Modeling & Simulation (M&S) Certification Examination

Study Guide

March 1, 2019

Table of Contents

1. Introduction

A Modeling and Simulation (M&S) Certification for High School and Technical School students is important, especially in the era of expanding applications of simulation, animation and gaming. With many new jobs being created in M&S, the workforce pipeline must be filled with skilled people. M&S growth is world-wide with positions available at all levels, requiring various skills in many application areas. Those high school students with a Science, Technology, Engineering and Mathematics (STEM) education are positioned very well for internships and entry level jobs in the M&S industry. The simulation industry needs engineers, graphic artists, education specialists, psychologists, contract administrators, technicians, programmers and many other disciplines to support a wide range of applications which is growing on a day-by-day basis. The underlying rationale for certification is to provide a qualified workforce able to support growing demands. The "supply" side for meeting these requirements is affected by: a) the number of people in the workforce who are retiring or eligible to retire within the next five years, b) the number of college graduates ready to enter the STEM workforce is at a new low and the "demand" side is impacted by the rapidly expanding use of simulation into areas such as defense, entertainment, medical, transportation, cyber security, manufacturing, aerospace, education and training. This certification program benefits the M&S industry by creating student interest and a higher level of competency in STEM disciplines that prepare students for M&S careers in many fields. The National Center for Simulation (NCS) M&S Certification Program provides the industry with a pool of skilled and motivated students to fill paid internship positions. Additionally, students who are participants in the NCS M&S Certification Program are better prepared and are more qualified as candidates for full time employment in the M&S industry, requiring less entry level training and improving overall productivity and company competitiveness is increased because the interns can assume low level STEM work that was formerly performed by entry level personnel. Our model for developing the pipeline of talent to support the M&S industry is shown in the figure below. NCS, in coordination with the Florida Departments of Education (FDOE) and Economic Opportunity (DEO), Career Source Florida, Inc. (CSFL), Career Source Central Florida (CSCFL), and Orange County and Seminole County Public Schools, developed this industry certification program in M&S for high school and technical school students. This certification program is aligned with the Florida M&S standards and is approved for Career and Professional Education (CAPE) Act funding. The NCS certification program is a national initiative and not regional. The program has its roots in Florida because of the high simulation activity in that state. The plan is to encourage other states to embrace the program, building the M&S workforce. In 2018, the NCS M&S industry certification was approved by the State of Virginia. That same year, NCS requested the State of Ohio to approve the same certification.

Florida's Modeling & Simulation STEM/M&S Workforce Pipeline
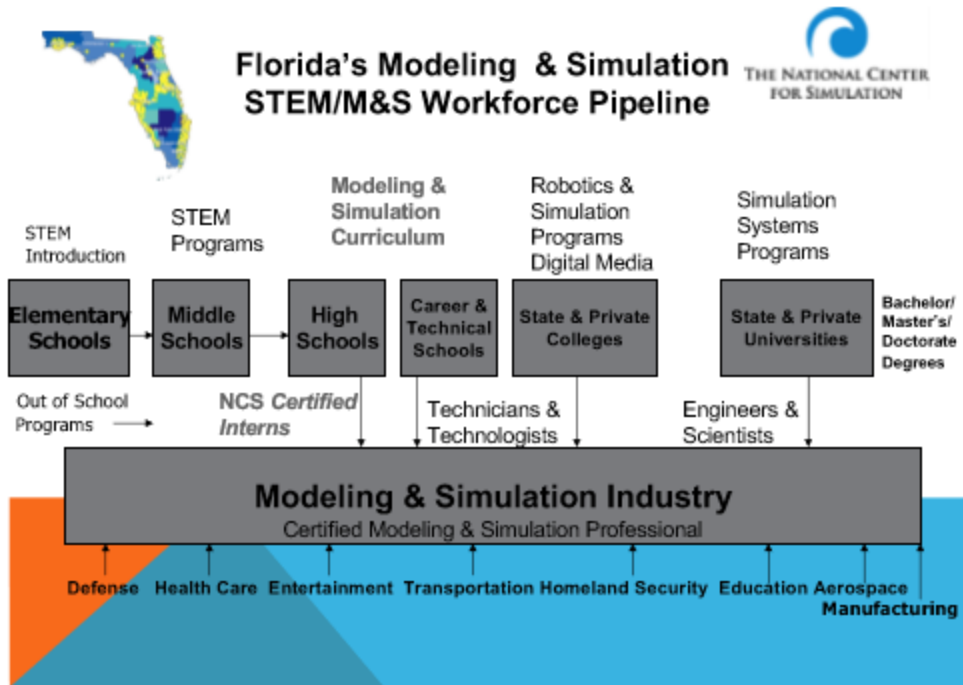
The Modeling and Simulation certification exam doesn't require a specific curriculum to follow for success; however, there is a compiled 4-year curriculum that can be accessed at (www.simulationinformation.com). The certification exam is designed to test student's understanding of applied technology concepts, tools and techniques used in the M&S Industry. Due to the scope of the M&S industry, students studying many different STEAM career pathways; such as, robotics, gaming, simulation, digital art and animation qualify to participate in joining the hundreds of students across Florida who have already earned their NCS Certification.

Lt Gen (Ret) Tom Baptiste, NCS President and Executive Director, added "This certification program creates a pool of skilled and motivated students in Central Florida who will be ready for recruitment in internships. Because of this program, these students will be better prepared and more qualified as candidates for full time employment in the M&S industry."

Special recognition to the NCS Examination Sub-Committee, led by Deb Yeagle and to Orange and Seminole County teachers Phil Tillery and Lyn Higgins for their tireless work in developing this Study Guide. Many others participated from industry, government and academia to include Elizabeth Burch, Sunny Simmonds, Cathy Matthews, Paul Paquette, Kevin Gouvia, Karen Connors and Alan Lynch.

Oversight is provided by a M&S Certification Board consisting of the following members:

Jeanine Matthews- Chair (Lockheed Martin), Elizabeth Burch (Dignitas Technologies), George Cheros (National Center for Simulation), Dr. Mike Macedonia (University of Central Florida), Maynard Zettler (Naval Air Warfare Center Training Systems Division) and Brent Smith (Consultant)

2. General Study Tips

To prepare for the certification exam, use this study guide and consider the study tips provided below:

• Find a study partner or form a study group
• Try to study every day
• Avoid cramming
• Spend more time on your weak areas
• Pick a time to study when you are most alert. Research shows that the morning and early evening is best.
• Stick to the study schedule
• Keep breaks short: 3-5 minutes is adequate
• Study one topic at a time
• The next day review what you learned the day before
• Make outlines and map out what you learned and develop questions from your outline
• Reading out loud helps reinforce the material
• Flash cards or index card may be helpful

Make sure you go to the NCS website to access the M&S Study Guide:
https://www.simulationinformation.com/education/articles/ncs-introduces-high-school-modeling-and-simulation-program-iitsec

Before progressing further in this guide, click the link to see a short video - M&S 101: https://www.youtube.com/watch?v=Ek-gVwWfIT4

3. What to expect when you take the Exam

The study guide is organized to help students and teachers focus on main concepts across six sections the M & S industry feels are important for students to understand. The M&S Industry has collaborated on the following sections represented on the NCS Certification Exam; Section 1-General Modeling & Simulation Terms (Vocabulary), Section 2- Project Management & Logistic Support, Section 3- Ethics, Entrepreneurship & Innovation , Section 4- Visualization, 3D Modeling & Animation, Section 5- Coding, Programming & Gaming , Section 6- Simulations & Simulators to ensure students passing the certification exam have a level of M&S understanding that will allow them to work as an intern in Industry while pursing STEAM careers.

Table 1 below shows the breakdown of questions for each section. The visualization, 3D Modeling & Animation section has the most weight due to entry level skills needed as well as most schools have the labs and teachers to support the content. Vocabulary is essential, students should be in the practice of using correct vocabulary when working on projects to prepare for internships in Industry.

Table 1: Percent of each topic represented on the exam:

General Modeling & Simulation Terms	Project Management & Logistic Support	Ethics, Entrepreneurship & Innovation	Visualization, 3D Modeling & Animation	Coding, Programming & Gaming	Simulations & Simulators
25%	10%	8%	30%	12%	15%

The certification exam consists of 50 questions, including multiple choices, true/false, and matching questions. Some questions will involve simple calculations to determine the answer. You will NOT be allowed to have Internet access through mobile phones, laptops, tablets, or any other device. The certification will be timed. You will have 55 minutes to complete the exam. Any questions that are not answered are considered incorrect. The certification exam questions are written to test your critical thinking skills. There are certainly many recall or memory items; however, most questions will have you reflect on what you have learned in your high school or technical school curriculum and conclude with the correct answer. If you like to memorize data, try to not only memorize the facts but think of an example, so you show application skills. If you do not understand the underlying material, then ask your teachers for an explanation and an example to help with your understanding. The fifty (50) questions are randomly selected from a bank of questions that test your knowledge in the sections mentioned above.

Section 1—General Modeling & Simulation Terms (Vocabulary)

1. Augmented Reality
   An enhanced image or environment as viewed on a screen, head-mounted, or other display, produced by overlaying computer-generated images, sounds, or other data on a real-world environment. Click the link below to see an example of how industry is applying real-time infusion of virtual environments and content within the physical world. https://www.dignitastechnologies.com/

2. Client/Server Model
   In the client-server model of computing, tasks are distributed between a service provider, called a server, and a service requester, or client. The client-server model was widely used in the early days of computing, when access to expensive mainframe computers was provided by dumb terminals. More recently, the client-server model proved crucial to the development of the Internet. There are several models for client-server interaction, with the main difference being the amount of work performed on each side.
   Click the link below to watch a short video:
   https://www.youtube.com/watch?time_continue=42&v=L5BlpPU_muY

   Click the link below to see a diagram courtesy of Google 2018.
   https://cloud.google.com/solutions/gaming/cloud-game-infrastructure

3. Discrete Event Model Simulation
   Models that simulate the operation of a system as a discrete sequence of events in time. Each event occurs at a particular instant in time and marks a change of state in the system. It is a valuable analysis tool for improving system effectiveness and efficiencies. Example: Model a queue, such as customers arriving at a bank to be served by a teller.
   Click the link below to see an example of how to apply a discrete event model simulation: https://www.mathworks.com/videos/model-a-discrete-event-system-overview-1-of-7-81124.html

4. Environmental Model
   A numerical model, parametric model, or database designed to produce an accurate and consistent data set for one or more parameters that characterize the state of the natural environment. The environmental simulation is a simulation that

depicts all or part of the natural or manmade environment of a system; for example, a simulation of the radar equipment and other tracking devices that provide input to an aircraft tracking system, it includes weather, terrain, sea states and all-natural conditions.

Click the link below to see an example of how industry is applying Environmental Modeling to create high fidelity simulations. https://bisimulations.com/

5. Fidelity
In the fields of scientific modelling and simulation, fidelity refers to the degree to which a model or simulation reproduces the state and behavior of a real-world object, feature or condition. Fidelity is therefore a measure of the realism of a model or simulation. feature or condition.

Functional Fidelity is the degree to which the simulated functions coincide with functions of the parent system (aircraft, railroad train, ship, etc.) Functional fidelity does not require the simulator to look exactly like the parent system whereas "physical fidelity" does require a "look alike".

Click the link below to see an example of how industry is applying fidelity in powerplant systems: https://www.gses.com/blog/simulation-training/high-fidelity/

6. Game Theory
Game theory is the study of strategic decision making. Specifically, it is "the study of mathematical models of conflict and cooperation between intelligent rational decision-makers." An alternative term suggested "as a more descriptive name for the discipline" is interactive decision theory. Game theory is mainly used in economics, political science, and psychology, as well as logic, computer science, and biology. The subject first addressed zero-sum games, such that one person's gains exactly equal net losses of the other participant or participants. Today, however, game theory applies to a wide range of behavioral relations and has developed into an umbrella term for the logical side of decision science, including both humans and non-humans (e.g. computers, animals).

Click the link below to learn a little more about Game Theory:
https://www.youtube.com/watch?v=3Y1WpytiHKE

7. Incubation (Business) Phase
Business incubation provides a nurturing, instructive and supportive environment for entrepreneurs during the critical stages of starting up a new business. The goal of incubators is to increase the chance that a start-up will succeed and shorten the time and reduce the cost of establishing and growing its business. If successful, business incubators can help to nurture the companies that will form the true creators of a region's or nation's future wealth and employment.

Click the link below to see an example of how UCF supports innovation:
https://incubator.ucf.edu/

8. Integrated Logistics Support (ILS)
The composite of the elements of support necessary to assure the effective and

economical support of a system or equipment at all levels of maintenance for its programmed life cycle. The elements of support are as follows:

    a. Design Interface (Reliability, Maintainability and Availability)
    b. Maintenance Planning
    c. Manpower and Personnel
    d. Training and Training Support
    e. Technical Data and Publications
    f. Packaging, Handling and Transportation
    g. Computer Support Resources
    h. Site Preparation and Facilities
    i. Support and Test Equipment
    j. Supply Support
    k. Logistics Information

Click the link below to see an example of logistics:
https://www.youtube.com/watch?v=4-QU7WiVxh8

9. Integrated Product Team (IPT)
Multidisciplinary group of people who are collectively responsible for delivering a defined product or process. IPTs are used in complex development programs/projects for review and decision making. The emphasis of the IPT is on involvement of all stakeholders (users, customers, management, developers, and contractors) in a collaborative forum. IPTs are created most often as part of structured systems engineering methodologies, focusing attention on understanding the needs and desires of each stakeholder.
Click the link below to see an example of how GE does business:
https://jobs.gecareers.com/ShowJob/Id/81903/Advanced-Lead-Engineer-Integrated-Product-Team-(IPT)-Lead/

10. Intellectual Property
A legal term that refers to creations of the mind. Intellectual property can be protected through patents, trademarks or copyrights. Click the link below to take a virtual tour of how Entrepreneurs can be come successful with their innovations.
http://www.theviplawfirm.com/virtual-tour.html

11. Link Blue Box
The first modern pilot trainer invented by Edwin Link of Binghamton, NY. The trainer, pneumatically operated, was used extensively in World War II to train US and allied pilots.
Click the link below to see an example of the Link Trainer:
https://www.youtube.com/watch?v=8YaAKPcDH6o

12. Live Simulation
A type of simulation that typically involves humans and/or equipment and activity in a setting where they would normally operate.
Click the link below to see an example of how Cubic is using live, virtual and

constructive simulations together:
https://www.youtube.com/watch?v=UMovgWzHj8o

13. Mathematical Model
    Mathematical models are usually composed of relationships and variables.
    Relationships can be described by operators, such as algebraic operators,
    functions, differential operators, etc. Variables are abstractions of system
    parameters of interest, that can be quantified. Several classification criteria can be
    used for mathematical models according to their structure. See examples:
    a. Linear vs. nonlinear: If all the operators in a mathematical model exhibit
       linearity, the resulting mathematical model is defined as linear. A model is
       nonlinear otherwise. The definition of linearity and nonlinearity is
       dependent on context, and linear models may have nonlinear expressions
       in them. For example, in a statistical linear model, it is assumed that a
       relationship is linear in the parameters, but it may be nonlinear in the
       predictor variables. Similarly, a differential equation is said to be linear if it
       can be written with linear differential operators, but it can still have
       nonlinear expressions in it. In a mathematical programming model, if the
       objective functions and constraints are represented entirely by linear
       equations, then the model is regarded as a linear model. If one or more of
       the objective functions or constraints are represented with a nonlinear
       equation, then the model is known as a nonlinear model. Nonlinearity,
       even in fairly simple systems, is often associated with phenomena such as
       chaos and irreversibility. Although there are exceptions, nonlinear systems
       and models tend to be more difficult to study than linear ones. A common
       approach to nonlinear problems is linearization, but this can be
       problematic if one is trying to study aspects such as irreversibility, which
       are strongly tied to nonlinearity.
    b. Static vs. dynamic: A dynamic model accounts for time-dependent
       changes in the state of the system, while a static (or steady-state) model
       calculates the system in equilibrium, and thus is time-invariant. Dynamic
       models typically are represented by differential equations.
    c. Explicit vs. implicit: If all of the input parameters of the overall model are
       known, and the output parameters can be calculated by a finite series of
       computations (known as linear programming, not to be confused with
       linearity as described above), the model is said to be explicit. But
       sometimes it is the output parameters which are known, and the
       corresponding inputs must be solved for by an iterative procedure, such
       as Newton's method (if the model is linear) or Broyden's method (if non-
       linear). For example, a jet engine's physical properties such as turbine and
       nozzle throat areas can be explicitly calculated given a design
       thermodynamic cycle (air and fuel flow rates, pressures, and
       temperatures) at a specific flight condition and power setting, but the
       engine's operating cycles at other flight conditions and power settings
       cannot be explicitly calculated from the constant physical properties.

d. <u>Discrete vs. continuous:</u> A discrete model treats objects as discrete, such as the particles in a molecular model or the states in a statistical model; while a continuous model represents the objects in a continuous manner, such as the velocity field of fluid in pipe flows, temperatures and stresses in a solid, and electric field that applies continuously over the entire model due to a point charge.

e. <u>Deterministic vs. probabilistic (stochastic):</u> A deterministic model is one in which every set of variable states is uniquely determined by parameters in the model and by sets of previous states of these variables; therefore, a deterministic model always performs the same way for a given set of initial conditions. Conversely, in a stochastic model—usually called a "statistical model"—randomness is present, and variable states are not described by unique values, but rather by probability distributions.

f. <u>Deductive, inductive, or floating:</u> A deductive model is a logical structure based on a theory. An inductive model arises from empirical findings and generalization from them. The floating model rests on neither theory nor observation but is merely the invocation of expected structure. Application of mathematics in social sciences outside of economics has been criticized for unfounded models. Application of catastrophe theory in science has been characterized as a floating model.

Click the link below to see an example of why mathematical models are important:
https://www.youtube.com/watch?v=xHtsuOB-TPw

14. <u>Mean Time Between Failure (MTBF)</u>
A way to quantify and measure how reliable a product or component, usually measured in tens of thousands of hours. It is the number of hours accumulated by a system or equipment divided by the number of failures experienced over that period of time.
Click the link below to see an example of how to calculate:
https://www.youtube.com/watch?v=9Lo1QfgMuTc

15. <u>Mean Time to Repair (MTTR)</u>
A way to quantify and measure the maintainability of a product or component. MTTR is calculated by measuring the time to complete maintenance actions over a period of time, adding them up and calculating the mean value in minutes or hours.
Click the link below to see an example of how to calculate:
https://www.youtube.com/watch?v=9Lo1QfgMuTc

16. <u>Mixed Reality</u>
The merging of both real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time.
Click the link below to see an example of how industry is applying mixed reality:
https://www.youtube.com/watch?v=v8wtHZDVdlc

17. <u>Objected Oriented Design</u>
The process of planning a system of interacting   objects for the   purpose of

solving a software problem. It is one approach to software design. An object contains encapsulated data and procedures grouped together to represent an entity.
Click the link below to see an example:
https://www.youtube.com/watch?v=xTI8R0e7a8E

18. Objected Oriented Programming
Programming language model organized around objects rather than "actions" or data rather than logic.
Click the link below to see an example of OOP:
https://dev.to/charanrajgolla/beginners-guide---object-oriented-programming

19. Peer-to-Peer Model
A decentralized communications model where each party have similar capabilities acting as both client and server on a shared network and either party can imitate a communication session.
Click the link below to see an example:
https://www.youtube.com/watch?v=w2u4eN_WWvc

20. Physical Model
A smaller or larger physical copy of an object.
Click the link below to see an example:
https://www.youtube.com/watch?v=XapBtOe8Blk

21. Process Model
Process of the same structure that are classified together into a model.
Click the link below to see an example:
https://www.orbussoftware.com/resources/videos/bpmn-distilled/benefits-of-process-modeling/

22. Project Management
The process and activity of planning, organizing, motivating, directing and controlling resources, procedures and protocols to achieve specific goals in scientific or daily problems. A project is a temporary endeavor designed to produce a unique product, service or result with a defined beginning and end (usually time-constrained, and often constrained by funding or deliverables) undertaken to meet unique goals and objectives, typically to bring about beneficial change or added value. The temporary nature of projects stands in contrast with business as usual (or operations), which are repetitive, permanent, or semi permanent functional activities to produce products or services. In practice, the management of these two systems is often quite different, and as such requires the development of distinct technical skills and management strategies.
Click the link below to see an example: https://www.process.st/project-management-steps/

23. Prototype
Original model like a sample on which to base future designs.   (A company designing a new toaster will first design and build a prototype, to test it out and see if it's any good or not. The same is true for simulators where a prototype is built before going to production.)
Click the link below to see an example:
https://www.youtube.com/watch?v=4XenqN5Ib9o

24. Quality Assurance
A way of preventing mistakes or defects in manufactured products and avoiding problems when delivering solutions or services to customers; which ISO 9000 defines as "part of quality management focused on providing confidence that quality requirements will be fulfilled". This defect prevention in quality assurance differs subtly from defect detection and rejection in quality control and has been referred to as a shift left as it focuses on quality earlier in the process.
Click the link below to see an example of how industry is applying it:
https://www.diffen.com/difference/Quality_Assurance_vs_Quality_Control

25. Requirements Traceability Matrix (RTM)
A sub-discipline of requirements management within software development and systems engineering. Requirements traceability is concerned with documenting the life of a requirement and providing bi-directional traceability between various associated requirements. It enables users to find the origin of each requirement and track every change that was made to this requirement. For this purpose, it may be necessary to document every change made to the requirement.
Click the link below to see an example of how industry is applying it:
https://www.sayonetech.com/blog/what-requirement-traceability-matrix-and-why-testers-should-use-it/

26. Reliability, Availability and Maintainability (RAM)
Reliability is the probability that an engineering system will perform its intended function satisfactorily (from the viewpoint of the customer) for its intended life under specified environmental and operating conditions. Maintainability is the probability that maintenance of the system will retain the system in, or restore it to, a specified condition within a given time period. Availability is the probability that the system is operating satisfactory at any time, and it depends on the reliability and the maintain ability. Hence, the study of probability theory is essential for understanding the reliability, maintainability and availability of a system.
Click the link below to see an example of how industry is applying it:
https://www.youtube.com/watch?v=CmvKa26IdSc

27. Risk Mitigation
The identification, assessment, and prioritization of risks (defined in ISO 31000 as the effect of uncertainty on objectives) followed by coordinated and economical

application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events or to maximize the realization of opportunities. Risk management's objective is to assure uncertainty does not deflect the endeavor from the business goals.

Click the link below to see an example of how industry is applying it:
https://www.youtube.com/watch?v=x7A9idByPA4

28. Serious Games

Games that simulate real-world events or processes to solve problems. These games can be used for law enforcement, medical applications and other simulations.

Click the link below to see an example of how industry is applying it:
https://www.youtube.com/watch?v=a6vCvgzS9ps

29. Simulation

The imitation of the operation of a real-world process or system over time. The act of simulating something first requires that a model be developed; this model represents the key characteristics or behaviors/functions of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time. Simulation is used in many contexts, such as simulation of technology for performance optimization, safety engineering, testing, training, education, and video games. Often, computer experiments are used to study simulation models. Simulation is also used with scientific modeling of natural systems or human systems to gain insight into their functioning. Simulation can be used to show the eventual real effects of alternative conditions and courses of action. Simulation is also used when the real system cannot be engaged, because it may not be accessible, or it may be dangerous or unacceptable to engage, or it is being designed but not yet built, or it may simply not exist. Training simulations typically come in one of three categories (Refer to National Training and Simulation Association- produced MS-101 on You Tube https://www.youtube.com/watch?v=M0iZ52kUOiQ).

   a. Live Simulations involve real humans and/or equipment and activity in an actual setting, for example, soldiers practicing in the field as part of an exercise. Time is continuous, as in the real world. Another example of live simulation is a disaster response team responding to mock emergency. In this scenario the people and equipment are real but the situation is simulated.

   b. Virtual simulations involve real humans with equipment that is partially, or completely, simulated. Examples include, a human operating a flight simulator, driving simulator, or nuclear power-plant simulator.

   c. Constructive Simulations involve humans and equipment that are both simulated. Most military strategic simulations are constructive. Other examples include crowd evacuation, disease spread, and weather predictions models. A constructive simulation for weather could anticipate the path of a hurricane using variables such as current and changing temperature, pressure, wind current and other weather factors. In summary, the differences among live, virtual, and constructive can be summarized as

follow: Live: real people – real equipment. Virtual: real people – simulated equipment. Constructive: simulated people – simulated equipment.

30. Synthetic Modeling
Constructed from extant, autonomous software components whose existence and purpose are independent of the underlying model they comprise.
Click the link below to see an example of how industry is applying it:
https://www.riaktr.com/synthetic-data-become-major-competitive-advantage/

31. Systems Engineering
An interdisciplinary field of engineering that focuses on how to design and manage complex engineering systems over their life cycles. Issues such as requirements engineering, reliability, logistics, coordination of different teams, testing and evaluation, maintainability and many other disciplines necessary for successful system development, design, implementation, and ultimate decommission become more difficult when dealing with large or complex projects. Systems engineering deals with work-processes, optimization methods, and risk management tools in such projects. It overlaps technical and human-centered disciplines such as control engineering, industrial engineering, software engineering, organizational studies, and project management. Systems engineering ensures that all likely aspects of a project or system are considered and integrated into a whole.
Click the link below to see an example: https://www.incose.org/about-systems-engineering

32. Virtual Reality (VR)
A hypothetical three-dimensional visual world created by a computer; user wears special goggle and fiber optic gloves etc. and can enter and move about in this world and interact with objects as if inside it. Can be referred to as immersive multimedia or computer-simulated life, replicates an environment that simulates physical presence in places in the real world or imagined worlds. Virtual reality can recreate sensory experiences, which include virtual taste, sight, smell, sound, and touch. Most up- to- date virtual reality environments are displayed either on a computer screen or with special stereoscopic displays, and some simulations include additional sensory information and emphasize real sound through speakers or headphones targeted towards VR users. Some advanced, haptic, systems now include tactile information, generally known as force feedback in medical, gaming and military applications. Furthermore, virtual reality covers remote communication environments which provide virtual presence of users with the concepts of telepresence and tele-existence or a virtual artifact (VA) either through the use of standard input devices such as a keyboard and mouse, or through multimodal devices such as a wired glove or omni-directional treadmills. The simulated environment can be similar to the real world in order to create a lifelike experience—for example, in simulations for pilot or combat training—or it differs significantly from reality, such as in VR games.
Click the link below to see an example:
https://www.youtube.com/watch?v=HBNH8tzsfVM

33. <u>Virtual Simulation</u>
Where actual players use simulated systems in a synthetic environment. Examples are for flight simulation, education where avatars are employed or medical simulation using human patient simulators.
Click the link below to see an example of how industry is applying it:
https://www.ama-assn.org/education/accelerating-change-medical-education/virtual-reality-taking-dummies-out-medical

34. <u>Work Breakdown Structure (WBS)</u>
A work breakdown structure (WBS) is depicted on a chart in which the critical work elements, called tasks, of a project are illustrated to portray their relationships to each other and to the project. The Project Team utilizes the WBS with a project milestone chart. The graphical nature of the WBS can help a project manager predict outcomes based on various scenarios, which can ensure that optimum decisions are made about whether to adopt suggested procedures or changes.
Click the link below to see an example:
https://www.youtube.com/watch?v=4h09ZT0lT8M

Section 2—Project Management & Logistics Support

Project Management

The Project Management Institute (PMI) was founded in 1969 when the aerospace, construction and defense industries recognized the need for professionalism in project management. It provides a forum to exchange ideas, problems and solutions as well as standardization of project management practices as a whole. PMI developed a Guide to the Project Management Body of Knowledge (PMBOK Guide) to present a set of standard terminology and guidelines for project managers that are generally recognized as good practice. The Project Management Institute offers seven certifications that recognize knowledge and competency, including the Project Management Professional (PMP) certification held by nearly 650,000 practitioners worldwide. PMI's standards for project, program and portfolio management are the most widely recognized standards in the profession.

A project is defined as a temporary endeavor undertaken to create a unique product, service or result. Projects have a definite beginning and end.   They can be long or short in duration and the outcome may be tangible or intangible. For example, a project to build a national monument will create a lasting result but a project to plan and execute a meeting is much more short term.

The project manager is responsible for the project from inception to completion, encompassing the following five processes:

1. Initiating – defining a new project (or a new phase of a project)
2. Planning – establishing the scope of a project
3. Executing – the processes performed to complete the work
4. Monitoring and Controlling – tracking, reviewing and regulating the project
5. Closing – finalizing all activities to formally close the project

Throughout these five phases, Project Managers are responsible for the <u>scope, cost, schedule, and quality</u> of the deliverable products and services required under the terms of the contract. Scope, cost and schedule are like the three legs of a stool: all three are required to balance, in this case, the project. A Project Manager needs to maintain the balance by keeping a project within the customer's scope, on time and within budget for it to be successful. How well each one of those areas is delivered is the quality – like fine workmanship on a stool.

- <u>Scope Management</u>**:** The contract normally includes a specification or Statement of Work (SOW) that describes what the customer intends to be delivered (scope). It should include all the work required, and only the work required, to complete the project successfully. The Project Manager will subdivide the project work into smaller, more manageable components which is called a Work Breakdown Structure (WBS). This analysis, along with project management software tools, enables the manager to develop reasonable time and cost estimates for executing the work to the customer's satisfaction.
- <u>Cost Management</u>**:** Cost management includes planning, estimating, budgeting, financing, funding and controlling costs so that the project can be completed within the approved budget.
- <u>Time Management</u>**:** The schedule is also a very important factor and includes close time management to ensure timely completion of the project.   This includes an estimate of how long the project will take and what resources are needed to complete the job.
- <u>Quality Management</u>: Quality management is determining the quality policies, objectives, and responsibilities so the project will meet the customer's needs (Performance requirements).

The Department of Defense (DoD) places emphasis on three factors: cost, schedule and performance. Cost and schedule are obvious. Performance is a measure of how well the system should perform when compared to the Specification and Statement of Work (SOW)., For example, if the specification for a flight trainer requires a visual display to have 180 degrees Field of View (FOV) and the contractor is having difficulty in developing one with that FOV, it must be reported by the Project Engineer to the Program Manager and identified as a "risk area". By doing so, the team can identify mitigation measures to get the design back up to the Specification requirements.

Risk is inherent in every endeavor. Every project has some risk in design, development or delivery and support. Risks can be in scope, schedule and/or cost. The Project Manager must assess that risk to develop reasonable cost and schedule estimates.

Very often, customers wish to know where those risks are so that they can be involved in risk mitigation (working around those risks). The Project Manager, with his or her team, must identify those risks and determine the impacts anticipated. From that activity, risk mitigation measures are identified to help lessen the effects of the risk areas identified.

Communication is a very important aspect of Project Management. The free flow of information within a project is vital to performance. Project teams can include members from diverse cultural and organizational backgrounds and effective communication creates a bridge among diverse team members. Today, most communications take place electronically. However, face-to-face meetings are very important. Integrated Product Teams (IPTs) are used throughout the government. The emphasis of the IPT is on involvement of all stakeholders (users, customers, management, developers, contractors) in a collaborative environment for project designs, reviews, and decision-making. A virtual form of face-to face meetings can be accomplished using technology such as web meetings and video conferencing.

Whether they realize it or not, students are immersed in the discipline of project management each time they plan a school play, plan their graduation, or enter a robotics competition. Exposing high school students to the formal Project Management Body of Knowledge will better prepare them for their future endeavors, whether that is in College or the workforce. Project Management is a skill that is in great demand across a wide spectrum of industries and organizations.
The management of projects requires a skill set that can be applied to projects of various sizes, commodities and services. The processes for managing projects include new and unique terms requiring definition and understanding. To be able to function in any aspect of business, government or academia one has to be familiar with project management. From a career perspective, students entering industry will have a definite advantage by understanding the role and functions of project managers and project teams.

Logistic Support

The support of a simulator is crucial in making sure that the system is available when it is needed. It takes a lot of planning and coordination to provide the support assets as required. This is accomplished through an effective Integrated Logistic Support (ILS) Program. ILS is defined as a composite of the elements of design and support necessary to provide for the effective support of the system for its programmed life cycle. The elements include the following:

- Reliability and Maintainability
- Design Interface
- Maintenance Planning
- Supply Support
- Support and Test Equipment
- Manpower and Personnel

- Training and Training Support
- Technical Data and Publications
- Computer Resources Support
- Facilities
- Packaging, Handling and Transportation

Through the ILS process we can maximize simulator Availability and deliver a system that will have minimum Life Cycle Costs.

The logistics program is managed by the Integrated Logistics Support Manager (ILSM) who reports directly to the Project Manager. The ILSM is at the same level as the Project Engineer for the project, having an equal voice when it is necessary to make trade-off decisions. All the team members constitute an Integrated Project Team (IPT). The following figure depicts a typical project **structure.**
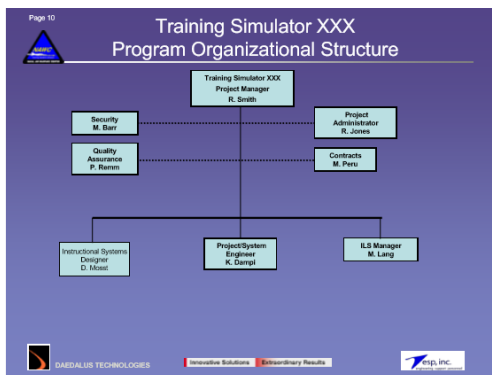
Systems Engineering

Systems engineering is an interdisciplinary approach to manage the technical realization of a successful project/program. Systems engineering processes provide technical insight into the holistic status of projects/programs. This is important for many reasons.

- Many technical disciplines work together for product solutions and interact with other design areas. If the design requirements aren't fully understood by all designers, there can be problems resulting. For example, if the visual system engineers do not fully understand the requirement for weather, a student pilot in the training system may see with their "out-the-window" view a clear and calm day, but the aircraft is not responding because the environmental engineers are simulating thunderstorms and wind shear effects based by a scenario setting not used by the visual engineers.
- There may be a trade-off required among the technical designers to meet computational size, timing or network limitations.
- There may be cost considerations that drive the solution to tailor the technical approaches.

- There may be schedule considerations which drive the solution a particular way.
- The technical solution may require more personnel to run or maintain the system than are available. The cost to maintain the system may be higher than the original cost of the system.
- The architecture (software/hardware) may not be conducive to making changes required to reflect future customer needs.

The systems engineering process provides tools to allow the team to provide the right level of data and insight for the program team to make the right decision. A few fundamentals of what's expected in systems engineering:

- Know the requirements (what's needed?!)
- The requirements are then further derived to better determine the technical design approach (Trace these in a **Requirements Traceability Matrix** (RTM))
- The **RTM** allows changes in design to flow back to the base requirements (training objective and training requirements for training systems).
- The **RTM** also flows to design documentation throughout the program, resulting in the basis for the test procedure.
- Capture Program Risks and document with impact and mitigation strategies. Document and Brief this to a Risk Team on a planned schedule. (no surprises!)
- Technical design reviews – these are held based on the progression of the design development to ensure to design is mature enough to go onto the next development stage.
- Continually evaluate the teams' status, personnel requirements, schedule considerations, interim product item completion.
- The amount of documentation and the extent of the review are based on the complexity and risk of the project/program.

Close coordination between project/systems engineering and logistics is necessary to guarantee sustainability once the system is put out in the field. We do not want the system to keep breaking down and the user becomes disenchanted with the system.

In the following figure, major program milestone activities are shown on the left and "logistics" actions and interfaces on the right side of the figure.
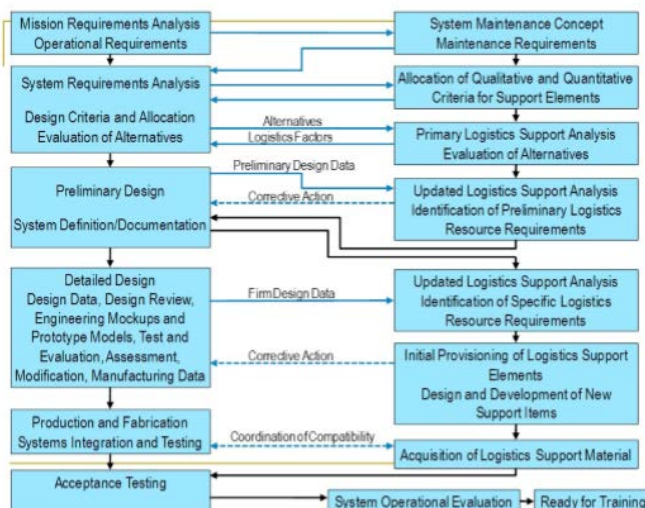
Section 3—Ethics, Entrepreneurship & Innovation

<u>Ethics</u>

Ethics objectives for industry employees are:

1) Apply ethical and legal issues (including copyright) with technology.
2) Develop understanding of professional and ethical responsibilities.
3) Perform ethical behaviors.
4) Use accepted netiquette - the correct or acceptable way of communicating on the Internet.
5) Communicate politely and civil.
6) Practice individual integrity and honesty.
7) Understand and practice copyright, citation and plagiarism laws.

Ethical integrity and character development are grounded in high expectations and fostering relationships, these must embody all that we as teachers, leaders, and role models do every day. **As a professional with access to company and government confidential information, you must understand and respond appropriately to the ethical, legal and limitation issues career professionals are subject to.**

Ethical standards are what it means to be a good person, the social rules that govern our behavior. Ethics in business is essentially the study of what constitutes the right and wrong behavior in the workplace environment (work place behavior is not the same as home behavior). A business is an organization whose objective is to provide goods or services for profit. The organization has a group of people that work together to achieve a common purpose. **The moral challenges that these people face each day along with a whole range of challenges that could occur, are why ethics plays such an important role in business.** Most large businesses have a written code of ethics, sometimes called a code of conduct to set the standards that employees are to follow. In summary a good M&S professional should refrain from engaging in or supporting any activity that would discredit the profession.

<u>Entrepreneurship and Innovation</u>

Click the link below to see an example of how industry supports entrepreneurship and innovation: http://www.theviplawfirm.com/start.html

To take an invention or new technology to market, innovators must learn the commercialization processes. Innovators need to learn the legal and technical steps needed to finance, produce and market a technology solution they have created.

Many universities have incubators that can facilitate the transition of moving an invention to the marketplace. These organizations also provide advice in the process. The protection of intellectual property is the necessary throughout the transition process. Without patents, copyrights, trademarks anyone can take a product/invention

as their own and begin to market it. A business plan is essential to gain support and secure loans for your product/invention.

Section 4—Visualization, 3D Modeling & Animation

<u>Visualization</u>

The use of simulation models in its earliest form was simply 'black boxes' - data going in and results coming out; however, psychologists noted that humans could quickly perceive trends by looking at graphs or even moving-images generated from the data, as displayed by computer-generated-imagery (CGI) animation. Using on-screen animations in a simulation model enables the status of the model to be viewed as it progresses. For example, a machine that breaks down may change its color to red. This enables visual cues to be passed back to the operator of the simulation model, so action could be taken. Additionally, visualization is useful in convincing decision makers of the model's credibility. For example, in manufacturing if the directors can see a visualization of the production line with widgets traveling down a conveyor belt, it would do more to sell the concept of the model than a 'black box', churning out data. **Click the link to see why industry thinks visualization, 3D modeling and animation are important:** https://mediadynamics.com/what-we-do/3d-animation/

Today visual simulation models are used in many disciplines. In geographical information systems (GIS) and meteorology, weather forecasting models balance the view of moving rain/snow clouds against maps that use numeric coordinates and timing of events. Similarly, computer simulations of CAT scans can simulate how a tumor might change, during an extended period of medical treatment, presenting the passage of time as a spinning view of the visible human head, as the tumor changes. Other applications of CGI computer simulations are being developed to graphically display large amounts of data, in motion, as changes occur during a simulation run.

Click the link to learn more about the history of 3D simulation:

https://srushtiviz.com/blog/how-interactive-3d-evolved-over-the-years-history-of-3d-visualization/

Difference between 2D and 3D.

3D objects have height, width, and depth, while **2D**objects only have height and width. Objects in the real world are 3-dimensional, because they have depth. A drawing on paper is often **2D**, but linear perspective is the process of creating a **2D image** that appears to be 3-Dimensional.

Click the link for detail on the role 2D and 3D graphics play in designing video games: https://en.wikipedia.org/wiki/Video_game_graphics

2D computer graphics is the computer-based generation of digital images—mostly from two-dimensional models (such as **2D** geometric models, text, and digital images) and by techniques specific to them. 2D images are important to 3D modeling and animation. Two main types of 2D images are raster and vector. **Click on the link to see a short**

video describing the difference between raster and vector images:
https://www.youtube.com/watch?v=-Fs2t6P5AjY

- **Raster images** are made up of a set grid of dots called pixels where each pixel is assigned a color value. Unlike a vector image, raster images are resolution dependent. When you change the size of a raster image, you shrink or stretch the pixels themselves which can result in a significant loss of clarity and very blurry image. Raster editors such as Photoshop or GIMP are great for photographs as well as for adding effects, shadows and textures to designs
A raster image, **also called a bitmap**, is a way to represent digital images. It can be created in a wide variety of formats, including the familiar .gif, .jpg, and .bmp. When a raster image is created, the image on the screen is converted into pixels. **Each pixel is assigned a specific value that determines its color. This format uses the red, green, blue (RGB) color system. An RGB value of 0,0,0 would be black, and the values go all the way through to 256 for each color, allowing the expression of a wide range of values.** In photographs with subtle shading, this can be extremely valuable. **Click the link to explore the RGB color system:** https://www.rapidtables.com/web/color/RGB_Color.html
**Click link to explore converting grey scale to RGB:**
https://www.tutorialspoint.com/dip/grayscale_to_rgb_conversion.htm
When the image is viewed, the pixels usually smooth out visually for the user, who sees a photograph or drawing. When blown up, however, the individual dots of color become apparent. While this effect is sometimes a deliberate choice on the part of an artist, it is usually not desired. Depending on resolution, some images can be enlarged to very large sizes, while others quickly become difficult to see. The smaller the resolution, the smaller the digital image file, so people who work with computer graphics must find a balance between resolution and image size.
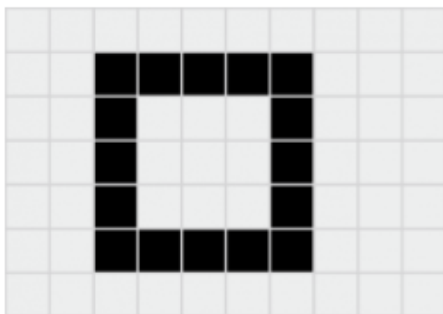
Raster images are constructed on a grid. Each grid square represents a pixel. The more pixels per inch the more detail the image has. Image files can be very large if the fidelity is high. Compression methods are used to reduce size, but the raster files still contain information about each pixel in image with or without color.
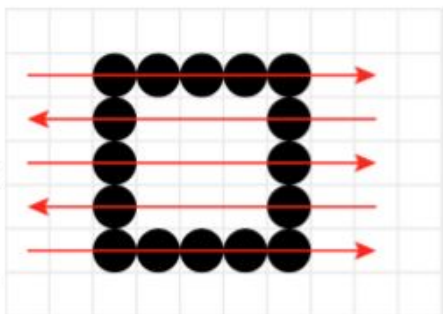
Lasers can be used to reproduce raster images using an engraving or raster mode. The red lines show how the scanning takes place. The machine pulses the laser on and off a certain amount of times per second.
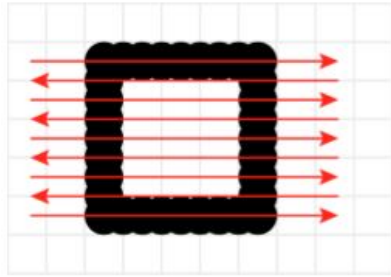
The resolution can be increased by overlapping dots, making a smoother line. The laser will have to scan back and forth more times, increasing production time.

- **Vector images** are made up of basic geometric shapes such as points, lines and curves. The relationship of the shapes is expressed as a mathematical equation which allows the image to scale up or down in size without losing quality. Logo designs and print work such as brochures and posters should be designed as vector images using vector drawing software like Adobe Illustrator, Corel Draw or Inkscape. Vector images are used in a variety of personal and business applications because of their scalable nature. Some of the most popular vector image uses are logos, web, print and character designs. Businesses often print logos on various surface mediums that require the image to be scaled beyond the original size without the loss of detail. In many instances, the use of vectors creates a uniquely crisp and clean design that some animators and designers prefer.
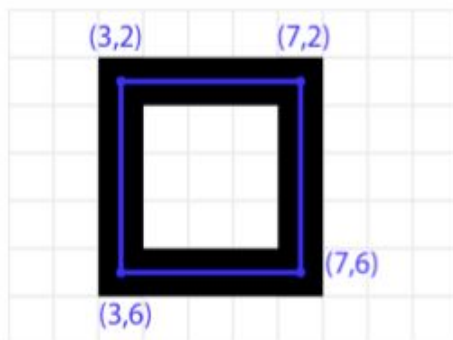
Vector images are also built on a grid based system, but it doesn't use pixels. Instead it uses a set of written instructions that describe the graphic element in terms of points called nodes. The vector line and nodes represented here in blue. The black line is called a stroke. It is a line that has a set width and a color. Because this is a closed shape, we could also fill it with a color. In the example image, Typical file formats for vector images are: .ai, .eps, .dxf , .pdf.
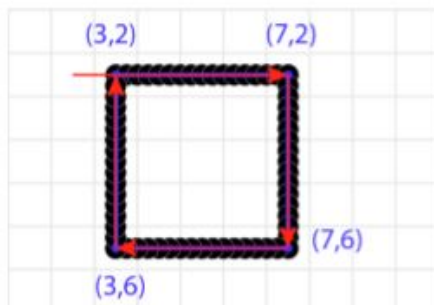
When we send a job to the laser for cutting, it's going to cut the vector line (blue, above). If there is a stroke, the laser will cut down the center of the stroke, not at the perimeter. The laser spot is 0.005″ in diameter. We can visually approximate what will get cut by setting our vector lines to a 0.5pt stroke.
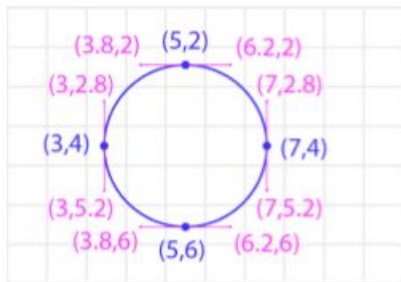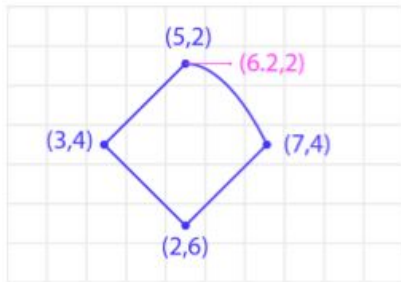
Creating a circle with straight segments, to many nodes and short segments are needed which leads to long run for the laser. The ability to define curves make the process more efficient. Handles can be used to define the length and arc of the curve. The length and direction of the handle line influences how the line is stretched from the node. Direct attention to the bottom image. Using only four nodes and correct handle placement, can create a perfect circle. Defining shapes using the fewest number of points leads to the most efficient cutting job.

Remember color theory! It is important for both raster and vector images. If Red, Green, and Blue are primary colors for **additive mixing**, then Cyan, Yellow, and Magenta are primary colors for subtractive mixing. **Click the link to see how color theory impacts visualization:** https://www.youtube.com/watch?v=YtH9eXWuf3Y
Click this link to see a short video on how humans see color: https://www.youtube.com/watch?v=l8_fZPHasdo

3D Modeling

In 3D computer graphics, 3D modeling is the process of developing a mathematical representation of any surface of an object in three dimensions via specialized software. The product is called a 3D model. Someone who works with 3D models may be referred to as a 3D artist. In order to understand how 3D modeling works, it helps to have a basic understanding of the key 3D modeling types out there.

1) NURBS Modeling
    a. NURBS stands for **Non-Uniform Rational Basis Spline**. A NURBS model is a mathematical modeling type commonly used to generate **curves** and surfaces. The main advantages of this modeling technique are the great flexibility and precision you have in generating your shapes.
2) Polygon Modeling
    a. Polygon models (also known as **meshes**) are a collection of **vertices, edges and faces** that define the model, which allows for easy and precise

editing of parts of your object. By changing the coordinates of one or several vertices, you can change the shape of the model.

    i. **Faces:** A face is the most basic part of a 3D polygon. When three or more edges are connected together (explained below), the face is what fills in the empty space between the edges and makes up what is visible on the polygon mesh. We painted one face on the image below in green.

    ii. **Edges**: An edge is another component of a polygon. Edges help define the shape of the models, but they can also be used to transform them. An edge is defined by two vertices at their end points (explained below). The edges of a single polygon are pictured in red in the image below.

    iii. **Vertices**: A vertex is the smallest component of a polygon model. It is simply a point in a three-dimensional space. By connecting multiple vertices with edges, you can create a polygon. These points can be manipulated to create the desired shape.

3) Parametric Modelling
   a. Parametric is a term used to describe a dimension's ability to change the shape of model geometry as soon as the dimension value is modified. Parametric modelling uses the computer to design objects or systems that model component attributes with real world behavior.

There are many styles of modeling once you choose the software you will use. **Click this link to watch 20+ styles of 3D modeling in 20 minutes:** https://www.youtube.com/watch?time_continue=6&v=DeHasEMCzcc

Animation

Animation is a method in which images or models are manipulated to appear as moving images. ... imparting life". The primary meaning of the English word is "liveliness" and has been in use much longer than the meaning of "moving image medium". There are 5 main types of animation.

1. Traditional Animation (2D Cell or Hand Drawn)
2. 2D Animation (Vector-Based)
3. 3D Animation (CGI, Computer Animation)
4. Motion Graphics (Typography, Animated Logos)
5. Stop Motion. (Claymation, Cut-Outs)

Click here to see a short video describing each type of animation:
https://www.youtube.com/watch?v=NZbrdCAsYqU
Click her to see a brief history of Disney animation:
https://www.youtube.com/watch?v=AqKfu_-WZ58

In the 1930s, Walt Disney wasn't happy with the state of animation at his company. He set up classes for his employees under the direction of Don Graham; from those

classes, 12 principles for animation emerged to help animators create more believable animations.

Principles of 2D Animation:

1) Squash and Stretch
   a. Three-dimensional (3D) objects have mass and volume, and they exhibit a certain amount of rigidity when moving. Real objects deform slightly during movement, revealing how rigid they are.
   b. Organic objects aren't completely rigid. They're usually softer and more malleable. When the movement of organic objects is stiff and rigid, it doesn't feel right. Manmade objects, on the other hand, tend to be stiff and rigid.
   c. The principle of squash and stretch is about showing objects flattening and elongating as they move to reveal their rigidity. The object should appear to retain its mass and volume, but it should also deform to appear more natural. For example, a bouncing ball will squash when it comes in contact with the ground, and then it will stretch after the bounce, elongating in the direction of movement.

2) Anticipation
   a. Real-world actions don't start immediately. An action in an animation occurs in three steps:
      1. Set up for the action
      2. The action
      3. Follow through on the action
   b. The setup is anticipation, which is typically a movement in the opposite direction (contrary movement) to the action.
   c. For example, to throw a ball, your arm winds up and moves back before moving forward to release the ball. This windup is anticipation. It signals the action to come and leads the viewer's eye to the object that will perform the action.
   d. Anticipation is often the most important part of any animation. It's also the part that typically lasts the longest. The greater the action, the longer and more exaggerated the anticipation should be.

3) Staging
   a. Staging is how you present objects. It provides context for the object and the animation, and it helps tell your story.
   b. For example, a cube displayed at an angle to any of its six sides will show the cube as a 3D object. If you're looking directly at one side though, it will appear to be a 2D square
   c. There are three main considerations with staging:
      1. Characters and objects should have strong silhouettes to more quickly understand them.

2. The environment (the stage) should be interesting, without drawing attention away from the characters, objects, and actions.

3. Major actions should be presented one at a time or it could potentially lead to confusion.

4) Straight Ahead Action and Pose-to-Pose
   a. Both are methods for creating an animation. In straight ahead action, you would draw everything in frame one and then move on to do the same in frame two. You would continue to draw every frame from first to last in sequence. This method allows animators to explore and discover as they go.
   b. With pose-to-pose, you draw important keyframes and then create in-between frames to connect them. This is how computer animation works, and it's the way you work with CSS animations. This method allows more planning up front and lets the computer do much of the work.

5) Follow Through and Overlapping Action
   a. In the section on anticipation, I mentioned that animation occurs over three steps and that the last step was following through.
   b. Follow through is similar to anticipation, except it occurs after the action instead of before it. Things don't stop suddenly in the real world any more than they start suddenly.
   c. When throwing a ball, your arm continues its motion after releasing the ball. When a ball bounces on the ground, it doesn't stop. It continues bouncing until eventually coming to rest. Both are examples of follow through.
   d. Overlapping action is similar. An example is your arms swinging as you run. The running is the major action and your swinging arms overlap it. The overlapping action should usually move at different speeds than main action.

6) Slow In and Slow Out
   a. Movement usually starts and ends slower than movement in between. Objects accelerate and decelerate. They ease into and ease out of the action. Your car isn't doing 60 mph the instant you step on the gas pedal. It doesn't go back to 0 mph instantly when you step on the break. It accelerates to 60 and decelerates back to 0.
   b. In practice, this means adding more keyframes to the start and end of an animation. It's not uncommon for anticipation to take up 25 percent of an animation and for follow through to take up a similar amount of time.

7) Arcs
   a. Most movement in the natural world occurs over an arc. The movement isn't a perfect straight line. You want to have movement follow arcs as opposed to straight lines where possible.

b. The shallower the arc, the faster the object will appear to move and the more pronounced the arc, the slower the object will appear to move. Keep in mind the arc of motion can be around any axis, which might mean into and out of the screen.

c. Mechanical movement is the exception to this principle. It's typically less curved and more linear than organic movement.

8) Secondary Action
   a. Secondary action is similar to overlapping action, and it can be difficult to determine if an action is secondary or overlapping at times. The difference is that overlapping action is the result of the main action, and secondary action is independent of the main action. For example, an alien with antenna might be walking (the main action), while the alien's antenna is moving around to sense the environment (secondary action). Whether the alien is walking or standing still, the antenna continues to sense the environment. Its movement is independent of the walking. Secondary action should remain minor when compared to the main action or their roles could be reversed. It should support the main action and make it more interesting.

9) Timing
   a. The key to good animation is timing. Slow in and out is a subset of this principle.
   b. The timing you use in an animation should give a sense of the object's characteristics: how heavy or light is it, for example.
   c. Timing can communicate a lot. A person blinking quickly might be seen as alert, whereas a person blinking slowly might appear tired. Changing nothing more than how quickly the eye blinks can help communicate the emotional state of the character.
   d. More than anything, timing is something you should experiment with when creating transitions and animations. Trial and error and your own judgment will go a long way here.

10) Exaggeration
    a. Oddly enough, to make animations appear more realistic, you have to exaggerate them. If animation tries to mimic reality too closely, it tends to appear stiff and lifeless.
    b. Exaggeration is often used to accent actions and emotions. A ball might squash and stretch more than it should. A cartoon windup before throwing a ball is usually shown as the arm spinning like a propeller in the opposite direction of the throw itself.
    c. You don't want to exaggerate everything. Use restraint. Exaggerate to add a little more life and excitement but not so much to completely destroy believability.

11) Solid Drawing

a. The idea behind solid drawing is to take the 3D space into account even while working in a 2D plane. The real world is 3D, and your animations should appear to live in that same world.

b. Shadows, gradients, scale, and perspective can all add depth to an animation creating the illusion of 3D space. Ironically, the trend toward flat design does the opposite. Fortunately, designers are already bringing back some depth, albeit subtler than before. For example, a flat rectangle doesn't say "button." Add a slight shadow or gradient, and it looks like something you push or click or tap.

12) Appeal
a. Appeal is like the charisma of a real person. It's the sum of everything that makes a character in an animation come to life.

b. Appeal is about trying to make characters and objects more interesting. It's about giving your animation a certain "je ne sais quoi," something enjoyable that's difficult to describe.

c. This principle is about the whole being more than the sum of the parts. If you consider all the other principles, you should at least find yourself on the right path toward appeal.

Principles of 3D Animation:

1) Visual Styling
a. Visual styling in three-dimensional computer animation means more than just how things are supposed to look.

b. Visual styling also has a significant impact on rendering, on animation techniques, and overall production complexity.

c. As we develop a visual look we must keep in mind that it is feasible to produce within the boundaries of the project.

d. A certain look for the skin of a beast, for example, might look cool but might also require too complex a rig, too detailed a model and too complex an animation process.

2) Blend Motion
a. It is possible today to blend motion from different sources, and we need to develop a clear approach for blending cartoon with realistic motion.

b. Before production starts it is necessary to define clear guidelines for a variety of motion/animation styles including cartoon physics, realistic cartoon, realistic human motion and rotoscoping.

c. We must direct live performers when capturing their motion to add intention to their movements.

3) Cinematography

a. We have absolute control over camera positions and movement in three-dimensional computer animation; we should make the cinematography a crucial component of our animation, not just an afterthought.
b. The composition, lighting, and sequencing of our moving images have a huge impact on storytelling.
c. Most of this work can crystallize during previsualization and the assembly of the three-dimensional animatics.

4) Facial Animation
   a. Most of the thoughts and emotions of characters are expressed on their faces.
   b. Three-dimensional computer animation offers more facial animation control than ever before, including the subtle motion of eyelids and eyeballs.
   c. Establishing early in the process the level facial control and techniques has a positive effect on the styling of the character and the design of the production flow.
   d. Building a catalog of facial morph targets or blend shapes for production and reuse is today as essential as building walk cycles.

5) Optimizing user-controlled Animation
   a. Computer and platform games put much of the animation control in the hands of gamers.
   b. This poses the challenge to create great animation that works regardless of what move the gamer decides to make.
   c. Games are a combination of user-controlled animation and preset/narrative animation.

Click the link to see a comparison of 2D and 3D animation: https://www.gamedesigning.org/animation/2d-and-3d-animation/

Creating a walk sequence is very important to learn early as an animator. **Click here to see a short video describing the steps to create a realistic walk cycle:** https://www.youtube.com/watch?v=2y6aVz0Acx0

To create a full animation there is a process call the animation production pipeline.

1) Pre-Production
   a. Story
   b. Storyboarding
   c. Editorial (Phase 1)
   d. Visual Development/Look Development
   e. Pre-Visualization
2) Production
   a. Modeling
   b. Surfacing
   c. Rigging

      d. Layout/Set Dressing/Animation prep
      e. Character Animation
      f. Crowds
      g. Character Effects / Simulation
      h. FX (Special Effects)
      i. Technical Direction
      j. Matte Painting
      k. Lighting

3) Post Production
      a. Compositing
      b. Music and Sound Design
      c. Editorial (Phase 2 = ongoing)
      d. Color Grading

Click here to see the full animation production process in detail:
https://blog.artella.com/index.php/2017/09/21/animation-production-step-step-guide-making-3d-animated-movie/

Section 5—Coding, Programming & Gaming

Evolution of software development

The DoD (Department of Defense) have applications developed using over 400 different software languages. Different languages are used to solve different problems. C++ is a more recent language with many usable extensions in the M&S workforce.

Process Models

Policy was put into place to reduce defects, meaning less reworks to improve quality of software's being used.

- SEI's CMMI established levels of maturity for software products
- ISO 9001 established quality standards for software products

Approaches to software development have evolved to address software from several approaches. A couple main development models used today are Waterfall and Evolutionary (Agile) development models. The development methods have also evolved to the following.

- Structure Analysis / Structured Design
- Object oriented
- Agile

A comparison of Waterfall and Agile Development Models: Click the link to see a short video explaining the difference between Waterfall and Agile approaches: https://www.youtube.com/watch?v=Tj-lavaMkxU

Waterfall Software Development Model	Agile Software Development
- sequential design process - progress is seen flowing downward (like a waterfall) - originated in manufacturing and construction industries - highly structure physical environments - changes after the fact are very costly to the point of almost impossible - a hardware-oriented model was adapted for software development - new development cycle was created to include six phases - preliminary design - detailed design - coding testing - unit testing - integration - testing - organizations including the DoD prefer to use evolutionary acquisition and iterative and incremental development (not the waterfall model)	- a group of methods - solutions evolve through collaboration between self-organizing cross-functional teams - promotes - active planning - evolutionary development - early delivery - continuous improvement - rapid & flexible response to change 12 principles - customer satisfaction - changing requirement = easy at any point - frequent delivery of working software - cooperation between business, people and developers - projects built around motivated trusted individuals - face-to-face conversations best form of communication - working software is the principal measure of progress - sustainable development (constant pace) - continuous attention to technical excellence and good design - simplicity is essential - self-organized teams - regular adaptation to changing circumstance

Gaming

The father of video games is Ralph Henry Baer (born Rudolf Heinrich Baer; March 8, 1922 – December 6, 2014) was a German-born American video game developer, inventor, and engineer, and was known as "The Father of Video Games" due to his many contributions to games and the video game industry in the latter half of the 20th

century. Click the link below to learn more about Ralph Henry Baer: https://www.simulationinformation.com/hall-of-fame/members/ralph-h-baer

Video games are computer- or microprocessor-controlled games. Computers can create virtual spaces for a wide variety of game types. Some video games simulate conventional game objects like cards or dice, while others can simulate environs either grounded in reality or fantastical in design, each with its own set of rules or goals.

A computer or video game uses one or more input devices, typically a button/joystick combination (on arcade games); a keyboard, mouse or trackball (computer games); or a controller or a motion sensitive tool. (console games). More esoteric devices such as paddle controllers have also been used for input.

There are many genres of video game; the first commercial video game, Pong, was a simple simulation of table tennis. As processing power increased, new genres such as adventure and action games were developed that involved a player guiding a character from a third person perspective through a series of obstacles. This **"real-time" element** cannot be easily reproduced by a board game, which is generally limited to "turn-based" strategy; this advantage **allows video games to simulate situations such as combat more realistically**. Additionally, the playing of a video game does not require the same physical skill, strength or danger as a real-world representation of the game, and can provide either very realistic, exaggerated or impossible physics, allowing for elements of a fantastical nature, games involving physical violence, or simulations of sports. Lastly, a computer can, with varying degrees of success, simulate one or more human opponents in traditional table games such as chess, leading to simulations of such games that can be played by a single player. **Click the links below to learn more about the history of video games:**

https://www.si.edu/spotlight/the-father-of-the-video-game-the-ralph-baer-prototypes-and-electronic-games/video-game-history

https://www.museumofplay.org/about/icheg/video-game-history/timeline

Click the link to learn about game design:
https://www.youtube.com/watch?v=G8AT01tuyrk

Game engines are software frameworks designed for the creation and development of video games. Developers use them to create games for consoles, mobile devices and personal computers. Click the link to see a short video on how game engines work: https://www.youtube.com/watch?v=DKrdLKetBZE

The core functionality typically provided by a game engine includes:

- a rendering engine ("renderer") for 2D or 3D graphics
- a physics engine or collision detection (and collision response)
- sound
- scripting

- animation
- artificial intelligence
- networking
- streaming
- memory management
- threading
- localization support
- a scene graph

The process of game development is often economized, in large part, by reusing/adapting the same game engine to create different games or to make it easier to "port" games to multiple platforms. **Click the link to see the top game engines of 2019:** https://instabug.com/blog/game-engines/

Section 6—Simulations & Simulators

Simulation and Simulators

Simulation is the imitation of the operation of a real-world process or system over time. The act of simulating something first requires that a model be developed; this model represents the key characteristics or behaviors/functions of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time. Simulation is used in many contexts, such as simulation of technology for performance optimization, safety engineering, testing, training, education, and video games. Often, computer experiments are used to study simulation models. Simulation is also used with scientific modeling of natural systems or human systems to gain insight into their functioning. Simulation can be used to show the eventual real effects of alternative conditions and courses of action.

Discrete Event Simulation

Click the links to watch a short video describing discrete event simulations: https://www.youtube.com/watch?v=21WQB0E-6-M

https://www.youtube.com/watch?v=adkeGlcqBAo

Discrete event simulation is an important system analysis technique. A discrete event simulation (DES) manages events in time. Most computer, logic-test, and fault-tree simulations are of this type. In this type of simulation, the simulator maintains a queue of events sorted by the simulated time they should occur. The simulator reads the queue and triggers new events as each event is processed.

Simulation is also used when the real system cannot be engaged, because it may not be accessible, or it may be dangerous or unacceptable to engage, or it is being designed but not yet built, or it may simply not exist.

Key issues in simulation include acquisition of valid source information about the relevant selection of key characteristics and behaviors, the use of simplifying approximations and assumptions within the simulation, and fidelity and validity of the simulation outcomes. Real time virtual simulators are perhaps the most familiar to students. People have observed, or experienced flight simulators used by the military, commercial airlines, nuclear power generation, space, entertainment, law enforcement, accident investigation, medical and other applications. Simulators are being used more frequently today for medical training by the military and for civilian applications.

Simulators save time, money and lives. Real time simulators were first used by the military with **Edwin Link, simulator pioneer**, introducing his **"Blue Box"** to the Army Air Corps to train pilots in flying instruments. The commercial airlines recognized the effectiveness of simulators and began to use them for aircrew training. With the introduction of the digital computer, it became possible to design simulators in computer software in lieu of expensive, single-purpose hardware. This versatility, led others to develop simulators for a wide range of applications. Homeland Security and law enforcement agencies seized the opportunity to use simulators in marksmanship and "shoot-don't shoot" trainers. Click the link to watch a short video about Edwin Link: https://www.youtube.com/watch?v=3c09a0XjJmQ

The entertainment industry began to introduce video games and location-based entertainment concerns such as theme parks took advantage of simulation technologies such as motion systems, visual displays, computer-generated imagery and even olfactory simulation to add realism to their rides.

Of late, the medical and health care community adopted simulation technology for training of nurses, EMT's, doctors, etc. The first such training device was the Human Patient Simulator: it breathes, has a heartbeat, blood pressure, etc.

Of course, the space program demanded and received high fidelity training simulators for individual and crew training. Putting a person on the moon would not have been possible without the use of simulators.

It appears that the range of simulator applications is only limited by the imagination of the human. There have been many studies that validate that time in a simulator can substitute for training time in an aircraft, for example. There is a very strong case for the transfer of training from a simulator to the parent system. This transfer can be quantified as the Training Effectiveness Ratio further described in this study guide. The issue of the fidelity (or amount of realism) of simulation as it affects the transfer of training must

be addressed. Levels of fidelity must be considered for part task trainers, full mission simulators and simulators networked together for team mission training.

Miller Curves: In the 1950's, Dr. Robert Miller of IBM postulated that the transfer of training (from simulator to the real system) increased non-linearly with an increase of fidelity (realism), and accordingly, the cost of the system increased non-linearly with that increase of fidelity. Further, he stated that there was an "optimum" level of fidelity where any further increase in fidelity did not yield a great amount of transfer of training. Over time, education psychologists have disputed this simplistic theory. Current thinking is that there are other factors besides fidelity that contribute to training effectiveness such as student attitude, instructor competency, realistic scenarios containing simulator utilization, etc.

Simulator Building Blocks -Generally, there is a set of components that are to be included in the overall design of a simulator regardless of application. Those building blocks are as follows:

1) Trainee Station (ex. cockpit area in a flight simulator)

2) Computational System (computer or network of computers)

3) Visual System (image generator, displays and data bases)

4) Instructor/Operator Station (Controls scenarios, inserts malfunctions, etc.)

5) Aural System (communications, engine noises, alarms, sensors, environmental noises, etc.)

6) Motion System (platform, g-seat/g-suit, motion seat, seat shaker)

7) Control Loader (ex. stick rudder forces in flight simulator)

8) Interface Hardware and Software (enables computers and other hardware/software to communicate)

Virtual Simulation **Input** Hardware

There is a wide variety of input hardware available to accept user input for virtual simulations. The following list briefly describes several of them:

Body tracking
 The motion capture method is often used to record the user's movements and translate the captured data into inputs for the virtual simulation. For example, if a user physically turns their head, the motion would be captured by the simulation hardware in some way and translated to a corresponding shift in view within the simulation.
Capture suits and/or gloves may be used to capture movements of user's body parts.

The systems may have sensors incorporated inside them to sense movements of different body parts (e.g., fingers). Alternatively, these systems may have exterior tracking devices or marks that can be detected by external ultrasound, optical receivers or electromagnetic sensors. Internal inertial sensors are also available on some systems. The units may transmit data either wirelessly or through cables.
 Eye trackers can also be used to detect eye movements so that the system can determine precisely where a user is looking at any given instant.

Physical controllers
Physical controllers provide input to the simulation only through direct manipulation by the user. In virtual simulations, tactile feedback from physical controllers is highly desirable in several simulation environments.
Omni directional treadmills can be used to capture the user's locomotion as they walk or run. High fidelity instrumentation such as instrument panels in virtual aircraft cockpits provides users with actual controls to raise the level of immersion. For example, pilots can use the actual global positioning system controls from the real device in a simulated cockpit to help them practice procedures with the actual device in the context of the integrated cockpit system.

Voice/sound recognition
This form of interaction may be used either to interact with agents within the simulation (e.g., virtual people) or to manipulate objects in the simulation (e.g., information). Voice interaction presumably increases the level of immersion for the user. Users may use headsets with boom microphones, lapel microphones or the room may be equipped with strategically located microphones.

Current research into user input systems
 Research in future input systems hold a great deal of promise for virtual simulations. Systems such as brain-computer interfaces (BCIs) Brain-computer interface offer the ability to further increase the level of immersion for virtual simulation users. Lee, Keinrath, Scherer, Bischof, Pfurtscheller proved that naïve subjects could be trained to use a BCI to navigate a virtual apartment with relative ease. Using the BCI, the authors found that subjects were able to freely navigate the virtual environment with relatively minimal effort. It is possible that these types of systems will become standard input modalities in future virtual simulation systems.

Virtual Simulation **Output** Hardware:

There is a wide variety of output hardware available to deliver stimulus to users in virtual simulations. The following list briefly describes several:

Visual display
Visual displays provide the visual stimulus to the user. Stationary displays can vary from a conventional desktop display to 360-degree wrap around screens to stereo three-dimensional screens. Conventional desktop displays can vary in size from 15 to 60+ inches. Wrap around screens are typically utilized in what is known as a Conventional

Automatic Virtual Environment (CAVE). Stereo three-dimensional screens produce three-dimensional images either with or without special glasses—depending on the design.

Head mounted displays (HMDs) have small displays that are mounted on headgear worn by the user. These systems are connected directly into the virtual simulation to provide the user with a more immersive experience. Weight, update rates and field of view are some of the key variables that differentiate HMDs. Naturally, heavier HMDs are undesirable as they cause fatigue over time. If the update rate is too slow, the system is unable to update the displays fast enough to correspond with a quick head turn by the user. Slower update rates tend to cause simulation sickness and disrupt the sense of immersion. Field of view or the angular extent of the world that is seen at a given moment Field of view can vary from system to system and has been found to affect the users sense of immersion.

Aural display several different types of audio systems exist to help the user hear and localize sounds spatially. Special software can be used to produce 3D audio effects, 3D audio to create the illusion that sound sources are placed within a defined three-dimensional space around the user. Stationary conventional speaker systems may be used to provide dual or multi-channel surround sound. However, external speakers are not as effective as headphones in producing 3D audio effects. Conventional headphones offer a portable alternative to stationary speakers. They also have the added advantages of masking real world noise and facilitate more effective 3D audio sound effects.

Haptic displays provide sense of touch to the user through Haptic technology. This type of output is sometimes referred to as force feedback.

Tactile tile displays use different types of actuators such as inflatable bladders, vibrators, low frequency sub-woofers, pin actuators and/or thermo-actuators to produce sensations for the user.

End effector displays can respond to user's inputs with resistance and force. These systems are often used in medical applications for remote surgeries that employ robotic instruments.

Vestibular displays provide a sense of motion to the user motion simulator. They often manifest as motion bases for virtual vehicle simulation such as driving simulators or flight simulators. Motion bases are fixed in place but use actuators to move the simulator in ways that can produce the sensations pitching, yawing or rolling. The simulators can also move in such a way as to produce a sense of acceleration on all axes (e.g., the motion base can produce the sensation of falling).

Simulators (systems) require **reliability, availability, and maintainability** (RAM) are system design attributes that have significant impact on the sustainment or total **Life Cycle Costs** (LCC) of a developed system. Additionally, the **RAM** attributes impact the ability to perform the intended mission and affect overall success. The standard definition of Reliability is the probability of success over a defined time interval (or mission), whereas Availability is defined as the percentage of time a system is considered ready to use when tasked. Maintainability is a measure of the ease and

rapidity with which a system or equipment can be restored to operational status following a failure.

The reliability, **mean time between failures** (MTBF) of a training simulator can be predicted using established methods. (Reliability Handbook, prior experience, failure rate tables, etc.). Given the selection of design hardware and software, experience and test tables can provide a range of expected values for Mean Time Between Failures **(MTBF)** and **Mean Time to Repair** (MTTR). Because most electronic equipment operates in the constant failure rate portion of the "bathtub" curve, failure rates of subsystems can be predicted individually and combined (added) to yield an overall value of **MTBF.** However, subsystem **MTBF's** CANNOT be added together to give an overall value. Each subsystem's **MTBF** must be converted to a "failure rate", Lambda., which is the reciprocal of **MTBF**. In other words, Failure Rate (Lambda) = **1/ MTBF**. There is no similar calculation using a reciprocal of **MTTR. MTTR** is calculated differently, it is a function of the Failure Rate.

As an example of calculating reliability **(MTBF)**:
Assume you are going to build a training simulator having three subsystems (A,B and C). Using predictive tables, the MTBF for each subsystem is given as follows:

Lambda

Subsystem	MTBF (Hours)	1/MTBF (Failures/Hr.)	MTTR (Minutes)
A	500	.002	20
B	300	.00333	30
C	200	.0050	25

Given the above, the overall **Failure Rate (Lambda)** of the total system is the sum of the subsystem failure rates or **.01033 Failures/ Hr.** Now, to find the overall **MTBF**, it is necessary to find the reciprocal, 1/Lambda. Therefore, the overall **MTBF= 96.8 Hours**.

Calculating the overall **MTTR** is more complicated. It requires the multiplication of each predicted maintenance time (in hours) multiplied by each subsystem failure rate. Those numbers are summed. Then that summed number is divided by the overall failure rate and the result is the system **MTTR** in Hours. In the case above, the overall system **MTTR is .427 Hours or 25.6 Minutes.**

The system predicted availability can be calculated by the relationship, A = MTBF/(MTBF + MTTR). This becomes 96.8/ (96.8 + .427) = **.996**

The figure below is a block diagram of a virtual simulation for a specific aircraft simulator. In doing reliability and maintainability predictions, values for MTBF and MTTR are estimated for each subsystem block (as shown for the visual and image generator

subsystems). Then they are combined in the manner described above to determine the predicted reliability and maintainability values.

Simulator Block Diagram
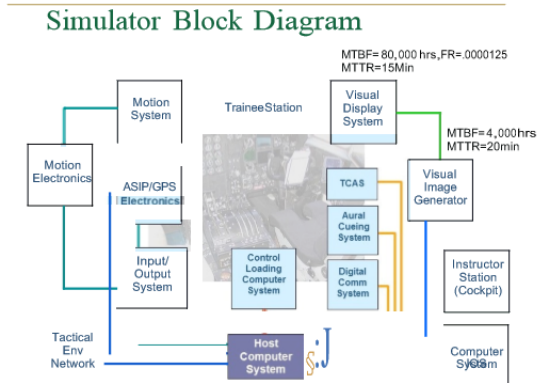
Calculating the Training Effectiveness Ratio (TER) of a simulator:

The Training Effectiveness Ratio (TER) of a simulator is an indicator of how substituting time in a simulator transfers to student performance in the operational system (aircraft). It is measured by comparing training time in the operational system (aircraft) with the combination of simulator plus aircraft times. This relationship is defined as follows: **TER**$= \dfrac{Yo-Yx}{X}$

 Where in situation A: Yo = Time in only the operational system (aircraft) to achieve a level of criterion performance.

 In comparison to situation B, achieving the same level of criterion performance in the operational system (aircraft) by training in the simulator and the operational system (aircraft).

 Yx = Time in the operational system (aircraft) when coupled with the simulator

 X = Time in the simulator when coupled with operational system (aircraft) As an example: A pilot achieves a certain level of proficiency after 100 hours in the aircraft. The pilot achieves the same level of proficiency after 80 hours in the aircraft AND 40 hours in the simulator.

 Training Effectiveness Ratio (TER) = $\dfrac{100 - 80}{40}$ = .50

Related to the TER is cost effectiveness. Time in a simulator is approximately 10% to 15% of the cost of operating an aircraft. In addition, simulator training is safe and is much more training effective. For example, training scenarios can be practiced repetitively without setting up similar situations using aircraft or other costly assets.

Instruction and feedback can be provided at will as opposed to waiting for a complete training exercise to be completed.

The exam review questions are located The National Center for Simulation Web-site: https://www.simulationinformation.com/

Click this link to access the sample exam for practice questions: https://www.simulationinformation.com/modeling-and-simulation-certification

Appendix A: How to Equip a M&S Lab 2019

Modeling, Simulation and Robotics	Software Needs	Hardware Needs
General Lab Computer Needs	**Window 10**	Game/Vr Ready PCs: ● **Dell XPS Desktop** Intel Core i7- 7700 cpu @3.60GHz 16.0 GB RAM 2Tb storage Windows 10 **(currently need upgrades)** Server/Render Farm: (not in place) ● 6-10 current Desktops connected to M & S lab network (closed).
Coding, Programming and Serious gaming	● **Arduino IDE** https://www.arduino.cc/en/Main/OldSoftwareReleases ● **Visual Studio** - 2015 or higher. Include plugins for SDK 8.1, UE4 and Unity (VS community comes with Unity download) ● **MatLab - School based license ($500)** https://www.mathworks.com/products/matlab.html ● **Unity** - free for education https://www.mathworks.com/products/matlab.html ● **Unreal Engine 4 - free** ● https://www.unrealengine.com/en-	● Arduino boards and various sensors. ● Various motors and servos. ● Robotics parts. ● Raspberry Pi boards ● Consumable materials-project specific

	US/education ● **github** -https://github.com/ ● **Project source control: Perforce -** https://www.perforce.com/ **or Subversion –SVN server -** https://www.visualsvn.com/server/ ● **Wwise Audiokinetics -** **https://www.audiokinetic.com/download** **/#windows**	
Visualization 3D modeling and Animation	● **Makerbot -** *h*ttps://www.makerbot.com/print/ ● **Stratasy -** http://www.stratasys.com/3d-printers/uprint-se-plus ● **Polar3D -** https://polar3d.com/ ● **Flashforge -** http://www.flashforge.com/inventor-ii/ *Content Creation Software:* ● **Autodesk Maya 2017** and up (Arnold Render) ● **Autodesk Mudbox 2017** and up Free Education License Products: https://www.autodesk.com/education/free-software/featured#free-software ● **Pixologic Sculptris** (A starting digital sculpting software) from the complete Pixologic **ZBrush** version. Free Download: http://pixologic.com/sculptris/	● 3D Printers ● Drawing tablets ● External hard drives for 3D models needed for printing

- Zbrush is better than Sculptris but not free.

Photo and Video editing:

- **Adobe Creative Cloud for Education** (It is a membership: $19.99/month)

- **Adobe Photoshop** – Imaging and design software.
- **Adobe Premiere** – Video editing software.
- **Adobe After Effects** – Standard Animation and Compositing Software.

Material, 3D Painting and Texture Map:

- **Allegorithmic** (texture and mapping, etc…)
  *Substance painter
  *Substance Designer

Free Education License for Teachers and Students.

https://www.allegorithmic.com/buy/education

- NUKE:
  https://www.foundry.com/products/nuke

- **xNormal** (Bake texture maps)

Free Download: http://www.xnormal.net/

- **NormalMap Online (GPU Powered)**

Free Download:
http://cpetry.github.io/NormalMap-Online/

	● **Parametric Software:** PTC Education https://www.ptc.com/en/education ● **Autodesk Fusion 360 -** https://www.autodesk.com/products/fusion-360/students-teachers-educators?td=aexfusion ● **Sound editing - Audacity** https://www.audacityteam.org/download/	
Ethics Entrepreneurship and Innovation	All software listed above and below. **Trello:** https://trello.com/ **Discord**	All hardware listed above and below.
Simulations and Simulators	● Oculus Rift - https://developer.oculus.com/ ● Vive -https://www.vive.com/us/ ● 3D Prepar (5 lic. currently) - https://www.prepar3d.com/ ● Halolens Developer for AR (future purchase)	● Oculus Rift Headsets ● Vive Headset ● Flight Controller (a variety) ● Pedals (flight) ● Steering wheel (driving) ● Pedals (driving) ● Simulator chair ● Motion capture Suit
Project Management and Logistics Support	All software listed above and below.	All hardware listed above and below.