# Demystifying the Worlds of M&S and MBSE

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# The Two Worlds

World of M&S

World of Engineering a System (MBSE)

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# Confusion abounds when the two worlds overlap

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# So one world at a time – Modeling and Simulation first

**World of M&S**

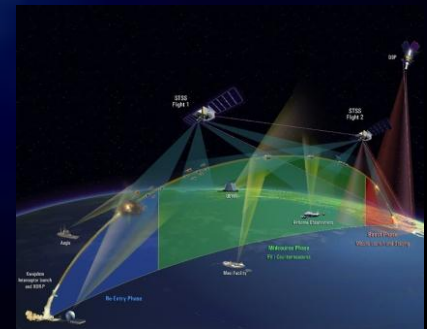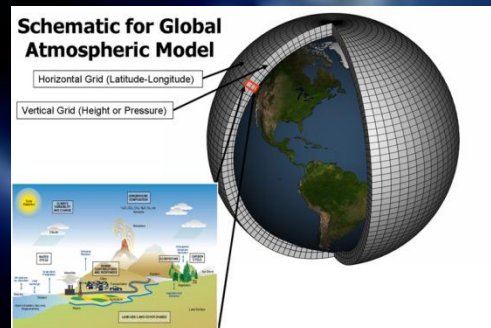**World of Engineering a System (MBSE)**

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# Modeling and Simulation (M&S) Background

★ **History of Modeling and Simulation**

- **M&S began with war-gaming – how to outwit and defeat an opponent**
- **Roman army conducted live training to hone their military skills using two opposing teams**
  - A "red" (offensive) team
  - A "blue" (defensive) team
- **1997 chess match between Garry Kasparov and IBM's Deep Blue**
  - Computing technology being infused into simulations
- **Increased computing capabilities have enabled the study of complex activities including**
  - Human Behavior modeling
  - Climate modeling
  - Missile Defense modeling

Schematic for Global Atmospheric Model

Horizontal Grid (Latitude-Longitude)

Vertical Grid (Height or Pressure)

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# So What is Modeling and Simulation?

★ **Two primary applications of simulations**

– **Used to learn things about the real world without actually manipulating it**

- Simulating complex activities (e.g. landing a man on the moon)

- Simulating complex systems (e.g. hurricanes)

- Simulating impractical events (e.g. launching a nuke to test missile defense)

– **Used to aid in the building of a new system / capability**

- Cost Models

- Trade Study Models

- Architecture Models

- Performance Models

- Testing Models

- Training Models



MISSION OVERVIEW

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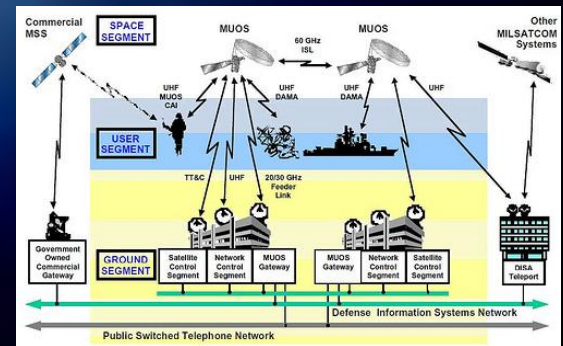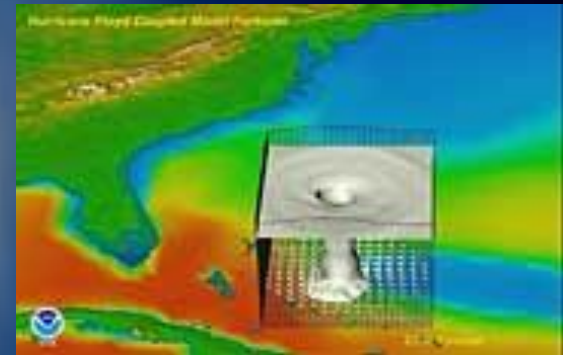
# Here are the key terms… in lay language

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# M&S Lexicon

## Model

- A *M*odel is a physical, mathematical, or otherwise logical abstract representation of a system, entity, phenomenon, or process with its own assumptions, limitations and approximations. (DoD 5000.59-M, January 1998)

## Simulator

- A device, computer program, or system that exercises the behaviors of the models in a prescribed order.

## Simulation

- Simulation is the act of using the simulator, with the models, to study real-world entities, processes or situations in controlled scenarios.

## Modeling and 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. (DoD 5000.59-M, January 1998)

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# M&S Evolution
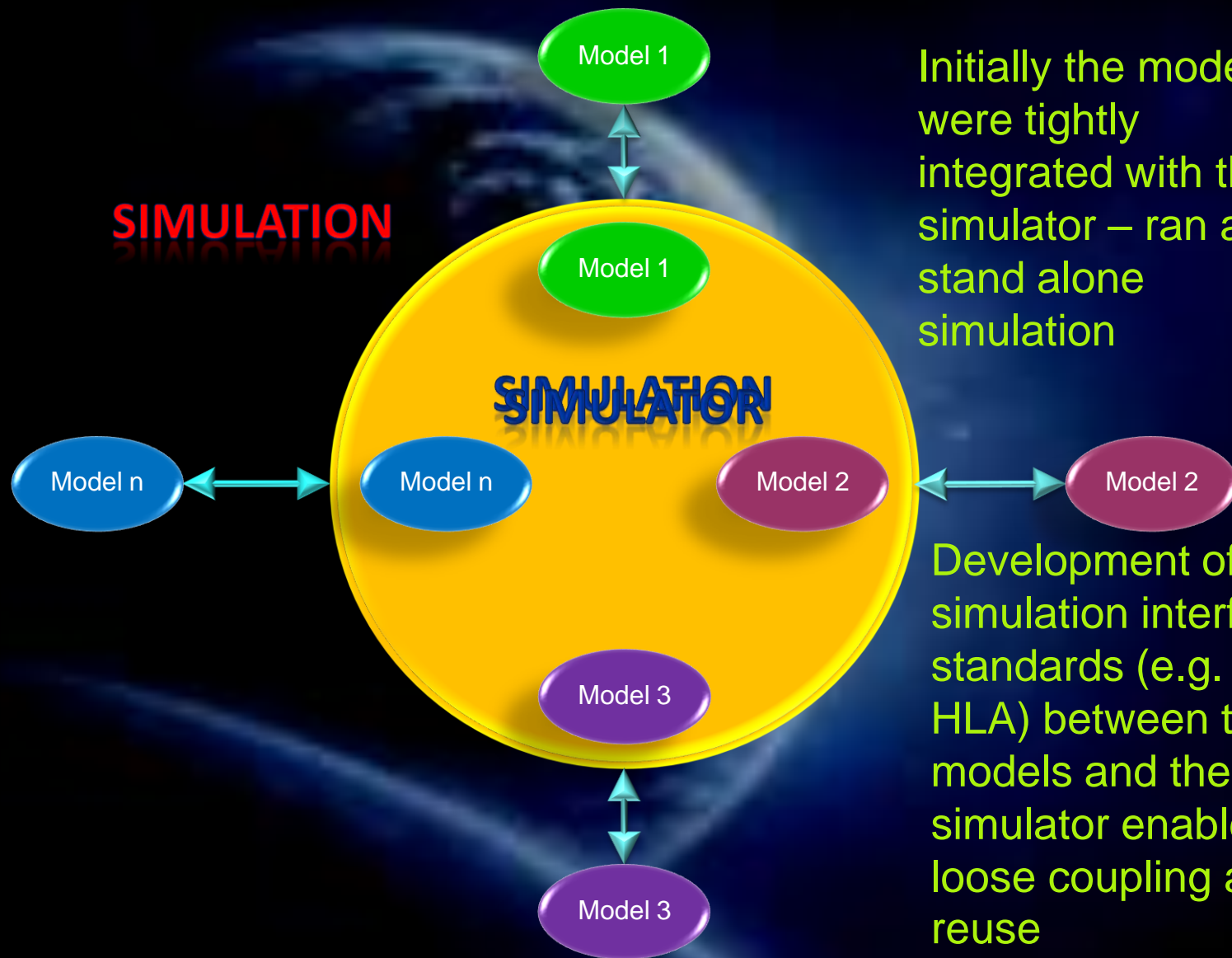


Initially the models were tightly integrated with the simulator – ran as a stand alone simulation

Development of simulation interface standards (e.g. DIS, HLA) between the models and the simulator enabled loose coupling and reuse

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# Now let's explore the other world –
# The World of MBSE

**World of M&S**

**World of Engineering a System (MBSE)**

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# So What is MBSE?

★ **Essentially, Model Based Systems Engineering (MBSE) is all about creating and evolving real world solutions using a model of the system – the "system model"**
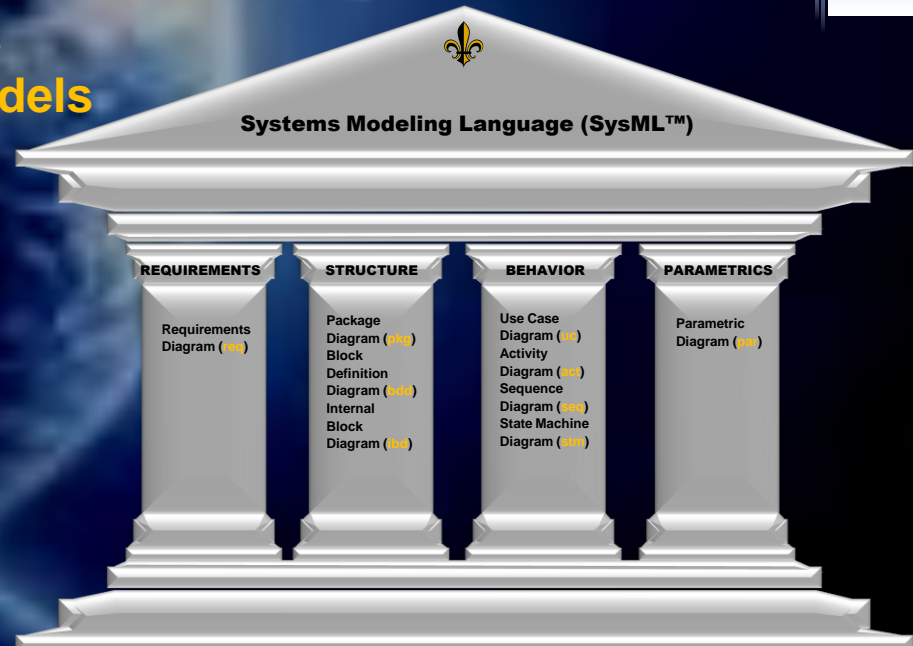
– **System design artifacts transitioned from document-based to model-based**

– Single source for the design "truth"

– **Formalizes the practice of systems engineering through the use of models (requirements, structure, behavior, parametrics)**

– **Results in quality/productivity improvements & lower risk**

– Increased rigor and precision

– Improved communications among system/project stakeholders

– Management of complexity

**Systems Modeling Language (SysML™)**

| REQUIREMENTS | STRUCTURE | BEHAVIOR | PARAMETRICS |
|---|---|---|---|
| Requirements Diagram (req) | Package Diagram (pkg) Block Definition Diagram (bdd) Internal Block Diagram (ibd) | Use Case Diagram (uc) Activity Diagram (act) Sequence Diagram (seq) State Machine Diagram (stm) | Parametric Diagram (par) |

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# System Modeling

★ **History of using models in the development of systems**

– Simple or single use models (e.g. architecture models)

– Executable system behavior models (e.g. state machines)

– Executable system models (system "model" transitions to simulation "Model")

★ **Model Based Systems Engineering (MBSE)**

– Systems engineering activities conducted using models of the system being built (system models)

– International Council on Systems Engineering (INCOSE) sponsored MBSE initiative in 2007 that described long term goals

– INCOSE collaborated with the Object Management Group to develop the System Modeling Language (SysML™)

– Provides a common system modeling language – essential for efficient communications

★ **Model Based Systems Development (MBSD) – Extending MBSE**

– Engineering activities conducted using models of the system being built throughout the entire system development (e.g. IT&E)

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# Here are the key terms…

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# Model Based Lexicon

## *m*odel

- A *m*odel in MBSE/D is an electronic representation that describes the thing you are building (making real) including its attributes, behaviors and relationships.

## Model Based Systems Engineering (MBSE)

- Model-based systems engineering (MBSE) is the formalized application of modeling to support system requirements, design, analysis, verification, and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases.  (INCOSE, Systems Engineering Vision 2020, Version 2.03, TP-2004-004-02, September 2007)

## Model Based Systems Development (MBSD)

- An engineering approach that promotes the use of models to develop, integrate and monitor systems across disciplines, environments and scenarios.

## Model Based Engineering

- Model-Based Engineering (MBE) as an approach to engineering that uses models as an integral part of the technical baseline that includes the requirements, analysis, design, implementation, and verification of a capability, system, and/or product throughout the acquisition life cycle. (NDIA – Final Report of the MBE Subcommittee)

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# Intersection of the Worlds



**World of M&S**

**World of Engineering a System (MBSE)**

★ **The intersection includes**

– **Analysis of Alternatives (AoA)**

– **Analysis models (e.g. performance, cost, etc.)**

– **Executable system models**

# The World of Complex Solutions

★ "Historically, systems engineering has been successful in bringing order to the development of systems as they have become increasingly complicated. But there is a big difference between complicated and complex," he says. "Complicated is decomposable, which is what systems engineering is based on. Complex systems are no longer strictly decomposable, and systems engineering has to adapt." Aviation Week Interview with Jeff Wilcox: Is It Time To Revamp Systems Engineering ? (http://www.aviationweek.com/Article.aspx?id=/article-xml/AW_11_01_2010_p72-265541.xml)

★ "MBSE extends to domains beyond engineering to support complex predictive and affects-based modeling that includes integration of engineering models with scientific and phenomenology models, social, economic, political models, and human behavioral models." Taken from INCOSE 2007 Symposium briefing (http://www.incose.org/enchantment/docs/07docs/07jul_4mbseroadmap.pdf)

# Model Evolution

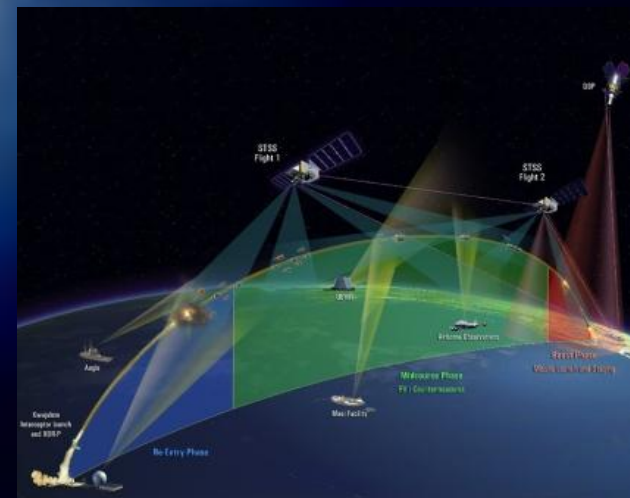★ **The evolution of a 'model' begins in the MBSE world**

- Models and simulations are used to understand and refine the solution to the defined problem (system _m_odel)

★ **The matured system model transitions into an analytical _M_odel in the World of M&S**

- Allows the modeled system to be experimented with in the realm of other solutions
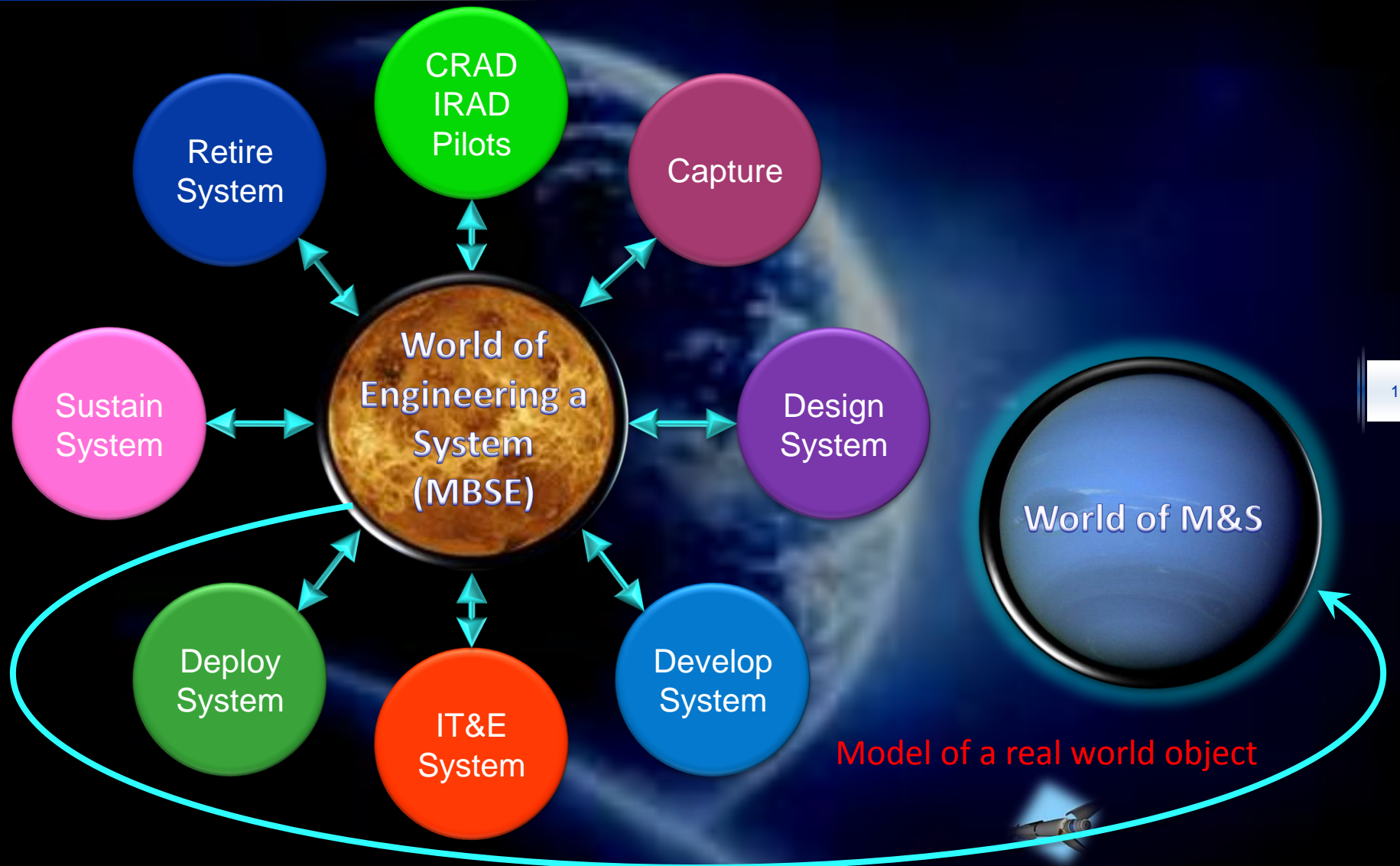  - Enables simulations of Systems-of-Systems
  - Become repository assets

★ **Evolution Example**

- _m_odel a missile interceptor to counter a threat (use _M_odels of the threat during development)
- Develop the interceptor
- Augment the _m_odel with empirical data to convert it to a _M_odel
- Use the missile interceptor _M_odel in performing war-gaming exercises

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# Model Evolution – The Transition

CRAD IRAD Pilots

Retire System

Capture

Sustain System

World of Engineering a System (MBSE)

Design System

World of M&S

Deploy System

IT&E System

Develop System

Model of a real world object

Both worlds are needed for the effective, efficient development of a complex system

# For Those Who Want to Dig Deeper

★ **Modeling & Simulation Committee**

http://www.ndia.org/Divisions/Divisions/SystemsEngineering/Pages/Modeling_and_Simulation_Committee.aspx

★ **Simulation Interoperability Standards Organization (SISO):**
http://sisostds.org/Home.aspx

★ **The Object Management Group (OMG) SysML website is at:**

http://www.omgsysml.org/

★ **An OMG SysML Tutorial is located at:**

http://www.omgsysml.org/INCOSE-OMGSysML-Tutorial-Final-090901.pdf

★ **INCOSE SE Vision 2020 is located at:**

http://www.incose.org/ProductsPubs/products/sevision2020.aspx

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# Questions?

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