

Syllabus for Applications of Engineering M&S Course

Course name: Selected Topics in the Application of Engineering Modeling and Simulation

- 1) **Course coordinator / point of contact and contact information:**
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- 2) **Course description:** This course provides the DoD acquisition professional with an overview of how typical engineering modeling and simulation applications support the acquisition process. A systematic approach will be used to demonstrate the function of physics based modeling and simulation in the design, production, operation and maintenance of complex systems. The course is broken into four general topic areas that address specific engineering features related to land vehicle systems, sea based systems, aviation systems and space-satellite systems. Investigations into the feasibility, utility, and risk of engineering modeling and simulation in each of these focus areas will be highlighting through the use of engineering case studies. Upon completion of this course, students should have a general awareness of engineering modeling and simulation applications in support of the acquisition lifecycle.
- 3) **Modules incorporated into Course:** Six modules as described in the topics.
- 4) **ESRs that the course supports and the corresponding level of mastery.**

General Awareness for ESRs E-1 through E-14 as stated below:

- E1) Structural Mechanics, Shock and Vibrations - Describe basic structural mechanics including stress-strain relations, buckling and fatigue, shock and vibration, and finite element methods in M&S.
- E2) Fluid Dynamics and Weapon System - Describe the basics of computational fluid dynamics for CFD application and use for M&S. Fluid dynamics of subsonic and supersonic weapons, warheads and their effects.
- E3) Dynamics and Control - Describe the basics of M&S in process and multi-physics (mechanical, electrical & hydraulic) based dynamic system controls.
- E4) Thermodynamics and Heat Transfer - Describe the fundamentals of thermodynamics and heat transfer with applications to M&S in engineering power cycles, propulsion and auxiliary system cycle analysis and design.
- E5) Materials and Fabrication - Describe the basic materials technology associated with manufacturing, welding and corrosion control. Have an introduction to composite, superconducting materials, and fiber optics as applied to M&S.
- E6) Acoustic and Electromagnetic Systems - Describe the fundamentals of acoustic and electromagnetic wave propagation in M&S applications.
- E7) Military Platform Systems Engineering – Apply a broad-based design oriented M&S approach for complex platforms that interact with air-land-sea-based hardware systems, command and control systems and combat systems.

- E8) Computers - Describe the basic computer system architecture, operating systems, networking and introduction to engineering software and their applications. Classify structured programming languages such as Fortran and C, and the use of such tools for code development. Recognize finite element/difference codes, with application to solve engineering problems including experience with selected software packages.
- E9) Electrical Engineering - Describe basic circuit analysis including DC and AC circuits. Describe the construction and operating characteristics of rotating machinery, static converters, power distribution systems and multi-phased circuits.
- E10) C4ISR - Describe the basic components, methods and alternatives for transferring information from one point to another both internal and external to the system being considered. Evaluate available technologies for achieving rapid/effective/jam-resistant information transfer.
- Networks – Describe the principles of networks applied to military applications including physical, command and control, and social networks and their implications for engineering design of systems.
- E12) Environment – Describe the fundamentals of terrestrial science (geology, oceanography, meteorology, and near-earth space science) to represent how systems interact with and are influenced by their environment.
- E13) Human Systems Integration – Describe the principles of Human Systems Integration. Describe the applications of M&S to support HSI design and analysis.
- E14) Aerodynamics – Describe the principles of aerodynamics with applications to M&S. Describe the cost, schedule, and iterative development nature of simulation testbeds used for flight software development through formal qualification.

- 5) **Prerequisites assumed, and corresponding level of mastery:** Introduction to Physics-based Modeling and Simulation, Fundamentals of Engineering Structural Systems, Overview of Computers, Weapons Platforms and Electrical Systems
- 6) **Course maturity:** Not previously taught.
- 7) **Number of contact hours and pace contemplated:** 3 hours of lecture/week for 16 weeks for a semester (or 4 hours of lecture/week for 12 weeks for a quarter).
- 8) **Proposed Delivery modality:** Initially resident (face-to-face).
- 9) **Proposed references and texts:** Course notes will be provided.
- 10) **Course learning objectives:**
 - a) Have a General Awareness of the most common types of physics-based modeling and simulation tools available to engineers, designers and analysts.
 - b) Describe the application of basic engineering M&S concepts in Land Warrior / Vehicle Systems

- c) Describe the application of basic engineering M&S concepts in Sea Based Systems
- d) Describe the application of basic engineering M&S concepts in Aviation Systems
- e) Describe the application of basic engineering M&S concepts in Space-Satellite Systems

11) Course Assessment Plan

- 1. Homework assignments.
- 2. Short essay papers.
- 3. Examinations

12) Topic list by hour of instruction and reference.

- 1. Module 1: M&S and the Acquisition Lifecycle (2 hours)
 - (1) Integration of Engineering M&S into the Acquisition Lifecycle (1hr)
 - (2) Survey of Common Engineering M&S Tools (1hr)
- 2. Module 2: Land Warrior / Vehicle Systems (10 hours)
 - (1) Vehicle, Engine, and Power Systems
 - (a) Introduction to the Dynamics of Moving Systems (1hr)
 - (b) Special Considerations for the Modeling of Vehicles (1hr)
 - (c) Fuel Systems, Batteries, and Other Power Systems (1hr)
 - (2) Armor and Blast Protection
 - (a) M&S of Explosion Phenomena (1hr)
 - (b) Layered Composite Materials- Armor and Blast Protection (1hr)
 - (c) Engineered Solutions to IEDs and Explosives (1hr)
 - (3) Human Systems Integration in Land Warrior Systems
 - (a) Hardware, Software, and Operator Interoperability (1hr)
 - (b) Communication Systems, Networks, and ISR (1hr)
 - (c) Warrior System Survivability Modeling (Biodynamics) (1hr)
 - (4) Synthetic Natural Environment (1hr)
- 3. Module 3: Sea Based Systems (9 hours)
 - (1) Propulsion Systems
 - (a) Implementing Kinetics Models (1hr)
 - (b) Assessing Design Impacts of Propulsor Choices thru M&S (1hr)
 - (c) Maneuvering, Hydrodynamics and Fluid Flow (1hr)
 - (2) Advanced Weapons Systems
 - (a) Overview of Electro-mechanical Control Systems (1hr)
 - (b) Efficiencies and Effectiveness of Weapon Systems (1hr)
 - (3) Electrical Power and Distribution Systems (1hr)
 - (4) Ship Survivability
 - (a) Review of Underlying Damage Mechanisms (1hr)
 - (b) Properly Modeling the Threat Environment (1hr)
 - (c) Understanding Engineering Simulation Response Data (1hr)
- 4. Module 4: Aviation Systems (9 hours)
 - (1) Aircraft Structures
 - (a) Structural Requirements and Modeling Considerations (1hr)
 - (b) Damage Tolerant Design – Fracture Mechanics Approach (2 hr)

(2) Light Weight Composites	
(a) Design Using Composites, Weight, Performance, and Cost Simulation	(2hr)
(b) Embedded Sensors, Smart Materials and Health Monitoring Systems	(1hr)
(3) Design Optimization	
(a) Aircraft Design Requirements and Modeling	(1hr)
(b) Incorporation of Vulnerability and Lethality in Design	(2hr)
5. Module 5: Space-Satellite and Launch Vehicle Systems	(10 hours)
(1) Flight Trajectories	
(a) M&S of Ballistic Missiles and Satellite Trajectories	(2hr)
(b) Control and Guidance Systems for Rockets	(2hr)
(2) Materials, Structures, Controls, Testing and Reliability in Spacecraft	
(a) Spacecraft Structures: Requirements Modeling and Simulation	(1hr)
(b) Attitude Control System and Thermal Control Systems	(1hr)
(c) Spacecraft Testing and Reliability	(1hr)
(3) Rocket Principles and Performance	
(a) Rocket Principles, Performance, and Trajectories	(1hr)
(b) Special Topics in Rocket Engines	(1hr)
(c) Power Systems for Satellites	(1hr)
6. Module 6: Applications to Design Space Exploration	(2 hours)
(1) M&S Example of a Satellite Subsystem	(2hr)
7. Review, Discussions, Exams	(4 hours)
	Total (44hr)

Recommended Reference Textbooks:

- Module 1: INCOSE Systems Engineering Handbook, C. Haskins, 2006
- Module 2: Fundamentals of Engineering Design, B. Hyman, 2002
- Module 3: Applied Naval Architecture, 1999, R.B. Zubaly, 1996
Fluid Mechanics, F. White, 1999
Customized Linear Control Systems Engineering, M. Driels, 2000
- Module 4: Structural Loads Analysis for Commercial Transport Aircraft: Theory and Practice, TL Lomax, 1996
Fundamentals of Aircraft Combat Survivability, Analysis and Design, R. Ball, 2003
Material Science and Engineering - An Introduction, W. Callister, 2000
Analysis & Design of Flight Vehicle Structures, EF Bruhn, 1973
Fundamentals of Structural Integrity: Damage Tolerant Design and Nondestructive Evaluation, AF Grandt
- Module 5: Satellite Technology and Its Applications, PRK Chetty, 1988
Astronautics, B.P. Blasingame, 1964
Design of Geosynchronous Spacecraft, BN Agrawal, 1986
- Module 6: Engineering Robust Designs with Six Sigma, JX Wang
System Reliability Theory – Models and Statistical Methods, A Hoyland and M Rausand