MODELS MODULE

INTRODUCTION:

In this module, you will learn about the role that models play in the field of Modeling and Simulation, including what models are, why they're important, and some of the types of models typically encountered. You'll also learn about what elements can and should be modeled, and about some of the challenges the M&S community faces with modeling.

A model is an abstraction of reality – a representation of another entity (DoD Directive 5000.59, 1994, P# 114). You see examples of models every day! In fact, taken to the extreme, almost anything and everything can be considered a model – even the mental representation you're now forming in your mind about M&S while taking this course.

DEFINITION:

In this topic area, you'll discover what the word "model" really means and you'll explore the difference between a model and a simulation.

When thinking of the word "model", what images come to your mind? Perhaps you see toy airplanes or designer fashions. These are correct uses of the word "model", but they don't portray the full spectrum of the concept.

A model is a physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process (DoD Directive 5000.59, 1994, P# 114). In other words, a model is a simplified substitute for a more elaborate or complex item. This enables the original item being modeled to be considered in simpler terms, so that its

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inherent complexity is not overwhelming. For example, architects often create smaller versions of the structures they plan to build as a means to visualize what they would look like. These "models" are much simpler to make than building the actual structure and they allow architects to make changes before finalizing the design.

People often confuse models with simulations, and use the two terms interchangeably (Naval Studies Board & National Resource Council, 1997a, Chapter 1). Therefore, the terms are not always used accurately. A *model* is a representation of some thing, but when that model is used dynamical over time to reflect change it becomes a *simulation*. For example, a plastic soldier is a model. However, when several of these "models" are used in a mock battlefield to express organization or strategy, they become a simulation.

Spotlight: A model is static, while a simulation is usually dynamic.

Activity: Model or Simulation? Try this game to help you understand the difference between *a model* and *a simulation*. Decide which sentence in each of the examples to follow describes a *model* and which sentence describes a *simulation*. Then, click and drag each sentence into the appropriate Model Area or Simulation Area to find out if you are correct.

- **Internet Shopping:** A woman answers questions on an interactive Internet site that allows her to build a 3-D image of herself. She then places graphic images of clothes onto this virtual model and rotates it 360 degrees before making her purchasing decisions. (My Virtual Model, Inc., 1991)

  Sentence 1, Response to the answer, Model: That's right the 3D image is a static representation or model of this woman shopper.
  Sentence 1, Response to the answer, Simulation: "No, this sentence describes a model that is a static physical representation of a woman."

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Sentence 2, Response to the answer, Model: "Be careful, that is not right. This sentence describes a moving simulation of a woman on shopping trip."
Sentence 2, Response to the answer, Simulation: Yes this sentence describes a simulated shopping trip.

Now try this one.

- **Court Cases:**. Jurors watch a computer-based re-creation of a car accident in which graphic images of two cars race along a street and collide. The defending attorney then interrogates a witness to determine if the blue car depicted in the re-creation was an accurate representation of the car she saw.

Sentence 1, Response to the answer, Model: "No, while this sentence does contain models, since the models are engaged in recreating an event, it is describing a simulation."
Sentence 1, Response to the answer, Simulation: That's right, since this sentence describes colliding cars, it refers to a dynamic experience, or a simulation.
Sentence 2, Response to the answer, Model: "Correct! The virtual blue car is a static representation, or a model of the actual car in the accident.
Sentence 2, Response to the answer, Simulation: "No. This sentence describes a static model and questions how well it represents a real entity.

That was good. Now let's try one that is a little tougher.

- **Boat Building:** A boat building company tests its new boat design by developing a small-scale replica. Before completing the design, the company places the boat in a special water tank. The team then subjects the boat to a wide variety of wave velocities to determine how well the boat will perform.

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Sentence 1, Response to the answer, Model: Yes, the small scale replica is a static representation or a model of the boat that is being design.

Sentence 1, Response to the answer, Simulation: "No, the boat replica is just a static model of the actual boat, and does not become a simulation until it includes dynamic motion."

Sentence 2, Response to the answer, Model or Simulation: "The boat is a model of the boat being designed, and the water tank itself is a model of the actual ocean. But when we place the model in the water tank, is it a model or a simulation? This is one of the *gray areas* that causes a confusion of terms. You will be learning more about other *gray areas* throughout this course as we further explore the field of M&S."

Sentence 3, Response to the answer, Model: No this is clearly a simulation since the waves are moving in various velocities to simulate actual events.

Sentence 3, Response to the answer, Simulation: That's right! Since the sentence describes a boat at various wave velocities it is referring to a simulation.

Topic summary: From this activity, you should remember that models are simple representations of complex things that tend to be static, while simulations are generally dynamic.

IMPORTANCE:

In this topic area, you will discover the critical role that models play to help us understand complex phenomena.

Models serve a very important role by enabling people to comprehend more complex concepts and processes by simplifying them into understandable and manageable representations. For example, a graph is a simple visual representation of a complex set of data. It is much easier for a scientist to look at a graph and understand the implications of those data than to read the actual numerical information.

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Models are also important because they provide a way to test our understanding of a concept or process. Many automobile manufacturers create computer models of engine components before they actually build them. This enables each part of the engine to be examined inside the computer before making the commitment to build it.

Most importantly, models are the foundation for developing dynamic simulations. They provide the physical characteristics and the performance boundaries within which simulations operate. In other words, models provide the rules and the data that allow simulations to function in a specific way for a specific purpose.

Returning to our example of the automobile engine, the theoretical specifications of the engine are entered into the computer program so that a "simulated" engine can be tested regarding its range of performance. This allows designers to identify any problems before production of the actual engine on the assembly line, which saves time, money and resources.

Topic Summary: To summarize, models play a critical role in helping people understand complex phenomena. They provide simplified representations, allow people to test their understanding, and form the basis of dynamic simulations.

PURPOSE:

In this topic area, you will discover how a model's purpose defines the way the model is created and the manner in which it should be used.

Models can serve many purposes…and the purpose of the model determines its characteristics, level of detail, and its appropriate usage. Take an aircraft ejection seat, as an example. If the purpose of the model were to determine the optimal size of the ejection seat for a specific aircraft cockpit, then it would probably not be important to

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detail the types of screws used to assemble the ejection seat as part of that model. Just having the specific shape and size of the ejection seat would be sufficient to determine how it would fit into the cockpit.

However, if the purpose of the ejection seat model were to instruct mechanics on how to install or repair the seat, then the level of detail of the model would need to be increased so that the screws were accurately represented. These two different versions of the ejection seat model demonstrate how the purpose of the model affects the level of focus necessary.

This "level of focus" is also called "level of aggregation." The aggregation level determines the type and characteristics of the data necessary to be included in the model. Aggregation can be depicted as a continuum. This Aggregation Continuum Model shows levels of aggregation ranging from the most close-up magnifying lens to the most expansive, zoom lens. Beginning at the level with the most detail, the levels might be referenced as: sub-component, component, entity, collection of entities, and higher-level organization (Amico, Bruzzone, & Guha,2001; Department of Defense, 1995, 2-2). There is no limit to how many levels up the continuum a model can go, including a model of the entire universe. However, for practical purposes, most models stop at a level of aggregation well below that.

Activity: Let's explore this further by returning to our example of an aircraft and its ejection seat. Click at each level of aggregation in this Aggregation Continuum Model to see the corresponding level of focus.

Notice something? The aggregation continuum was just referred to as a "model". This is another example of how a model can use simple graphics to illustrate a

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complex concept—such as aggregation. This model will be used and expanded upon throughout the EMS course, so when you encounter the model in the topics to come, think about how it is being used to portray new concepts.

The level of aggregation is determined by the specific purpose for the model. Using a good model for the wrong purpose can provide inaccurate results just as using a poor model for the right purpose. For example, using a flat Earth model would not work in a simulation for determining the range to a distant ship because the ship would not "sink" below the horizon. This is true, regardless of the level of modeling detail on the actual ship. Therefore, to ensure the model is developed and used appropriately, the purpose of the model and the resulting simulation must constantly be reassessed and validated against end-user needs. This requires working closely with the end-users in order to understand their needs and expectations.

Topic Summary: In this topic area, you learned that the model's purpose determines the level of aggregation built into the model, ranging from the sub-component level and typically going up to the higher level organization. In turn, the aggregation level affects how the model can and should be used.

TYPES:

This topic area explores the different types of models that exist in the field of M&S, many of which we encounter in our every day lives.

Models can be categorized into three types: physical, mathematical and process. A physical model is one whose physical characteristics resemble the physical characteristics of the item being modeled (DoD Directive 5000.59, 1994, P# 123). In

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other words, a physical model looks or feels like its original counterpart. Examples of physical models are toy airplanes, architectural blueprints, and statues.

> **DRILL DOWN**, *Virtual Physical Model:*
>
> "I would say now when people think of a physical model they are really thinking in terms of a virtual model, such as a workspace on a new ship. You may want to model that in a virtual sense to ensure that there is room for the maintenance aspects of the equipment that is going in there, and really influence the design of the platform itself by modeling it first in a virtual sense." (Gary Fraas, videotaped interview, ITSEC, November 2002, Orlando, FL: Integrity Arts & Technology, Inc.)

A mathematical model is a symbolic abstraction whose properties are expressed by numerical symbols or relationships (DoD Directive 5000.59, 1994, P# 113). In other words, a mathematical model uses numbers to describe something. An example of a mathematical model is a ballistic equation that depicts a shell trajectory. An example of a mathematical model that most people use in their daily lives is a budget forecast. When creating a budget forecast, we are building a model based on past experience and trends. It's important to remember, however, that any model is just a model. Not reality.

Mathematical models have several unique characteristics. If a mathematical model depicts a fluid progression, it is called a continuous model (DoD Directive 5000.59, 1994, P# 84). If it depicts a segmented progression, it is called discrete (DoD Directive 5000.59, 1994, P# 89).

For example, let's consider a model of the tuning dial on a radio. If during a simulation, we can freely turn the knob across the dial, then the simulation is based upon a *continuous* model. If, however, it is a button that tunes the radio in incremental steps, then the simulation is based on a *discrete* model. Use the mouse to tune the two radios to

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see the difference between a continuous and discrete model. After exploring, press the FORWARD button to go on.

Another characteristic of mathematical models is how the results from that model are determined. If a mathematical model generates results through known relationships that are consistent and repeatable, then that mathematical model is called deterministic (DoD Directive 5000.59, 1994, P# 89). An example of a *deterministic* model is a chemical reaction (Defense Modeling and Simulation Office, n.d., Staff Officer's Course). The same amounts of the same substances when mixed under the same conditions will always yield the same result.

However, if the results of a mathematical model are decided by one or more *random* variables, then that mathematical model is said to be *stochastic* (DoD Directive 5000.59, 1994, P# 116). Since stochastic models utilize random variables, their results are *not always* the same.

An example of a stochastic model is a weather prediction (Defense Modeling and Simulation Office, n.d., Staff Officer's Course). One can never be certain of the actual outcome, but can speak of the statistical probabilities of certain weather occurrences.

There is a variation of stochastic models where each variable of the model has a calculated range of probabilities, for example, based on the bell curve (Defense Modeling and Simulation Office, n.d., M&S Staff Officer Course). These special stochastic models are called Monte Carlo models (DoD Directive 5000.59, 1994, P# 134).

In the M&S community the terms stochastic, probabilistic and Monte Carlo are often incorrectly used interchangeably. If you look at this diagram, you can see that stochastic and probabilistic are synonymous terms. However, Monte Carlo is a subset of

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stochastic models. All Monte Carlo models are stochastic. But not all stochastic models are Monte Carlo.

Spotlight: The terms stochastic and probabilistic are interchangeable, while the term Monte Carlo refers to a subset of stochastic models.

Activity: Types of Mathematic Models: Understanding the different types of mathematical models can be tricky. This exercise will help you practice distinguishing between the different terms. In the examples that follow, listen to the model description, and then click and drag the icon to the appropriate Discrete Area or Continuous Area.

- **Model description**: A model that depicts an air pressure gauge.
    - **Response to Discrete answer:** No. A *discrete* model shows *segmented* progression. This model shows the continuous rise and fall of air pressure.
    - **Response to Continuous answer:** That's right. This model depicts a *fluid* non-segmented progression of air pressure. It is a continuous model.

Now try this one.

- **Model description:** A model depicting the numbers of customers in a line that increases or decreases by one**.**
    - **Response to Discrete answer**: Yes! A discrete model shows segmented progression that you *can* count one by one.
    - **Response to Continuous answer:** Oops. That's not right. A continuous model shows fluid progression, and these customers are increasing one by one.

In the examples that follow, listen to the model description and then click and drag the icon to the appropriate, deterministic, stochastic or Monte Carlo area.

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- **Model description**: A model depicting that uses many trials to determine the most likely number of passengers that will fail to show for a flight.
  - **Response to discrete & stochastic answers:** No, that's not right. This model uses many trials to determine the most probable result, just like rolling dice.
  - **Response to Monte Carlo answer**: Yes, this model has a calculated range of probabilities, or an expected range of no-shows. The model runs many trials to determine the most probable number of passengers who will miss the flight.

Now, try this one!

- **Model description**: A model within a simulation that generates random events, such as a traffic model that incorporates sporadic car crashes and traffic jams.
  - **Response to deterministic & Monte Carlo answers:** That's not correct. This model utilizes random events, such as car crashes. Also, it *doesn't* describe the use of many trials to predict an outcome.
  - **Response to stochastic:** That's right! This is a stochastic model with random car crashes. Notice that the model also produces random results. Sometimes the traffic flows freely. Other times, it's stalled.

Here's one more!

- **Model description:** Children build a model of an erupting volcano using household ingredients from a recipe.
  - **Response to deterministic answer:** Correct! Since the children are following a recipe, there is limited variability, and the result is repeatable.
  - **Response to stochastic and Monte Carlo answers:** Sorry, that's not right. Since the volcano model is being built from a recipe of ingredients, it yields repeatable events.

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Great before moving on, there is just one other type of mathematical model that you should be aware of.

A physics-based model is a term that is used often, that means different things to different people, and that is often used to make a model sound more official. However, when used properly, the term actually refers to a mathematical model that is based upon the laws of physics. Let's listen to Ron Wolff explain what the term means…

> A Physics based model is based on real world Physics and we know that the boundaries are only to the limits of Physics itself, which right now are pretty wide. So, in essence we have an unlimited model. The problem with Physics based models is they are usually very computational intensive. But that we are actually addressing very rapidly with the development of computer systems, it's getting more and more you are seeing simulations both for training and testing that are in fact using Physics based models instead of empirical data." (Ron Wolff, videotaped interview, ITSEC, November 2002, Orlando, FL: Integrity Arts & Technology, Inc.)

Empirical data is data that you would get from going out and doing a live fire test, physically collecting sample points, and drawing a curve to those data. The problem with using empirical data to build a model is that it is bound by the limits of the data that you can collect. It doesn't say anything about what happens if your boundaries exceed the limits of your test data. So, ideally what you would rather have is a physics-based mathematical model because it is based on the laws of physics and not limited to the data collected empirically. You have learned a lot about mathematical models and you should now be able to identify the differences between the various types.

Now, let's look at a third type of model, the process model. Process models are conceptual representations that assist the understanding of steps, tasks, events, or activities (Defense Modeling and Simulation Office, n.d. Staff Officer's Course). Process models are often used to identify critical aspects of a system when a physical model is

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inappropriate or because our level of understanding does not support a mathematical representation. An example of a process model is the three-box model of human memory (Shiffin & Atkinson, 1969). This flowchart uses boxes and arrows to depict how information flows from short-term memory into long-term memory for storage.

The M&S development model is another example that uses boxes and arrows to depict processes (Amico, Bruzzone, & Guha, 2001). In this instance, the flowchart depicts the activities that developers engage in while creating M&S applications. This model is explored further in the M&S Process module.

Topic Summary: In this topic, we covered three types of models: physical, mathematical and process. You also learned about the following different characteristics of mathematical models: continuous versus discrete, deterministic versus stochastic or Monte Carlo—and physics-based.

WHAT TO MODEL?

In this topic area, you will discover the vast number of things that can be modeled, explore the question, "what should be modeled?" , and learn about the critical success factors for the development and implementation of all models.

Equipment, systems, environments, human characteristics, interactions, and behaviors are commonly modeled today. In order to be useful, however, the purpose of the model must first be determined. The purpose will help to guide which aggregation level is necessary for the model. This should be decided before the modeling effort begins. For example, with equipment, we might choose to model the tire treads on a car, the tire as a whole, the entire vehicle, a collection of this type of car, or perhaps even all

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the cars in the world. In order to know which is appropriate, you must know how the model is going to be used.

Types of systems that can be modeled include models of the human body, DNA, or transportation patterns. Military systems that are modeled include: weaponry, logistics, intelligence and computer-generated forces. Sometimes models are created to depict the environment. Examples of environmental models include: land – the type of terrain, like mountains, rivers, and forests; sea – like currents, ocean bed, reefs, and temperature gradients; atmosphere – the air which not only includes weather conditions, but also smoke and density that changes with altitude and temperature; space – objects and how they function beyond the Earth's atmosphere; and temporal effects--day versus night and seasonal impacts.

People and human characteristics may also be modeled. It is important to remember that a model may be of an individual human or of an aggregate group at any level. Also, human characteristics, interactions, or behaviors are often considered in the development of *other* models. For instance, most equipment that is being modeled needs to take into account how a person would *use* that piece of equipment. That makes the human interaction a necessary part of the model, even for an inanimate object. As an example, turn signals in an automobile are customarily located on the left side of the steering column because before automatic transmissions, a driver's right hand was needed to shift gears. Modeling is sometimes done to test the practicality of equipment design decisions such as this.

Another important point to remember is that any model of human interaction or behavior might introduce random elements that impact the model. This makes most

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models that include the human element *stochastic* or *probabilistic*. For example, creating a model to represent a technician repairing a piece of equipment would require determining how long the repair might take. However, there are many factors when incorporating the technician's performance into the model that can impact this time variable, like fatigue or illness. So even data collected from real technicians performing the task will not provide a realistic model, unless these random elements are incorporated. From this example you can see that the more complex a task is, the more difficult it is to model.

However, there are some models that include the human element that are considered *deterministic* because they have a fixed and consistent outcome. These deterministic models are not usually as complex as their stochastic counterparts.
For example, modeling the distance between a steering wheel and the driver's seat would rely upon base measurements of human arm and leg length. Once determined, these variables would remain consistent and would not be affected by random factors.

Activity:

Characteristics of Models: Now try this activity to help check your understanding of what can be modeled and of aggregation level. In the examples that follow, listen to the model description. Then decide *what* is being modeled—equipment, systems, environments, or people—and click on the appropriate area. Then decide the level of aggregation at which the item is modeled and click on the diagram at the appropriate level. Be careful though, you'll soon learn that it's not as clear cut as you might think!

- **Model description:** Engineers develop a model of a bobsled to help Olympic champions train for their competition.

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- **Response to Human, Environment, & System:** Be careful! The bobsled is something that's being used as a tool. Try again!
- **Response to Equipment:** Yes, since this is something that people are using as a tool, it is an example of equipment.

Now decide the level of aggregation.

- **Response to Sub-component, Component, Collection of Entities, Higher Level Organization**: No, one entire item is being modeled, not a piece of something, nor a collection of many items. Try again.
- **Response to Entity:** That's right! Since the model is of the entire bobsled, it is at the entity level.

That was good. Now let's try one that is a little tougher.

- **Model description:** A patient learns about her asthma condition by examining a model of the human respiratory system.
  - **Response to Human:** Yes, this is related to *humans*. However, it is also a *system*. This is one of those gray areas we spoke about earlier.
  - **Response to Environment & Equipment:** No, that's not correct. Think about how you would you describe the human respiratory system. Try again.
  - **Response to System:** Yes, this is certainly modeling a system, yet the system itself is part of a human being. This is one of those gray areas we spoke about earlier.

Now decide the level of aggregation.

- **Sub-component:** No. A lung would be a sub-component or part of the respiratory system. So at what level is the respiratory system itself?
- **Response to Component:** Yes, in this case, the human being is the entity and the respiratory system is one *component* of that entity.

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- **Response to Entity, Collection of Entities, and Higher Level Organization:** No, the sentence describes a model of one part of a single human entity. So at what level is the respiratory system itself?

All right. Let's do one more. Decide what characteristic is being modeled.

- **Model description:** Using computer software technology, 3-D models of all the buildings in a city are developed for use in Military Operations in Urban Terrain (or MOUT) simulations.

  - **Response to Human:** No, a building is not a human.
  - **Response to Environment:** Yes, this is the closest match. A building certainly is an environment that we live in. Yet, most people don't think of a building as an environment.
  - **Response to Building:** No, we don't typically think of a building as a system. If the buildings were interconnected in some way, however, they would form a system. Try again.
  - **Response to Equipment:** No, a group of buildings may contain equipment, but they are not equipment per se. Try again.

Now decide the level of aggregation

  - **Response to Sub-component, Component, Entity, :** No. The sentence describes the modeling of more than one entire building. Try again
  - **Response to Collection of Entities:** No. This is a model of ALL the buildings in a city. This suggests a higher structure. Try again.
  - **Response to Higher Level Organization:** Yes, this is the most accurate answer since there are several buildings which take the form of a higher-level organization like a city.

As you can see, we can model just about any phenomenon—including humans, systems, equipment, and the environment. And we can model these phenomena at a variety of

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aggregation levels—ranging from sub-components to higher level organizations. That opens the issue of just what *should* we model? Just because we *can* model something, doesn't *necessarily mean we should*.

So – what *should* be modeled? The answer hinges upon using the purpose to define the characteristics of the model. Think about the cockpit seat introduced earlier. If the purpose of the model is to support a *training* simulation, such as how to operate the ejection mechanism in the seat, then all of the critical information and cues necessary to perform that task must be modeled as accurately and completely as possible. Otherwise, trainees might learn to ignore or undervalue critical information necessary to complete the task.

If, on the other hand, the purpose of the model is to provide design and manufacturing support for equipment, then the accuracy of the physical parameters of the ejection seat model might take precedence. Knowing the model's intended use is critical for developing models that have an appropriate level of aggregation and that utilize accurate and valid source information.

Modeling and training *all* of the critical tasks necessary to perform an operation are also important considerations when planning *what* to model. In the case of pilot training, for instance, it could be a mistake to leave out the critical role of the air traffic controller in the training task model. This might mean that the pilot's first interaction with an air traffic controller could occur while in flight, potentially distracting the pilot trainee or causing confusion so that the trainee is unable to use air traffic control information effectively.

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No matter what the characteristics or aggregation level, all models share certain critical success factors. They must be accurate and authoritative (Amico, Bruzzone, & Guha, 2001). They must also be accessible by the user community, the people who will utilize the models. And finally, since many things that are appropriate to model are so complex and affected by so many variables, the user must be aware of the limitations of the model. Knowing the limitations will help the user to understand the appropriate use of the model and how valid it is for that use.

When evaluating a model you should always seek out where the information came from? (Amico, Bruzzone, & Guha, 2001) Is it valid? Are the algorithms used appropriate for this model? Were the data obtained from an approved source?

Spotlight: The validity of the model is directly related to the accuracy of the data behind it.

Watch out for buzz words or catch phrases such as "modeling down to the unit level" or "we train as we fight." These phrases don't replace accurate and authoritative models.

Why are these critical success factors so important? Think about the following situations which illustrate these points:

- **Accurate:** What if flight simulators were based upon models that didn't accurately portray real operating controls? Would you trust a pilot who was trained on one of these simulators?

  DRILL DOWN: *Accuracy*
  There was a case in which we were going to adapt a visual system to a Marine Core fighter airplane because it was a commercially available system and if we just tied them together we would've saved a lot of development cost. When the Marines flew the simulator … the first attempt, the visual system broke up. The reason the visual system broke up is the visual system was designed for commercial aircraft… The Marine Core did a slow roll with that simulator and it was not designed into the system…They forgot to check in the model the fact that

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they had the proper range of variables for that particular parameter. (Vince Amico, videotaped interview, ITSEC, November 2002, Orlando, FL: Integrity Arts & Technology, Inc.)

- **Authoritative:** What if a military commander didn't trust a certain simulation and its underlying model? If the model doesn't have sufficient credibility, do you think that commanders would trust the results of the exercises they conducted using the simulation?

DRILL DOWN: *Authority*
It has been my experience particularly in training exercises that some commanders come into that training environment anticipating that the simulation is not going to accurately portray their war plan. So, very often once the engagement is conducted…whatever the consequence of that activity was, they were likely to disallow and suggest that wasn't how their weapon system would have performed. If the real operator had been in the weapon system that is not what they would have done (Herb Grover, videotaped interview, ITSEC, November 2002, Orlando, FL: Integrity Arts & Technology, Inc.).

- **Accessible:** What would happen if an architect built you a house, but never showed you any models like blueprints or elevation drawings? Do you think the final home design would meet your expectations?

- **Limitation Awareness**: What if a battalion commander used a computer-based simulation (designed to train communication skills) to try to validate a battle plan? Do you think his plan would be valid?

Topic Summary:

In this topic, you explored what can be modeled, and how there can be shades of gray when categorizing model characteristics into equipment, systems, environment or human. Further, you have once again encountered how critical the model's purpose is. In this instance, purpose determines "what should be modeled." And finally, you learned

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that in order to be effective, models must be accurate, authoritative, accessible to the user, and they must have clearly defined limitations.

CHALLENGES:

In this topic area, you will explore some of the challenges regarding the development and implementation of models.

- The modeling and simulation community continually faces challenges regarding the development and use of models. Being aware of these challenges is an important step in ensuring accuracy and success of an M&S project.
- Nothing can ever be modeled perfectly. If it could be, then it would not be a model. It would be an exact replica of the real thing.

  Vince Amico has some words of wisdom about this topic…

  > Modeling and simulation represents the real world to a degree, to a degree less than perfection, and when people say, " I would like to have something simulated" realistically, what they are saying is that what they see and what they want has a gap…The challenge will always be there, we will never have a simulation that represents the real world perfectly. The important point is that it represents it well enough to do the task that it was assigned to do. (Vince Amico, videotaped interview, ITSEC, November 2002, Orlando, FL: Integrity Arts & Technology, Inc.)

  So, making sure an individual model used in a simulation is valid requires those involved with M&S to narrow their focus, define the specific purpose for the model and make accurate assumptions based on the end use for that model.
- The model must continually be validated against the end-user's needs. Constantly monitoring the development and application of a model so that it meets the requirements of the end-user is critical to not only ensuring the validity of the simulation in which the model will be used, but also the accuracy of the model itself.

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Ron Wolff has some words of caution about this…

> It's pretty simple to put together a system that looks visually pleasing to the eye and that doesn't produce any real data that is going to support your program. That is very dangerous. You can literally spend millions of dollars on something that looks very pleasing, and you have no data. So, take the time to question the models and verify that in fact they are validated to real data. (Ron Wolff, videotaped interview, ITSEC, November 2002, Orlando, FL: Integrity Arts & Technology, Inc.)

- Since the modeling process may take a long time, sometimes the original requirements can get "lost" in the shuffle of project management. Let's listen to Vince Amico thoughts on this issue…

  This process takes a long time, years. And, in order to keep the end goal consistent with the original requirement you must insist on there being user involvement throughout the development process. He must be involved as it goes through each step of the process. The reason for that is each one of us in our role in that process puts a spin on it from our orientation. What *we* think he said, not what he said, but what we think he said. And, if you have too many of those perturbations and amplifications and simplifications you end up with a product that doesn't meet what the user stated in the beginning. So it's important that you keep this as a tight system always referring back to the user every step of the way (Vince Amico, videotaped interview, ITSEC, November 2002, Orlando, FL: Integrity Arts & Technology, Inc.)

  Without this end-user validation at every step in the modeling process, a model might be useless.

- For effective modeling, end-user expectations must be managed in terms of available resources, technology, time, and costs.

  Remember, the purpose of the model should guide your expenditure of resources.

  Let's hear what Milt Stretton has to say about this topic…

  > It goes back again to purpose…the reason that I am using Modeling and Simulation. I have to look closely at that and just don't choose a set of models for the sake of having them, because they might not fulfill your purpose. So, do the upfront work first before you put your resources into something that may not address the purpose that you are doing in the first place (Milton

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> Stretton, videotaped interview, ITSEC, November 2002, Orlando, FL: Integrity Arts & Technology, Inc.

- A common challenge is managing the end-user's expectations. Determining what is really necessary to model and to what level of detail are critical decisions that have a tremendous impact on labor, schedule and budget. What the end-user might desire is not always necessary and may not be technologically possible. For example, the end-user might want to model down to the square inch, but the budget and computer power may only allow modeling to the square foot. Including these unrealistic capabilities may be at the expense of being able to complete the project.
- Don't fall in love with your model.

  Let's hear from Michael Macedonia about just what this means and how it might impact the effectiveness of an M&S project…

> The reason people fall in love with their models is because they are very complex systems. It takes sometimes years to understand and become an expert with these simulations. And it's very difficult to detach our … humanness from that and become detached from it and understand all it *is* is a *tool*. But unfortunately for some people they think, for example, "Now I have a hammer and everything now is a nail with my simulation." Everything becomes "nailable" to that simulation (Michael Macedonia, videotaped interview, ITSEC, December 2002, Orlando, FL: Integrity Arts & Technology, Inc.)

A common challenge is that users or developers may become so involved with their models that they cannot maintain a clear or unbiased perspective. Being able to recognize when a model is no longer valid or appropriate to your current need is a critical component for success in M&S. Just because a model works for one purpose does not mean that it is the actual "truth" (Michael Macedonia,

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videotaped interview, ITSEC, December, 2002, Orlando, FL: Integrity Arts & Technology, Inc.) Other models can also be appropriate. No model, no matter how well constructed, is appropriate for everything.

Topic Summary:

Now that you have learned about some of the challenges of modeling, let's review the guidelines for managing those potential obstacles. Since nothing can ever be modeled perfectly, manage your resources and the end-user's expectations to develop *only* what is required to realize the model's purpose. Don't fall in love with your model; instead, strive to maintain an unbiased perspective and ensure that the model is validated against the end-user's current need.

MODELS MODULE SUMMARY

This topic reviews the major concepts covered in the Models Module.

A model is a representation of some thing that allows us to simplify complex phenomena and to test our understandings. One of the most important things to remember about models is that they are the foundation for many simulations. Remember, a model tends to be static, while a simulation is generally dynamic.

There are three types of models: physical, mathematical and process. Mathematical models can be characterized as either discrete or continuous. That means they depict either segmented or fluid progression. Mathematical models can also be described as either deterministic or stochastic. That means that the results are either repeatable or they are variable. And we also introduced a special kind of stochastic model called a Monte Carlo model that incorporates variables with a calculated range of

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probabilities. Think of rolling dice over and over again to determine the probability of both die landing on the number two.

One of the most essential things to remember is that the model's purpose determines the way the model is created and how it should be used.

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