Certified Modeling and Simulation Professional

Professional Development Workshop

5 April 2022

Ivar Oswalt, PhD CMSP

The MIL Corporation

- ➢ 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, begun in 2019, culminated this week with the launch of CMSP 3.0

- ➢ Improvements incorporated streamline the processes, 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 Special Event informative and valuable*

➢ 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, Processes, and Infrastructure

➢ Certification Exam

- Sample Questions

➢ Review of Topics

➢ CMSP Current Events

➢ Jeopardy Game

➢ Course Evaluations

➢ 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 a Gaming Simulation (Jeopardy!), Knowledge of M&S Fundamentals

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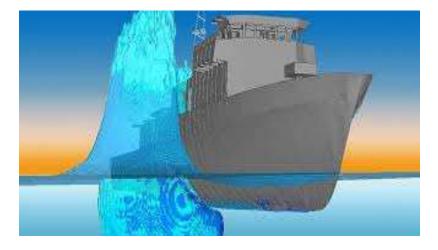
➢ **Ivar Oswalt**

- 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 2019

- *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...

- ➢ Dr. Mikel Petty, University of Alabama in Huntsville

- ➢ Dr. Amy Henninger, The Office of the Director, Operational T&E

- ➢ Mr. Bill Waite, The AEgis Corporation

- ➢ Mr. William V. Tucker, Boeing

- ➢ Ms. Margaret Callahan, The MIL Corporation

- 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

➢ 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 Rational: 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

➢ Provides applicants a mind-growing experience

■ Understand areas of M&S that you've never explored before!

➢ Increasingly delivers a supportive and career enhancing community

■ CMSP Quarterly Newsletter, Mentorship Program, Local and Regional Events

■ CMSP Member Children Scholarship Being Developed

➢ 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

➢ Communicates an indicator of currency

■ Publications, presentations, CEUs required for renewal

➢ 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 and experience
- 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

➢ Ensure that successful candidates have an appropriate and representative understanding of the full spectrum of M&S, i.e., across the BoK

➢ 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, is that especially the CMSP Practitioner and Master exams requires applicants to research and learn new M&S topics and facts

- ➢ Scope is defined by a consensus-based M&S Body of Knowledge (BoK)

- ➢ Composed from ~1K questions drawn from all topics and subtopics in BoK that reside in a question bank

- ➢ 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

- ➢ It is a "take-home" test to be completed within twenty-four hours

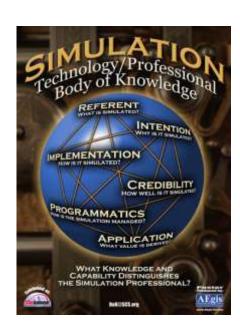- ➢ Each exam type requires a 70% score to pass (skipped questions are scored as incorrect)

➢ 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*
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

CMSP

- ➤ 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

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

- ➤ Finish

– 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

NTSA

➤ 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

➢ 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
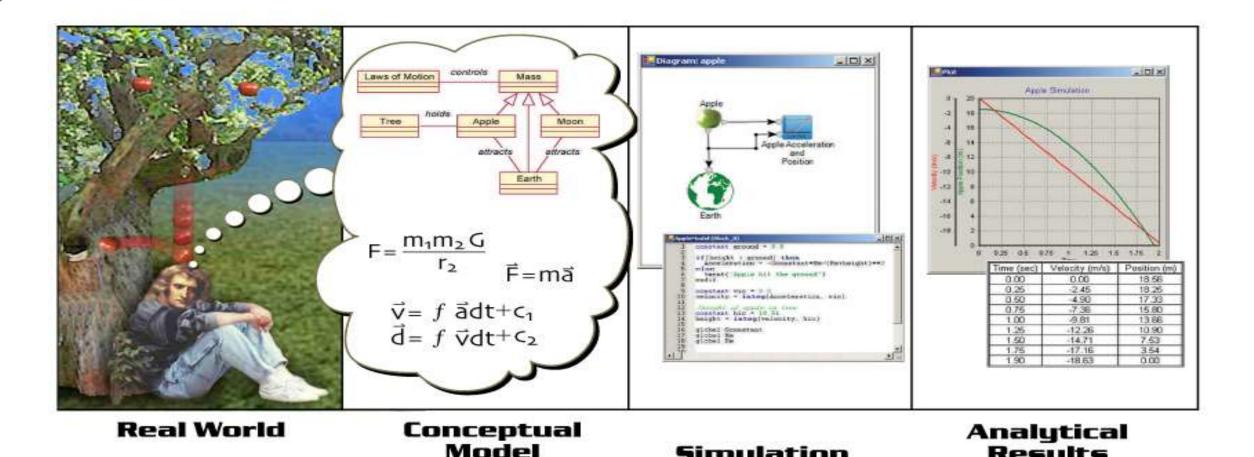
Real World — **Conceptual Model** — **Simulation** — **Analytical Results**

➢ *How would you define each step?*

- **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
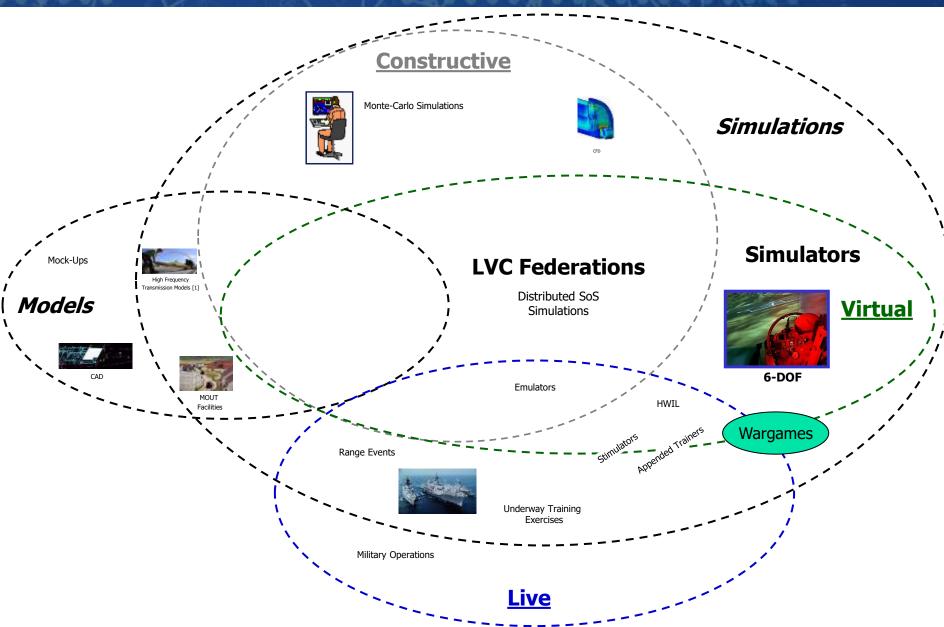
Where do M&S Systems that you know fit?

Wargames?

Constructive

Monte-Carlo Simulations

CFD

Simulations

Models

Mock-Ups

High Frequency Transmission Models [1]

CAD

MOUT Facilities

LVC Federations

Distributed SoS Simulations

Emulators

Simulators

Virtual

6-DOF

HWIL

Stimulators

Appended Trainers

Wargames

Range Events

Underway Training Exercises

Military Operations

Live

19

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

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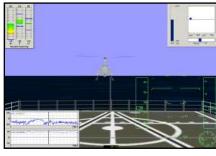
➢ Important and cross-cutting M&S application types; modeling methods and organizing principles for each.

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

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

➢ 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

➢ # 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

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

- ➤ 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

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

What are some other domains of use?

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

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

➢ 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

➢ 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

➢ 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
```

➢ 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

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:

Stochastically varying initial conditions → Deterministic model → Stochastically varying results

Probability distributions used to model variability in initial conditions

e.g., physics-based model

Multiple runs with run-to-run variability in results; analyzed statistically

MC2:

Fixed initial conditions → Stochastic model → Stochastically varying results

Specific known or given initial conditions

e.g., probability-based model

Multiple runs with run-to-run variability in results; analyzed statistically

MC1 Missile impacts [Zhang, 2008]

MC2 Bombing accuracy [BanksJ, 2010]

➢ Model state variables change only at a discrete set of points in time ("events")
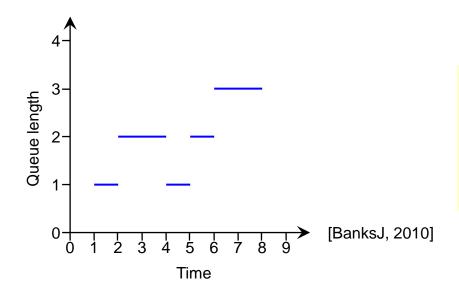
➢ Simulation using discrete models and event handling / event-driven

➢ E.g., Aircraft launch $\rightarrow$ Arrives on station $\rightarrow$ 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
```

35

➢ 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

➢ 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

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.

- 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

40

➢ **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?"

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

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?

ACCEPTABILITY CRITERIA

But "How Fit"?

Intended Use Components or Aspects?

Likely Employment Environment?

Degree of Trust or Confidence?

DECISION

Requirement

Capability

- ➢ 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

CMSP

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

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

➢ 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

| Define Simulation Environment Objectives ① | Perform Conceptual Analysis ② | Design Simulation Environment ③ | Develop Simulation Environment ④ | Integrate and Test Simulation Environment ⑤ | Execute Simulation ⑥ | Analyze Data and Evaluate Results ⑦ |

Corrective Actions / Iterative Development

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!

➢ 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

©2001 How Stuff Works

➤ Virtualized Hybrid Simulation Systems

➤ ?

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

➤ 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

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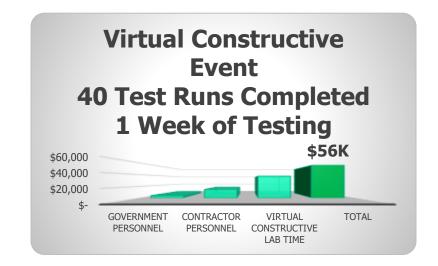
➢ Business of M&S and M&S as a business; professional conduct for M&S practitioners; M&S workforce.

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
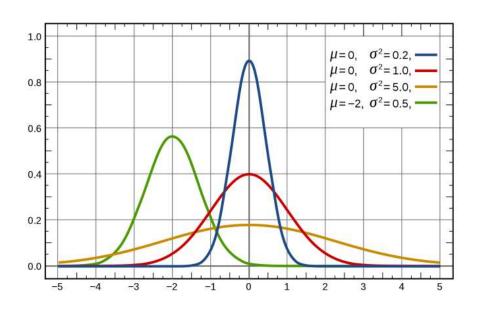   7.4 M&S Business Practice and Economics
   7.5 M&S Industrial Development

Virtual Constructive Event
40 Test Runs Completed
1 Week of Testing

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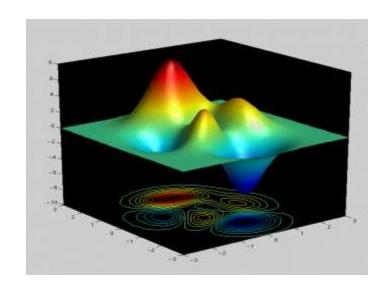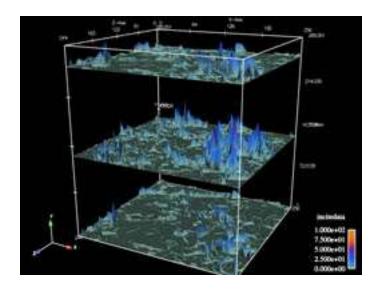
➢ Simulations generate incredible amounts of data; interpreting this data is often aided by using information visualization, sometimes called scientific visualization

➢ **Number**

  ■ Total: ~2000 questions
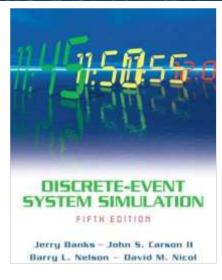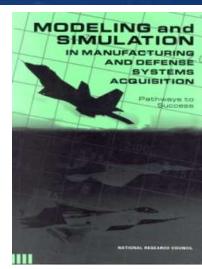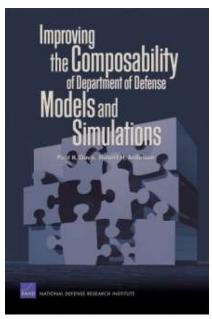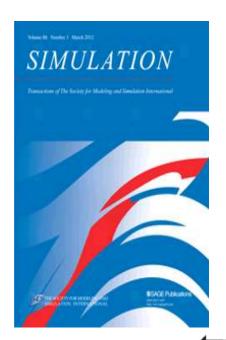
  ■ Varies by CMSP Level

➢ **Sources**

  ■ Each question based on specific source

  ■ Sources: published, peer-reviewed, publicly available

    - Journal papers, conference papers, books

    - More than 175 sources

    - List available

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

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

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

NTSA

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

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

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

$\rightarrow$ Cost matters in procurement, purchasing, acquiring…
$\rightarrow$ Performance is a need, desired aspect, requirement…

➢	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

CMSP

➢ 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."

NTSA

Had Enough?

➢ 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

Models

Simuland
P-51D Mustang

Models

Physical model
Represents:
Appearance
Abstracts:
Size

Physical model
Represents:
Aerodynamics
Omits:
Ailerons

Physical model
Represents:
Flight
Omits:
Appearance

[Bollay, 1951]

Visual model
Represents:
Appearance
Omits:
Flight

Functional model
Represents:
Aerodynamics
Omits:
Appearance

[Han, 2012]

Aggregate model
Represents:
Combat
Abstracts:
Pilot skill

➢ 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

➢ Since the 90s, when DMSO and the Service M&S Offices were established, there have been a set of technical goals. 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.

➢ **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.

➢ **Personnel**: Uniform, Civilian, and Contractor. Uniform Officer M&S personnel designators include Army FA57, Navy's 6202, and Marine Corps' 8825.

➢ **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, The NILE process), LVC Network Security, Contracting, etc.

- ➢ CMSP Evolution: Version 1.0 in 2001, 2.0 in 2010, 3.0 Released This Week
- ➢ 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
  - ■ Has Created a Vibrant Community of Practice
    - Quarterly Newsletter
    - Local Meetings (post COVID)
    - Conference Presence
      - E.g., I/ITSEC Over the Last Week
        - Special Event, Career Fair Participation
        - State of the Nation and then Reception
        - Presentation at University Cohort Session
        - Professional Development Workshop

CMSP 3.0 Initiatives

- ➤ 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 LEVELS

PROFESSIONAL VECTOR

M&S Professional Knowledge, Skills, and Abilities

MASTER
- Ability to independently plan and lead complex M&S technical projects
- Expert level skills in developing and applying M&S products, processes, and standards
- Ability to convey level of confidence and/or risk associated with M&S or LVC-based results
- Capability to derive and specify high level and detailed requirements with measurable acceptability criteria
- Expert knowledge in M&S planning, development, application, VV&A, or post-event analysis
- Ability to create advanced and integrate new M&S concepts, methods, and techniques
- Knowledge of virtual and augmented reality, serious gaming, war gaming, and commercial gaming
- Advanced knowledge of system and open architectures and engineering modeling
- Knowledge of virtual machines, virtualization, and visualization to include 3D results presentation
- Expert ability to use M&S to solve training, acquisition, experimentation, analysis / assessment, and similar
- Demonstrated M&S expertise based on academic, technical, or operational experience and background
- State-of-the-art knowledge or experience in a multitude of engineering or scientific disciplines
- Proficiency with Live, Virtual and Constructive simulations and their integration

PRACTITIONER
- Proven practical proficiency and competency in all major areas of M&S design, development, and application
- Ability to conduct M&S experiments and projects as well as to analyze, visualize and interpret data
- Ability to analyze M&S requirements, develop M&S methods, and prepare related reports and technical documents.
- Knowledge of M&S risk assessment techniques and/or systems acquisition risk management experience
- An understanding of software configuration management and quality control tools and techniques
- Knowledge of M&S related to assessment of system s development, supportability, and maintainability
- Familiarity of means and techniques to calculate M&S return on investment (ROI) and to articulate its value
- Knowledge of M&S-related acquisition strategies, policies, and regulations
- Knowledge of M&S community within industry, academia, and Government
- Ability to develop simulations using modern software development languages, processes, and tools
- Understanding of Verification, Validation, and Accreditation (VV&A) processes and procedures
- Ability to plan, organize, and coordinate work of multi-disciplined M&S/LVC technical teams
- Ability to present M&S-based results and convey results within a wide range of application communities

APPRENTICE
- Basic knowledge of M&S principals, methods, and practices (conceptual model development, Verification, Validation and Accreditation)
- Ability to apply knowledge of modeling and simulation, engineering, mathematics and science to projects/tasks
- Knowledge of protocols and other modeling standard architectures (i.e., HLA, DIS, TENA)
- Knowledge of process standards (e.g., The Distributed Simulation Engineering and Execution Process) and networks
- Familiarity with various models and systems supporting major application areas: Acquisition, Assessment, Training, Experimentation, Support to Operations
- Awareness of physics-based modeling and simulation and human factors
- Awareness of the infrastructure needed to run M&S systems (e.g., data, threat, scenarios, activities, processes, value thresholds, sensor settings)
- Ability to function as Integrated Product Team (IPT) member
- Ability to plan and execute M&S activities under direct supervision of a Practitioner or Master

INTERN
- Ability to articulate the similarities and differences between M&S and Live, Virtual, and Constructive Simulation
- Knowledge of fundamental tools, architectures, standards, reuse and interoperability approaches as well as associated physical, functional, and organizational instances of each
- Demonstrate a sound understanding of M&S fundamentals: definitions, applications, relationships, types
- Basic technical education in High School and passing of proctored M&S Examination designed by the National Simulation Center
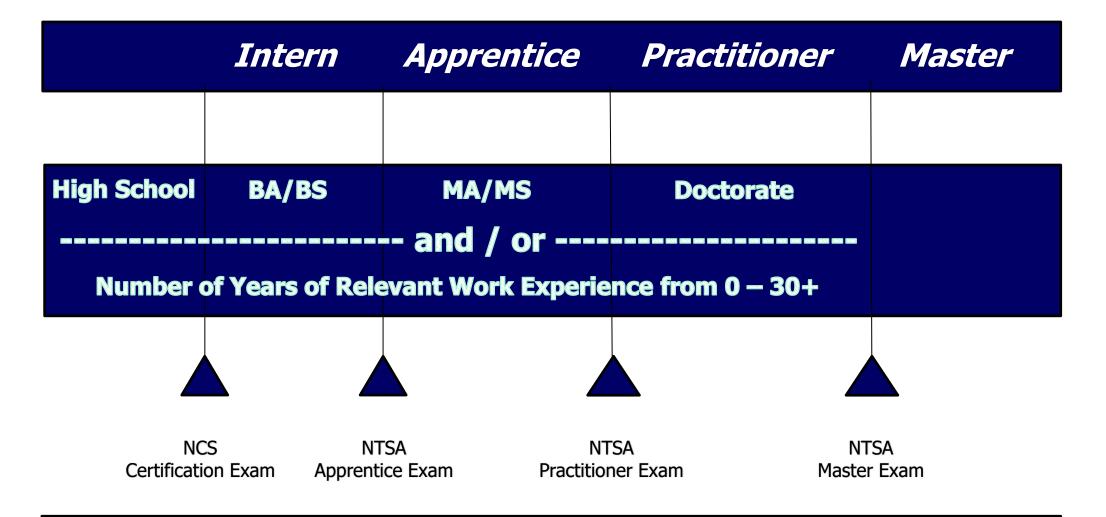
INTERN   APPRENTICE   PRACTITIONER   MASTER
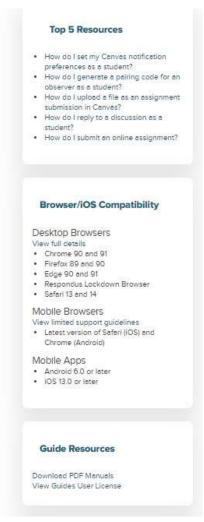
➢ The platform we are using is called Canvas

➢ 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

➢ 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

> 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

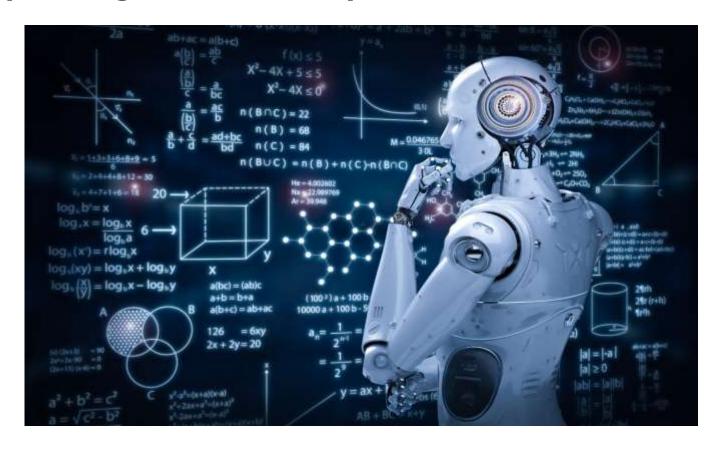**Keep striving, we need to stay smarter than the machines!**

➢ Feedback

➢ Q&A

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