Certified Modeling and Simulation Professional

Professional Development Workshop

2 December 2022

Ivar Oswalt, PhD CMSP

The MIL Corporation

0800

! BOTTOM LINE UP FRONT !

- CMSP is the only comprehensive M&S professional certification in the U.S.
- It provides differentiation, community awareness, specialized networks, and membership benefits
- Its Reinvention culminated at I/ITSEC 2021 with the launch of CMSP 3.0
- Improvements incorporated streamline the processes, provide four levels, update the examination, and are creating a vibrant community of practice
- *All M&S practitioners seeking to enhance their credentials and to add a level of distinction to their qualifications - from Intern, Apprentice, Practitioner, and Master Levels - will find this PDW informative and valuable*

WORKSHOP OUTLINE

- Learning Objectives
- Introductions
  - Acknowledgements
- Role of M&S and CMSP
- Certification Exam
  - Philosophy
  - Overview
  - Tracks and Topics / Subtopics
  - Tips, Techniques, and Timeline
- Overview of Topics / Subtopics
  - M&S Types, Applications,…
- The “Type is Right” Game
- Certification Exam
  - Sample Questions
- Review
  - Topics
- CMSP Current Events
- Jeopardy Game

- Course Evaluations

LEARNING OBJECTIVES

- After this PDW, Attendees will be able to:
  - Describe CMSP's Motivation / Origin and Development
  - Articulate the Ways CMSP Could Benefit their Career Progression
  - Recount the Process for Becoming a CMSP
  - Define CMSP Levels and Types of Questions to be Asked on the Exam
  - Characterize Key Features and Functions of M&S and Supporting Processes
  - Demonstrate, via Gaming Simulations Knowledge of M&S Fundamentals

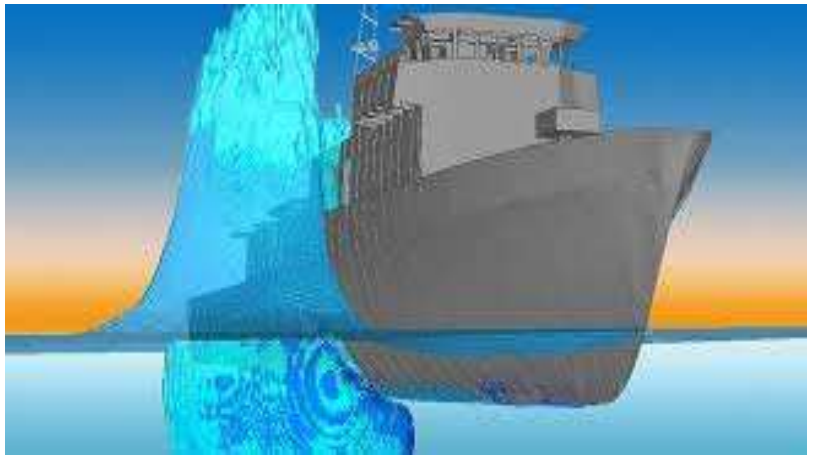
  - ***Successfully Apply, Pass the Appropriate Exam, and Become a CMSP of the Type that Matches Your Qualifications and Experience***

INTRODUCTIONS

- **Ivar Oswalt**
  - 30+ Years of M&S experience, supporting the Navy's M&S Office, DoD M&S Office, NRL, etc.
  - PhD in 1989, CMSP in 2019, NET+ in 2022
  - *Simulation-Based Trainings Incorporation of ML*, MODSIM Best Paper and I/ITSEC BFATG 2019
  - *Operationalizing AI in Simulation Based Training*, I/ITSEC 2021
  - The Modeling and Simulation Profession, John Wiley & Sons, 2017 - Chapter Contributor, e.g., Observations on ROI
  - *Calculating ROI for U.S. DoD M&S*, Hirsch Prize Recipient, ARJ, 2011
  - Currently: DON M&S and VV&A Management SECNAVINST, NMSO PP&S, NRL VV&A Support
- **Around the Room**

- I'm Motivated To Go From...

- To...



ACKNOWLEDGEMENTS

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- Mr. Bill Waite, President, The AEgis Corporation
- Mr. William V. Tucker, Boeing
- Ms. Margaret Callahan, The MIL Corporation
- Mr. Daryl Wynn, NSWC DD DNA

ROLE OF M&S

- Provides assessment without operating or destroying expensive items
- Creates immersive training environments that are otherwise impossible
- Enables the analysis of extremely complex multi-variate problems
- Forecasts the future state of incredibly complex processes
- Allows the controlled examination of items within secure multi-spectral environments
- Increasingly, M&S learns!

"Science used to be composed of two endeavors, theory and experiment. Now it has a third component: computer simulation, which links the other two." [Colwell, 1999] [Colwell, 2000]

Rita R. Colwell, Ph.D.
Director, NSF
1998-2004

ROLE OF CERTIFICATION

- Certification is the formal confirmation of particular characteristics of a person or organization and is normally provided by an external review, education, assessment, or audit
- Examples Include: Certified Public Accountant (CPA), Professional Engineer (PE), Project Management Professional (PMP), and Network+ (NET+) IT Professional
- Professional Rationale: Certification helps to establish the legitimacy of any occupational field and to standardize the quality of its membership
- Organizational Rational: Certification helps to demonstrate the qualifications / discriminators of an entity (Corporation, Research Center, etc.)
- Personal Rational: Certification demonstrates and individual's commitment to superior professionalism, upholding industry standards, and continued learning

ROLE OF CMSP

- Is a sign of distinction and increasingly formally recognized
  - Within the leadership of the M&S community
  - Within draft DoD and Service M&S Procurement Guidelines
- Increasingly delivers a supportive and career enhancing community
  - CMSP Quarterly Newsletter, Mentorship Program, Local and Regional Events
  - CMSP Member Children Scholarship Being Developed
- Communicates an indicator of currency
  - Publications, presentations, CEUs required for renewal

DESCRIPTION & REQUIREMENT AREAS

- The CMSP is a professional certification, governed by NTSA and administered by the M&S Professional Certification Commission
- It designates individuals who have attained knowledge and experience in M&S – ***the extent to which varies by level***
- Requirements for certification are:
  - Evidence of sufficient M&S education/experience and Skills/Knowledge form
  - Supporting references forwarded from professional colleagues
  - Passing an examination
  - Signing a statement of ethics
  - Paying application fee
- CMSP is good for 4 years, after which recertification is required
  - Continuing education, papers, presentations, etc.
  - Paying a fee

EXAM PHILOSOPHY

- Ensure that successful candidates have an appropriate and representative understanding of the full spectrum of M&S
- Designed to be a challenging trial to garner respect and credibility and to demonstrate professionalism
- Degree of exam difficulty is targeted to level of certification being sought – Intern, Apprentice, Practitioner, or Master – and includes proctored and take-home types
- Study is required to successfully complete the examination
- But part of the intent, especially for Practitioner and Master, is that applicants will research and learn new M&S knowledge

EXAMINATION OVERVIEW

- Scope is defined by a consensus-based M&S Body of Knowledge (BoK)
- Composed from 1K+ questions drawn from all BoK topics and subtopics
- Every question is traceable to a published, publicly-available, and peer-reviewed source
- Each candidate is provided an automatically generated exam instance consisting of questions selected from the question bank
- The exam instances are customized by level
- An on-line learning management system allows candidates to take the exam conveniently
- Each exam type requires a 70% score to pass (skipped questions are scored as incorrect)

EXAMINATION DETAILS

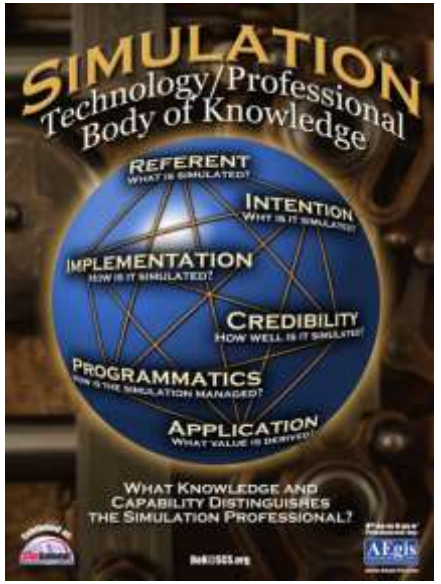
- Apprentice applicants will take Part I to complete the Apprentice level exam. Part I consists of 40 multiple choice questions. You will have four hours to complete the Apprentice exam.

- Practitioner applicants will take Part I and Part II to complete the Practitioner level exam. Each part of the Practitioner exam consists of 40 multiple choice questions for a total of 80 questions for both parts. You will have four hours to complete Part I and six hours to complete Part II. Part II must be completed within seven days of completing Part I.

- Master applicants will take Part I, Part II, and Part III to complete the Master level exam. Each part of the Master exam consists of 40 multiple choice questions for a total of 120 questions for all three parts. You will have four hours to complete Part I, six hours to complete Part II, and eight hours to complete Part III. All three parts must be completed within 14 days of beginning Part I.

EXAM TOPICS AND SUBTOPICS

- Intent
  - Include topics spanning the M&S Body of Knowledge (BoK)
- Structure
  - 8 topics, 54 subtopics
- Content:
  - Initially based on SimSummit M&S Body of Knowledge Index
  - Revised per expert recommendations
  - Revised per source availability and topic testability



CERTIFICATION TOPICS AND SUBTOPICS

1. **Concepts and context**
1.1 Fundamental terms and concepts
1.2 Categories and paradigms
1.3 History of M&S

2. ***Applications***
2.1 Training
2.2 Analysis
2.3 Experimentation
2.4 Acquisition
2.5 Engineering
2.6 Test and evaluation

3. ***Domains / Question Context***
3.1 Combat and military
3.2 Aerospace
3.3 Medicine and health care
3.4 Manufacturing and material handling
3.5 Logistics and supply chain
3.6 Transportation
3.7 Computer and communications systems
3.8 Environment and ecology
3.9 Business
3.10 Social science
3.11 Energy
3.12 Other domains of use

4. ***Modeling Methods***
4.1 Stochastic modeling
4.2 Physics-based modeling
4.3 Structural modeling
4.4 Finite element modeling and CFDs
4.5 Monte Carlo simulation
4.6 Discrete event simulation
4.7 Continuous simulation
4.8 Human behavior modeling
4.9 Multi-resolution simulation
4.10 Other modeling methods

5. ***Implementation***
5.1 Modeling and simulation life-cycle
5.2 Modeling and simulation standards
5.3 Development processes
5.4 Conceptual modeling
5.5 Specialized modeling and simulation languages
5.6 Verification, validation, and accreditation
5.7 Distributed simulation and interoperability
5.8 Virtual environments and virtual reality
5.9 Human-computer interaction
5.10 Semi-automated forces/computer generated forces
5.11 Stimulation

6. **Supporting tools, techniques, and resources**
6.1 Major simulation infrastructures
6.2 M&S resource repositories
6.3 M&S organizations

7. **Business and management of M&S**
7.1 Ethics and principles for M&S practitioners
7.2 Management of M&S projects and processes
7.3 M&S workforce development
7.4 M&S business practice and economics
7.5 M&S industrial development

8. **Related communities of practice and disciplines**
8.1 Statistics and probability
8.2 Mathematics
8.3 Software engineering and development
8.4 Systems science and engineering

EXAM TIPS / TECHNIQUES / TIMELINE

- Complete pre-requisites: Application, References, Etc.
- Pick Level — *Consider your strengths and limitations…*
- Pick Start Time — *Consider your time commitments, etc.!*
- Gather Up Source Material
- Start
- Finish

My Suggestions…

- Skim
- Segregate
  - Easy, Medium
  - Hard, Super Hard
- Answer
  - Normal Question Strategies Apply
- Submit

- Read the entire question
- Answer questions you know first
- Eliminate wrong answers
- Look for words from the question in the answers
- Select the best answer
- Read every answer option
- Make an educated guess

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FIRST - WHY DO WE NEED M&S ?

- Typically, M&S is performed to generate data to support a decision maker or an activity

- M&S can be used to provide data to support studies to:
  - **Describe** how systems could, would, or do operate
  - **Predict** how much a system will cost, or how many units will be required, or the effects of a change
  - **Predict** the effect of changes to the system
  - **Prescribe** best approach to a problem or condition

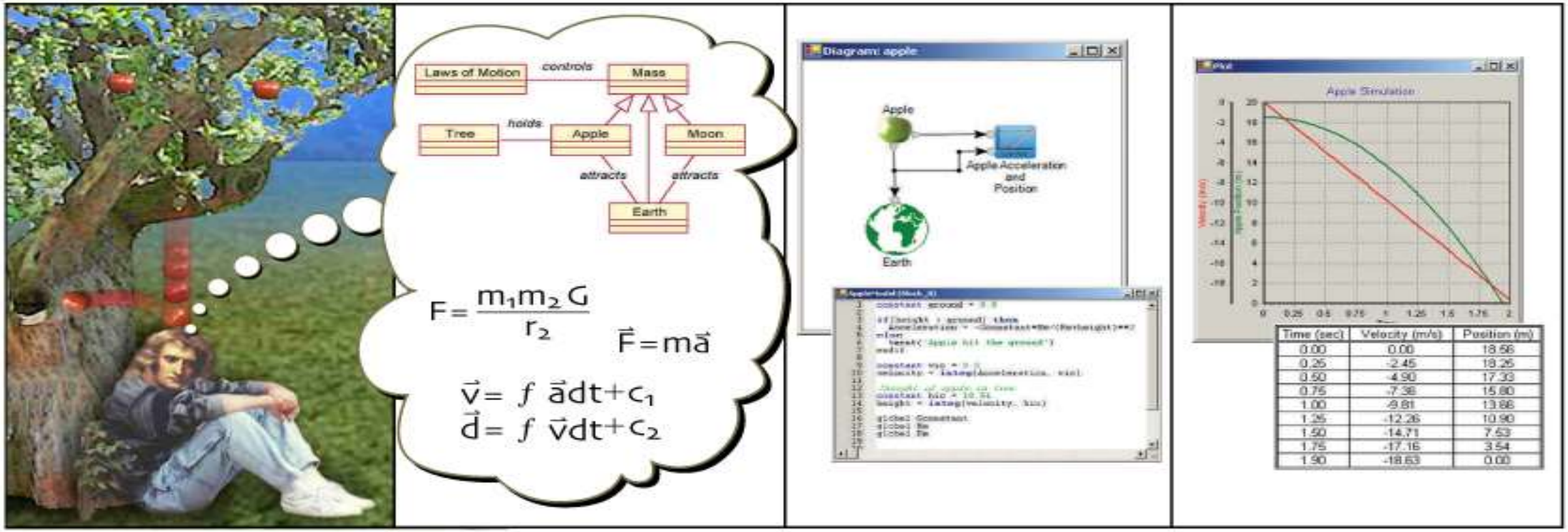
- Why not use the real system?
  - Not yet available
  - Too dangerous or expensive to use
  - ***Live tests can be destructive***
  - Need to simulate system under unusual or undesirable environmental conditions
  - Need to analyze randomness in a system
  - Impossible to observe internal processes

TOPIC 1: CONCEPTS AND CONTEXT

- Essential terminology, foundational concepts, community consensus categorizations, and overarching modeling paradigms; history of the development and use of M&S.

1. Concepts and context
   - 1.1 Fundamental terms and concepts
   - 1.2 Categories and paradigms
   - 1.3 History of M&S

FOUNDATIONAL CONCEPT - ABSTRACTION



Real World | **Conceptual Model** | **Simulation** | **Analytical Results**

- *How would you define each step?*

FOUNDATIONAL CONCEPT - DEFINITIONS

- **Model**: A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process
- **Conceptual Model**: An implementation neutral (simplified) representation of a system that provides a bridge between the developer and the user
- **Simulation**: A method for implementing a model over time
- **Game**: A form of competitive play or sport, governed by rules, for entertainment or learning
- **M&S Includes**: Emulators, prototypes, simulators, stimulators, appended trainers, etc.
- **Monte-Carlo Simulations**: Uses (pseudo) random samples of parameters or inputs to explore complex behavior
- **Distributed or Federated Simulations**: Geographically remote simulations acting against each other in an LVC environment
- **Live Simulation**: Real people operating real systems in a synthetic environment
- **Virtual Simulation**: Real people operating simulated systems in a synthetic environment
- **Constructive Simulation**: Simulated people operating simulated systems in a simulated environment
- **Parametric**: System-level represented by a set of generic algorithms and data structures
- **Engineering**: Captures component functionality rather than the details of signal processing
- **Emulative**: Sub-component / signal processing level of detail sufficient to support detailed analysis

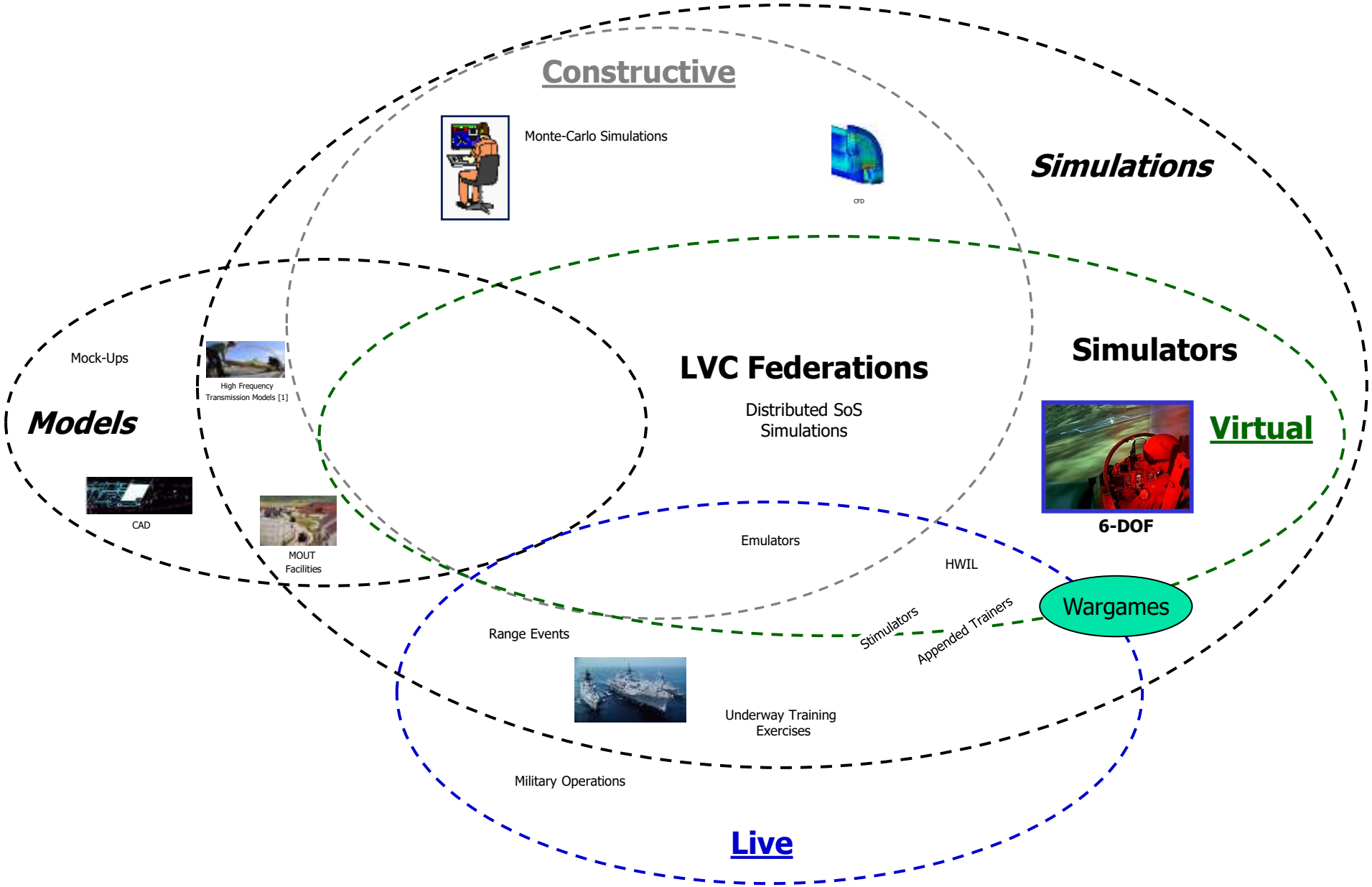




FOUNDATIONAL CONCEPTS – VENN DIAGRAM

Where do M&S Systems that you know fit?

Wargames?



M&S HISTORY

The1942 model C-3 Link Trainer was manufactured by Link, an organ and player piano maker. It was used by the allies during World War II to train pilots to fly using only instruments. During World War II, 6271 Link trainers were delivered to the Army and 1045 to the Navy. The Link trainers were also used by 35 foreign countries. Movement of the trainer is accomplished by vacuum operated bellows, controlled by valves connected to the control wheel (or stick) and rudder pedals. An instructor sat at the desk and transmitted radio messages which the student in the Link heard through his earphones.

So:

- What has changed?
- What has NOT?

Puppets

Simple 6DOF

Simple PC

Multiple PCs+

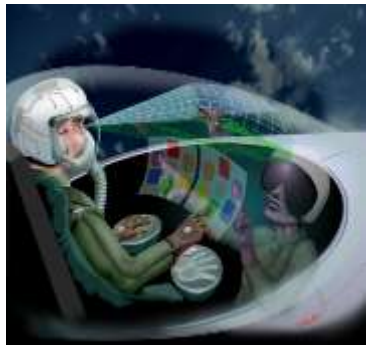
PC Cockpit and Visuals

PC Cockpit and 3 Visuals

Emulated Cockpit and Visuals

6DOF and Visuals

Multiple 6DOFs and Visuals+



6DOF, Visuals+, Associates

A/C Plus Other Warfare Areas

Plus Multi-Echelon C2

FOUNDATIONAL CONCEPT – MORE DEFINITIONS

- **Simuland**: The object, process, system, or phenomenon to be simulated. For instance, in mannequin-based patient simulators, the simuland is a human patient
- **Calibrate:** To calibrate a model is to determine reasonable values for critical model parameters
- **Referent**: A codified body of knowledge about a thing being simulated
- E.g., Validation Referent: Is the best or most appropriate codified body of information available that describes characteristics and behavior of the reality represented in the simulation
- **Constraint Model**: Constraint-based modeling is a scientifically-proven mathematical approach, in which the outcome of each decision is constrained by a minimum and maximum range of limits
- **Conceptual Model**: Conceptual modeling is the abstraction of a simulation model from the real-world system that is being modeled and describing it in an implementation neutral manner
- **Functional Model**: Is a (graphical) representation of a system. Each building block represents a discrete function. The inputs and outputs flow in and out of the system and between functions.
- **Declarative Model**: Uses symbolic expressions to represent models. With such expressions, it is possible to formalize high-level mathematical models that would be difficult or impossible to perform directly on a lower-level simulation program
- **Agent Based Model**: Agent models are generally top-down, with the model focusing on the overall collective behavior of the set of agents

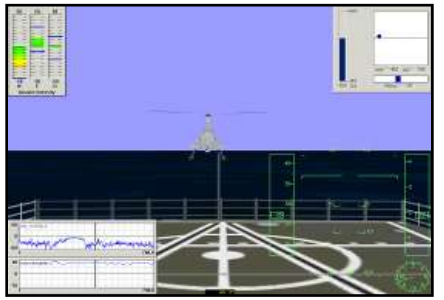




TOPIC 2: APPLICATIONS OF M&S

- Important and cross-cutting M&S application types; modeling methods and organizing principles for each.

2. Applications of M&S
   - 2.1 Training
   - 2.2 Analysis
   - 2.3 Experimentation
   - 2.4 Acquisition
   - 2.5 Engineering
   - 2.6 Test and Evaluation



Digital Modeling

Hardware In-The-Loop

Systems Test and Measurement Facilities

Flight Testing
Open Air Training

TRAINING

M&S used to produce learning results for a user or participant

- Realistic enough to produce useful skills or knowledge
- ***Safer***, more forgiving of mistakes
- Encounter unusual and/or dangerous situations

MUCH SAFER, BUT…

- In October 1992, the TCG Muavenet, a Turkish Navy Destroyer was crippled by two Sea Sparrow missiles
- These missiles were launched from the USS Saratoga during a NATO Exercise
- Senior officers on watch on the Saratoga decided to take advantage of the NATO exercise to rehearse the procedures for responding to a simulated attack, according to the Navy investigation
- The American sailors, awakened late at night, mistook a drill for an actual attack
- The result was the killing 5 Turkish sailors and the wounding of 15

ANALYSIS

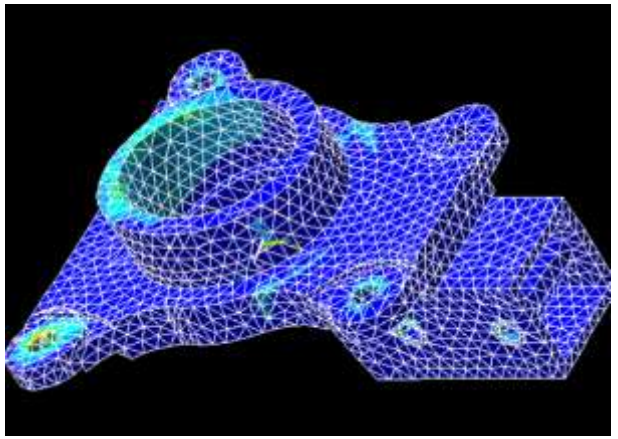
- M&S used to define / understand, predict, or assess a real or notional system or idea
- To answer questions
- Repeatability often desirable
  - To avoid confounding variability
- Careful experimental design
-
  - Trials planned in advance to cover cases
  - Multiple trials for statistical significance

JCATS, Wurtsmith AFB

ENGINEERING

- M&S used to develop, analyze, or test an engineering design

- Model artificial systems and components
- Models are physics-based, no “behavior”
- No virtual environment or simulators
- User not expected to benefit from experience of execution
- Primary goal: Generate useful information



FEM of a bracket

5 Min

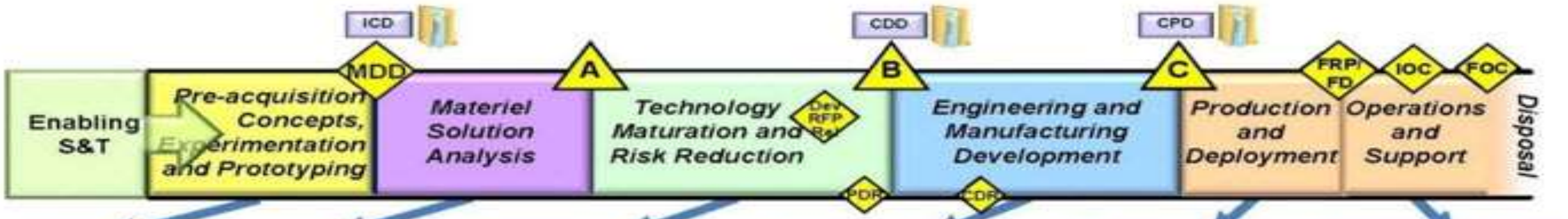
https://www.facebook.com/NUWCNewport/videos/the-matrix-the-weapons-analysis-facility/10151096373222083/

TEST AND EVALUATION

- M&S can be a source of additional test “data” when actual testing is:
  - Too expensive or impractical to conduct
  - Too dangerous to conduct
  - Prohibited by treaties, laws, or policies
- Result in savings in cost, schedule, and/or number of test articles
- Can provide higher confidence levels due to having more data

- But…
  - Accuracy - M&S cannot fully replicate live T&E
  - Real world outcomes dependent on interactions which are complex and difficult to fully understand, quantify and model
  - M&S can be very expensive to develop, especially for first user
  - M&S is not a replacement for testing - By law, OE & OS cannot be evaluated solely via M&S
  - VV&A can be very expensive and time consuming

M&S ACROSS THE ALC



Analysis of Alternatives

- Concept of Operations (CONOPS) modeling
- Cost / schedule / performance trades
- System interoperability discoveries
- Portfolio coverage analysis

Analysis of Alternatives

- Assess materiel solutions
- Estimate life cycle costs
- Model CONOPS and mission context
- Interoperability and warfighter integration analysis
- Industrial / manufacturing capability analysis
- Supportability and sustainment modeling

Technology Maturation and Risk Reduction

- Trade studies
- System threat integration
- Model environment and demonstrate technology
- Interoperability and supportability analysis
- Operational suitability and affordability
- Industrial / manufacturing capability and readiness assessment
- Estimate manpower/cost
- Model system to performance specifications
- T&E planning
- Human interface prototyping

Develop Affordable and Executable Manufacturing Process

- Ensure operational supportability
- Reduce logistics footprint
- Survivability analysis
- Human Systems Integration (HSI)
- Design for producibility
- Demonstrate system safety
- Verify functionality and performance to specifications/needs
- Manpower estimates

Manufacturing Development

- Industrial / manufacturing readiness assessment
- Environment, Safety, and Occupational Health (ESOH) models
- Military equipment valuation
- Corrosion prevention and control
- Refine LCSP
- Production qualification testing
- Verify and validate production configuration
- Economic analysis

Post-Production Support

- Supply chain management
- Monitor performance and adjust product support
- Training
- Supportability assessments
- Disposal planning
- Validate failures and determine root causes
- Determine system risk / hazard severity
- ECP impact analysis

AoAs

TOPIC 3: DOMAINS OF USE OF M&S

- Domains in which M&S has found wide use; key modeling methods and applications for each.

3. Domains of use of M&S
   - 3.1 Combat and Military
   - 3.2 Aerospace
   - 3.3 Medicine and Health Care
   - 3.4 Manufacturing and Material Handling
   - 3.5 Logistics and Supply Chain
   - 3.6 Transportation
   - 3.7 Computer and Comms Systems
   - 3.8 Environment and Ecology
   - 3.9 Business
   - 3.10 Social Science
   - 3.11 Energy
   - 3.12 Other Domains of Use

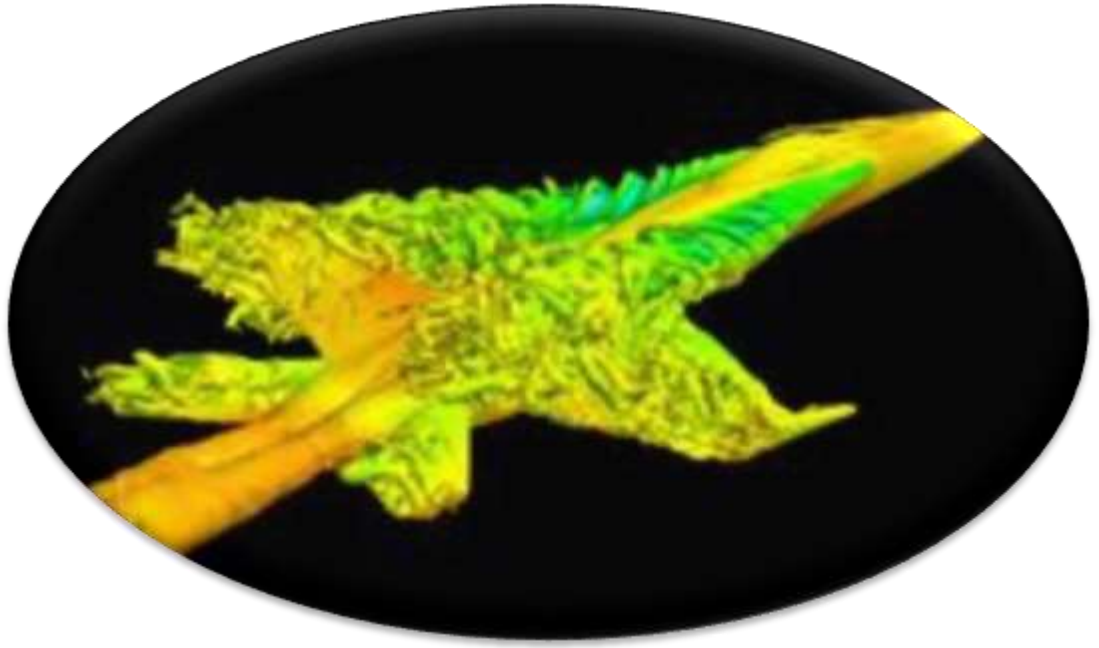
What are some other domains of use?

Cybersecurity
Networking
Chemistry
Biology / Bio-Sciences
City Planning
Construction
Highway Design

TOPIC 4: MODELING METHODS

- Technical aspects of widely used modeling methods; characteristics and suitable applications for each.

- Modeling Methods
  - Deterministic
  - Stochastic Modeling
  - Physics-based Modeling
  - Finite Element Modeling and CFD
  - Monte Carlo Simulation
  - Discrete Event Simulation
  - Continuous Simulation
  - Human Behavior Modeling
  - Multi-resolution Simulation
  - Real-time Simulation
  - Other Modeling Methods



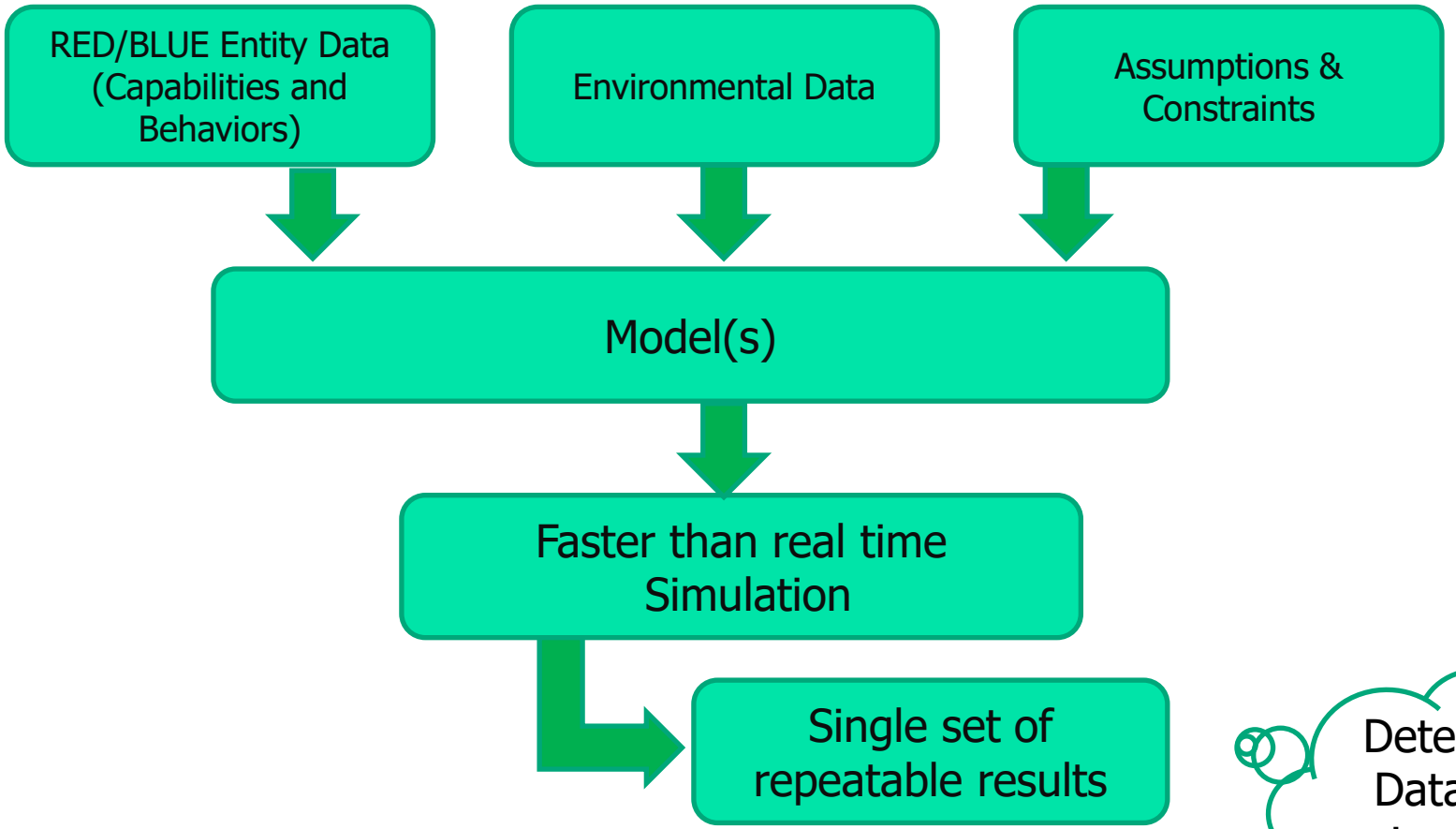
DETERMINISTIC

- Model where a given set of inputs will produce a determined, unique set of outputs

- Example: *Chess*
  - No dice rolls or random elements
  - Same decisions → same results

- Example: Engineering simulation
  - FEM simulation of engine part
  - Physics-based models deterministic
  - Output determined by input

DETERMINISTIC CONSTRUCTIVE SIMULATION



Deterministic Data results in discrete results

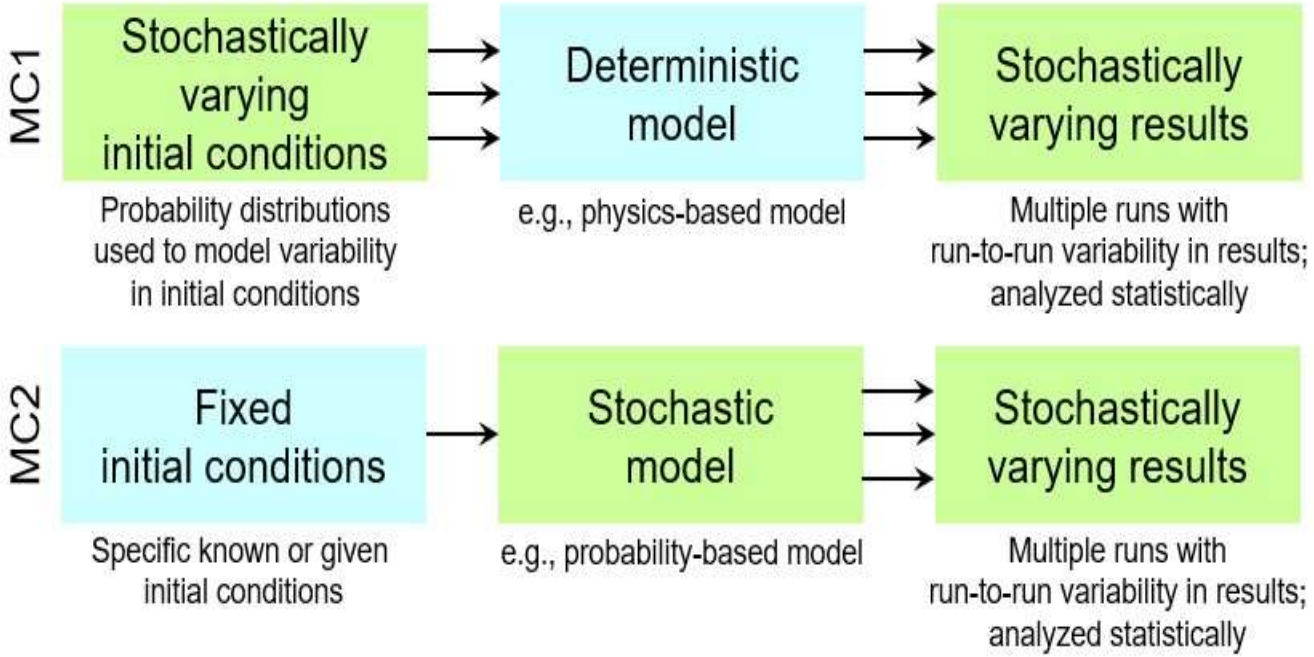
Two Types

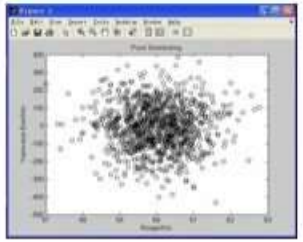
Stochastic initial conditions input to deterministic model

- Randomly generated initial conditions provided as input, model calculates results deterministically

Deterministic initial conditions input to stochastic model

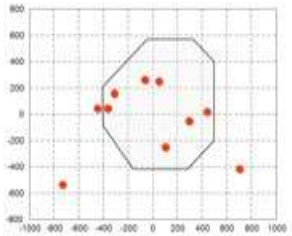
- Given input, model calculates results stochastically to generate physics or process outcomes





MC1
Missile impacts
[Zhang, 2008]

MC2
Bombing accuracy
[BanksJ, 2010]



STOCHASTIC CONSTRUCTIVE SIMULATION

RED/BLUE Entity Data (Capabilities and Behaviors)

Environmental Data

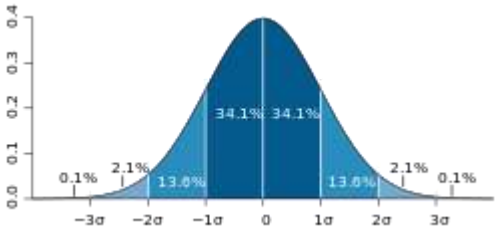
Assumptions & Constraints

Model(s) w/ probability distributions

Faster than Real Time "Monte Carlo" Simulation (100+ replications)

100+ sets of randomly distributed results

Mean, Std Dev, 95% confidence Interval



Stochastic Data results in Probabilistic insights

IMPLICATIONS

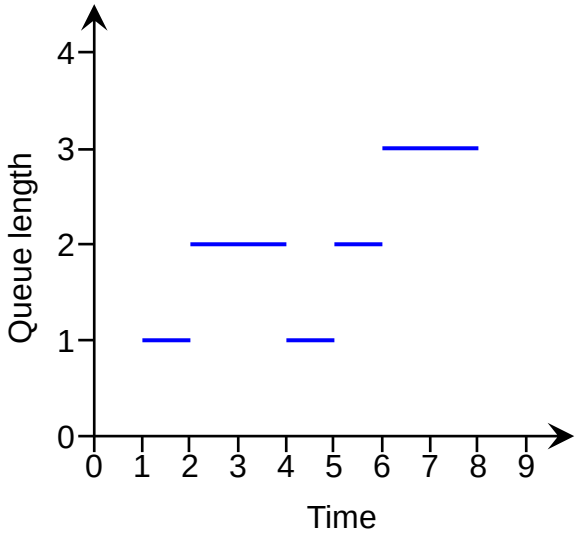
- **Deterministic simulations** are especially useful in training where repeatable scenarios are required to provide consistent synthetic training venues

- **Stochastic simulations** are valuable when there are many sources of uncertainty that interact in unforeseeable ways, e.g., warfare analysis. They:
  - Can be computationally quite complex and normally require more in-depth statistical and computational abilities
  - Can be used for sensitivity and Design of Experiments analysis
  - Represent ~~the~~ real-world variability of inputs and parameters

- **Stochastic simulations** provide analysts and decision makers with “likelihood” information (example: 80% chance of mission success) and enable decision making flexibility

DESCRETE EVENT SIMULATION

- Model state variables change only at a discrete set of points in time (“events”)
- Simulation using discrete models and event handling / event-driven
- E.g., Aircraft launch → Arrives on station → Starts close-air-support

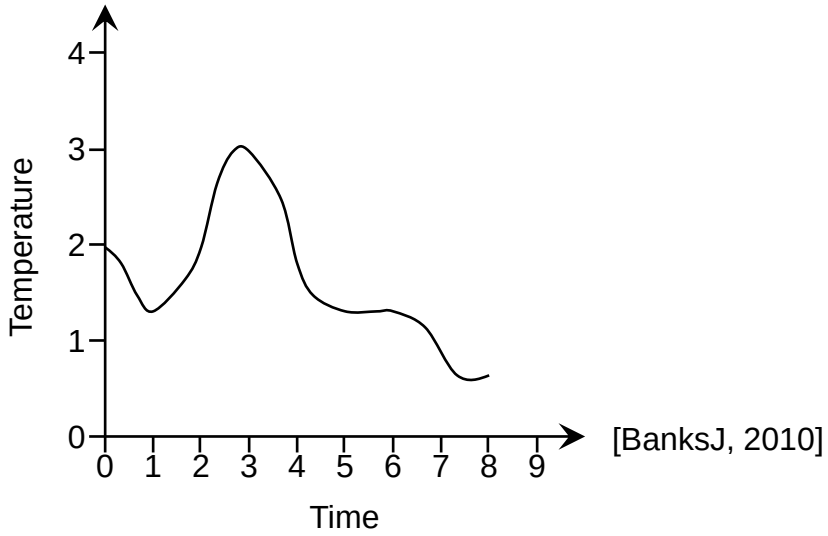


[BanksJ, 2010]

```
t = 0
while t < end_time
    t = time of next event e
    process event e
    possibly schedule future events
endwhile
```

CONTINUOUS

- Model where state variables change (pseudo-) continuously over time. Typically, time advances in small fixed time steps
- AKA “time-stepped” [Banks J, 2010]
- Continuous simulation uses continuous models



[BanksJ, 2010]

```
t = start_time
while t < end_time
    t = t + Δt
    calculate simulation state at t
endwhile
```

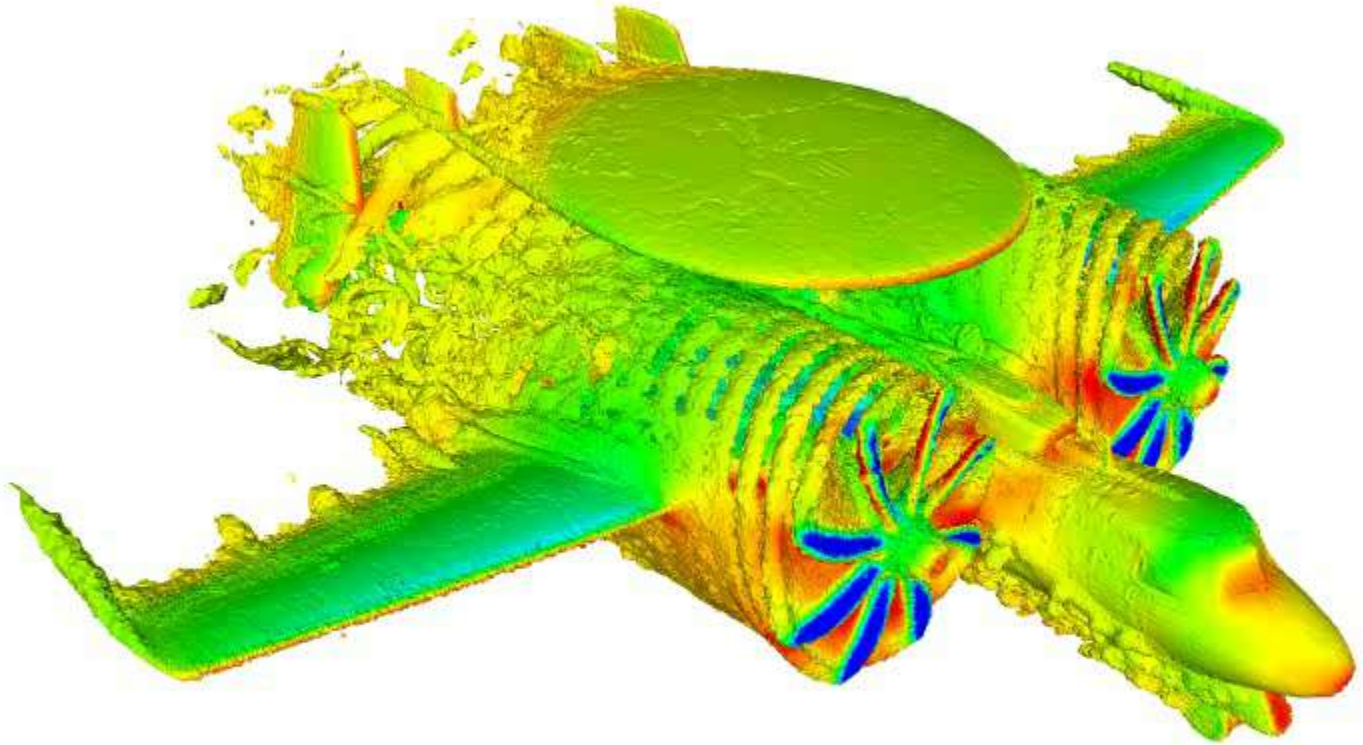
REAL-TIME SIMULATION

- Real-time simulations often include interaction with live components (possibly humans) and interact with real-world systems
  - Yet, the clock might still jump ahead, back, or advance at a faster or slower rate – but the clock is shared among the simulation and the real world

- Example – A flight simulator or a Hardware in the Loop (HWIL) Test Bed

COMPUTATIONAL FLUID DYNAMICS

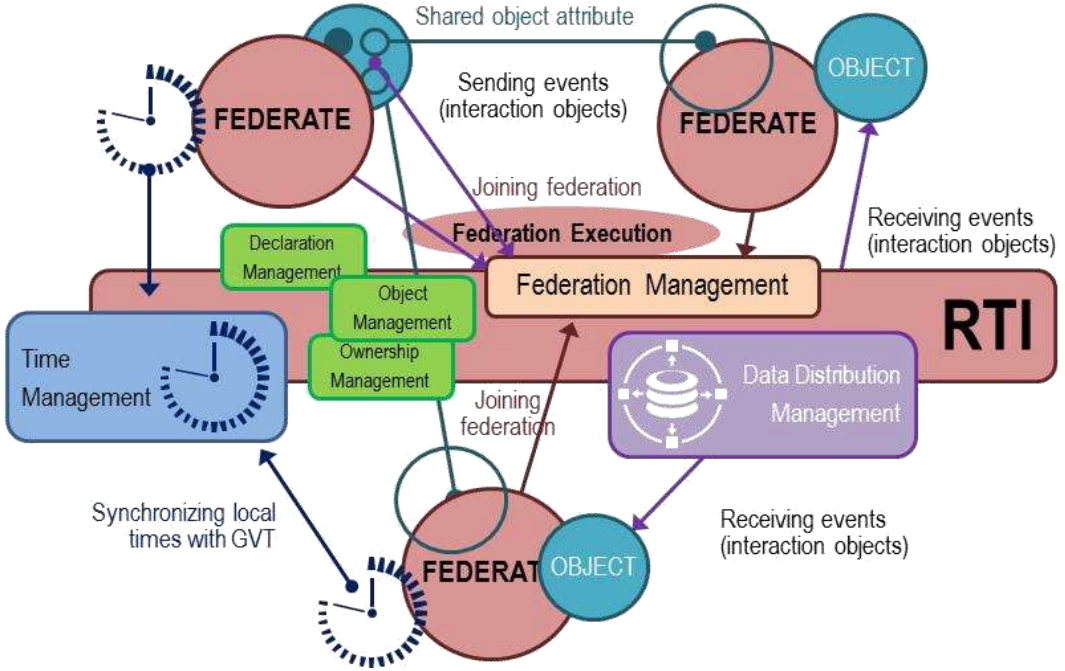
- CFD is the process of mathematically modeling a physical phenomenon involving fluid flow and solving it numerically using high performance computer resources
- The propeller geometry investigated is representative of a modern eight-bladed design for high-speed turboprop transport aircraft



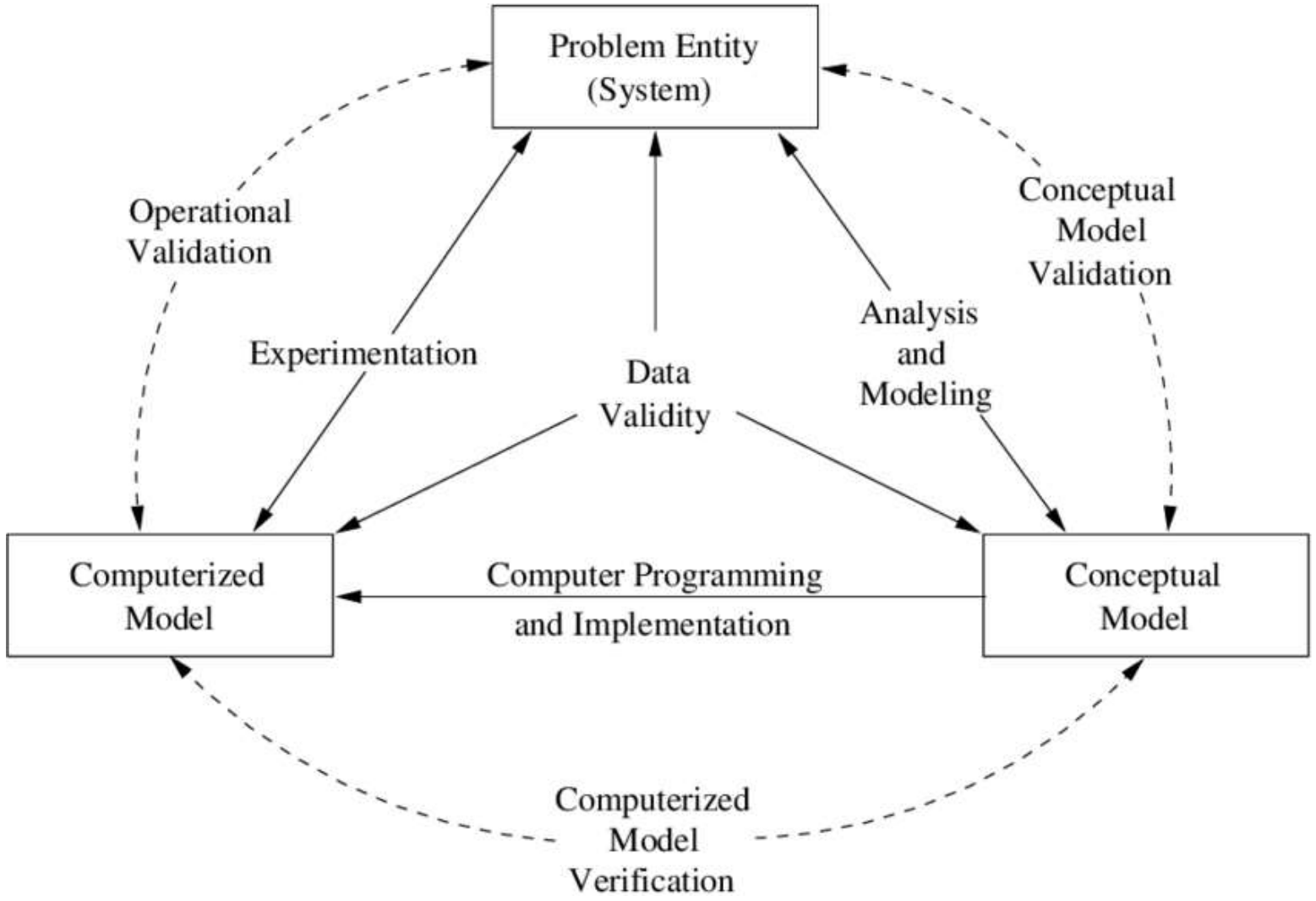
TOPIC 5: SIMULATION IMPLEMENTATION

- Engineering principles and practices for developing and validating M&S systems; M&S standards; special models.

5. Simulation implementation
   - 5.1 Modeling and simulation life-cycle
   - 5.2 Modeling and simulation standards
   - 5.3 Development processes
   - 5.4 Conceptual modeling
   - 5.5 Specialized languages
   - 5.6 Verification, validation, and accreditation
   - 5.7 Distributed simulation and interoperability
   - 5.8 Virtual environments and virtual reality
   - 5.9 Human-computer interaction
   - 5.10 Semi-automated forces
   - 5.11 Stimulation

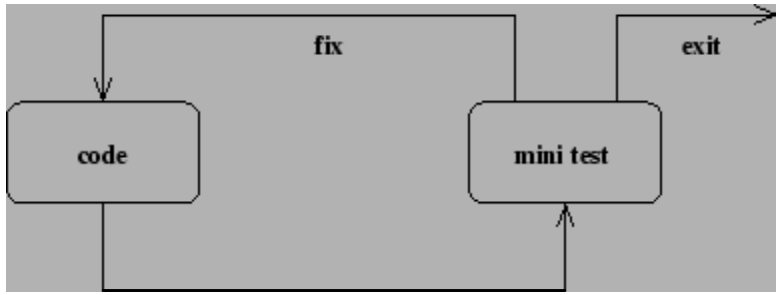


MODEL (M&S) DEVELOPMENT PROCESS



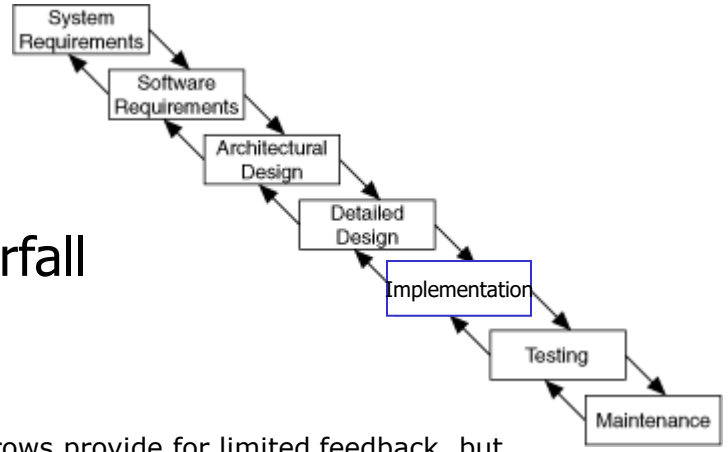
Verification and Validation of Simulation Models, Robert G. Sargent, Simulation Research Group, Department of Electrical Engineering and Computer Science, College of Engineering and Computer Science, Syracuse University, 1998

SOFTWARE (M&S) LIFE-CYCLE MODELS 1 of 2



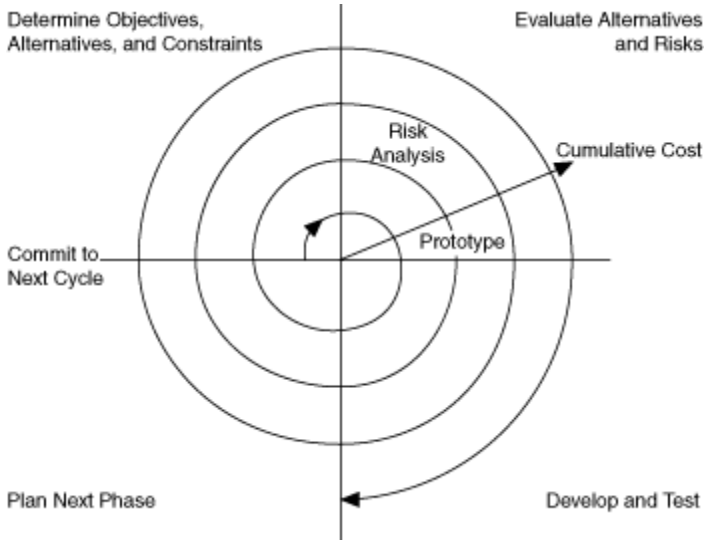
Code & Fix

Problems: No Requirements, No Design



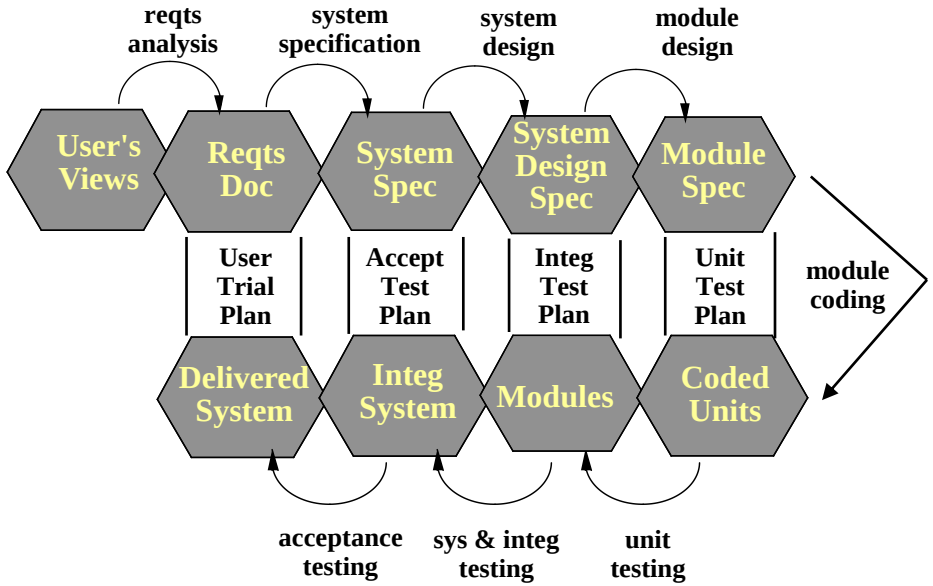
Waterfall

Problem: Arrows provide for limited feedback, but no iterations, and no mechanism for prototyping.



Spiral Model

Notes: Spiral model added iterations and rapid prototyping



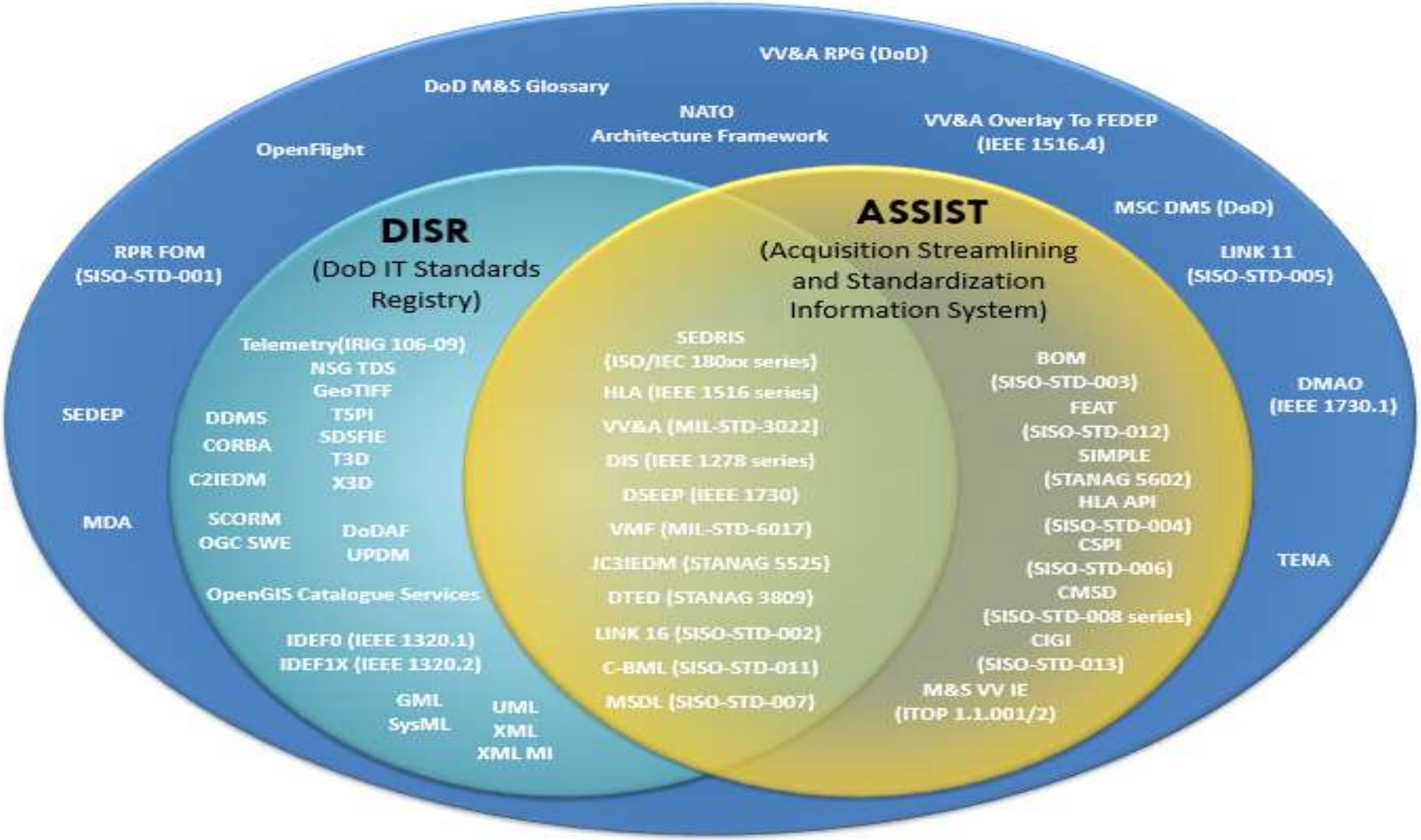
Ould & Unwin

Ould, M. A. and Unwin, C. (1986). *Testing in Software Development*. Cambridge University Press, Great Britain.

SOFTWARE (M&S) LIFE-CYCLE MODELS 2 of 2

- Agile evolved to constantly define and execute small development activities (2-week sprints!)
  - Define requirements, select what seems achievable in short sprint, try to build that piece and test it internally…after many sprints, requirements have been met, deliver
- DevOps evolved from agile to integrate constant testing and delivery of capability to customers/users
- DevSecOps is just the next evolution to include security considerations into the process

M&S STANDARDS



VV&A

- **Verification** is the process of determining that a model implementation accurately represents the developer's conceptual description and specifications.
  - It answers the question, "Did we build it correctly?"

- **Validation** is the process of determining the manner and degree to which a model is an accurate representation of the real-world from the perspective of the intended uses of the model, and of establishing the level of confidence that should be placed on this assessment.
  - It answers the question, "Did we build the right thing?"

- **Accreditation** is the formal certification that a model or simulation is acceptable to be used for a specific purpose. A recognized subject matter expert in the field can accomplish accreditation.
  - Accreditation answers the question, "Does it meet my needs?"

DETERMINING VV&A REQUIREMENTS

Determined/Categorized Requirements According To The Three Pillars of M&S/Tool Credibility

Intended Use

What the M&S shall do…

- **Requirement #1**
- **Requirement #2**
- …
- …
- **Requirement #(n-1)**
- **Requirement #n**

Requirement

ACCEPTABILITY CRITERIA

CAPABILITY REQUIREMENTS

What can the M&S do (the functions) and to what level of detail (fidelity)?

Detailed Functional Decomposition

Clearly Stated Assumptions & Limitations

ACCURACY REQUIREMENTS

How well does the M&S do what it is designed to do and is it relatively error-free?

- *Software Accuracy*
- *Data Accuracy*
- *Output Accuracy*
- *Configuration Management*

USABILITY REQUIREMENTS

What do users need to operate the M&S correctly and without introducing errors?

What are the implications of the Assumptions & Limitations?

RISK ASSESSMENT: *How fit is the M&S system to satisfy the intended use with respect to the specified Capability and Accuracy and Usability?*

Capability

ACCEPTABILITY CRITERIA

But "How Fit"?

Intended Use Components or Aspects?

Likely Employment Environment ?

Degree of Trust or Confidence?

DECISION

VALIDATION

- The validity of the system refers to the relation between the model, simulation, and real world
  - Often thought of as the degree to which a model faithfully represents its system counterpart

- Types of validity:
  - Replicative validity requires that the model and system agree at the I/O level
  - Predictive validity requires the ability to predict new / emergent unseen behavior
  - Structural validity requires that the M&S mimics step-by-step, component-by-component fashion the way in which the system does its transitions.

- Validation is the process of testing the M&S for validity
  - Face Validation - Subject Matter Expert (SME) expectations
  - Benchmarking - Another simulation with established credibility
  - Results Validation - Test Data, Operational Data, Historical Data

- Validation techniques have well-known limitations:
  - Disagreements among SMEs
  - Uncertain benchmark simulation credibility or inadequate fidelity
  - Test data availability, limitations, and cost

DETERMINING VV&A REQUIREMENTS

Determined/Categorized Requirements According To The Three Pillars of M&S/Tool Credibility

Intended Use

What the M&S shall do…

Requirement #1

Requirement #2

…

…

Requirement #(n-1)

Requirement #n

Requirement

ACCEPTABILITY CRITERIA

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Capability

ACCEPTABILITY CRITERIA

But "How Fit"?

Intended Use Components or Aspects?

Likely Employment Environment ?

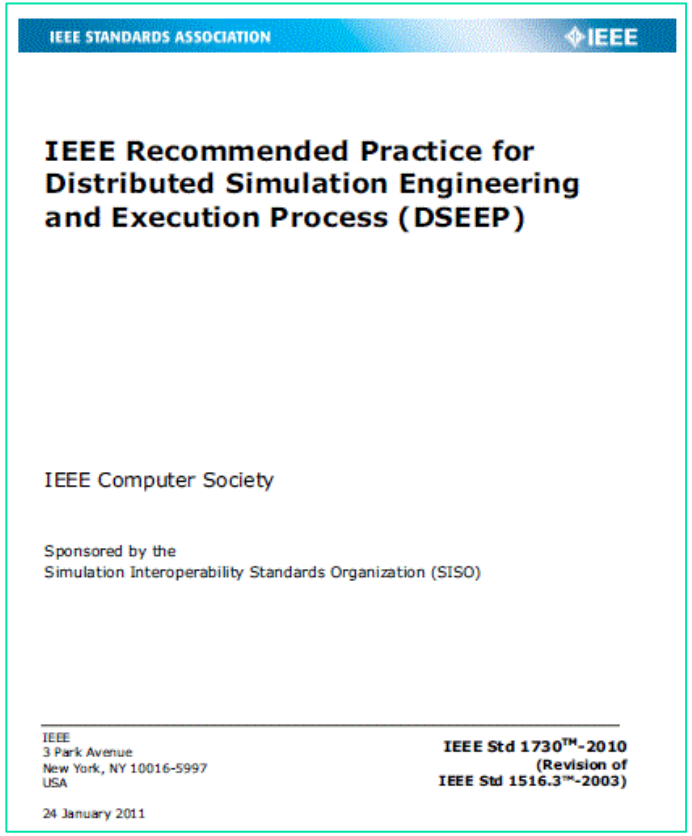
Degree of Trust or Confidence?

DECISION

M&S FEDERATION ENGINEERING STANDARDS

Distributed Simulation Engineering and Execution Process (DSEEP)

- An architecture-neutral, high-level process framework into which the lower-level systems engineering practices native to any distributed simulation user can be easily integrated
- Applies to federation engineering in a single-architecture environment


IEEE STANDARDS ASSOCIATION

IEEE

IEEE Recommended Practice for Distributed Simulation Engineering and Execution Process (DSEEP)

IEEE Computer Society

Sponsored by the
Simulation Interoperability Standards Organization (SISO)

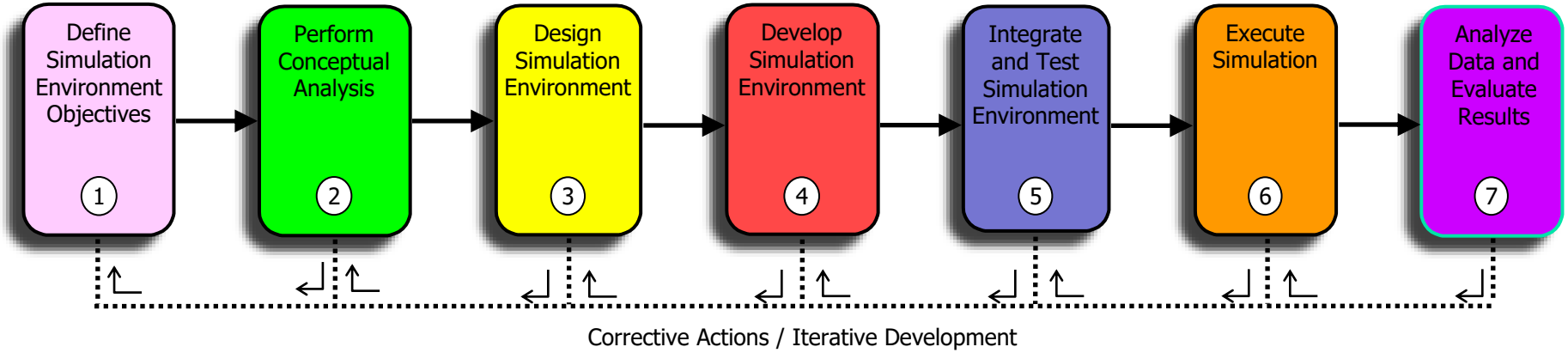
IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 1730™-2010
(Revision of
IEEE Std 1516.3™-2003)

24 January 2011

DSEEP TOP LEVEL VIEW

- The DSEEP was developed based on several, widely-adopted, authoritative systems engineering processes
- These processes were adapted and extended to address engineering requirements unique to distributed simulations



DSEEP ACTIVITIES

Step	(1) Define Simulation Environment Objectives	(2) Perform Conceptual Analysis	(3) Design Simulation Environment	(4) Develop Simulation Environment	(5) Integrate and Test Simulation Environment	(6) Execute Simulation	(7) Analyze Data and Evaluate Results
Activities	Identify User/Sponsor Needs Develop Objectives Conduct Initial Planning	Develop Scenario Develop Conceptual Model Develop Simulation Environment Requirements	Select Member Applications Design Simulation Environment Prepare Detailed Plan Design Member Applications	Develop Simulation Data Exchange Model Establish Simulation Environment Agreements Implement Member Application Designs Implement Simulation Environment Infrastructure	Plan Execution Integrate Simulation Environment Test Simulation Environment	Execute Simulation Prepare Simulation Environment Outputs	Analyze Data Evaluate and Feedback Results

Each major step of the DSEEP consists of multiple activities, each of which has multiple inputs, tasks, and outcomes that must be evaluated during federation engineering.

VIRTUAL ENVIRONMENTS & VIRTUAL REALITY

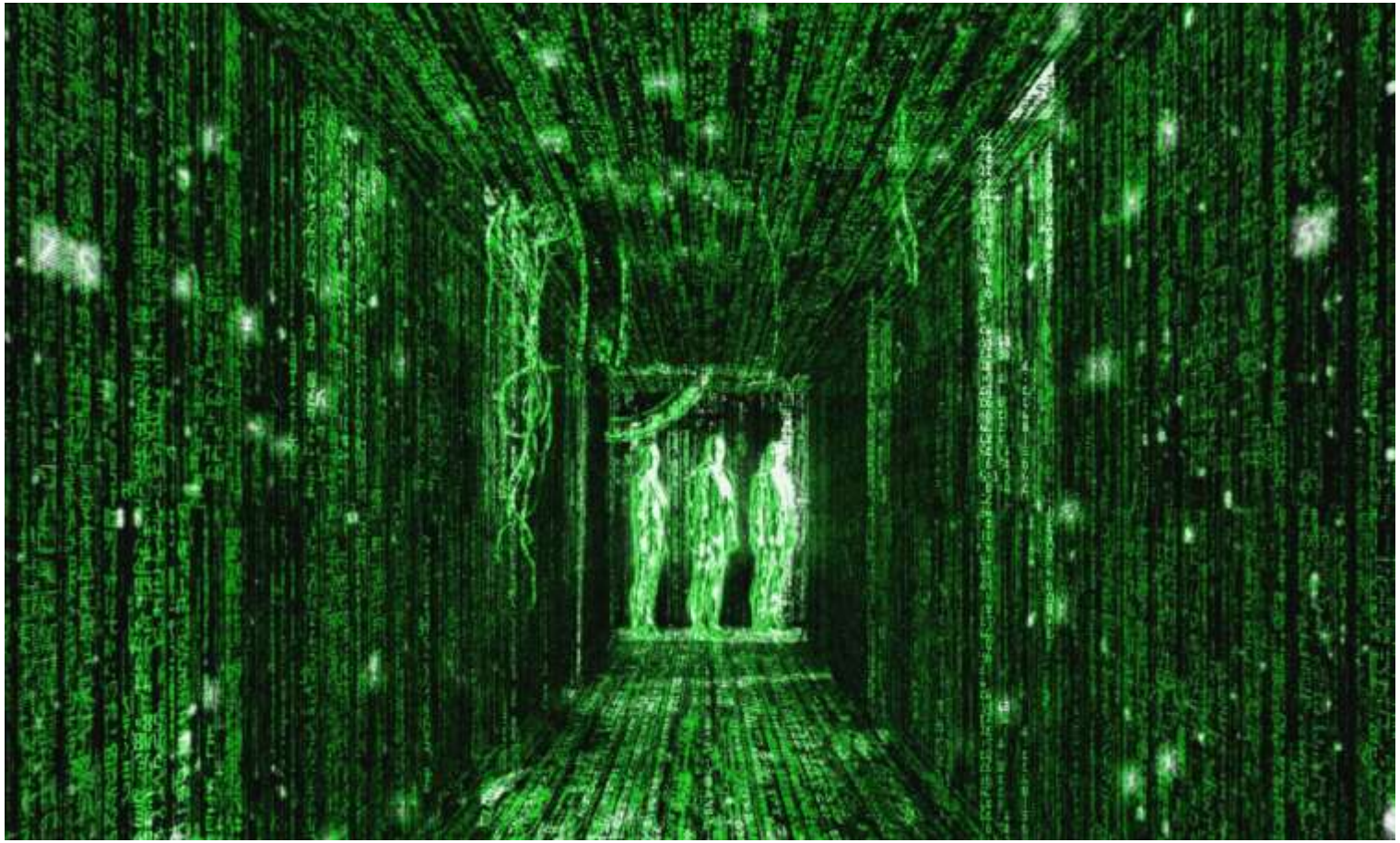
- Virtual Scene Realism
- Natural Interaction
- User Controls Environment
- Displays
  - CAVE
  - HMD
  - LCD/CRT/Plasma
  - Stereoscopic
  - Multi-Modal
- Immersion!

AUGMENTED REALITY

- Integrating computer displays into real-world environments
- This technology will be fueled by improvements in position and orientation technologies as well as dynamic real-time database updates

WHAT IS MISSING?

- Virtualized Hybrid Simulation Systems
- ?

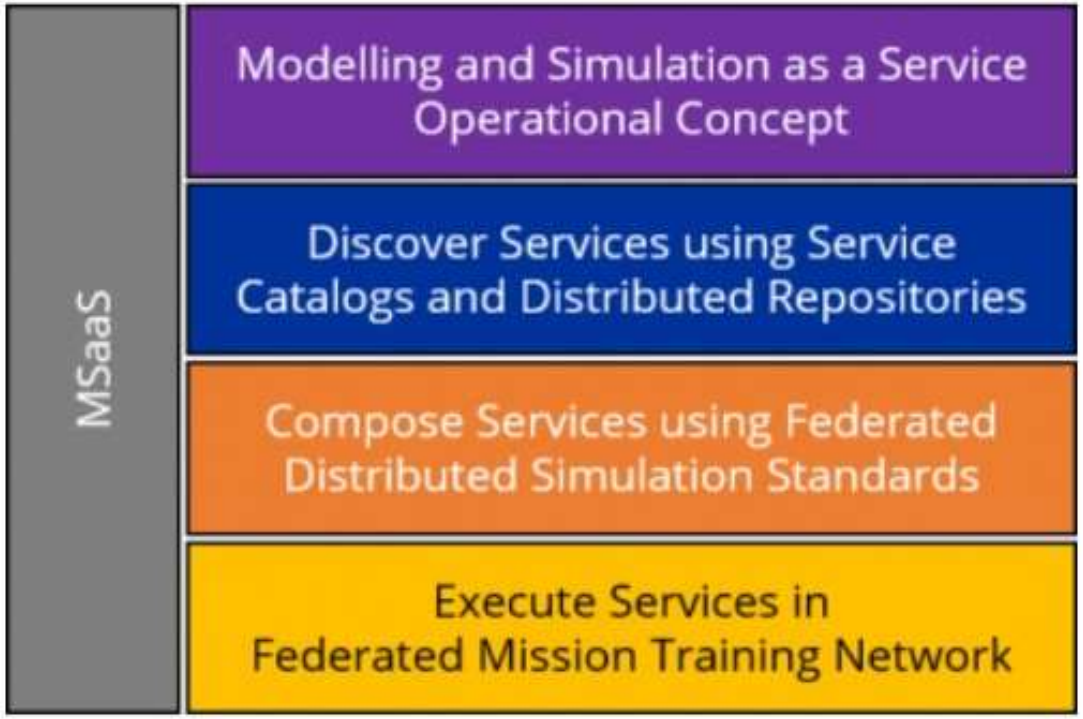


The Matrix's "digital rain" is one of the most recognizable images from the film. ANIMAL LOGIC/WARNER BROS

TOPIC 6: SUPPORTING TOOLS, TECHNIQUES, RESOURCES

- Technical infrastructures, M&S resources, and organizations supporting the development and use of M&S.

6. Supporting tools, techniques, and resources
   - 6.1 Major simulation infrastructures
   - 6.2 M&S resource repositories
   - 6.3 M&S organizations



https://nmsg.sto.nato.int/themes/msaas

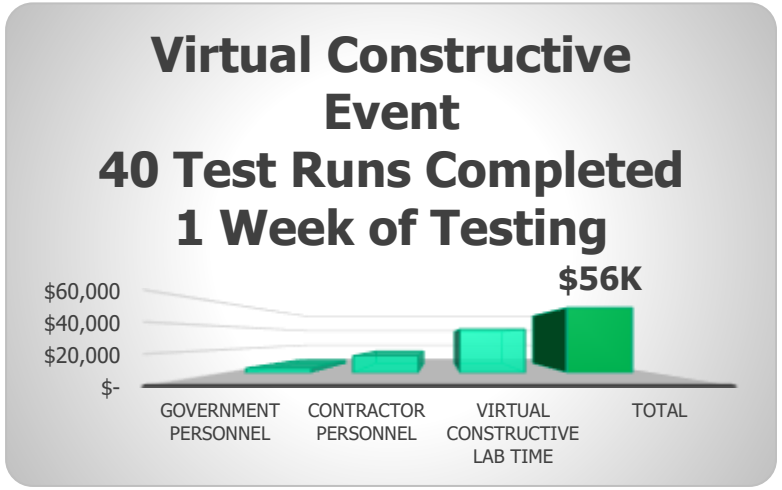
M&S DOD / SERVICE ORGANIZATIONS

- Promote interoperability and use of M&S capabilities; reuse of M&S capabilities; R&D to respond to emerging challenges
- Develop and provide updates to supporting manuals, guidebooks, and best practice guides
- Oversee core Service M&S projects, and support the development and use of enabling publications, collaborative environments, and portfolio management activities
- Support development of common M&S and VV&A tools, interfaces, services, and capabilities
- Review and provide recommendations on M&S and VV&A issues including those pertaining to data standards, metadata/repository guidelines, contracting, and cybersecurity
- Support and expand M&S workforce education and strengthen M&S training and education content and capabilities
- Conduct and participate in M&S technical exchanges and workshops to promote collaboration, coordination, and efficient implementation of models, simulations, and data
- Maintain their Service's part of DON M&S capabilities management tools; provide inputs to DoD M&S Enterprise discovery and access capabilities

TOPIC 7: M&S BUSINESS & MANAGEMENT

- Business of M&S and M&S as a business; professional conduct for M&S practitioners; M&S workforce.

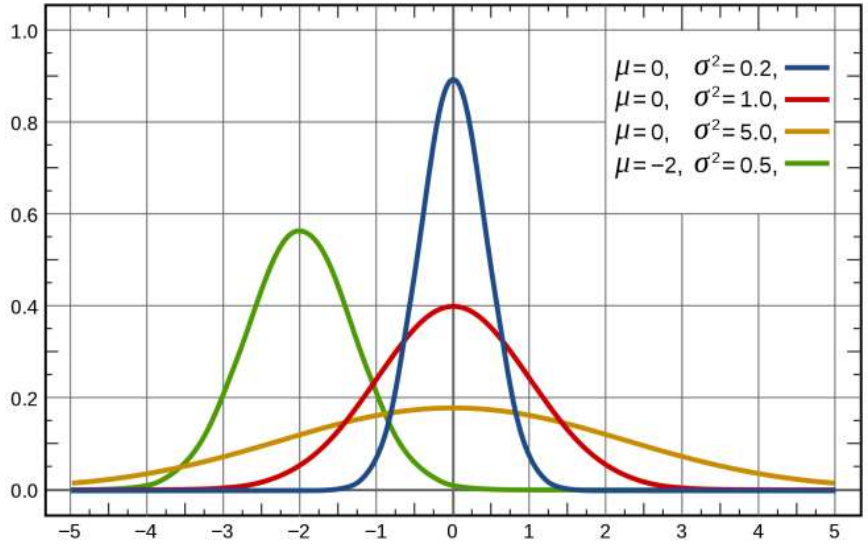
7. Business and management of M&S
   - 7.1 Ethics and Principles for M&S practitioners
   - 7.2 Management of M&S Projects and Processes
   - 7.3 M&S Workforce Development
   - 7.4 M&S Business Practice and Economics
   - 7.5 M&S Industrial Development



TOPIC 8: RELATED COMMUNITIES OF PRACTICE AND DISCIPLINES

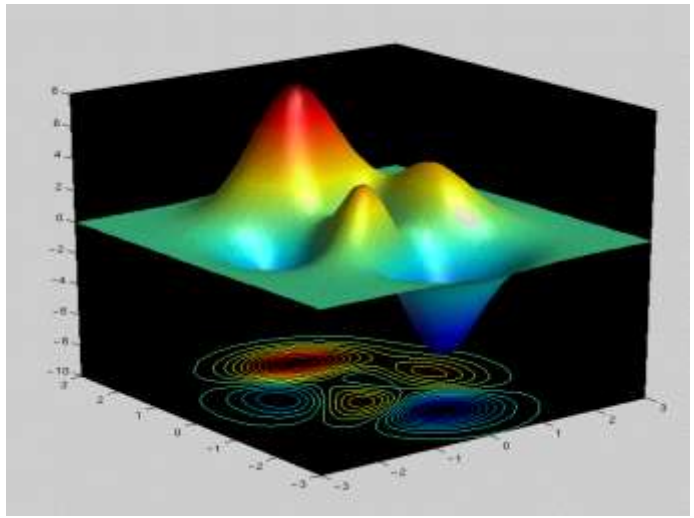
- Non-M&S topics with which M&S professionals should have some familiarity.

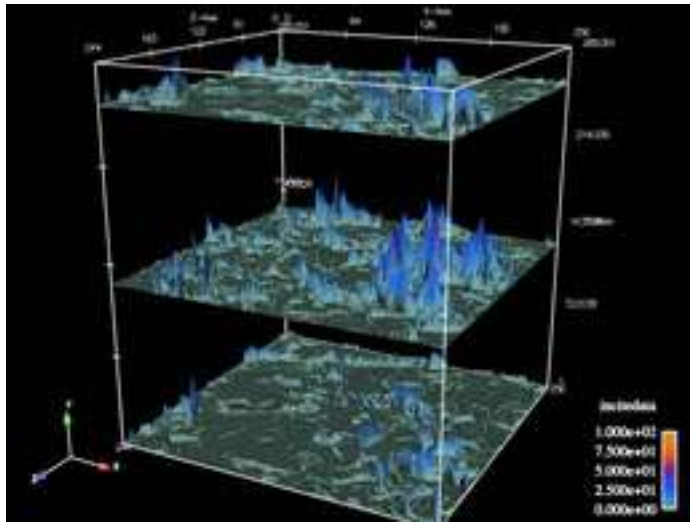
8. Related Communities of Practice and Disciplines
   - 8.1 Statistics and Probability
   - 8.2 Mathematics
   - 8.3 Software Engineering and Development
   - 8.4 Systems Science and Engineering



VISUALIZING THE RESULTS

- Simulations generate incredible amounts of data; interpreting this data is often aided by using information visualization, sometimes called scientific visualization





WORKSHOP OUTLINE

- Learning Objectives
- Introductions
  - Acknowledgements
- Role of M&S and CMSP
- Certification Exam
  - Philosophy
  - Overview
  - Tracks and Topics / Subtopics
  - Tips, Techniques, and Timeline
- Overview of Topics / Subtopics
  - M&S Types, Applications,…
- The “Type is Right” Game
- Certification Exam
  - Sample Questions
- Review
  - Topics
- CMSP Current Events
- Jeopardy Game

- Course Evaluations

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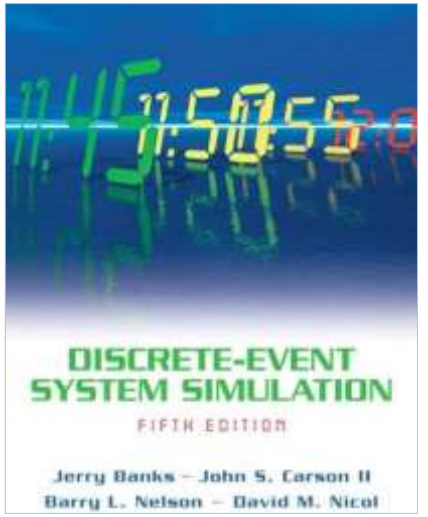
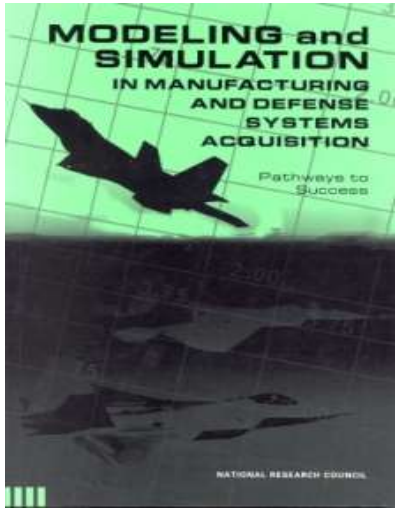
- CMSP Current Events
- Jeopardy Game

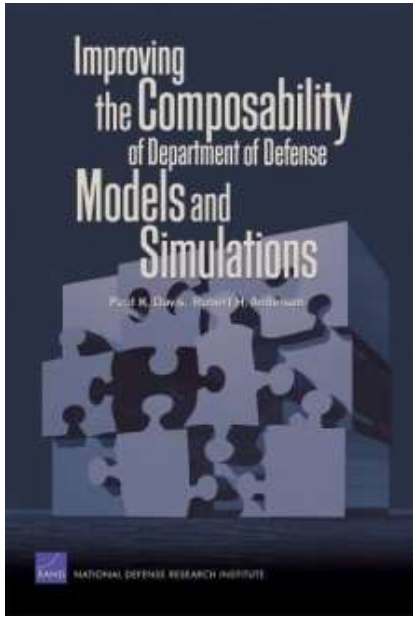
- Course Evaluations

OVERVIEW OF QUESTIONS

- Number
  - Total: 1,000+ questions
  - Selection: Varies by CMSP Level
- Sources
  - Each question based on specific source
  - Sources: published, peer-reviewed, publicly available







SAMPLE QUESTION #1

What type of simulation is often based on differential equations?

A. Discrete event simulation
B. Continuous simulation
C. Monte Carlo simulation
D. Cellular automata simulation

A differential equation is any equation which contains derivatives, either ordinary derivatives or partial derivatives

There is one differential equation that everybody probably knows, that is Newton's Second Law of Motion. If an object of mass M is moving with acceleration A and being acted on with force F then Newton's Second Law tells us that F = MA

SAMPLE QUESTION #2

During a simulation of a physical system, the modeled system's state changes over time according to the state variable equations. These equations usually derive from _____.

A. Hardware specifications

B. Interface documentation

C. Requirements definitions

D. Scientific knowledge about the system

A state variable is one of the set of variables that are used to describe the mathematical "state" of a dynamical system. Intuitively, the state of a system describes enough about the system to determine its future behavior in the absence of any external forces affecting the system

A system is a group of interacting or interrelated elements that act according to a set of rules to form a unified whole. A system, surrounded and influenced by its environment, is described by its boundaries, structure and purpose and expressed in its functioning

SAMPLE QUESTION #3

Which of the following terms is best defined as “the process of determining whether an implemented model is consistent with its specification”?

A. Verification
B. Validation
C. Accreditation
D. Calibration

- VERIFICATION - The process of determining that a M&S’ implementation and its associated data accurately represents the developer's conceptual description and specifications
- VALIDATION - The process of determining the degree to which an M&S system and its associated data are an accurate representation of the real world from the perspective of the intended uses of the model
- ACCREDITATION - The official certification [determination] that a model, simulation, or federation of models and simulations and its associated data are acceptable for use for a specific purpose
- CALIBRATION - The comparison of measurement values delivered by a device under test with those of a calibration standard of known accuracy

SAMPLE QUESTION #4

In the context of simulation, what is benchmarking?

A. An output analysis technique based on specialized time series metrics

B. An event tagging mechanism used in discrete event simulation languages

C. A comparison between a model's output and the outputs of other models or simulations

D. The execution of a simulation with test input to confirm correctness

Benchmarking Defined

Evaluate or check (something) by comparison with a standard

Benchmarking is the practice of comparing processes and performance metrics to industry bests and best practices

SAMPLE QUESTION #5

True or False: Once accredited, a model may be used for any application without further testing.

True or False: Once accredited, a model may be used for <u>any</u> application without further testing.

Applications = Training, Analysis, Experimentation, Acquisition, Engineering, Test and Evaluation

FALSE

SAMPLE QUESTION #6

Which of the following terms best describes use of models and simulation by the military, for the purposes of obtaining insight into the cost and performance of military equipment?

A. Geo-Navigation
B. Exploration of Advanced Technologies and Concepts
C. Training
D. Requirements and Acquisition

Describes use of models and simulation by the military, for the purposes of obtaining insight into the *cost* and *performance* of military equipment

→ Cost matters in procurement, purchasing, acquiring…
→ Performance is a need, desired aspect, requirement…

EXAMPLE QUESTION #6, WITH METADATA

Question	Which of the following terms best describes use of models and simulation by the military, for the purposes of obtaining insight into the cost and performance of military equipment?
Correct answer	Requirements and acquisition
Incorrect answer	Exploration of advanced technologies and concepts
Incorrect answer	Training
Incorrect answer	Geo-navigation
Type	User/Manager
Difficulty	3 (Moderate)
Topic	3.1 Combat and military
Source	R. D. Smith, *Military Simulations & Serious Games*, Modelbenders Press, Orlando FL, 2009.
Page number	38

- True or False : A real aircraft flying in DoD designated air-combat-maneuvering airspace is simulation.

- *LIVE SIMULATION* – Involves real people operating real systems in a simulated area of responsibility
- *VIRTUAL SIMULATION* – Involves real people operating simulated systems
- *CONSTRUCTIVE SIMULATION* – Involves simulated people operating simulated systems

ANSWER – **True**

"Everything but war is simulation."

LVC SIMULATION – NAVY TRAINING CAPABILITY

SUMMARY AND REVIEW

Had Enough?

KEY TERMS AND TYPES - MODEL

- A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process
- To an observer *B*, an object *A** is a model of an object *A* to the extent that *B* can use *A** to answer questions that are of interest about *A*
- Representation of something else, normally a “real-world” system
- Some aspects of the modeled system are represented in the model, others not

Simuland
P-51D Mustang

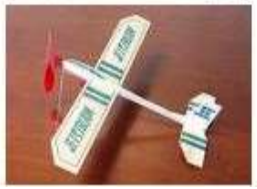
Models

Physical model
Represents:
Appearance
Abstracts:
Size

Physical model
Represents:
Aerodynamics
Omits:
Ailerons

[Bollay, 1951]

Physical model
Represents:
Flight
Omits:
Appearance



Models

Visual model
Represents:
Appearance
Omits:
Flight

[Han, 2012]

$$\iiint_{\Omega} \mathbf{P}\frac{\partial \mathbf{W}}{\partial t}\,d\forall + \iint_{A_c} \mathbf{H}\cdot\mathbf{n}\,dS = \iint_{A_c} \mathbf{H}_v\cdot\mathbf{n}\,dS$$

Functional model
Represents:
Aerodynamics
Omits:
Appearance

Aggregate model
Represents:
Combat
Abstracts:
Pilot skill

SIMULATION

- The imitation of the operation of a real-world process or system over time
- A technique for testing, analysis, or training in which real world systems are used, or where a model reproduces real world and conceptual systems

Simulation Environment	Acronym	Description
Digital Simulation	DSIM	A full digital representation of the system and intended operational environment
Hardware in-the-Loop	HITL	A simulation environment that includes actual system hardware
Software in-the-Loop	SITL	A simulation environment incorporating actual system software and logic
Operator in-the-Loop	OITL	A simulation environment designed to include inputs and decisions from at least one operator
Land-Based Test Facility	LBTF	A simulation environment, constructed on an open range, which incorporates various aspects of DSIM, HITL, SITL, OITL, and/or live-test assets
Laboratory/Chamber	LAB	A facility allowing for the stimulation via DSIM, HITL, SITL, and/or OITL, of various aspects of an operational system in a closed secure environment
Threat Representation	TR	Any engineering representation (physical or digital) of a threat system which will be used
C4I System Integration Environments and Facilities	C4IEF	A Command, Control, Communications, Computers, and Intelligence (C4I) environment, that operates external to the System Under Test (SUT)/System of Systems (SoS), and provides the capability to test system function and interoperability.
Reliability Simulation	RSIM	A simulation that provides reliability predictions for the SUT in live/captive carry/chamber or DSIM to represent the SUT

M&S GOVERNANCE GOALS

- Since the 90s, there have been a set of technical goals pursued by empowered organizations
- Progress has been made in all (e.g., ships in one sim no longer hover above waves provided by another), yet there is still much to do in:
  - **Composability**: The degree to which an M&S user can effectively develop, from a pallet of components, an executable simulation to address a question of interest.
  - **Interoperability**: The ability of an M&S system to provide services to and accept services from others, and to use these services to operate effectively together.
  - **Reuse**: Using again, in whole or part, existing M&S tools, data, or services.
  - **Scalability**: The ability of a simulation to maintain time and spatial consistency as the number of entities and accompanying interactions increase.

M&S - KEY FACETS

- **Facets = T**echnologies, processes, and infrastructure components that make M&S possible and practical but also innovative and adaptive. They include:

- **Algorithms**: A set of rules to be followed in performing calculations or problem-solving operations, especially by a computer. Includes Artificial Intelligence and Machine Learning to enable M&S to adapt and improve its capabilities.
- **Data**: Facts, descriptors, statistics, etc. with the level of accuracy and pedigree required for M&S systems to generate results with a given level of confidence.
- **Distributed/Federated**: Use of geographically dispersed assets and standardized protocols (e.g., DIS, HLA) to execute M&S / LVC events and exercises.
- **Networks**: Host M&S / LVC including: JMETC, NETTN, DREN, and SDREN.
- **Security / Cybersecurity**: Federated, distributed, and networked M&S systems and LVC simulations implement RMF via ATOs, IATTs, etc. issued by ISSMs, FAOs, and the NAO.
- **Standards and Guidelines**: Exist for architectures (e.g., HLA, AMIE), processes (e.g., DSEEP), LVC Network Security, Contracting, etc.

WORKSHOP OUTLINE

- Learning Objectives
- Introductions
  - Acknowledgements
- Role of M&S and CMSP
- Certification Exam
  - Philosophy
  - Overview
  - Tracks and Topics / Subtopics
  - Tips, Techniques, and Timeline
- Overview of Topics / Subtopics
  - M&S Types, Applications,…
- The “Type is Right” Game
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- Review
  - Topics
- CMSP 3.0 & Current Events
- Jeopardy Game

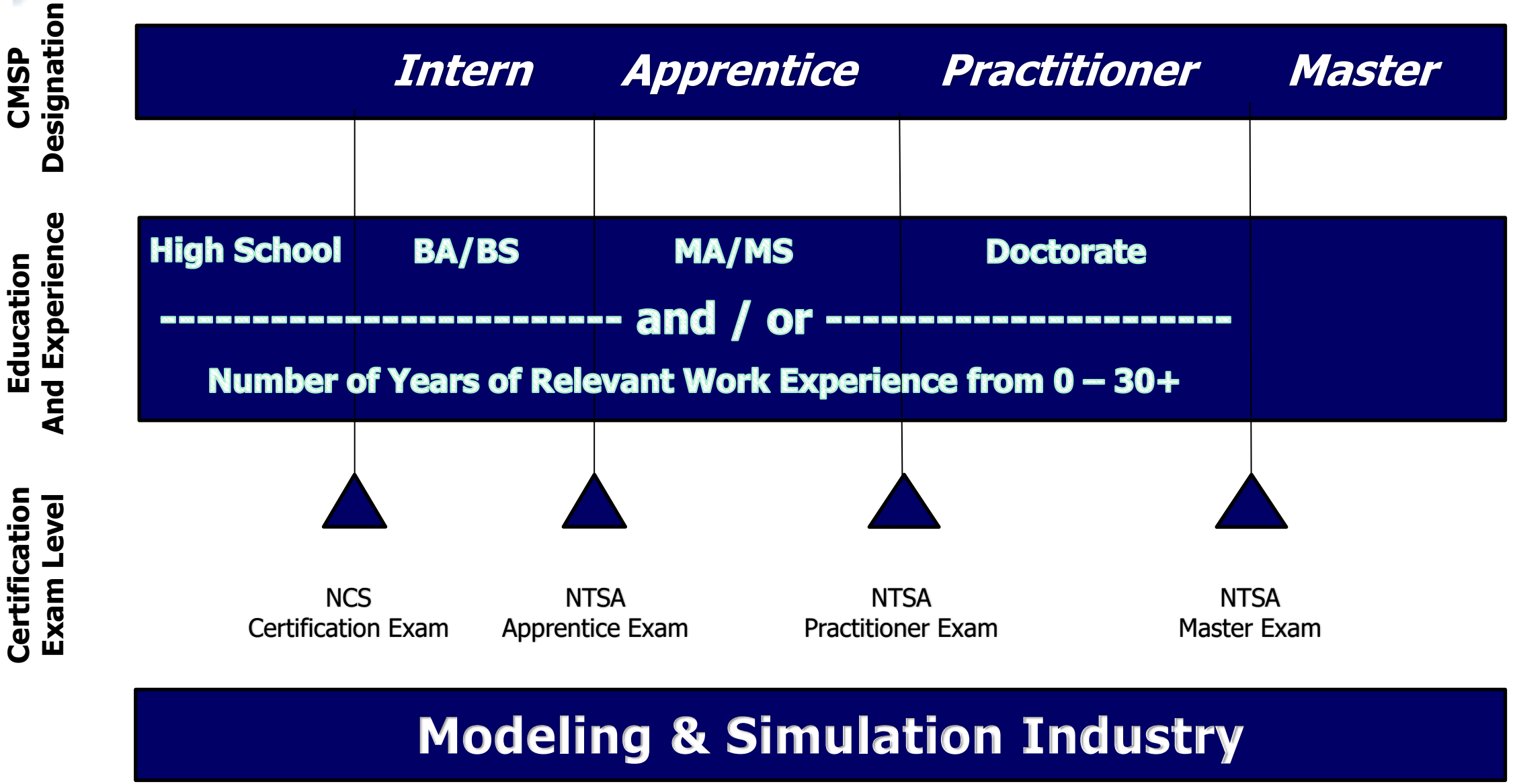
- Course Evaluations

NEW FEATURES OF CMSP 3.0

- CMSP Evolution: Version 1.0 in 2001, 2.0 in 2010, 3.0 Released

- CMSP 3.0
  - Now Includes Four Integrated Levels – Intern, Apprentice, Practitioner, and Master
  - Streamlines the Processes and Employs a Learning Management System
  - Updates the Examination
  - Creating a Vibrant Community of Practice
    - Quarterly Newsletter
    - Local Meetings (post COVID)
    - Conference Presence - I/ITSEC Over the Last Week
      - Special Event
      - STEM and Career Fair Participation
      - State of the Nation and then Reception
      - Professional Development Workshop

CMSP LEVELS


CMSP Designation
Intern
Apprentice
Practitioner
Master
Education And Experience
High School
BA/BS
MA/MS
Doctorate
and / or
Number of Years of Relevant Work Experience from 0 – 30+
Certification Exam Level
NCS Certification Exam
NTSA Apprentice Exam
NTSA Practitioner Exam
NTSA Master Exam
Modeling & Simulation Industry

APPRENTICE LEVEL

- This level is designed for individuals who are new to the M&S field and serves as a foundation for future advancement
- Identifies individuals who have demonstrated an awareness of basic M&S concepts, methods, and applications
- Individuals possess an entry-level understanding of M&S principles and practices and are committed to expanding their knowledge and understanding of the M&S discipline
- E.g., Basic knowledge of M&S principles, methods, practices, and project lifecycles and awareness of general M&S concepts, such as abstraction, model attributes (e.g., validity and resolution), time representation, and environment (e.g., Live, virtual, and Constructive)

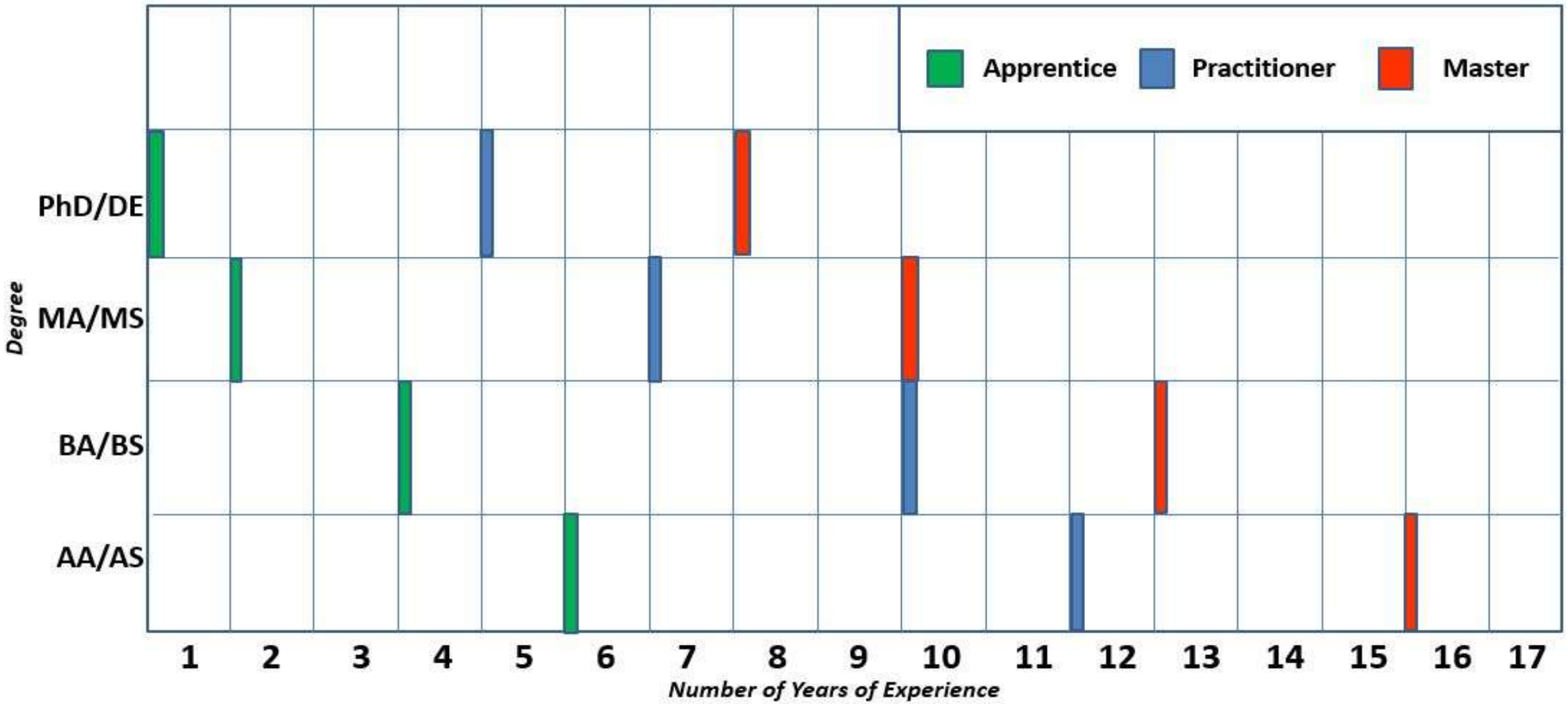
PRACTITIONER LEVEL

- This level designates professionals who possess applied knowledge of M&S principles and practices in a variety of domains
- They understand M&S applications and their role in addressing current and future challenges in specific contexts
- Designed for M&S professionals who have a demonstrated ability to lead technical teams, conduct short-term studies, translate project requirements into model contexts, and coordinate with SMEs and key stakeholders
- Ability to develop basic models and simulations using modern software development languages, processes, and tools, including configuration management, VV&A, and quality control

MASTER LEVEL

- This level designates professionals who have a demonstrated understanding of the M&S BoK its application in a variety of contexts
- Possess the capability to plan and execute short- and long-term M&S projects, design and implement complex and sophisticated models, conduct advanced research, communicate findings, and expand the application of M&S into new domains
- Ability to independently plan and lead complex M&S technical projects, to derive and specify high level and detailed requirements with measurable acceptability criteria, etc.
- Demonstrated ability to present M&S designs, implementation architectures, and results to other M&S professionals and to senior leaders

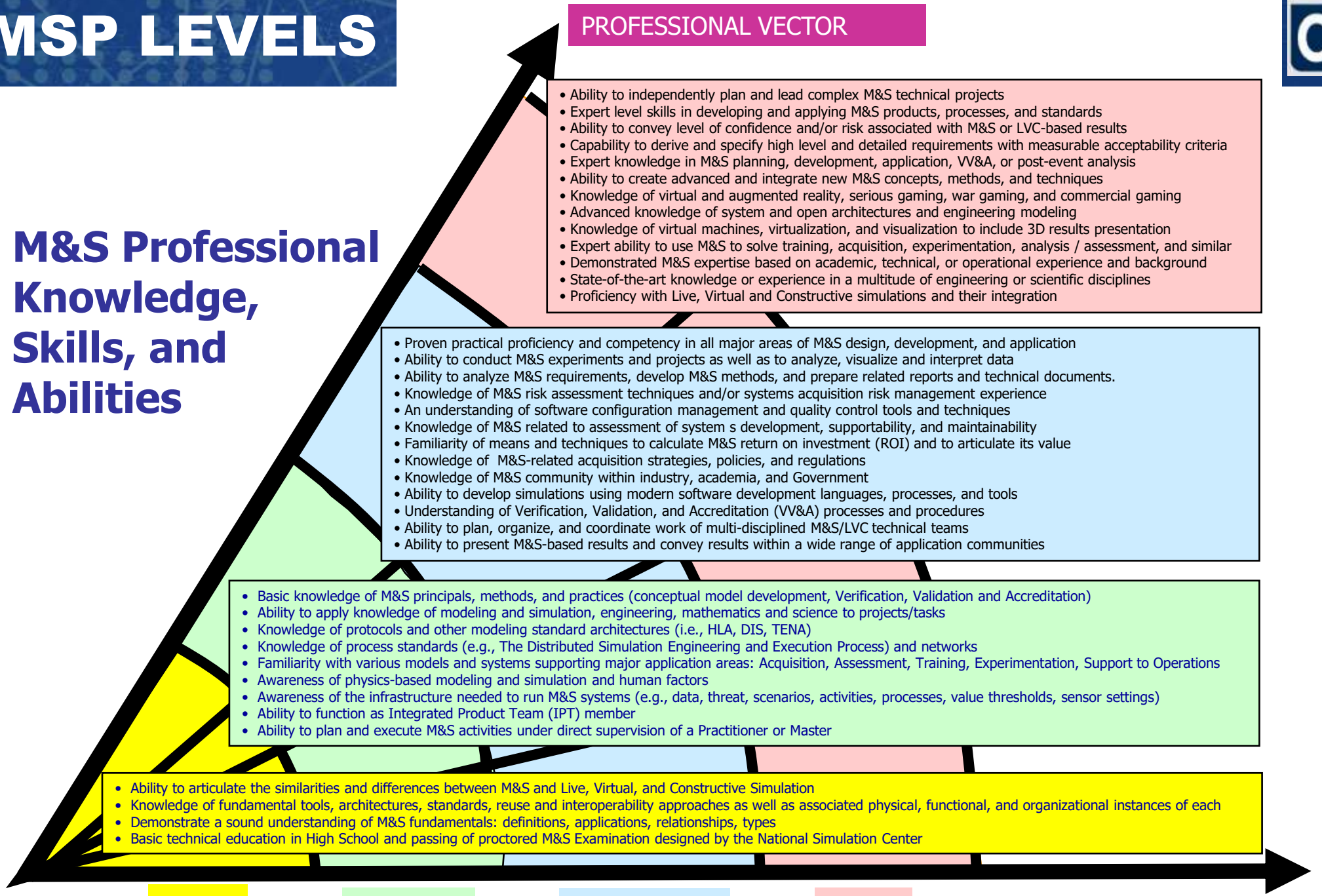
QUALIFICATIONS TO TAKE - A/P/M - EXAMS



Will specify and account for unique situations

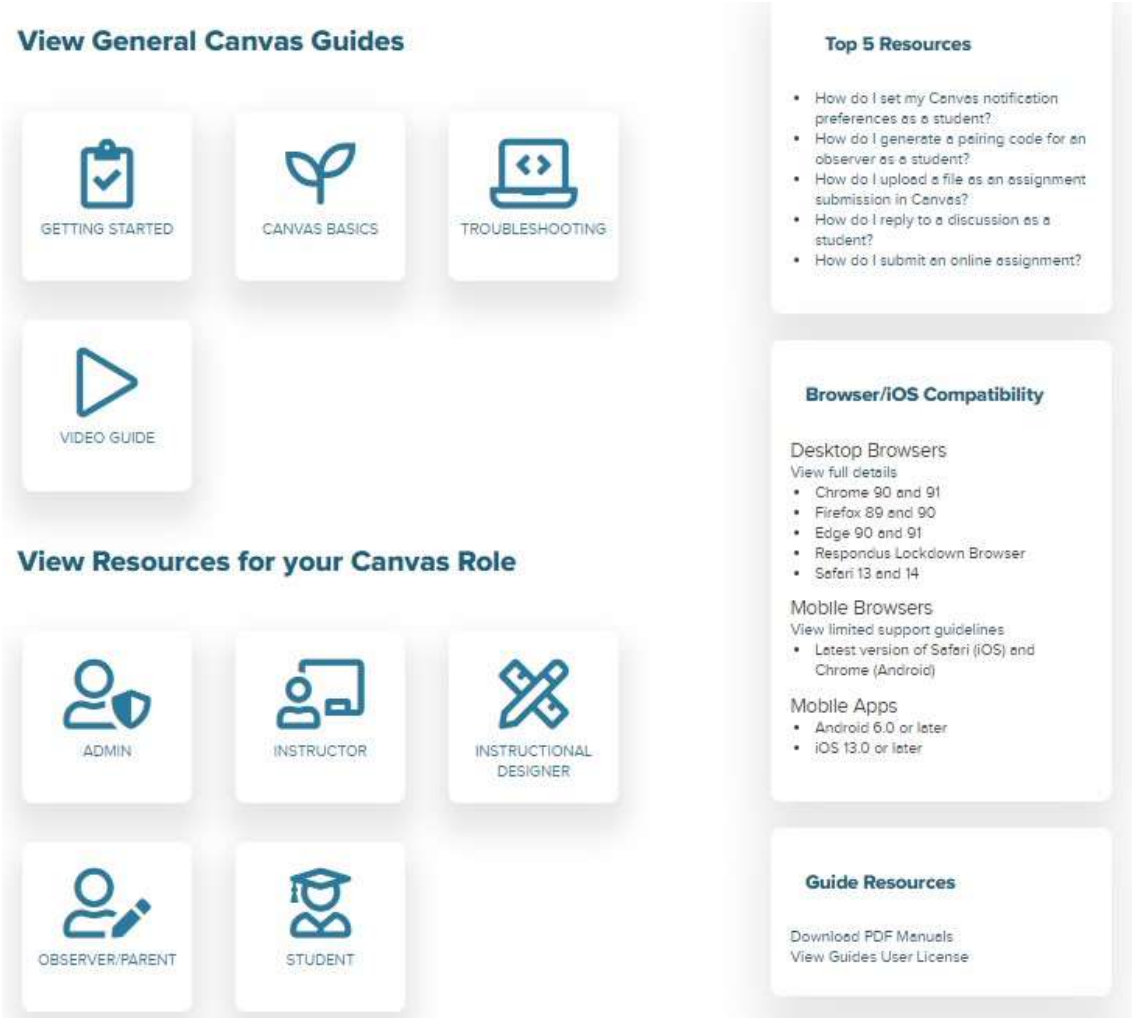
CMSP LEVELS

M&S Professional Knowledge, Skills, and Abilities

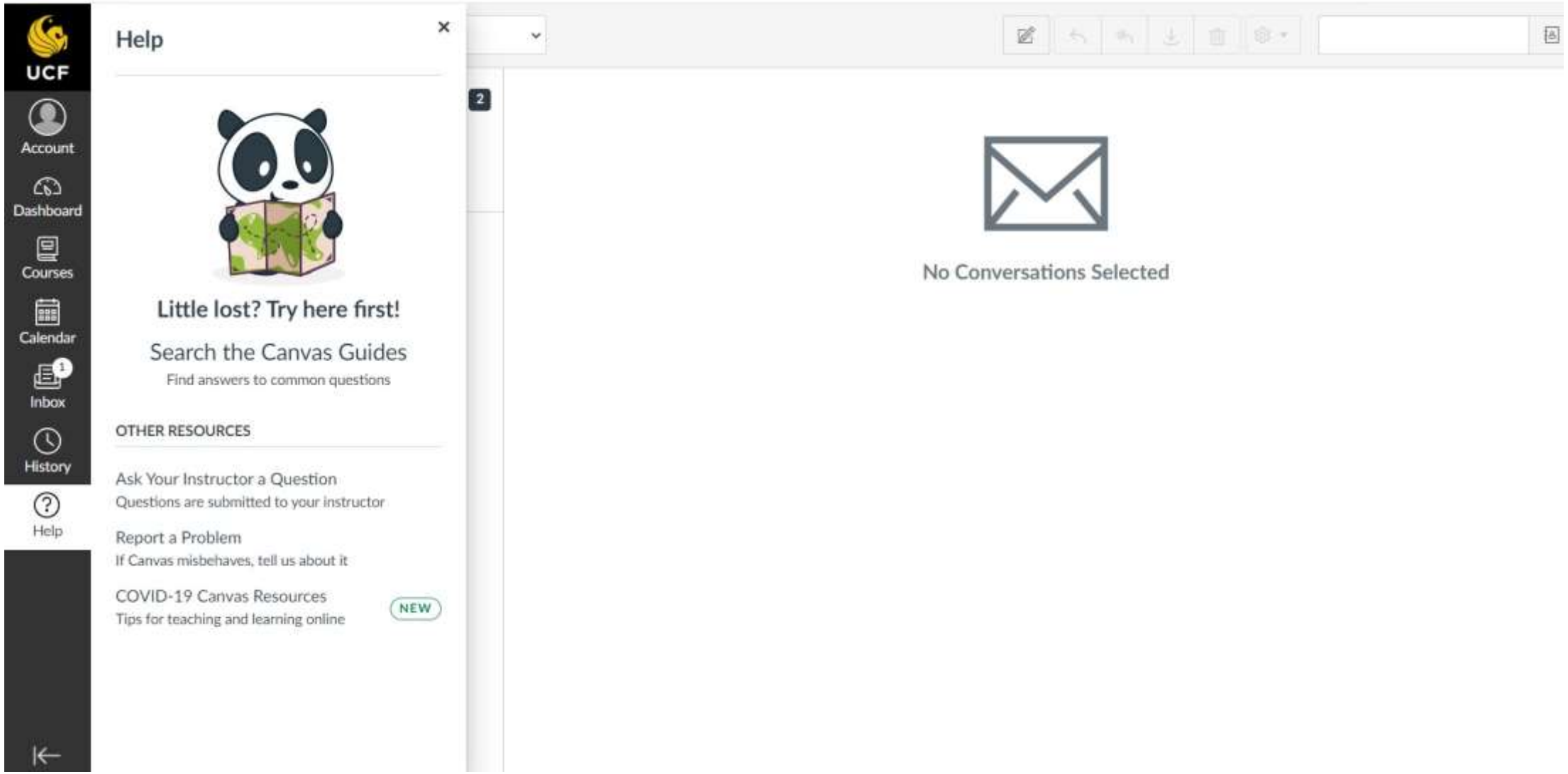


LEARNING MANAGEMENT SYSTEM

- The platform we are using is called Canvas
- It's a learning management system used by UCF and many others
- CMPS 3.0 is built like a course on the platform
- Here is a link to a short "Student tour" video
  - https://community.canvaslms.com/t5/Video-Guide/Canvas-Overview-Students/ta-p/383771



LEARNING MANAGEMENT SYSTEM



LEARNING MANAGEMENT SYSTEM

CMSP 3.0 CURRENT EVENTS

- Increase demand by Government/Industry/Academia, etc.
- Improve awareness in Academia/Industry/Government/Professional Societies, etc.
- Use Restructured the CMSP certification process and artifacts
- Collaborate/Cooperate/Compete with Other Certifications
- Increase Certificate Holder Engagement (Both New Certifications and Renewals)
- Consider New Certifications (e.g., MBSE, LVCP)
- Explore CMSP Sub-Certifications (e.g., Engineering, Logistics,)
- Employ Revised and Updated the CMSP Exam

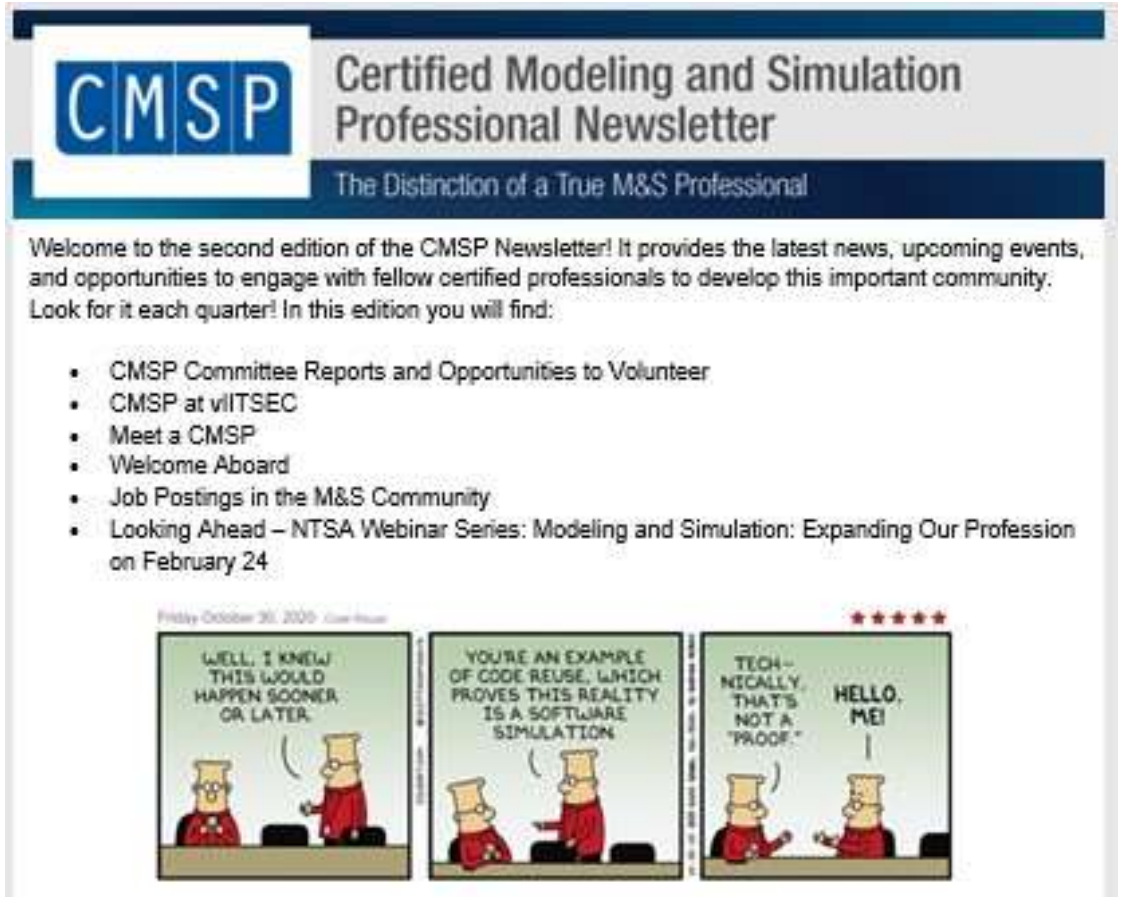
Participants and Contributors Welcome!

CMSP - ENGAGEMENT PROPOSALS

- Engage Current and Past CMSP Recipients
  - Re meetings, newsletter (with list of alumni), and certificate renewal
- Schedule CMSP Meeting (State of the Nation at I/ITSEC)
  - Aggressively follow-up on recommendations and engage attendees
- Create and Initiate a CMSP Mentorship Program
  - Each current CMSP Recipient mentor 1 prospect per year
- Establish “CMSP Guild”
  - Meetings on Topics of Interest, Newsletter, Special Events, Nominations and Awards
- Create a Renewal Support System
  - Reminders, resources, etc.
- Submit articles on CMSP to M&S publications (SISO, SCS, Etc.)
- Activities are Ongoing re Other Committee initiatives

CMSP NEWSLETTER

- Education, Certification, Institutionalization
  - 3.0 is aggressively working to support the Expansion of Our Profession
- CMSP Newsletter now being distributed regularly
- Volunteers are being sought for
  - Mentors
  - Committee Members
  - Exam Question Generators
- CMSP 3.0 looks forward to assisting with the Institutionalization of M&S



CMSP

Certified Modeling and Simulation Professional Newsletter

The Distinction of a True M&S Professional

Welcome to the second edition of the CMSP Newsletter! It provides the latest news, upcoming events, and opportunities to engage with fellow certified professionals to develop this important community. Look for it each quarter! In this edition you will find:

- CMSP Committee Reports and Opportunities to Volunteer
- CMSP at I/ITSEC
- Meet a CMSP
- Welcome Aboard
- Job Postings in the M&S Community
- Looking Ahead – NTSA Webinar Series: Modeling and Simulation: Expanding Our Profession on February 24

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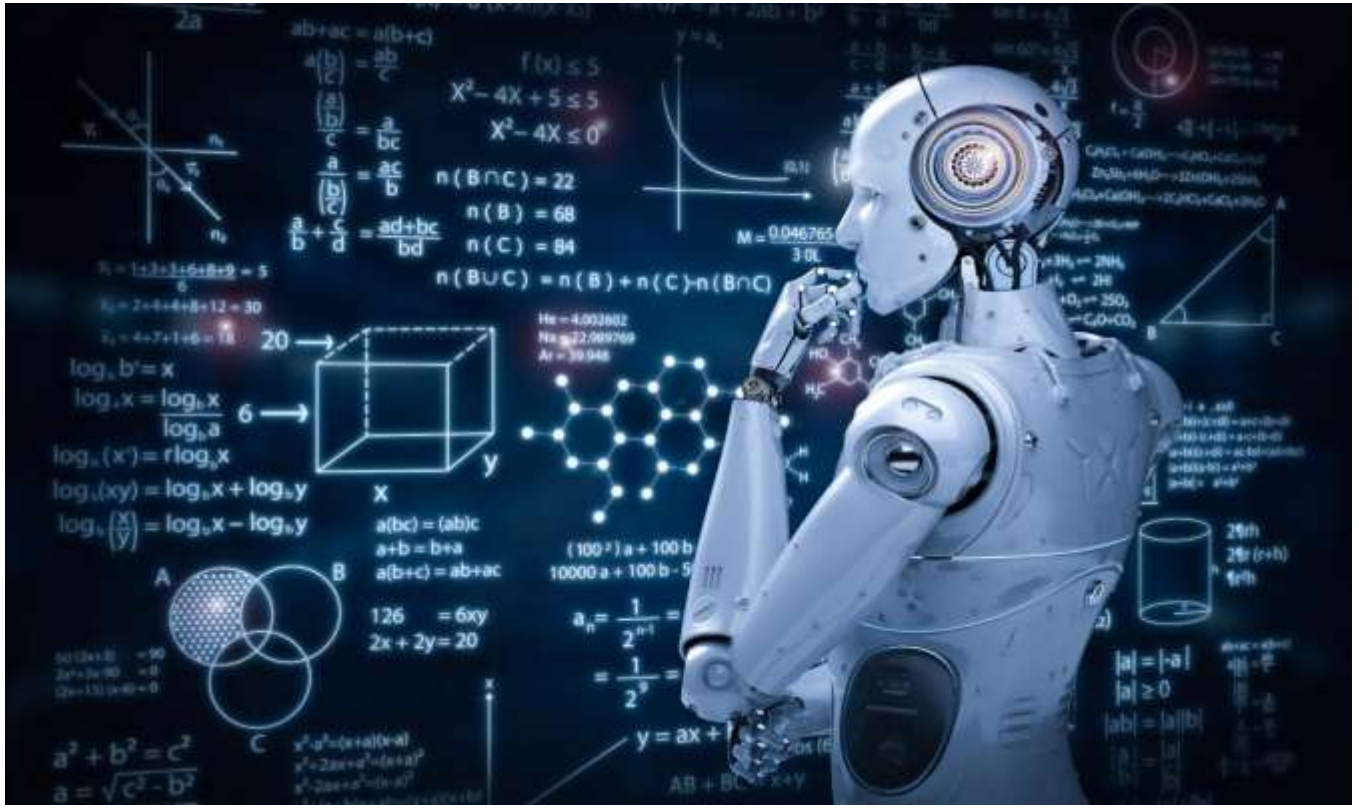
CMSP PDW CONCLUSIONS

Keep striving, we need to stay smarter than the machines!

- Feedback
- Q&A



- For more information email Carol Dwyer at cdwyer@ndia.org