# M&S 101

## Introduction to Modeling and Simulation

# Sponsored by

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*in*
*June 99*

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# Questions that Modeling and Simulation 101 will answer for you:

Where have we been with M&S and how did we get here?

Where is M&S Today ?

What are the key DoD M&S programs?

How is representation done in M&S?

What is VV&A?

What is the DoD role in M&S?

What are the key M&S terms and what do they mean?

What is the Common Technical Framework?

What are the benefits and challenges of M&S?

What other M&S opportunities are available?

# Schedule for M&S 101

## Block 1

Overview

History

Basic Jargon

DoD Role in M&S

DoD M&S Structure

M&S
Functional Areas

DoD M&S Programs

## Break
## 10 Minutes

## Block 2

Introduction

DoD Master Plan

CTF

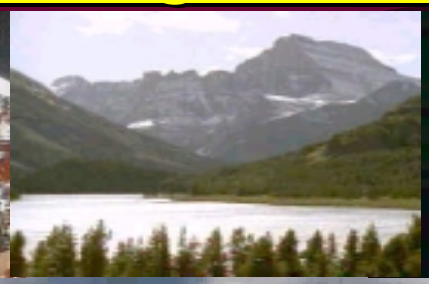
Representation

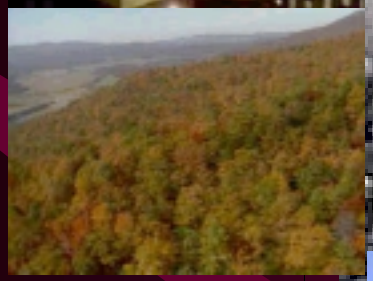
Common Services

Benefits of M&S

Summary

# *What is Modeling and Simulation?*





**An attempt to imitate real world processes or facilities**

# Modeling and Simulation

**"Modeling and Simulation does not work in isolation. Other technologies and non technology factors are closely integrated and act in conjunction with one another."**

**Marco Iansiti, Harvard Business School, 1998**

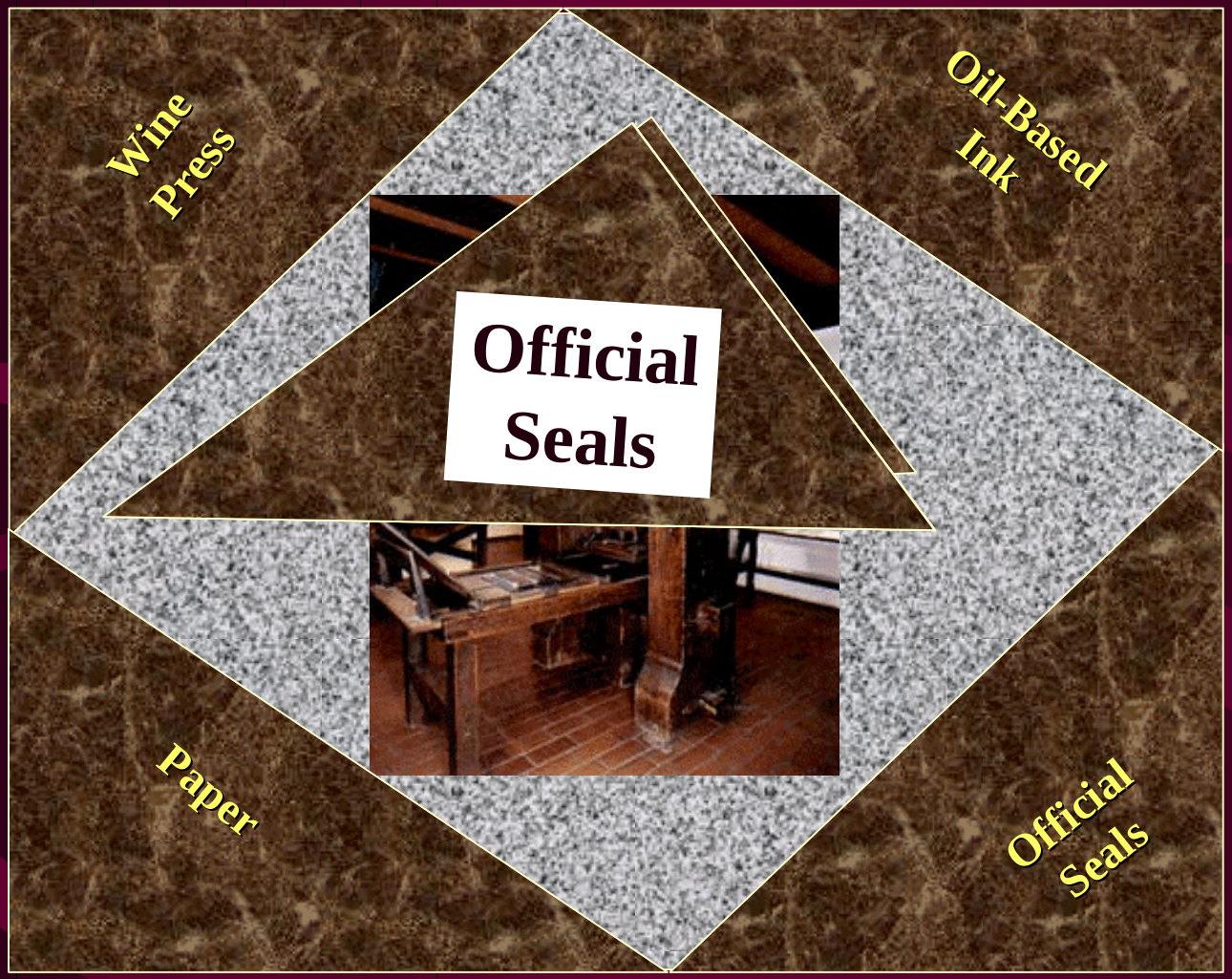
**Creates a New Language**

**Causes Organizations to Focus the Scope of Changes**

**Causes Organizational Changes**

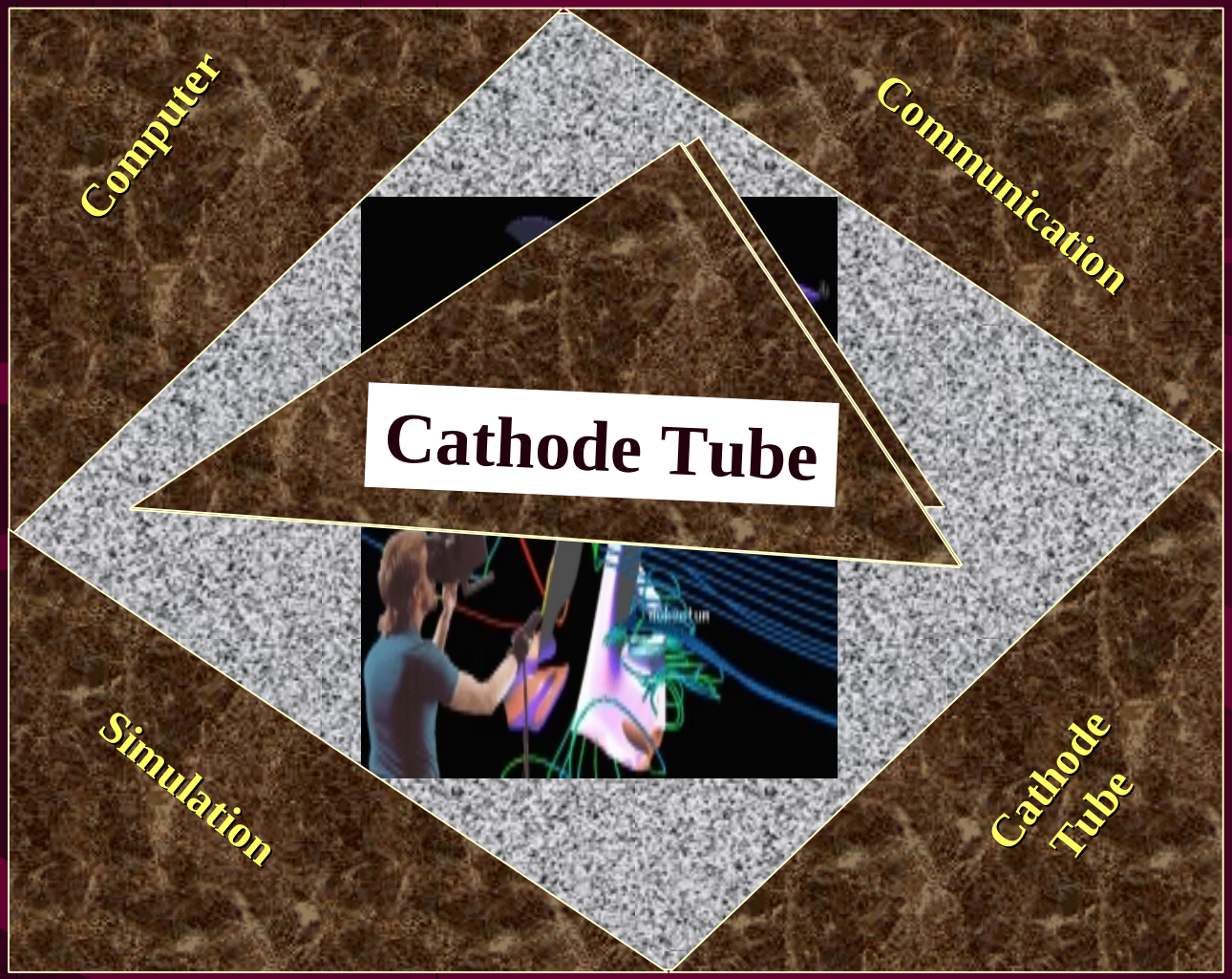
# First Information Age - 1452 Gutenberg Printing Press

## *Integration of Technologies*



# Today's Information Age

## *Integration of Technologies*



# Organizational Changes

| Challenges in 1494 | Challenges Today |
| --- | --- |
| Control over standards | Control over standards |
| Distribution of books poorly organized | Locating information difficult |
| No transport systems for books | Communication bandwidth problems |
| No "advertising" mechanisms | No "advertising" mechanisms |
| Low literacy rate in Europe | Lack of education for M&S |

# Organizational Changes

## Creation of New Jobs

***Then*** **- Traveling raconteurs stood in the market and read from books as a means of making a living as entertainers**

***Now*** **- Web masters create information sources on the Internet**

## Society Changed

***Then*** **- Elders lost some respect, because no longer were their memories so highly valued**

***Now*** **- Information instantaneous - less need to rely on other individuals; example, locating airline information**

# Stumbling Blocks to Organizational Changes

***What happened to the scribes?***

**Most were put out of business due to the press copying at 1/1000 of the price, but many scribes lingered on:**

- **To postdate entries in a family Bible**
- **To make copies of deeds and wills for county governments**

***What is happening today?***

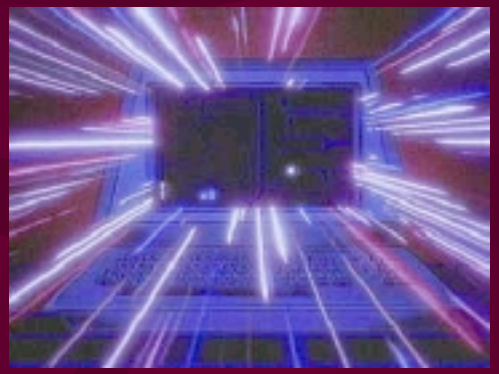
**Individuals feel threatened and numerous occupations are adjusting. Some, like the scribes, are lingering on:**

- **Contracts protecting job types and descriptions**
- **Education programs failing to adopt new practices**

# Creating
# a
# New Language

# Modeling and Simulation Jargon

**M&S has its unique jargon, strange to the uninitiated but no more so than the language of other disciplines. Requires multi-disciplinary vocabulary.**



# User Perspective

I want to conduct a training simulation for the entire Ranger Regiment in which U.S. forces restore democracy to a small South American country. Included in this event, I want to simulate in a virtual environment for an early morning parachute assault onto an International Airport and a Military Airfield, in order to neutralize the enemy forces and secure airfields for the arrival of follow on forces. I want it real enough so my rangers can feel the dew on their necks and the smoke in the air.

## *Intelligence Community*

"Need to produce R&S overlays to

## *Cartographer*

"We need to create a grid.

## *Psychologist*

"We must understand what the concept of sensing & perception based upon the informational process within the three functions of memory"

information within acceptable limits of accuracy."

effects, counterintelligence/human intelligence, and force protection"

# Simulation Developer Perspective

## Communication

Digital Subscriber Line

Asymmetric DSL

Asynchronous Transfer Mode

Basic Aggregated Digital

Integrated Services Digital Network

Latency

Optical Carrier

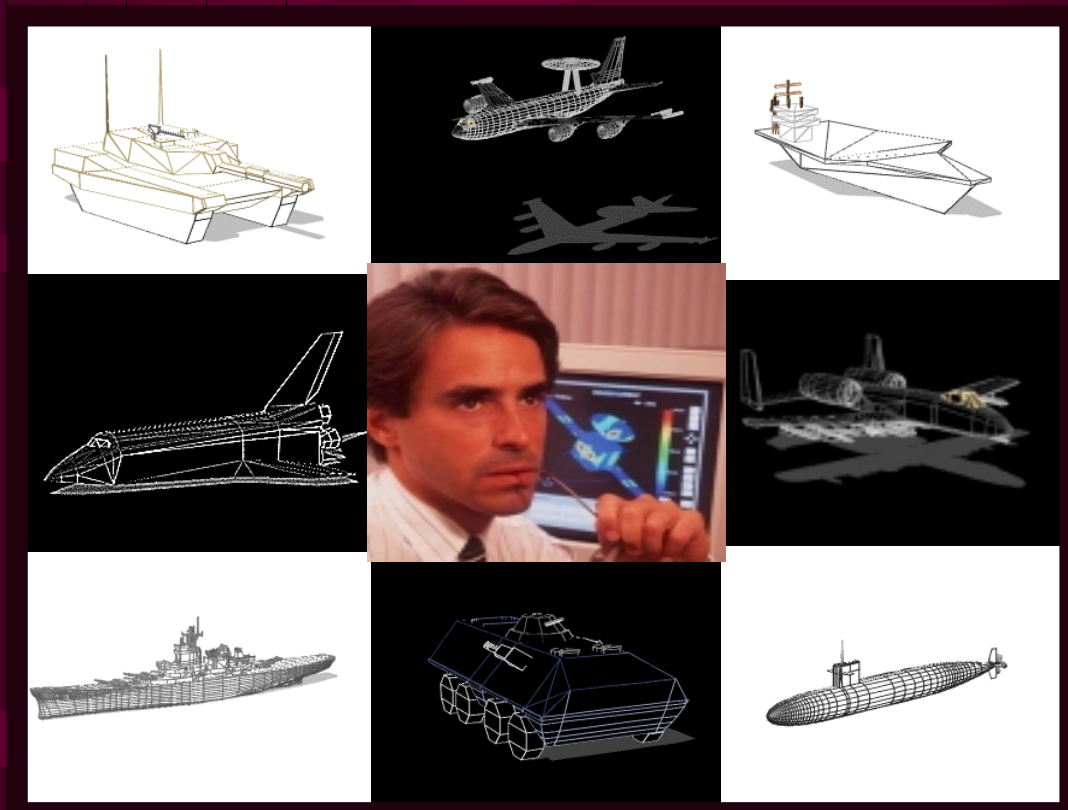
Symmetric

Synchronous Optical Network

# Definition of a Model

***Model*** **- "A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process."**

**DoD M&S GLOSSARY, Jan 98**



# Classes of Models

"A ***mathematical model*** is a symbolic model whose properties are expressed in mathematical symbols and relationships."

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The representation is comprised of procedures (algorithms) and mathematical equations.

# Classes of Models

## Example of a Mathematical Model

**STINGER MISSILE CHARACTERISTICS**

| | |
|---|---|
| Type | Supersonic, surface-to-air |
| Diameter | 2.75 inches |
| Length | 58 inches |
| Guidance | Passive infrared homing and modified proportional navigation |
| Range | Excess of 4 kilometers |
| Speed | Mach 2.2 |
| Warhead | High explosive |
| Motor | Rocket, solid propellant, two-stage) |

Acceleration Rate 1 Meter per .5 second

*A = Acceleration Rate*

*S = Speed of projectile*

*W = Warhead blast Radius*

*E = Effective Range*

*S2 = Target Speed*

*D = Distance of Target*

*R = Range at Engagement*

$$R = A + \frac{D}{(D/S + D/S2)}$$

*R = Probability of hit / damage*

# *Classes of Models*

A ***physical model*** is a model whose physical characteristics resemble the physical characteristics of the system being modeled. **DoD M&S GLOSSARY, Jan 98**

***Physical models*** are the symbolic forms utilized for simulators.

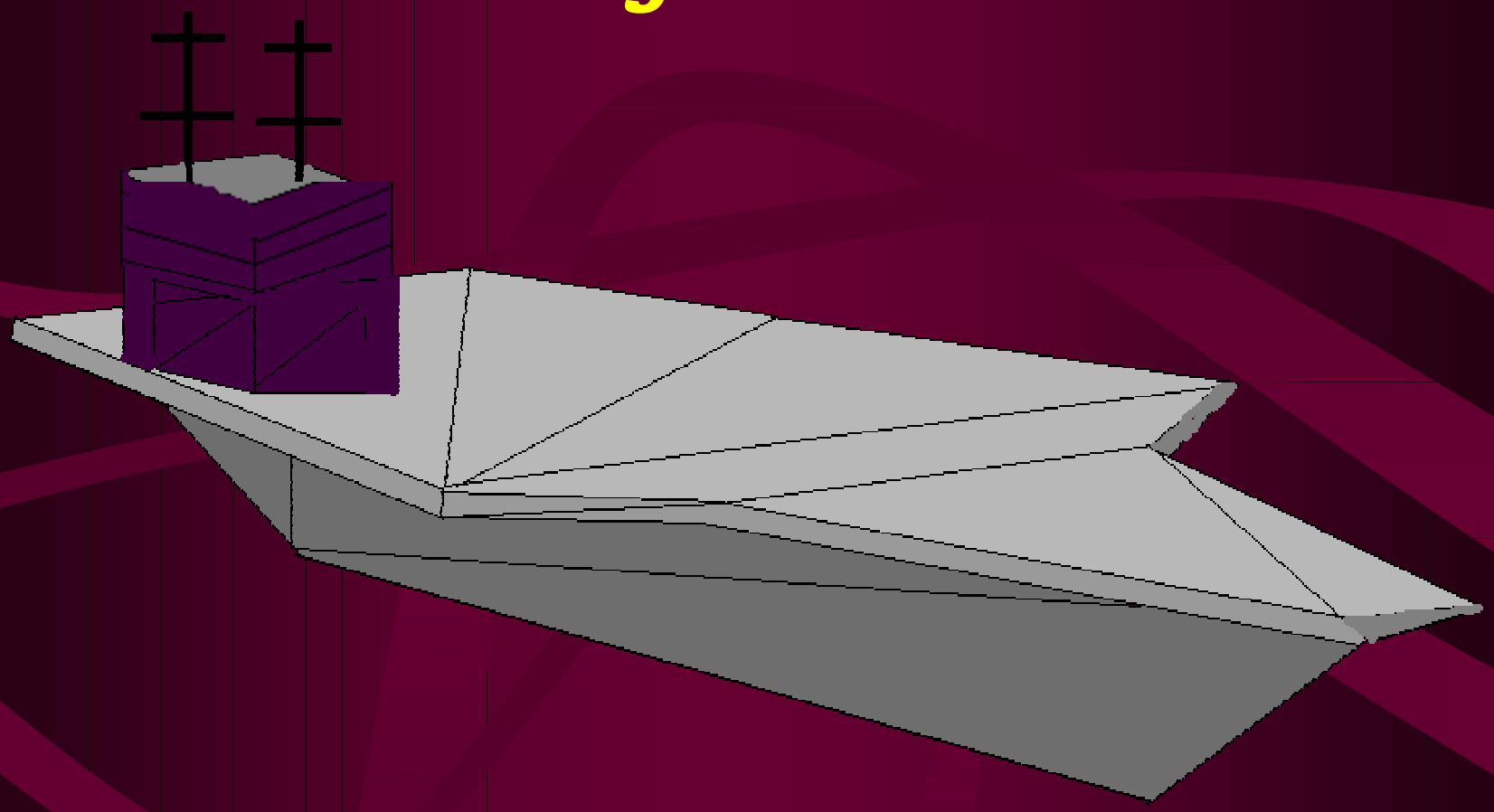
# ***Concept of Polygons***

**A *polygon* is a flat plane figure with multiple sides, the basic building block of virtual worlds. The more polygons a computer can display and manipulate per second, the more realistic the virtual world will appear. Humans perceive the equivalent of 80 million polygons at more than 30 frames per second in normal vision.**

**DoD M&S GLOSSARY, Jan 98**

# Concept of Polygons

**A closed plane figure bounded by straight lines**



# Concept of Pixels

**A *pixel* is a "picture element," that refers to the smallest visual unit in an image on a computer display.** **DoD M&S GLOSSARY, Jan 98**

***Any of the small discrete elements that together constitute an image (as on a television screen)***

# *Classes of Models*

***Process Model*** **models the processes performed by a system.**

**DoD M&S GLOSSARY, Jan 98**

**Process Models allow for the expression of dynamic relationships of a situation expressed by mathematical and logical processes.**

# *Classes of Models*

## Example of a Process Model

| *Clear Deck* | *Check Air Craft* | *Fix Catapult* | *Pre-Launch Checks* | *Launch Sequence* | *Launch Air Craft* |
|---|---|---|---|---|---|

| Manpower Time to Do Conditions Equipment | Visual Checks Problems Fix | Hook-up Check Verification | In Aircraft On Deck Tower | Pilot Tasks Deck Tasks Tower Tasks | Pilot Tasks Deck Tasks |
|---|---|---|---|---|---|
| $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ |

T = Time

$$T_1 + T_2 + T_3 + T_4 + T_5 + T_6 = \text{Time to Launch Aircraft}$$

# What is a Simulation

**Simulation - A method for implementing a model over time.** **DoD M&S GLOSSARY, Jan 98**

# Types of Simulation

**Live Simulation - A simulation involving real people operating real systems.** DoD M&S GLOSSARY, Jan 98

**Live simulations:**

- involve an individual or groups
- may use actual equipment
- may provide a similar area of operations
- live simulation can not be fully replicated

# ***Types of Simulation***

## Example of a Live Simulation

***May Result in Large Resource Expenditure!***

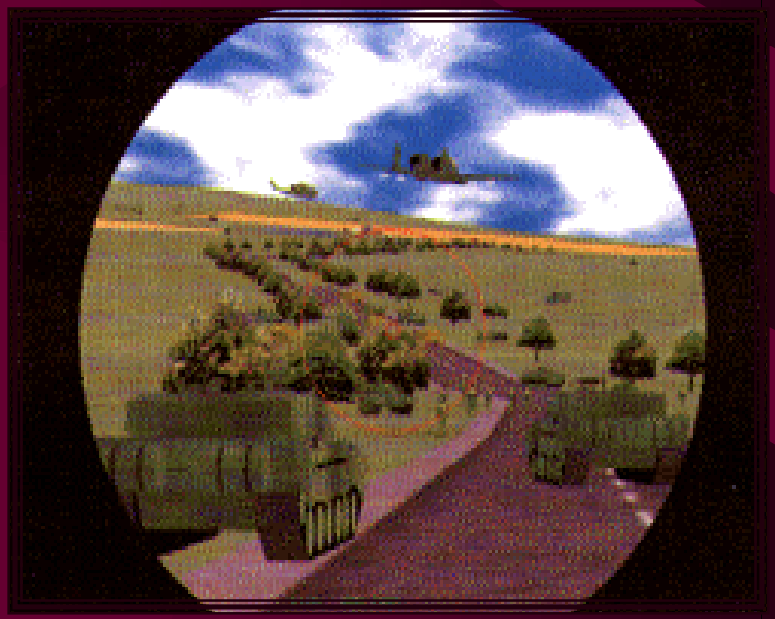
# Types of Simulation

***Virtual Simulation*** **- A simulation involving real people operating simulated systems. Virtual simulations inject human-in-the-loop in a central role by exercising motor control skills (e.g., flying an airplane), decision skills (e.g., committing fire control resources to action), or communication skills (e.g., as members of a C4I team).**

**DoD M&S GLOSSARY, Jan 98**

# ***Types of Simulation***

## Example of a Virtual Simulation

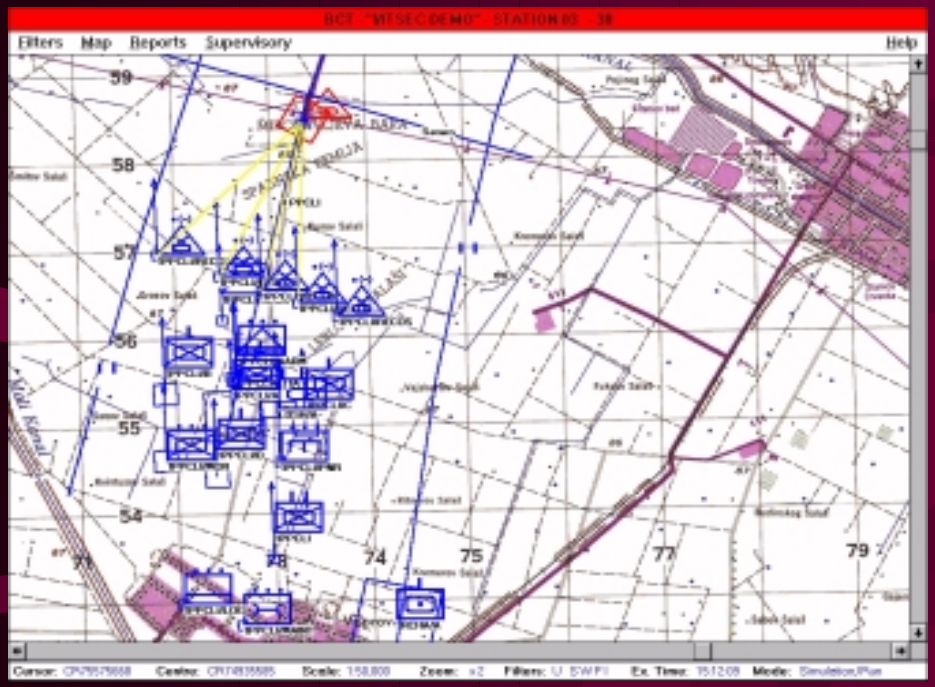


# *Types of Simulation*

***Constructive Model or Simulation -*** **Models and simulations that involve simulated people operating simulated systems. Real people stimulate (make inputs) to such simulations, but are not involved in determining the outcomes.** **DoD M&S GLOSSARY, Jan 98**

# Types of Simulation

## Example of a Constructive Simulation




**Constructive simulations:**
- make measurements
- generate statistics
- perform analysis

**Constructive simulations offer the ability to:**
- analyze concepts
- predict possible outcomes
- stress large organizations

***Most constructive simulations use a large number of established legacy models.***

# Distributed Simulation (DS)

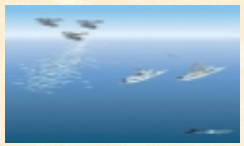
**Simulations need to be interactive through current state-of-the-art communication systems.**

Constructive

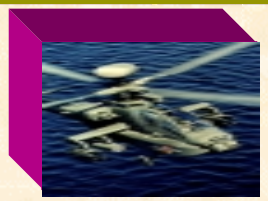
Live

Virtual

**Can be across the world or across the room!**



Virtual

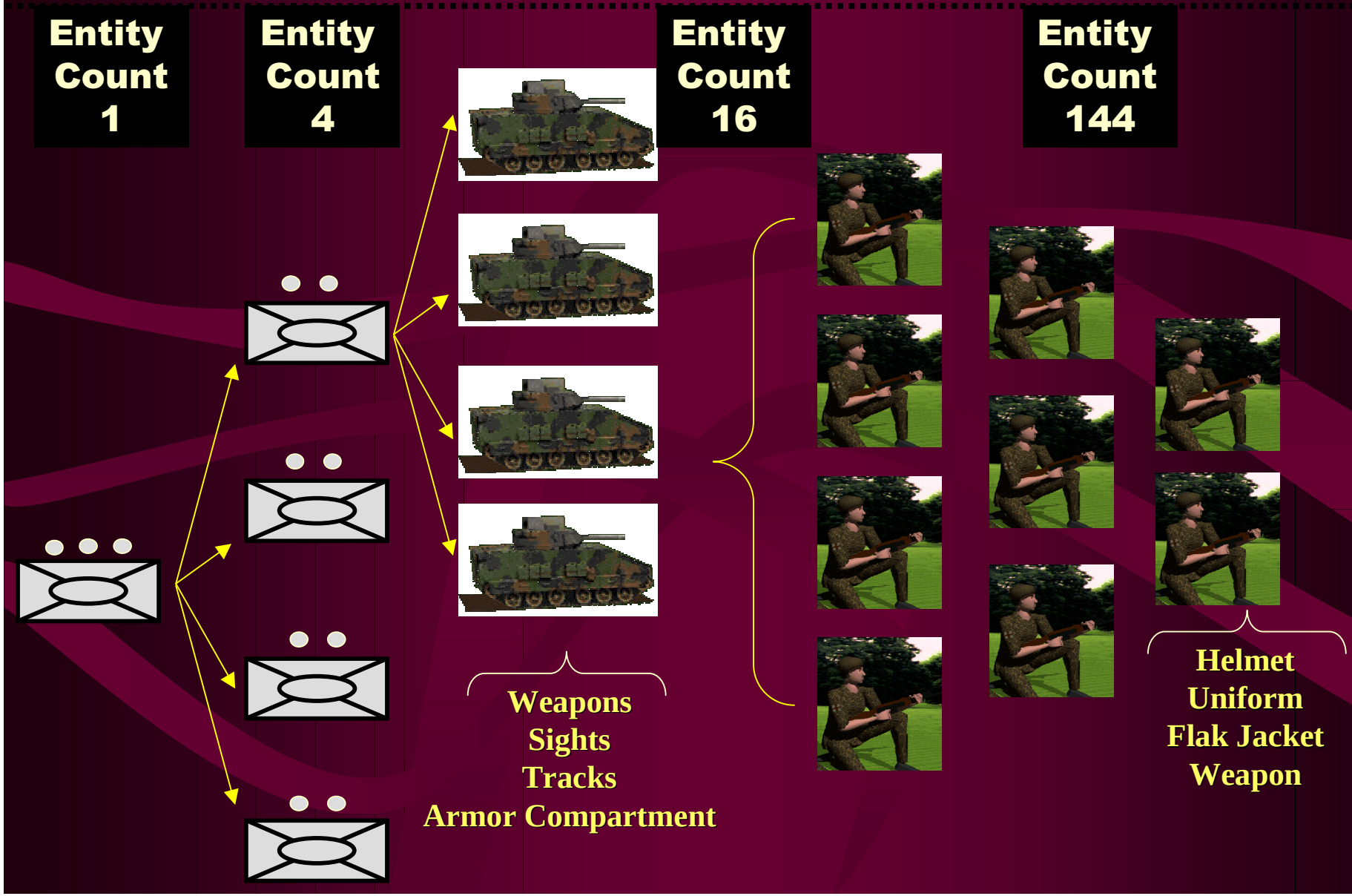


Live

Constructive

# Concept of Aggregation and Disaggregation

## Moving from Constructive Simulation to a Virtual World



# *Fidelity vs. Resolution*

***Fidelity*** **is the accuracy of the representation when compared to the real world.**

**DoD M&S GLOSSARY, Jan 98**

**Vs**

**A model or simulation is said to have fidelity if it accurately corresponds to or represents the item or experience it was created to emulate.**

# *Fidelity vs. Resolution*

***Resolution.*** **The degree of detail and precision used in the representation of real world aspects in a model or simulation.**

**DoD M&S GLOSSARY, Jan 98**

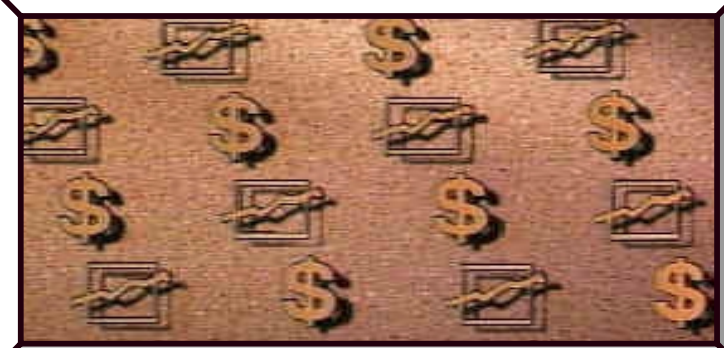
**Vs**

**Resolution means the fineness of detail that can be represented or distinguished in an image.**

# Causes Organizational Changes

# Factors that Effected the Use of M&S in DoD

Increased Requirements



Less Resources

Concerns of Readiness

# "America's First Battles" By Charles Heller and William Stofft

Long Island 1776
897 captured
1000 killed, wounded, or captured

Buna Nov 1942-Jan 1943
492 casualties

Queenston Heights 1812
300 losses; British took 1000 prisoners

Kasserine Pass Jan-Feb 1943
2,816 men killed or wounded and
2,459 men taken prisoner
(US II Corps).
Other elements about 5,000 men killed

Rio Grande 1846
American casualties -- 1,300 killed

Task Force Smith July 1950
150 casualties and the loss of all equipment
Another casualty was American morale

San Juan Hill and El Caney 1898
220 casualties and 1300 wounded

Cantigny May 1918
2378 casualties with 488 missing

Ia Drang Valley, Oct-Nov 1965
325 killed and 524 wounded

**How can we train the warfighting leadership to experience the "first battle" prior to combat?**

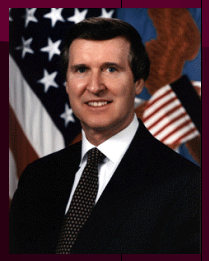
***Solution - Through Simulation***

# Initially M&S was Strictly a Service Function In DoD

***The direction and focus of M&S was not always clear!***

# *Defense Science Board Concept*

## Mission of the Defense Board:



**Advise the Secretary of Defense**

**Through the Under Secretary of Defense for Acquisition and Technology**

**On Scientific And Technical Matters**

**As they affect the perceived needs of the Department of Defense**

- Thirty-two members and seven ex officio members
- Members selected on the basis of their preeminence in:
  - Science
  - Technology and its application to military
  - Operations
  - Research
  - Engineering
  - Manufacturing and Acquisition process

# *1988 Defense Science Board Report on Computer Applications to Training and Wargaming*

**Computer-based simulated scenario only practical and affordable means for Joint Commanders to exercise decision skills and war plans.**

**Promote Joint Simulation Usage**

# DoD Mission for Modeling and Simulation

## Mission

To strengthen the use of modeling and simulation in joint education, training and military operations; research and development; test and evaluation; analysis; and production and logistics.

DepSecDef Memorandum, "Modeling and Simulation Management Plan,1991

# DoD M&S Vision

**Provide readily-available, *operationally-valid* environments to:**

- **train jointly, develop doctrine and tactics, formulate operational plans, and assess war fighting situations**
- **support technology assessment, system upgrade, prototype and full scale development, and force structuring**

**DepSecDef Memorandum, "Modeling and Simulation Management Plan,1991**

# *DoD M&S Vision (cont.)*

***Common use*** **of environments that promotes closer** ***interaction*** **between operations and acquisition communities**

- **allow maximum utility and flexibility**
- **by constructing M&S environments from** ***affordable, reusable, interoperable components*** **through an open system architecture**

**DepSecDef Memorandum, "Modeling and Simulation Management Plan,1991**

# Objectives

## Investment

- Implement a Long-Range M&S Investment Strategy
- Promote Initiatives to fill Critical Technology Gaps

# Under Secretary of Defense (Acquisition and Technology)

**Director**
**Defense Research and Engineering**
***(DDR&E)***

**Executive Council for Modeling and Simulation**
***O-8/SES reps from across DoD***

***Training Council***

***Analysis Council***

***Acquisition Council***

**Defense Modeling and Simulation Office**
***(DMSO)***

**Modeling and Simulation Working Group**
***(MSWG)***
***O-6/GM15 reps from across DoD***

**M&S Executive Agents**

**Architecture Management Group**

**Task Forces**

**Technical Work Groups**

**Functional Work Groups: Training, Analysis, Acquisition**

**Joint Staff**

**AMSO**

**AF-XOC**

**NAVMSMO**

**MC-OSI**

# *Executive Agents*

**A *DoD M&S Executive Agent* is a DoD Component to whom the USD(A&T) has assigned responsibility and delegated authority for the development and maintenance of a specific area of M&S application, including relevant standards and databases, used by or common to many models and simulations.**

**DoD M&S GLOSSARY, Jan 98**

# Causes Organizations to Focus the Scope of Changes

# Modeling and Simulation Master Plan (MSMP)

***The MSMP is a:***

**DoD Plan** ***under*** **Authority USD(A&T)** ***and*** **Coordinated through DoD Components**

## *The MSMP establishes:*

**Short-term Goals and Objectives (Present to 6 Years)**

**Long-term Goals and Objectives (Beyond 6 Years)**

## *The MSMP provides:*

**A Road Map That Delineates the Management, Investment, And Technical Strategies**

**Joint and Common Use Applications of M&S**

**Assessment Of Current M&S Capabilities**

**DoD M&S GLOSSARY, Jan 98**

# Focus of M&S through the DoD Master Plan

**Objective 1**

Develop a common technical framework for M&S

**Objective 2**

Provide timely and authoritative representations of the natural environment

**Objective 3**

Provide authoritative representations of systems

**Objective 4**

Provide authoritative representations of human behavior

**Objective 5**

Establish an M&S infrastructure to meet developer and end-user needs

**Objective 6**

Share the benefits of M&S

# M&S Functional Areas

## Training

## Acquisition

## Analysis

# M&S Functional Areas

Analysis Functional Area

Training Functional Area

Acquisition Functional Area

... the best of the best...but...

- Not linked
- Meet localized needs only
- No data exchanged
- Hundreds of models and simulations make it difficult to know what's available

# Training Functional Area

**Training simulations generally fall into three categories:**

- **Exercises**
- **Education**
- **Military Operations**

**Training can be broken down further into two additional categories and subcategories:**

- **Individual**
  - **procedural**
  - **cognitive thinking**
  - **motor skills**
- **Collective**
  - **staff decision making**
  - **crew skill training**
  - **maneuver training**

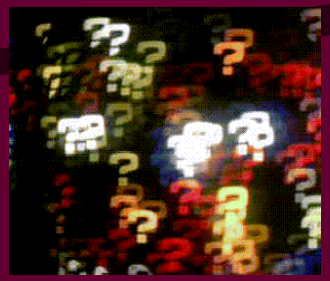
# *Analysis Functional Area*

***Analytical Simulations*** **fall into two subcategories:**

- ***Operations support***
  - **Control of daily operations**
  - ***Decision-making support*** **in logistical and administrative areas**
  - ***Decision-making support*** **for tactical and strategic decision-making**

- ***Evaluation***
  - **Simulations of an** ***analytical nature***
  - **Evaluation simulations are further divided into two types:**
    - ***(1) force capability and requirements***
    - ***(2) combat developments***

# What M&S Adds to Analysis



- ***Another tool to assist in decision making***
- ***Rapidly answer the "What If" questions***
- ***Low cost means to test failure***
- ***ID logistic constraints***
- ***Means of focusing issues***
- ***Provides the "missing expert"***
- ***Rapid turn around with multiple runs***

# Acquisition Functional Area

Acquisition Simulations fall into three subcategories:

- *R&D Simulations* include all those that are used for both the *design and development of equipment and weapons systems*. Also included are those used for *"pure" research*. Excluded from this group of simulations are those

***Test & Evaluation Simulations***

***Production & Logistics Simulations***

- **Assist in determining *logistics requirements, system productivity assessments, and industrial base appraisals***
- **Support the DoD's procurement, transportation, and maintenance of personnel, materiel, and facilities.**

***testing, and operational testing***.

- *P&L Simulations* include those applications that assist in determining *logistics requirements, system productivity assessments, and industrial base appraisals*. These simulations support the DoD's procurement, transportation, and maintenance of personnel, materiel, and facilities.

# Acquisition Functional Area

**"The bottom line is that integrated product and process development, backed up by a *strong commitment to computer-based modeling and simulation* tools, provides a dominant competitive edge in the commercial marketplace and a *clear warfighting edge* on the battlefield."**

Honorable Paul Kaminski

USD (Acquisition & Technology)

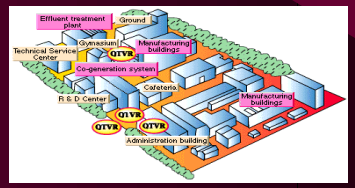
**Testing and Evaluation**

**FAA Crash Analysis**

**Research and Development**

**Super Hornet First Flight Test**

**Production and Logistics**




**Virtual Factory**

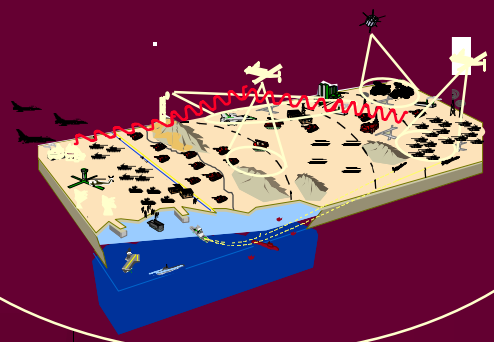
# *DoD M&S Programs*

# *DoD M&S Programs - JSIMS*

**JSIMS is a single, *distributed*, *seamlessly integrated* simulation environment. It includes a *core infrastructure* and *mission space objects*, both maintained in a *common repository*. These can be *composed* to create a simulation capability to support Joint or Service training, rehearsal, or education objectives.**

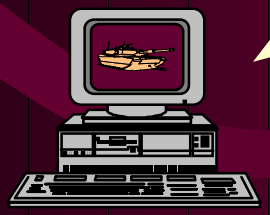
**Live/Range**

**JSIMS Battlespace**



**Live/Real World $C^2$**

**Other Systems**



**JSIMS interacts with separately developed systems via well defined interfaces**

**Virtual Simulators & Stimulators**

# *DoD M&S Programs - JWARS*

**Meets user analytical requirements by developing a fully integrated, state-of-the-art model of Joint Warfare. JWARS:**

**- represents joint and component functions, processes, warfare operations**
**- is based in joint doctrine and capable of representing future warfare**
**- aids in force structure, acquisition, and theater CINC course of action analyses**

## ***PAYOFF***

***MODERNIZATION***

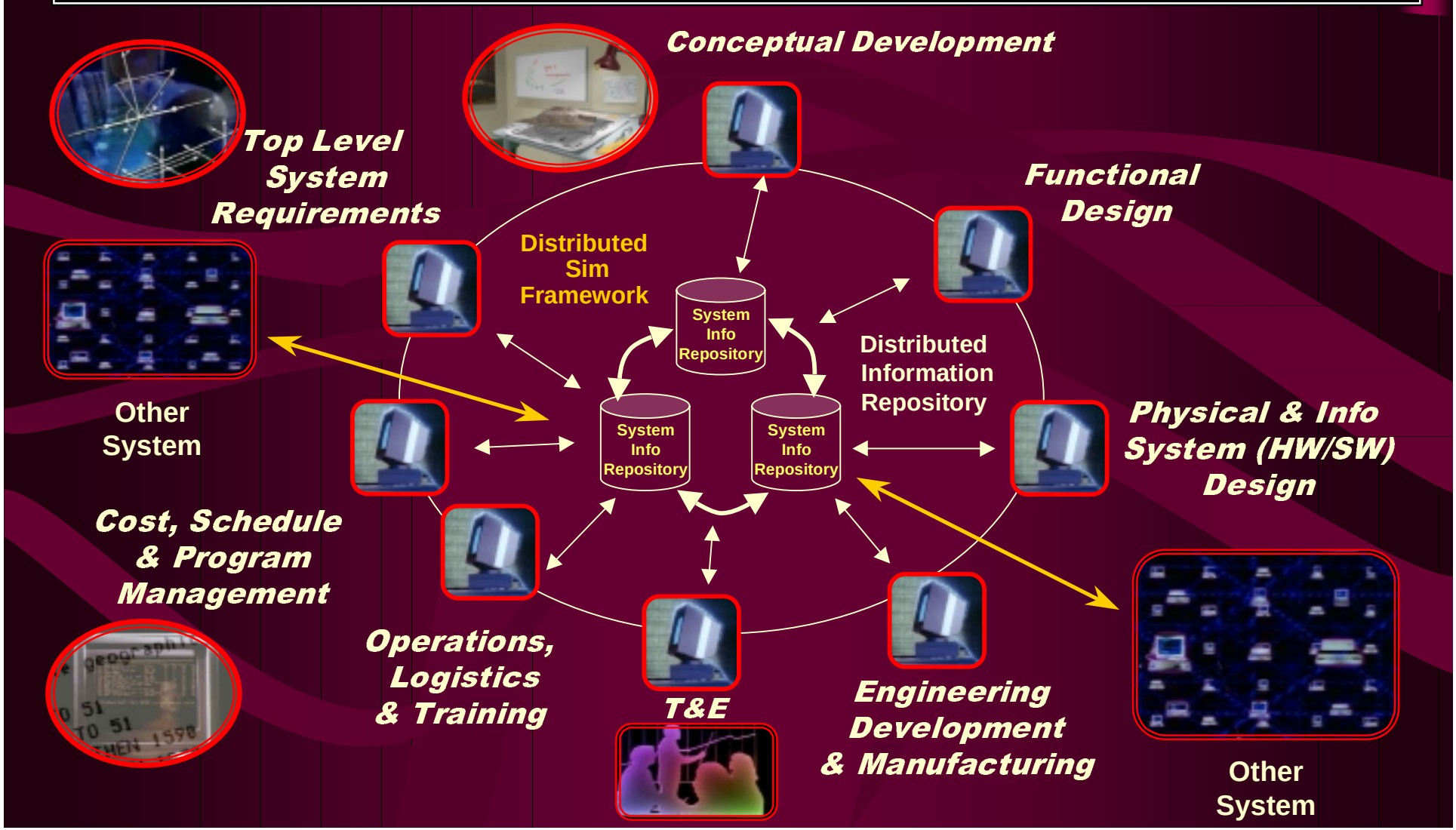
***FORCE STRUCTURE***

***KEY ISSUES***

***WARFIGHTING***

# Acquisition - Simulation-Based Acquisition (SBA)

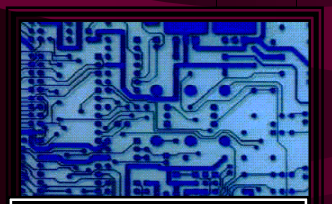
- Reduces the time, resources and risk associated with acquisition
- Increases quality, military utility and supportability of systems
- Reduces operating and maintenance costs
- Enables Integrated Product and Process Development (IPPD) during full acquisition cycle



# DoD M&S Programs - JMASS

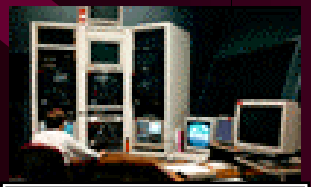
"We need some ***common standards***, ***interfaces*** and ***environments*** to provide for interactive, reusable modeling and simulation capabilities...JMASS is a distributed object oriented architecture which provides--infrastructure, published standards and reusable code, which will lead to more knowledgeable users and consistently reliable results at every stage of development with estimated millions of dollars saved as a result."

***Dr. Patricia Sanders***
***DTSE&E***

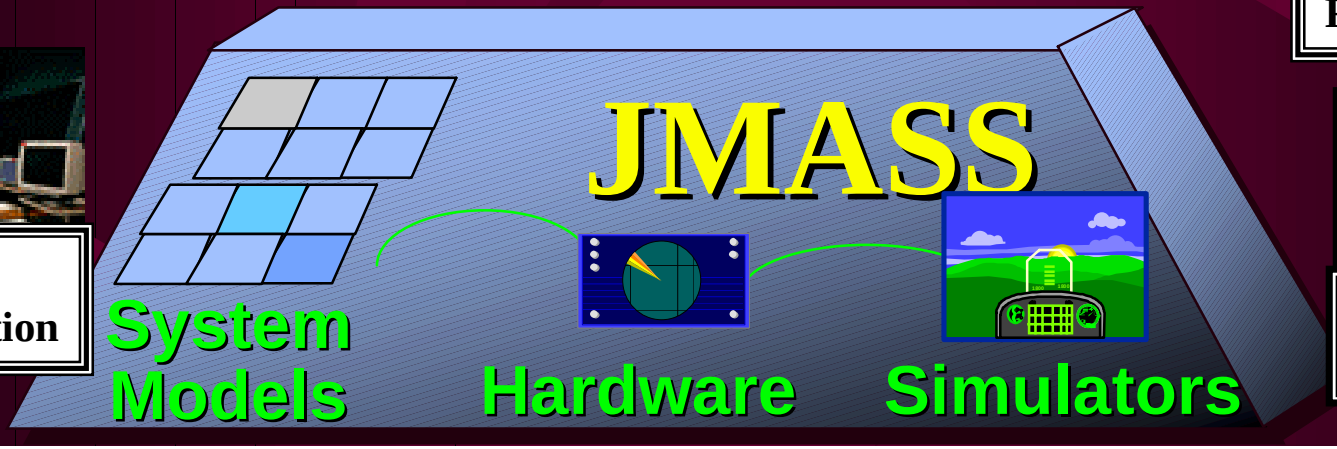


Common Architecture

Authoritative Representations

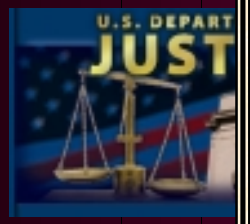


Joint Participation

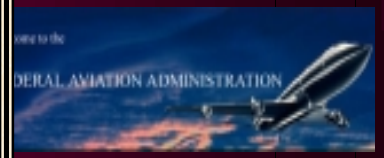


Common Environments

# *Other Federal Government Agencies Involved with M&S*




Department




deral Aviation
dministration

FEMA
Federal Emergency Management Agency

**Federal Emergency Management Agency**

**National Fire Academy**

**Community Emergency Response Team (CERT)**

United Stat

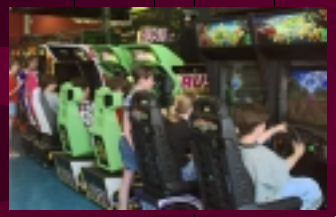
Department of Commerce

# Not Just a DoD or Government Initiative !

## Entertainment

Movies

Theme Parks



Games

## Industry

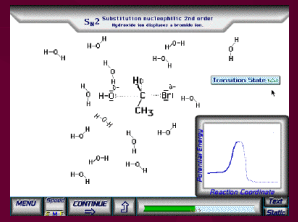
Maritime

Aerospace

Auto Industry

## Academia

Research



Enhanced Curriculum

Performance Applications

## ***Summary of Part One***

**Overview**

**History**

**Basic Jargon**

**DoD Role in M&S**

**DoD M&S Structure**

**M&S Functional Areas**

**DoD M&S Programs**

# *Break!*