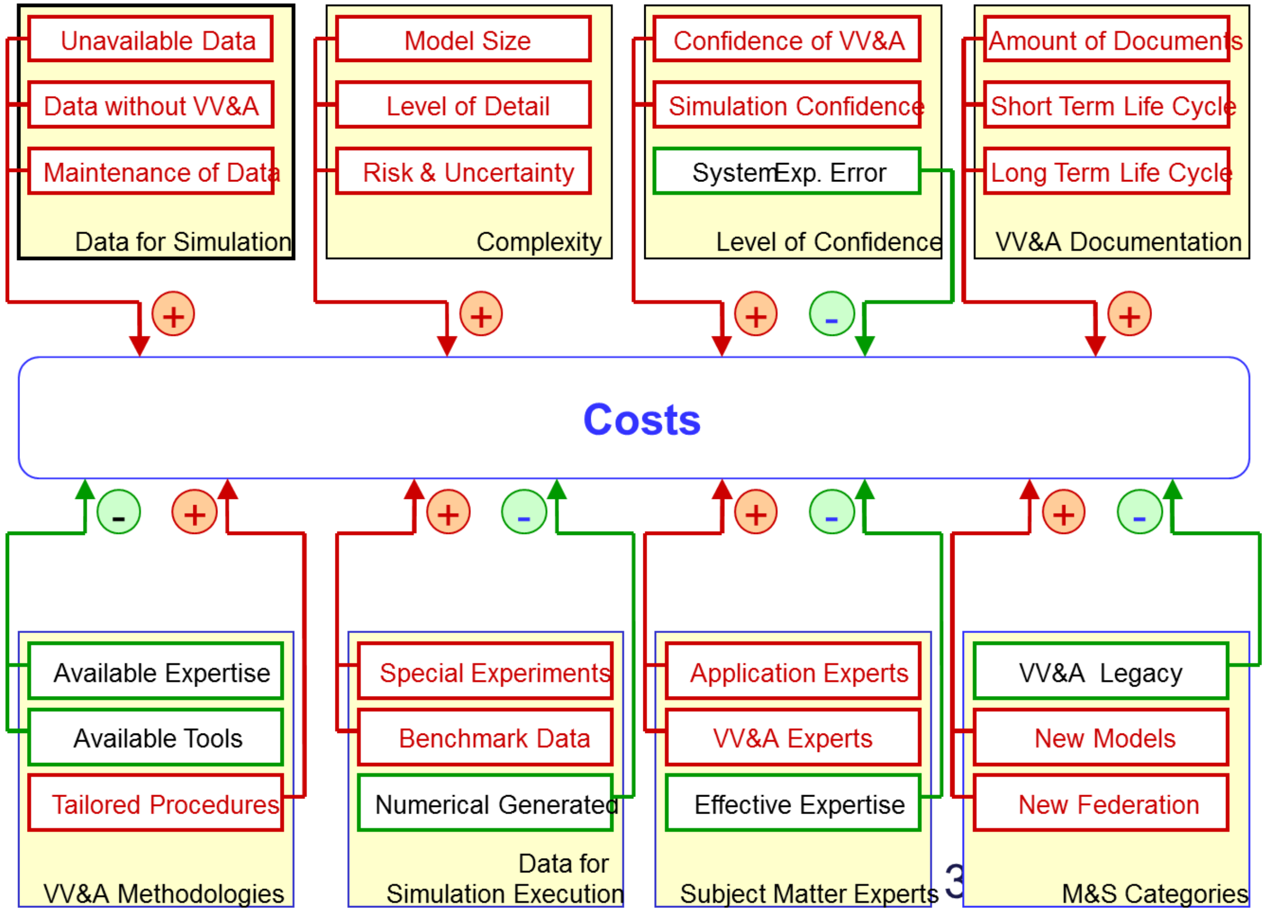
- It is critical to understand, that due to the high not linear nature of most of simulation models it is not possible to apply superposition principle.
- Due to this reason it even more evident that even if all the sub models, objects or federates are able to pass VV&T (Validation, Verification and Testing) this fact don't allows to conclude that the overall simulator is validated and verified
- It is necessary to conduct tests and experiments and to complete specific VV&A (Verification Validation and Accreditation) even on the whole Federation to guarantee this results



General Cost Drivers



Cost Driver Overview



Terminology and Definitions (1)

- System and Model
- State Variables
- Entities
- Resources
- Attributes
- Activities and Delays
- State of a system
- Simulation Model

Terminology and Definitions (2)

- A System is a collection of mutually interacting objects (entities) that are affected by outside forces.
- A Model is a representation of an actual system. A model must be complex enough to achieve the objectives for which the model has been developed.
- The system State Variables are the collection of all information needed to define what is happening within a system to a sufficient level at a given point in time
- An Entity represents an object that requires explicit definition; dynamic entities and static entities (Resources)







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Terminology and Definitions (3)

- The descriptors of an entity are called its Attributes.
- An Activity is a period of time whose duration may be known prior to commencement of the activities (duration can be constant, random value, result of an equation, etc.)
- A Delay is an indefinite duration caused by some combination of systems conditions.
- The state of a system is defined in terms of the numeric values assigned to the attributes of the entities.
- The Simulation Model is the representation of the dynamic behavior of the system by moving it from state to state in accordance with well-defined operating rules (Pritsker, 1986).

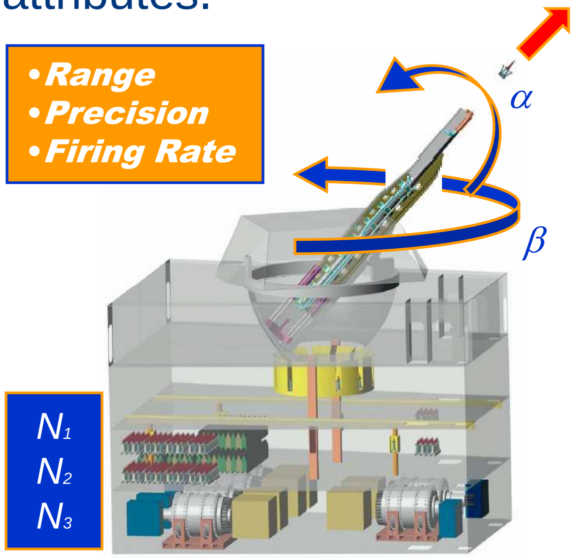






Variable Vs. Invariable Attributes

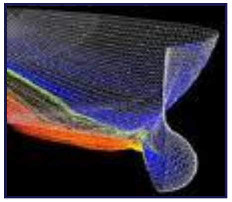
- **Attributes** are descriptors of entities. The value of an attribute can vary over time (variable attribute) or not (invariable attribute). Normally, we are more concerned with modeling the variable attributes.
- Examples of variable attributes are:
  1. The number of assemblies in a queue.
  2. The status of a machine (which leads to the determination of utilization).
  3. The finish time of an assembly.
  4. Whether or not the doctor is busy.

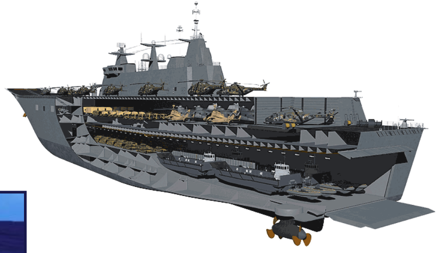


- Examples of invariable attributes are:
  1. The routing for a part.
  2. The sequence of procedures to be performed on a hospital patient with a particular set of symptoms.

Purposes of Simulation Modeling

- Simulations allow inferences to be drawn about systems without building them or disturbing them.





- Simulation can be used for
  - design
  - operational analysis
  - performance assessment
  - education & training

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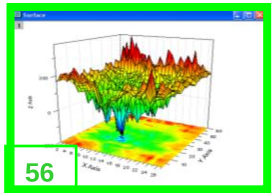


Deterministic and Stochastic Simulation

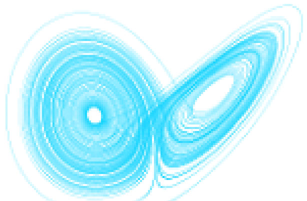
Classification on the base of the Model Nature:

Deterministic Simulation

A Simulation based on models where statistical distribution are not in use, including just deterministic behaviors

Stochastic Simulation

A Simulation reproducing a system with variables regulated by not known statistical phenomena by implementing pseudorandom variables



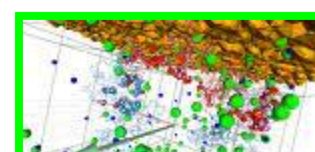
Time Speed in Different Simulation

Classification on the base of Simulation Speeds:

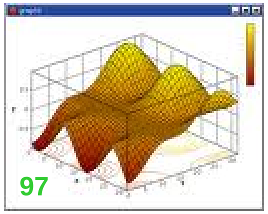
- **Real Time Simulation**
  A Simulation where time evolves at same speed of a real clock

- **Fast Time Simulation**
  A Simulation able to evolves faster than the real system under analysis

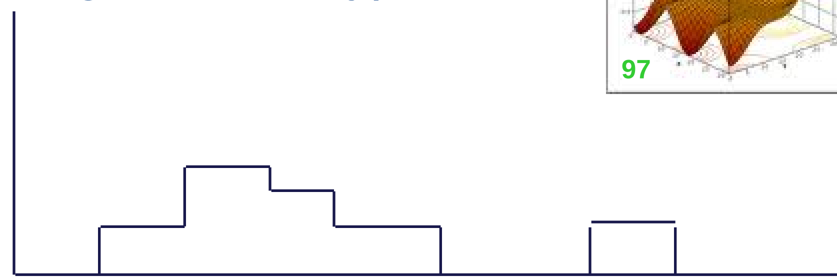
- **Slow Time Simulation**
  A Simulation unable to evolve at same speed of real system under analysis

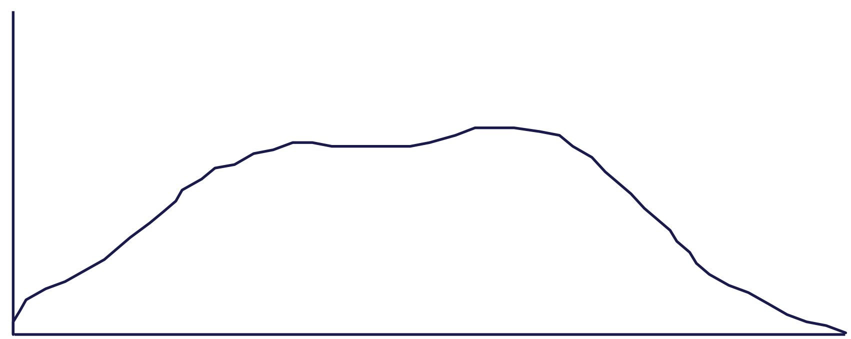


Classification Criteria for M&S in Military Applications



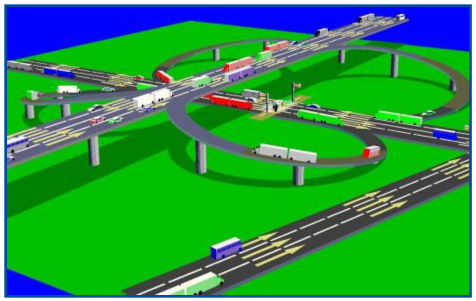
Discrete (dependent variables change discretely)

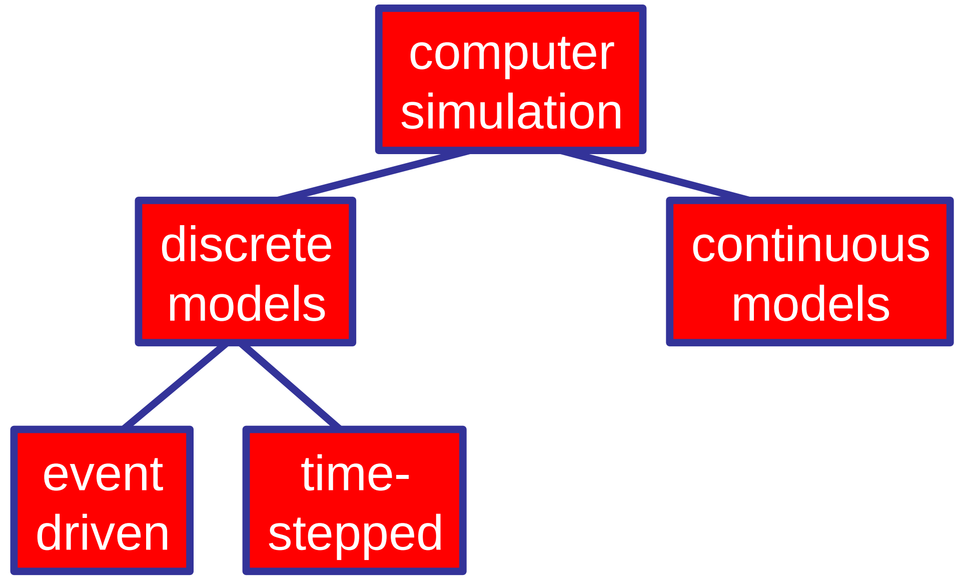




Continuous (dependent variables change continuously)

Simulation Taxonomy





Continuous time simulation

- State changes occur continuously across time
- Typically, behavior described by differential equations

Discrete time simulation

- State changes only occur at discrete time instants
- Time stepped: time advances by fixed time increments
- Event stepped: time advances occur with irregular increments

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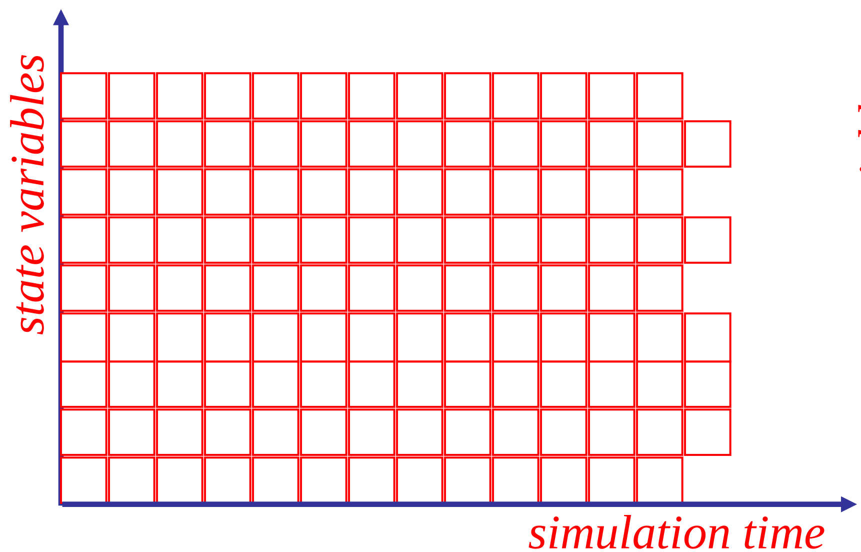
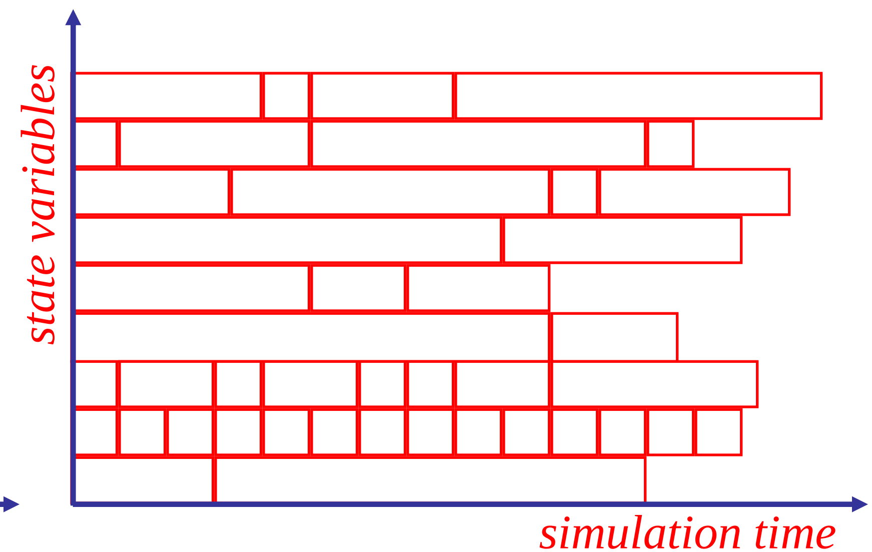
Time Stepped vs. Event Stepped

Goal: compute state of system over simulation time



Time Stepped Execution



Event Driven Execution

Time Stepped Execution (Paced)

While (simulation not completed)

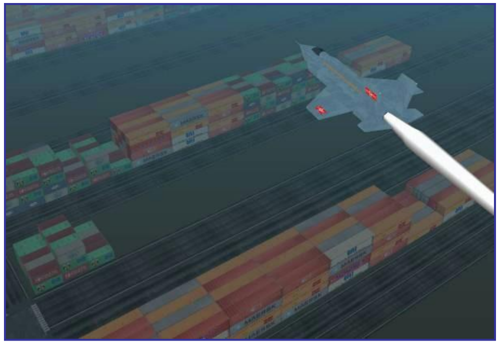
{

Wait Until (W2S(wallclock time) ≥ current simulation time)

Compute state of simulation at end of this time step

Advance simulation time to next time step

}



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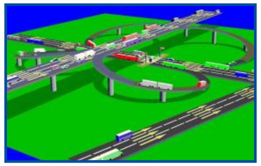
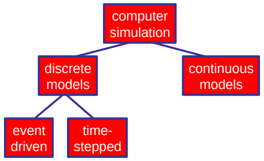
Combined Discrete-Continuous Models (Hybrid)

The behavior of the model is simulated by computing the values of the state variables at small time steps and by computing the values of attributes and global variables at event times.

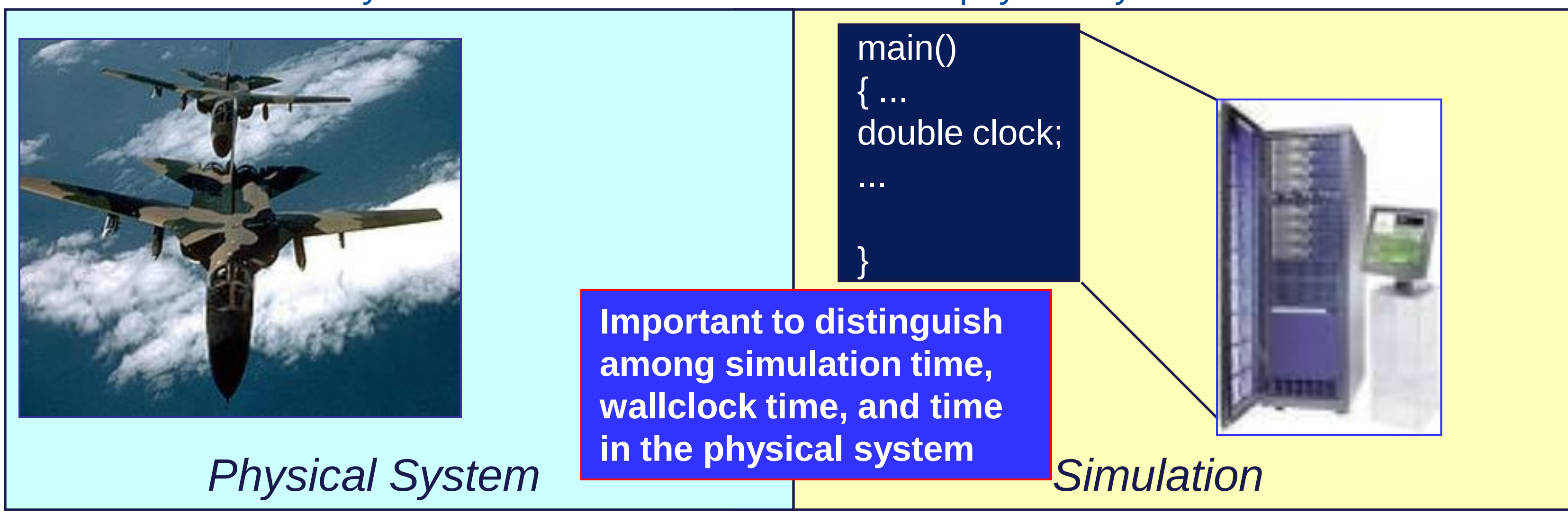
- Discrete change made to a continuous variable (i.e. vehicle efficiency after maintenance operations)
- A threshold value for a continuous variable may induce a new event (i.e. starting of vehicle maintenance operations after a certain time)
- Change in the analytical relationships between continuous variables at discrete time instants (i.e. change in the equation governing the acceleration of a vehicle when human being is in the vicinity of the vehicle





Different Time Concepts

- *physical system*: the actual or imagined system being modeled
- *simulation*: a system that emulates the behavior of a physical system



physical time: time in the physical system

- Noon, December 31, 2010 to noon January 1, 2011

simulation time: representation of physical time within the simulation

- floating point values in interval [0.0, 24.0]

wallclock time: time during the execution of the simulation, usually output from a hardware clock

- 9:00 to 9:15 AM on October 10, 2010

Simulation Time Concept

Simulation time is defined as a totally ordered set of values where each value represents an instant of time in the physical system being modeled.

For any two values of simulation time T_1 representing instant P_1, and T_2 representing P_2:

- Correct ordering of time instants
  - If $T_1 < T_2$, then P_1 occurs before P_2
  - 9.0 represents 9 PM, 10.5 represents 10:30 PM
- Correct representation of time durations
  - $T_2 - T_1 = k (P_2 - P_1)$ for some constant k
  - 1.0 in simulation time represents 1 hour of physical time

Paced vs. Unpaced Execution

Modes of execution

- ***As-fast-as-possible*** execution (unpaced): no fixed relationship necessarily exists between advances in simulation time and advances in wallclock time
- ***Real-time*** execution (paced): each advance in simulation time is paced to occur in synchrony with an equivalent advance in wallclock time
- ***Scaled real-time*** execution (paced): each advance in simulation time is paced to occur in synchrony with S * an equivalent advance in wallclock time (e.g., 2x wallclock time)

Simulation Time = $W2S(W) = T_0 + S * (W - W_0)$

W = wallclock time; S = scale factor

W_0 (T_0) = wallclock (simulation) time at start of simulation

(assume simulation and wallclock time use same time units)

Paced execution (e.g., immersive virtual environments) vs. unpaced execution (e.g., simulations to analyze systems)

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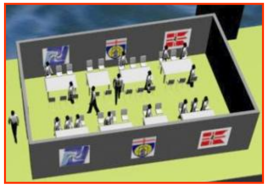
Simulation and Integration with Other Advanced Techniques

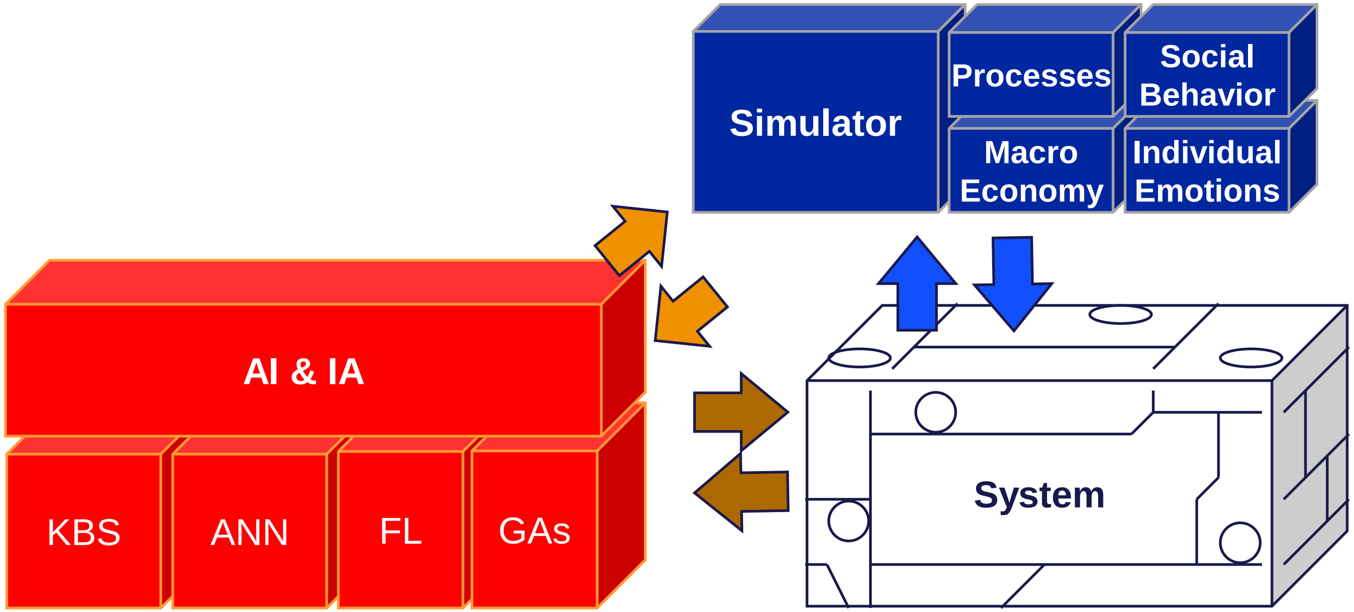
Artificial Intelligence (AI) & Intelligent Agents (IA)	Advanced Techniques
Knowledge Based Systems	**Simulation**
Artificial Neural Networks	**Chaos Theory**
Fuzzy Logic	**Metamodels & DOE**
Genetic Algorithms	**Optimization Techniques**

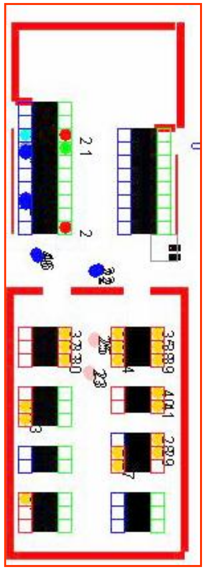


This integration is sometime reported in literature as Hybrid Simulation

Integration as Additional Challenge

The square stone to success in the application of new methodologies is the integration of different techniques and on interoperability among multidisciplinary models





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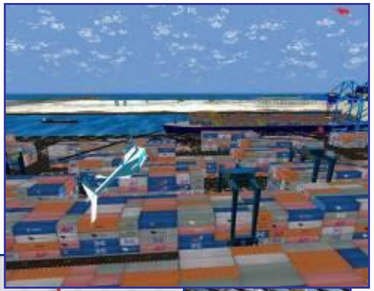

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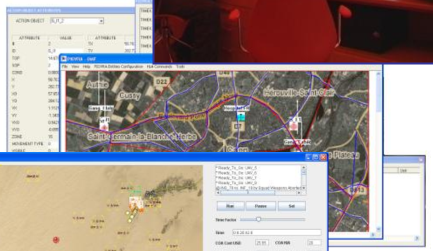

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