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Modeling, Simulation, and Analysis Fundamentals

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Agenda

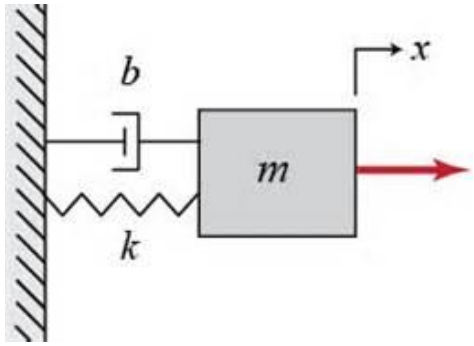
- **Modeling, Simulation, and Analysis Fundamentals**
  - Who, What, Why, When, and How
- **Terms of Enterprise Architecture Assessment**
- **Analysis with an Acquisition Focus**
  - Types of Analysis and Methodology

History

- 1800's Army Corps of Engineers water projects
  - Cost Benefit Analysis
- 1941 U.S. Navy spawned operations research
  - Effectiveness analysis
- 1958 "Systems Analysis" Coined
- 1965 DoD Cost of Operational Effectiveness
  - Cost-Operational Effectiveness Analysis requirement
- 2000 DoD Analysis of Alternatives
  - Added focus on interoperability in an operational environment

What is a Model?

- Model – is any physical or mathematical representation (object or process) used to communicate, educate or understand



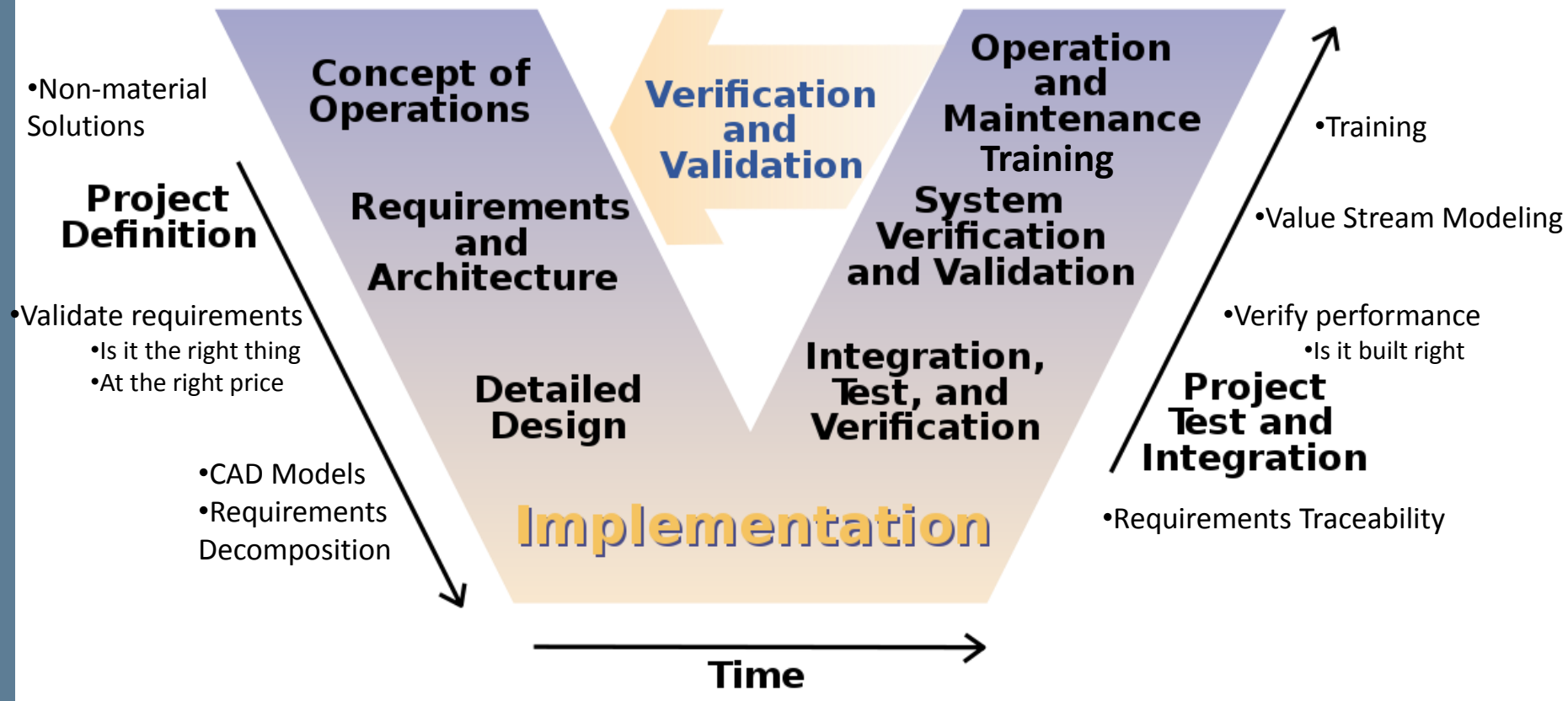
- Computer model – is a computer program or database that contains a mathematical model

Why Do We Model?

- One fundamental reason
  - Better understand a problem
- Four aims
  - To visualize a system as it is or as we want it to be
  - Specify the structure or behavior of a system
  - Guides constructing a system
  - Document the decisions we have made

We Model to Simplify Reality

When Do We Model?



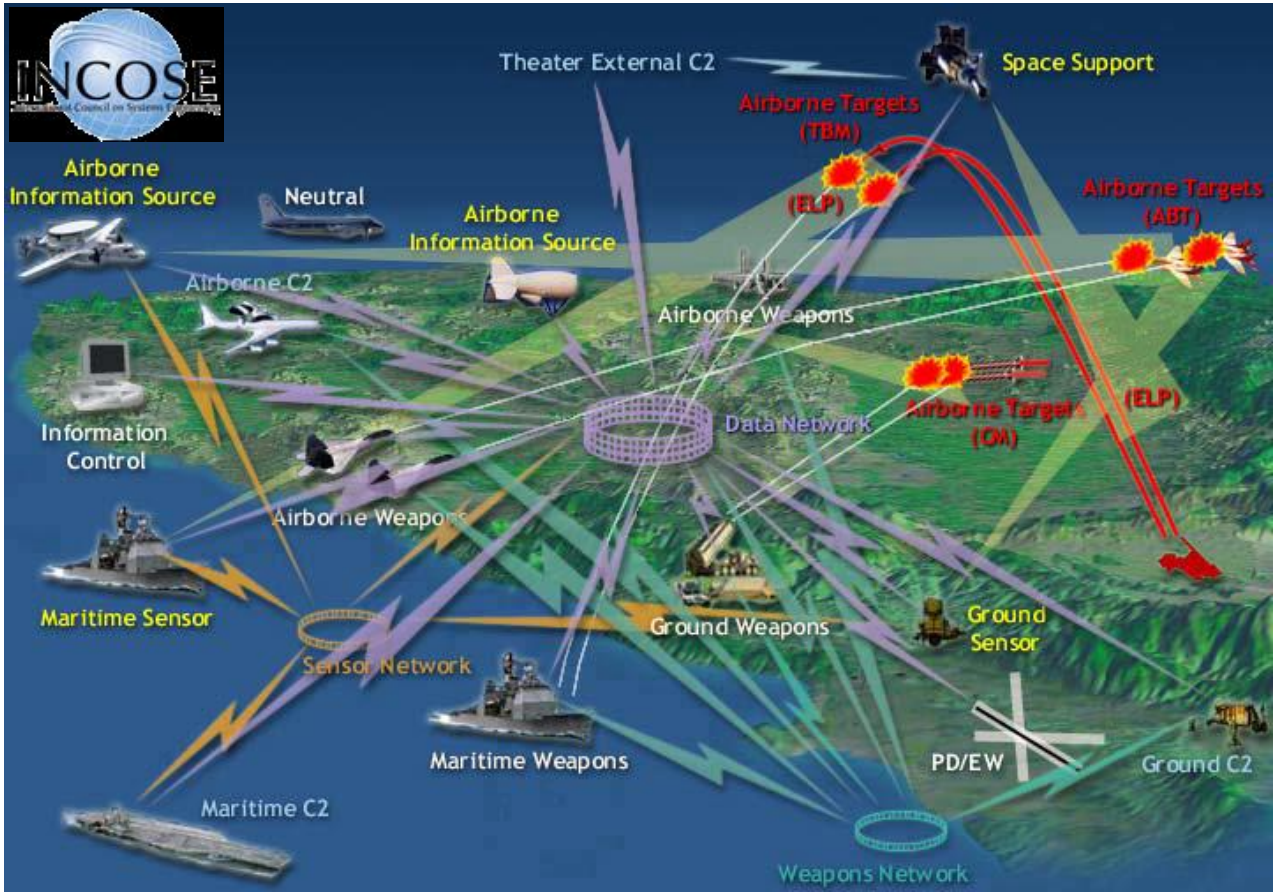
MS&A Applied Throughout Life-Cycle

What is a Simulation?

- Simulation – is a collection of models that represent objects or processes within an executable framework (Stratego, MB Operation, Fire Drill)

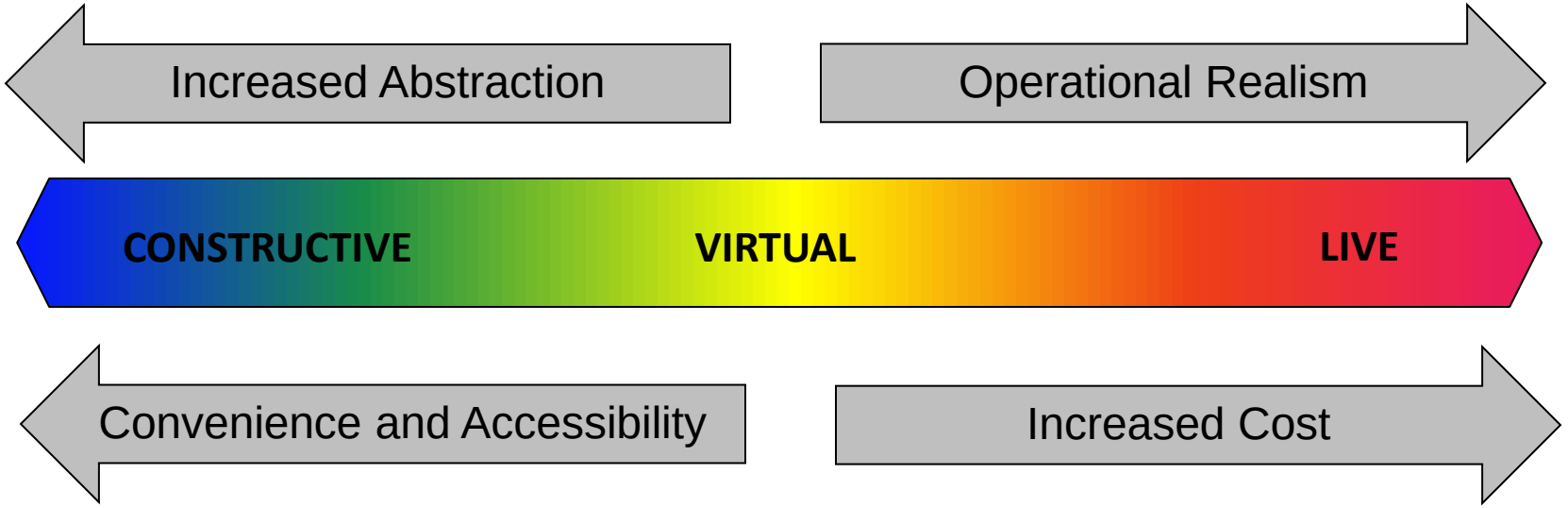
- Computer Simulation – simulation the executes on a computer (ESAMS, Warcraft, America's Army)

Why Do We Simulate?



Simulate to Simplify Complexity

Styles of Simulation



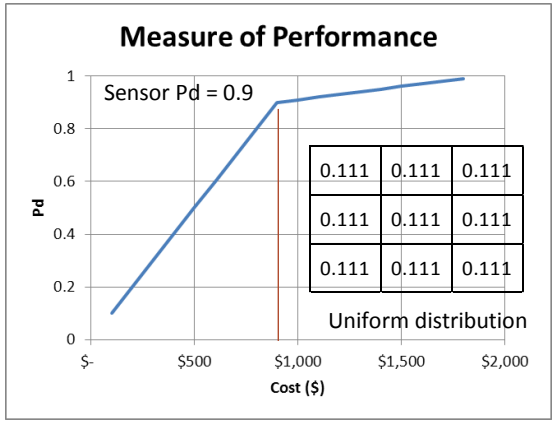
- Simulations generally come in three styles: constructive, virtual, and live.
- A simulation also may be a combination of two or more styles
- Each style can be deterministic, stochastic, or Monte Carlo

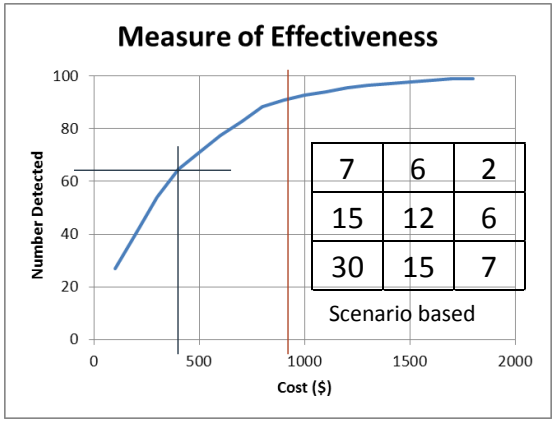
Types of Analysis

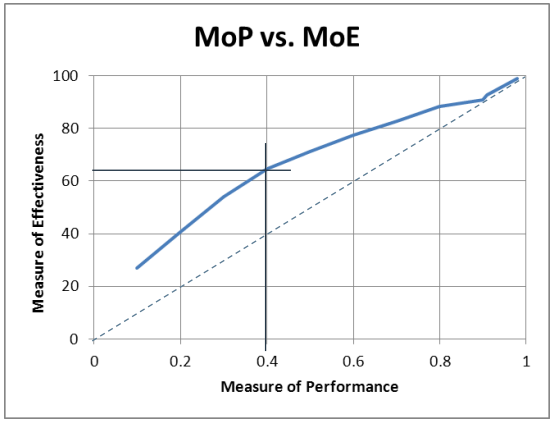
- **Performance**
  - A comparative measure of the level of operation or function of a material, sub-system, system, or architecture
  - Environment based on mathematical distributions (Uniform, normal, etc)
  - Results are, generally, ratios or probabilities (MPG, Pd, Pk)
- **Effectiveness**
  - A comparative measure of performance of a system in an operational environment
  - Environment based on discrete values (e.g. Defense Planning Guidance)
  - Results are, generally, raw numbers of things (Number of kills, detections, gallons of fuel)
- **(Military) Utility**
  - A comparative measure of the effectiveness of a system in to achieve large-scale objectives
  - Utility analysis should include the full scope of the program, development, operation, maintenance, and disposal.
  - Results are, generally, numbers of things (FLOT movement, Number of kills, Tons of cargo, gallons of fuel)

Defined by analysis objectives not size of system

Effectiveness vs Performance



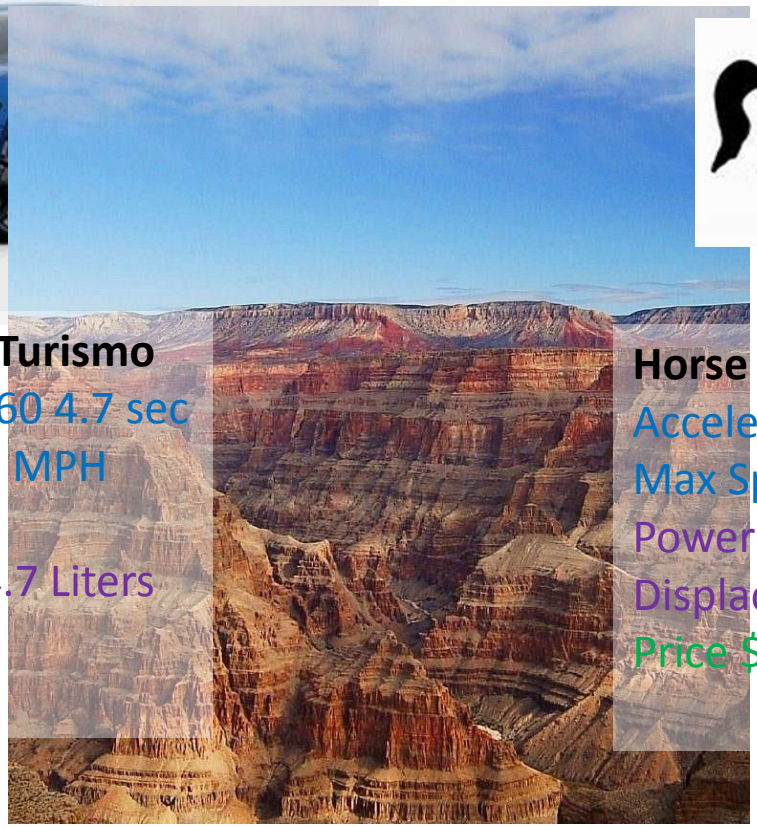


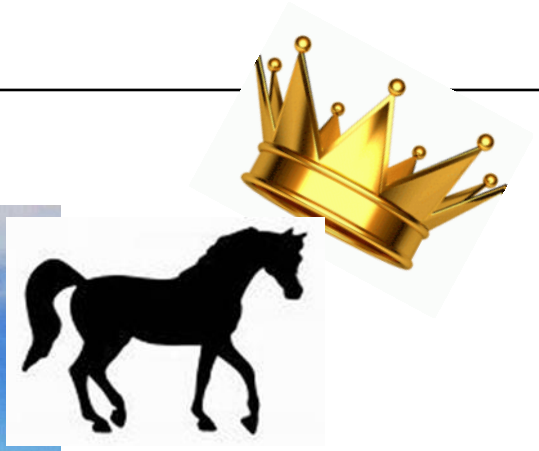


- We know it costs more to get marginal increases in performance
- As the performance of a system increases at some point it contributes less to the overall effectiveness
- This effect is more pronounced when examining effectiveness
- The difference between best values is requirements creep

Example: The Race

Maserati GranTurismo
Acceleration 0-60 4.7 sec
Max Speed 185 MPH
Power 454 HP
Displacement 4.7 Liters
Price $132,000

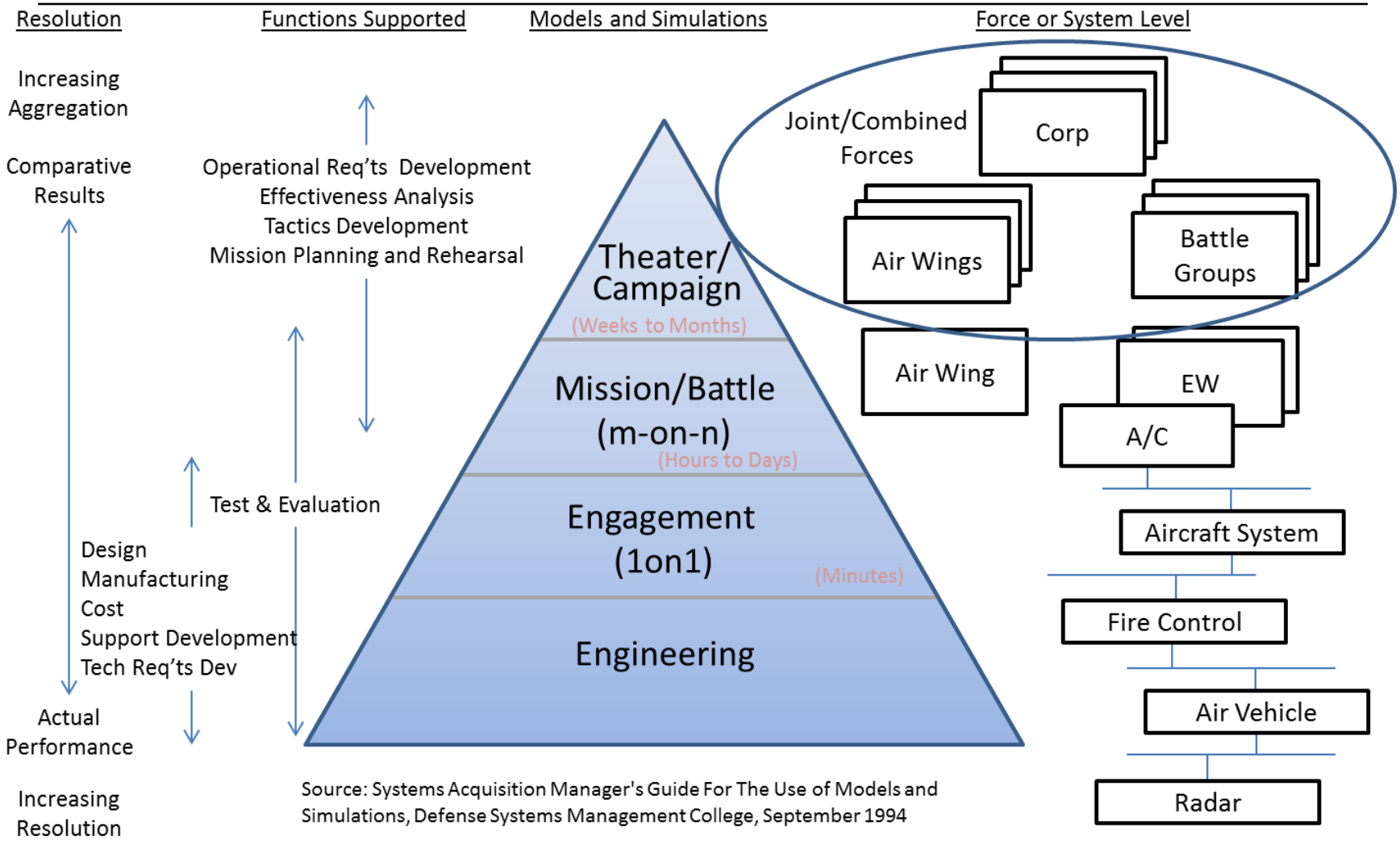




Horse
Acceleration 0-45 1.5 sec
Max Speed 45 MPH
Power 1 HP
Displacement N/A
Price $10,000

The Course

Hierarchy of Models and Simulations



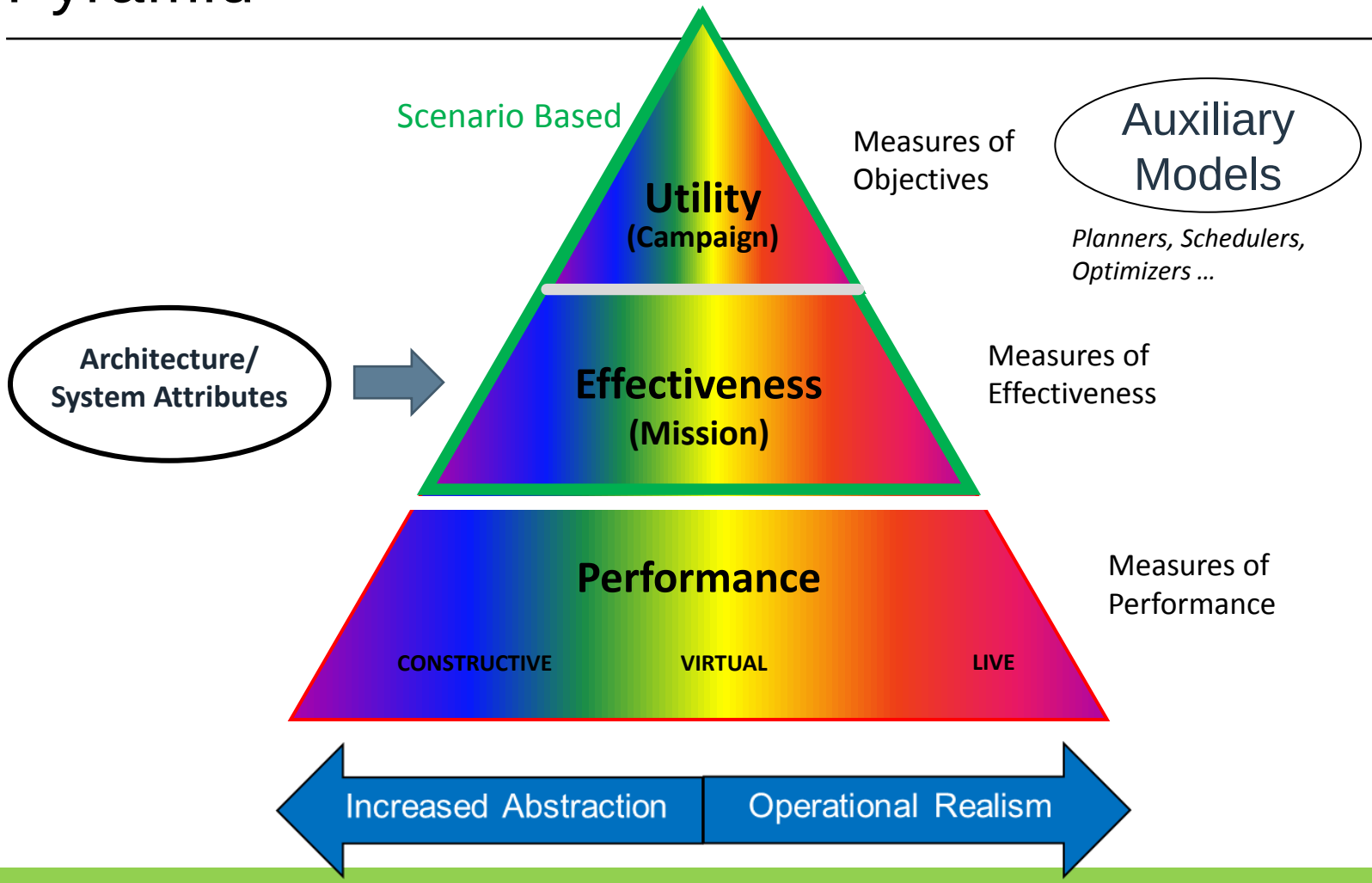
Source: Systems Acquisition Manager's Guide For The Use of Models and Simulations, Defense Systems Management College, September 1994

A new model for Modeling, Simulation, and Analysis is needed

New Model

- Build a new model to better represent MS&A
- M&S used to support analysis
- Use model and simulation definitions
- Account for
  - 3 Levels of analysis
  - 3 Styles of simulation

Modern Modeling, Simulation, and Analysis Pyramid



A better fit with systems theory

Benefits of MS&A

- Increased understanding
- Reduced Risk
  - Technical
  - Cost
  - Schedule
  - Operational
  - Safety
- Better documentation

MS&A leads to decreased cost

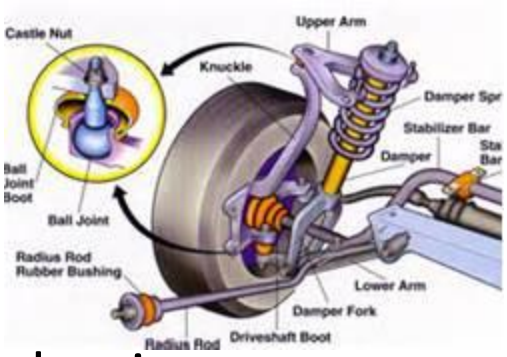
Limitations

- “All models are wrong. Some are useful.” - George Box
- Models won’t tell you what will happen. They will tell you what might happen with some degree of likelihood and level of risk.
- Awareness
  - Limits of the scenario and environment
  - Assumptions used in creating models
  - Tool Selection
  - Limitation imposed by models and simulations
  - Experience and integrity of team performing analysis

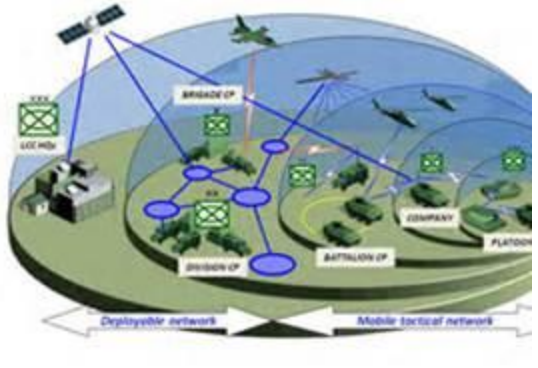
MODEL BASED ACQUISITION:
TERMS OF ENTERPRISE ARCHITECTURE

Systems

- System – is a process, object or collection of objects that accomplish a function.



- System-of-Systems – a collection of systems that interact. These systems were not necessarily designed to directly interact. The interaction of these many systems may produce unique emergent behaviors.



A system is anything you define it to be

Architecture Definitions

- Architecture - structure of components, their relationships, and the principles and guidelines governing their design and evolution over time [SBIRS Engineering Acronym Dictionary]
- Architecture - a blueprint for constructing and integrating all aspects of a SW-intensive system [SBIRS Engineering Acronym Dictionary]
- Architecture – visual plan
- Architecture - the fundamental organization of an enterprise (or system) embodied in its components, their relationships to each other, and to the environment, and the principals guiding its design and evolution. (IEEE 2000).
- **Architecture – a model of a system**

Architecture is THE model in "model based acquisition"

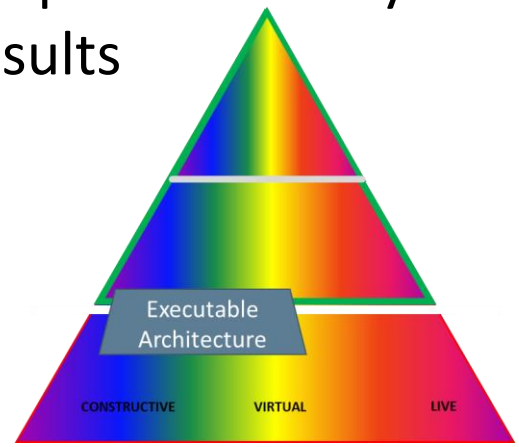
DoD Acquisition

- Joint Capabilities Integration Development System (JCIDS)
  - United States Department of Defense (DoD) procedure which defines acquisition requirements and evaluation criteria for future defense programs
- Department of Defense Architecture Framework (DoDAF)
  - An architecture framework for the United States Department of Defense (DoD) that provides visualization infrastructure for specific stakeholders concerns through viewpoints organized by various views
  - Required for all major IT programs (or programs that incorporate IT)
  - All complex military system contain information technology

JCIDS and DoDAF guide most DoD Acquisitions

Architectural Models

- Model Based Systems Engineering “models” the architecture
  Replaces documents with models
  - SySML is a schema that captures and stores system data
  - Architecture tool is the workhorse that facilitates views
- Executable Architectures (EA)
  - computer simulations that utilize elements pulled directly from the architecture database to drive results
  - *usually* performance based simulations
- Modeling and simulation has always been the heart of systems engineering
  - Goes beyond MBSE and EA

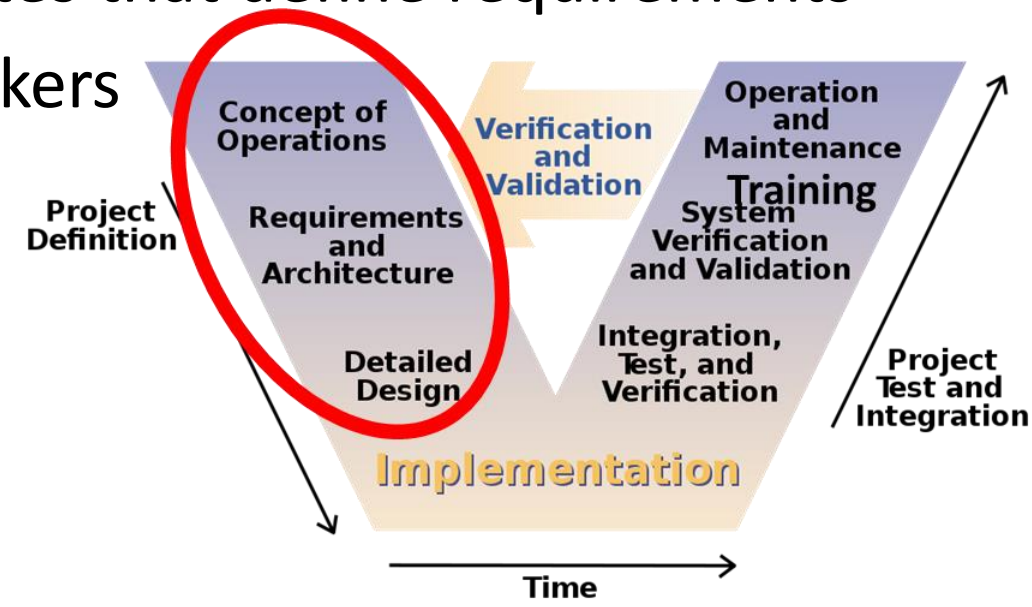


Systems Engineering **REQUIRES** MS&A Beyond MBSE

ANALYSES
WITH AN ACQUISITION FOCUS

Goal of analysis

- Identify, clarify, validate needs or requirements
- Assess architecture(s) to meet operational needs
- Identify key attributes that define requirements
- Inform decision makers



Modeling & simulation facilitates analysis

Analysis application

- (Military) Utility
  - Means for determining mission prioritization
  - Compare and contrast concept impact on final outcome
  - Compare apples-to-fruit pie
- Effectiveness
  - Means for Concept of Operations development
  - Compare and contrast design concepts
  - Can compare apples-to-oranges
- Performance
  - Means for “system” design
  - Compare and contrast similar systems
  - Can compare apples-to-apples

Use right level of analysis to answer questions

Capability Based Assessment

- Capability Based Assessment comprised of performance, effectiveness, and utility
- Capability is any combination of attributes, performance, effectiveness, and utility that describes or measures the level of operation or function of a material, sub-system, system
- Capability was the only term used in defense analysis until 1965

Stakeholder needs

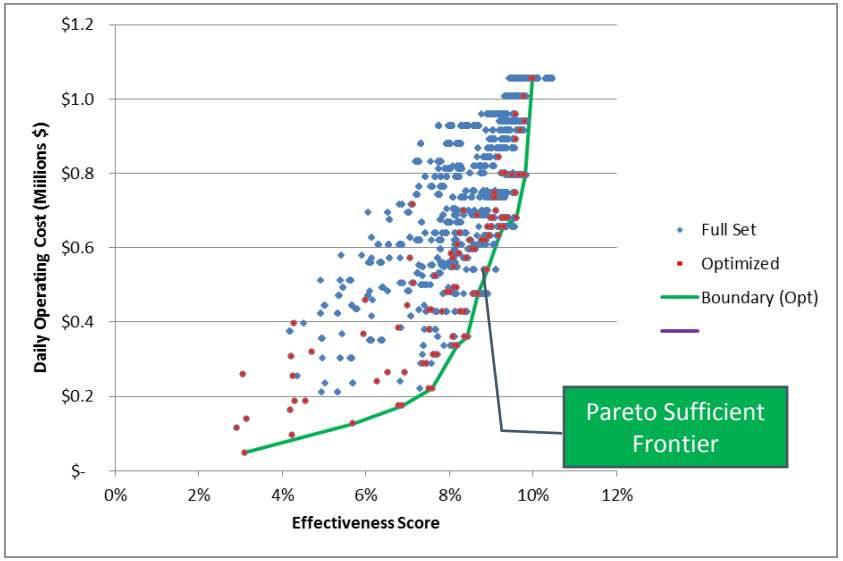
- Stakeholders (generally) do not have requirements, they have wants and needs
- Identify potential gaps with Quality Functional Deployment analysis (aka House of Quality)
- Establish needs statement
  - Gap/Overlap Utility Analysis
  - Military Utility Analysis can quantify mission mix
  - DoD: Initial Capabilities Document (ICD)
- Develop concepts to address needs
  - Initially supported by performance analysis
  - Optimized using effectiveness analysis
  - Balanced using utility analysis

Requirements

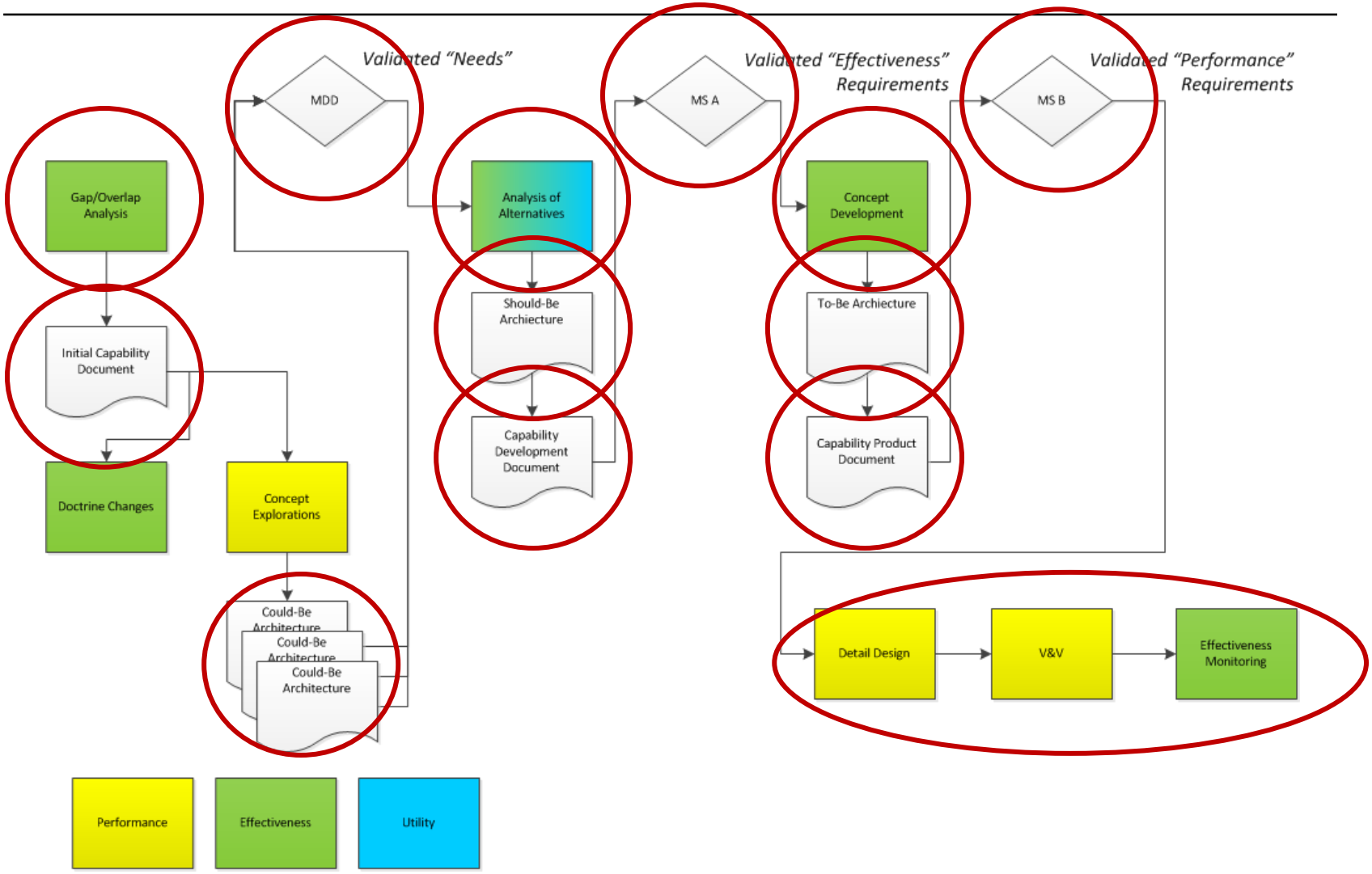
- A requirement is a documented formal statement that specifies a characteristic, attribute, capability, constraint, or quality of a system that meets stakeholder need to perform a particular function or service.
- The technical requirements must also be completed by deriving the additional requirements and constraints that affect the system and its cost and risk over its life cycle such as the threat, natural environment, and policy and legal constraints.
- There are different types of technical or engineering requirements. The common categories are:
  - Architectural requirement
  - Functional requirement
  - Non-functional requirement
  - Derived requirement
  - Performance requirement
  - Constraint

Cost analyses

- Cost-Performance
  - Assesses value based on technological capability
- Cost-Effectiveness
  - Assesses value based on meeting operational capabilities
- Cost-Utility
  - Assess value based on balancing capabilities
- Cost-Feasibility
  - Assess the pecuniary feasibility
- Cost-Benefit
  - Assesses value based only pecuniary motives



Milestones and methods



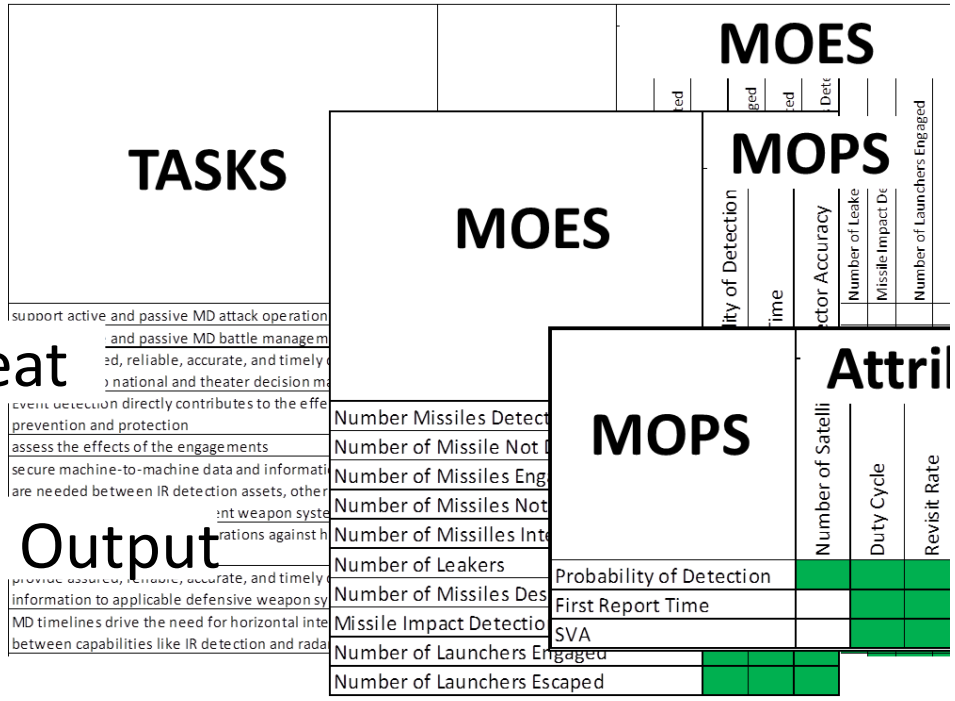
MS&A Taxonomy

Analysis	Measures	Model Type	Scope
	System attributes	Architecture	Static
Performance	Performance	Performance	Fixed Condition
Effectiveness	Effectiveness	Mission	Tactical Operational
(Military) Utility	Objectives	Campaign	Strategic Operational

Capability – any combination of attributes, performance, effectiveness, or utility that that describes the physical or functional ability of a system.

The Analysis Plan

- Prepare a plan like a college lab experiment
  - Authoritative Mission Statement
- Scope of Analysis
- Task->MoO->MoE->MoP->Model Mapping
- Justify Model Selection
  - MoO/MoE/MoP
- Assumptions/Limitations
  - Modeling limitations
  - Scenario/Weather/Threat
- Cost Measures
- Sample Plots of Expected Output
- Could-Be Architectures



Summary

- Apply right levels of analysis to make informed decisions
- Performance **IS NOT** effectiveness
- Use analysis to
  - Increase understanding
  - Refine CONOPS
  - Establish mission level requirements
  - Establish system level requirements
  - Decompose system level requirements
- Reap benefits
  - Validation of the concept or design
  - Reduce Technical risk, cost risk, and schedule risk

Bibliography

- "Analysis of Alternatives (AoA) Handbook," AFMC/A5 Office of Aerospace Studies, June 2013
- "Systems Acquisition Manager's Guide for the Use of Models and Simulations," Defense Systems Management College, September 1994
- "Systems Engineering Handbook 2011," INCOSE, v3.2.2
- "U.S. Army Center of Military History - History of Operations Research in the United States Army, Volume 1: 1942-1962." Ed. Charles R. Shrader. Office of the Deputy Under Secretary of the Army for Operations Research United States Army, 2006
- "U.S. Army Center of Military History - History of Operations Research in the United States Army, Volume 2: 1961-1973." Ed. Charles R. Shrader. Office of the Deputy Under Secretary of the Army for Operations Research United States Army, 2006
- "'What's New' in Requirements, Periodic Refresher Training, " HQ USAF/A5R-P, Pentagon 5E800, Requirement Training; June 2013
- "Requirements Orientation, Air Force Operational Capability Requirements Development," HQ USAF/A5R-P, Pentagon 5E800, Requirement Training; June 2013
- AFSC-TR-65-5, "Weapon System Effectiveness Industry Advisory Committee (WSEIAC) Final Report of Task Group II Prediction – Measurement (Concepts, Task Analysis, Principles Of Model Construction)." January 1965. Air Force Systems Command, United States Air Force.
- Air Force Analyst's Handbook, On Understanding the Nature of Analysis, U.S. Air Force, January 2000
- Box, G. E. P., and Draper, N. R., (1987), Empirical Model Building and Response Surfaces, John Wiley & Sons, New York, NY. P. 424
- CJCSI 3170.01G, Joint Capabilities Integration and Development System, Chairman Of The Joint Chiefs Of Staff, 1 March 2009

Bibliography

- Department of Defense DIRECTIVE Number 5000.59, August 8, 2007
- DoDAF 2.0, “DoD Architecture Framework Version 2.0, Volume 1: Introduction, Overview, and Concepts”, 28 May 2009
- Feuchter, Christopher A. Air Force Analyst’s Handbook, On Understanding the Nature of Analysis, U.S. Air Force, January 2000, p. 41
- Grady Booch, James Rumbaugh, Ivar Jacobson, "The Unified Modeling Language User Guide SECOND EDITION," Addison Wesley Professional, May 19, 2005
- Habayeb, A. R. System Effectiveness. Oxford, England: Pergamon, 1987. Print.
- IEEE Recommended Practice for Architectural Description of Software-Intensive Systems. 2000
- Levin, Henry M., and Patrick J. McEwan. Cost-effectiveness Analysis: Methods and Applications. Thousand Oaks, CA: Sage Publications, 2001.
- Modeling and Simulation (M&S) Glossary, Department of Defense, October 1, 2011
- Morse, Philip K., and George E. Kimball. Methods of Operations Research. Washington, D.C.: Operations Evaluation Group, Office Of The Chief Of Naval Operations, Navy Department, 1946. Print.
- NATO - Joint Analysis Handbook 3rd Edition
- SBIRS Engineering Acronym Dictionary
- Shabman, Leonard. "Making Benefit Estimation Useful: Lessons from Flood Control Experience." Diss. Virginia Tech, 1997. Journal of Contemporary Water Research & Education (1997): n. pag. Print.
- SMC Systems Engineering Primer & Handbook, Volume 1, 4th Edition, 11 March 2013

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- Performance **IS NOT** effectiveness
- Use analysis to
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  - Refine CONOPS
  - Establish mission level requirements
  - Establish system level requirements
  - Decompose system level requirements
- Reap benefits reduced risk
  - Technical, cost, schedule

Bibliography

- The American Heritage Dictionary
- USAFHQ, “Air Force Standard Analysis Toolkit and Analysis Approach,” DTIC ADA497516
- WSEIAC AFSC-TR-65-4 - Volume III, FINAL REPORT of TASK GROUP IV, COST-EFFECTIVENESS OPTIMIZATION, 1964