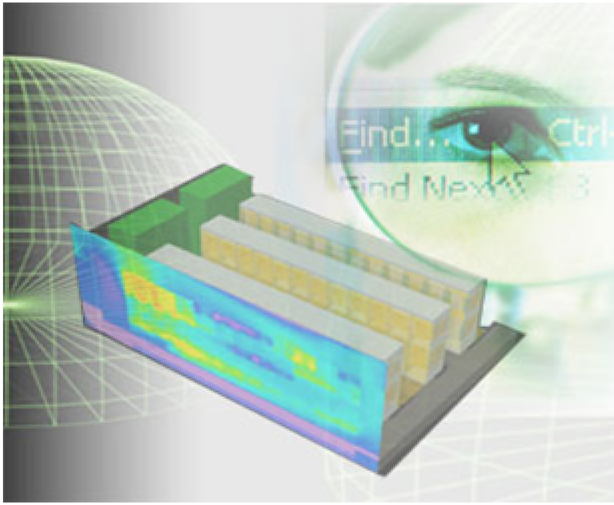
## Welcome to Technical Activites

This lesson addresses various technical activities needed to establish a product support strategy during the Technology Development phase. One of the key tools available to the LCL is Modeling and Simulation (M&S). M&S, combined with test and evaluation, can be a powerful tool the LCL can use to increase reliability and maintainability of a product.



## Objectives

Upon completion of this lesson, you will be able to:

- Identify the correct technology readiness level.
- Define the types of simulation and the verification, validation, & accreditation (VV&A) process.
- Identify modeling and simulation methods and challenges related to improvement of system reliability and maintainability.

This lesson will provide you with information regarding the LCL's role in various technical activities, associated with developing the initial product support strategy.

## Managing Technology Risk

Technology risk must be actively managed to deliver and support increments of warfighting capabilities on time and on budget. In order to do this and develop an effective product support strategy the LCL needs to know and understand Technology Readiness Assessments (TRA) and the maturity level of the technology.

Per DoD Instruction 5000.02, Enclosure 4, the TRA is a regulatory information requirement for all acquisition programs. It is a systematic, metrics-based process that assesses the maturity of critical technology elements (CTEs), including sustainment drivers. The TRA should be considered not as a risk assessment, but as a tool for assessing program risk and the adequacy of technology maturation planning. The TRA scores the current readiness level of selected system elements, using defined Technology Readiness Levels (TRLs). The following table from the Defense Acquisition Guidebook shows the risk and technology maturity relationship.

| Technology Maturity | Technology Description |
|---|---|
| Low Risk | Existing Mature Technologies |
| Medium Risk | Maturing Technologies; New Applications of Mature Technologies |
| High Risk | Immature Technologies; New Combinations of maturing Technologies |

**Figure 5.4.2.5.1.F2. Technology Risk Consideration**

## Managing Technology Risk, Cont.

Technology Readiness Levels (TRLs) are a set of nine graded definitions/descriptions of stages of technology maturity. They were originated by the National Aeronautics and Space Administration and adapted by the DOD for use in its acquisition system. Additional information about TRLs is provided below.

1. Basic principles observed and reported.
2. Technology concept and/or application formulated.
3. Analytical and experiemental critical function and/or characteristic proof of concept.
4. Component and/or breadboard validation in laboratory environment.
5. Component and/or breadboard validation in relevant environment.
6. System/sub-system model or prototype demonstration in a relevant environment.
7. System prototype demonstration in an operational environment.
8. Actual system completed and qualified through test and demonstration.
9. Actual system proven through successful mission operations.

**Popup Text**

**Basic Principles Observed and Reported**

Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.

**Technology Concept and / or Application Formulated**

Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.

**Analytical and Experimental Critical Function**

Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.

**Component and / or Breadboard Validation (Lab)**

Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.

**Component and / or Breadboard Validation (Relevant)**

Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.

**System / Sub-System Model**

Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.

**System Prototype Demonstration**

Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.

**Actual System Completed**

Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.

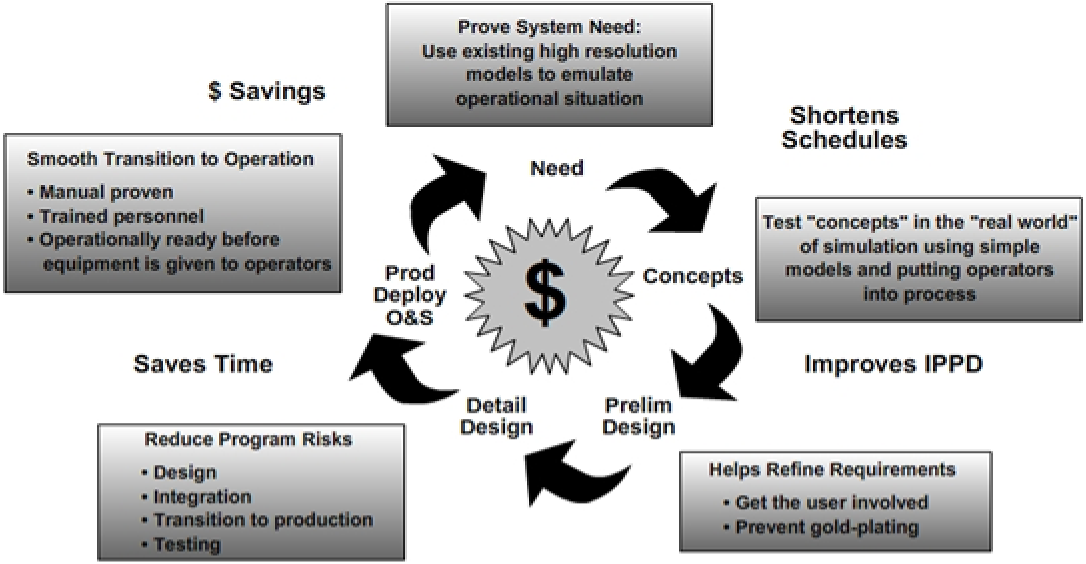
**Actual System Proven**

Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

## Using Modeling and Simulation (M&S) to Reduce Technology Risk

A valuable tool for the LCL is Modeling and Simulation (M&S). A model is a physical, mathematical, or logical representation of a system entity, phenomenon, or process. A simulation is the implementation of a model over time. A simulation brings a model to life and shows how a particular object or phenomenon will behave. The LCL can use M&S to manage and reduce technology risk associated with new and evolving technologies. This will assist the LCL as he/she develops product support strategies and plans.

As illustrated below, the use of M&S can reduce the cost and risk of life cycle activities.




Sometimes it's the only way to verify or validate

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**Long Description**

Advantages of Modeling and Simulation, System Engineering Fundamentals, Defense Acquisition University, 2001. At the center of the figure is a dollar sign in a starburst. There are five arrows forming a clockwise circle around the starburst, indicating that there are advantages to modeling and simulation across the life cycle: Need; Concepts; Preliminary Design; Detail Design; and Production, Deployment, Operations & Sustainment. M&S can help prove system need by using existing high-resolution models to emulate operational situation. This shortens schedules. M&S can help test “concepts” in the “real world” of simulation using simple models and putting operators into process. This improves the Integrated Product and Process Development (IPPD). With regard to preliminary design, M&S can help refine requirements. It can get the user involved and prevent gold-plating. Sometimes it’s the only way to validate. With regard to detail design, M&S can reduce program risks in the areas of design, integration, transition to production, and testing. This saves time. With regard to Production, Deployment, Operations & Sustainment, M&S can assist with smooth transition to operation. The manual is proven, personnel are trained, and the environment is operationally ready before the equipment is given to the operators. This can lead to savings.

## Types of Simulation

There are three types of simulation:

- Constructive simulations represent a system and its employment. They include computer models, analytic tools, mockups, Integrated Definition (IDEF), Flow Diagrams, and Computer-Aided Design/ Manufacturing (CAD/CAM).
- Virtual simulations represent systems both physically and electronically. Examples are aircraft trainers, the Navy's Battle Force Tactical Trainer, Close Combat Tactical Trainer, and built-in training.
- Live simulations are simulated operations with real operators and real equipment. Examples are fire drills, operational tests, and initial production run with soft tooling.

Click here to view a Transcript of the video on the right.

Constructive Simulation


STOP PLAY PAUSE

*This video provides examples of constructive, virtual, and live simulations.*

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**Popup Text**

**Constructive**

Models and simulations that involve simulated people operating simulated systems. Real people stimulate (make inputs) to such simulations, but are not involved in determining the outcomes.

**Virtual**

A simulation involving real people operating simulated systems. Virtual simulations inject human-inthe-loop (HITL) in a central role by exercising motor control skills (e.g., flying an airplane), decision skills (e.g.committing fire control resources to action), or communication skills (e.g., as members of a C4I team).

**Live**

A simulation involving real people operating real systems.

**Long Description**

Video showing examples of constructive, virtual and live simulations.

## Verifying, Validating, and Accrediting the Model

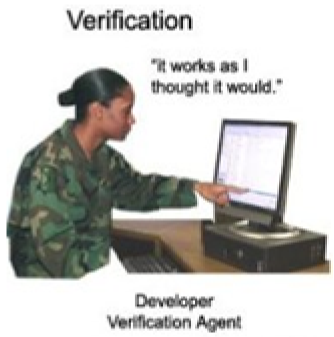
In order to build confidence in the assessment of technical risk when employing M&S, it is important to verify, validate, and accredit (VV&A) the model.

Verification is the process of determining that a model implementation accurately represents the developer's conceptual description and specifications that the model was designed to.

Validation is the process of determining the manner and degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model, and of establishing the level of confidence that should be placed on this assessment.

Accreditation is conferred by the organization best positioned to make the judgment that the model or simulation in question is acceptable. That organization may be an operational user, the program office, or a contractor, depending upon the purposes intended.

See DoDI 5000.61, DoD Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A) for additional information.



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**Popup Text**

**Verification**

The process of determining that a model or simulation implementation accurately represents the developer's conceptual description and specification. Verification also evaluates the extent to which the model or simulation has been developed using sound and established software engineering techniques. (DoD Directive 5000.59 and DoD 5000.59-P (references (f) and (g)).)

**Validation**

The process of determining the degree to which a model or simulation is an accurate representation of the real-world from the perspective of the intended uses of the model or simulation. (DoD Directive 5000.59 and DoD Instruction 5000.61 (references (f) and (h)).)

**Accreditation**

The official certification that a model or simulation is acceptable for use for a specific purpose. (DIS Glossary of M&S Terms and DoD Directive 5000.59 (references (b) and (f)).)

**Long Description**

The graphic shows three photos representative of Verification, Validation and Accreditation.

- Verification - There is a photo of a warfighter at a computer; she represents the Developer/Verification Agent. She is thinking, "It works as I thought it would."
- Validation - There is a photo of a man working on equipment; he represents the Functional Expert/Validation Agent. He is thinking, "It looks just like the real thing."
- Accreditation - There is a photo of people at a meeting; they represent the Requestor

User/Accreditation Agent. They are thinking, "It suits my needs."

## Knowledge Review

What is the process of determining that a model implementation accurately represents the developer's conceptual description and specifications that the model was designed to?

- [x] Verification
- [ ] Live Simulation
- [ ] Accreditation
- [ ] Constructive Simulation

Check Answer

**Verification** is the process of determining that a model implementation accurately represents the developer's conceptual description and specifications that the model was designed to.

**Verifying, Validating, and Accrediting the Model (VV&A), Cont.**

VV&A of M&S is often necessary in cases where:

- Complex and critical interoperability is being represented (such as prognostics)
- Reuse is intended (it becomes a life cycle tool for support)
- Safety of life is involved
- Significant resources are involved

**Verifying, Validating, and Accrediting the Model, Cont.**

There are also other factors the LCL should consider when employing M&S, such as fidelity, planning, balance, and integration. Select each factor to read the details.

Fidelity

Planning

Balance

Integration

**Popup Text**

**Fidelity**

The degree to which aspects of the real world are represented in M&S. It is the foundation for development of the model and subsequent VV&A. Cost effectiveness is a serious issue with simulation fidelity, because fidelity can be an aggressive cost driver. The correct balance between cost and fidelity should be the result of simulation need analysis. M&S designers and VV&A agents must decide when enough is enough. Fidelity needs can vary throughout the simulation.

**Planning**

Planning should be an inherent part of M&S, and, therefore, it must be proactive, early, continuous, and regular. Early planning will help achieve balance and beneficial reuse and integration. With computer and simulation technologies evolving so rapidly, planning is a dynamic process.

**Balance**

Refers to the use of M&S across the phases of the product life cycle and across the spectrum of functional disciplines involved.

**Integration**

Obtained by designing a model or simulation to inter-operate with other models or simulations for the purpose of increased performance, cost benefit, or synergy. Multiple benefits or savings can be gained from increased synergy and use over time and across activities.

## Leveraging Overall M&S Activities

LCLs should leverage overall M&S activities within the program when addressing technical risk associated with supportability. By doing this, it not only reduces the cost of the effort, but more importantly helps ensure that the supportability parameters, assumptions and boundaries are aligned and integrated with the overall system development. In some instances, there may be M&S efforts outside of the program in other programs or in other functions and activities (the services, JCS, or industry) that may also be relevant and usable.

## Using M&S to Increase Reliability, Availability, and Maintainability (RAM)

It is very important for the LCL to know that during pre-systems acquisition, the most important activity is to understand the users' needs and constraints. Knowing these needs and constraints, LCLs can use M&S as a tool to increase reliability and maintainability.

According to the DOD Guide for Achieving Reliability, Availability, and Maintainability (RAM Guide) many factors affect RAM. They are:

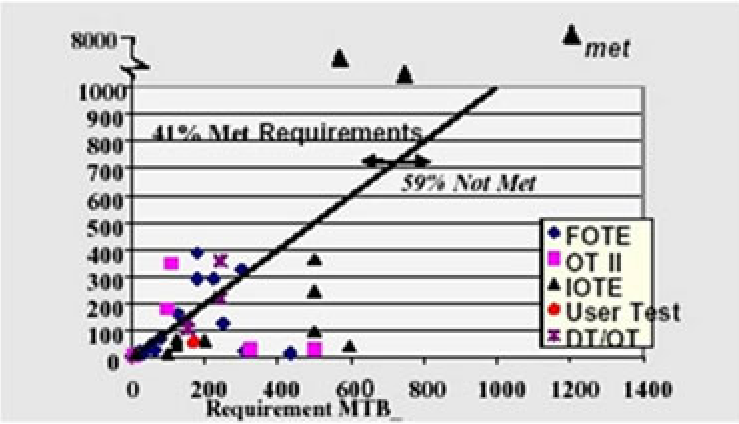
- System design
- Manufacturing quality
- The environment in which the system is transported, handled, stored, and operated
- The design and development of the support system
- The level of training and skills of the people operating and maintaining the system
- The availability of material required to repair the system
- The diagnostic aids and tools (instrumentation) available to them

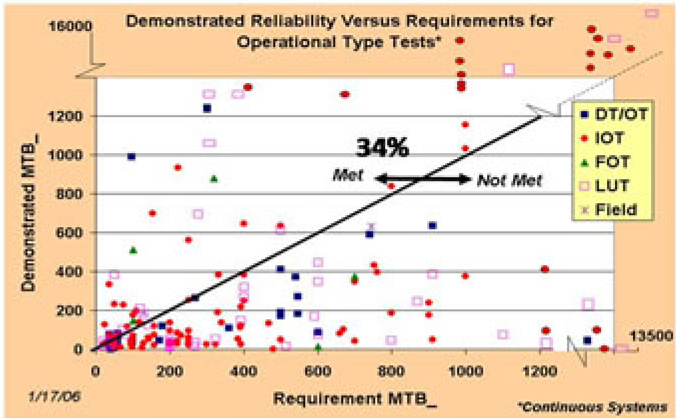
All these factors and their inter-dependencies must be understood to achieve a system with a desired level of RAM. M&S is a useful tool to develop this understanding and to also identify risks and establish mitigation strategies.

## Challenges to Improving RAM

Despite a growing recognition of RAM, challenges in improving RAM remain. While the speed, range, firepower, and overall mission performance of weapons systems has improved dramatically over the years, RAM problems have persisted. RAM problems slow the development and fielding of systems, drive up the total ownership cost, and degrade operational readiness and mission accomplishment at the strategic, operational and tactical levels. New complex digital designs have increased software development and integration issues and the importance of integrated diagnostics.

A study of some defense systems provides an example of the breadth of the reliability problem. Data came from operational tests of systems from 1985-1990 and 1996-2005, respectively. The percentage of systems meeting reliability requirements decreased from 41 percent to 34 percent.

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**Long Description**

Demonstrated Reliability vs. Requirements for Operational Tests, 1985-1990 from the DoD Guide for Achieving Reliability, Availability, and Maintainability, August 3. 2005; and image on the right: Demonstrated Reliability vs. Requirements for Operational Test, 1996-2005 from undated U.S Army RDECOM presentation “Contracting for Reliability”, Each figure shows a graph of Requirement MTB_ on the x-axis, with values ranging from 0 to 1400, and Demonstrated Reliability on the y-axis. In the left image, the values on the y-axis range from 0 to 8000. In the right image, the values on the y-axis range from 0 to 16000. The left image shows that for the total number of operational tests in the 1985-1990 period, 41% met requirements and 59% did not meet requirements. The right image shows that for the total number of operational tests in the 1996-2005 period, only 34% met requirements.

## Why Systems Fail to Achieve RAM

According to the RAM Guide, the following reasons were identified as to why systems fail to achieve RAM:

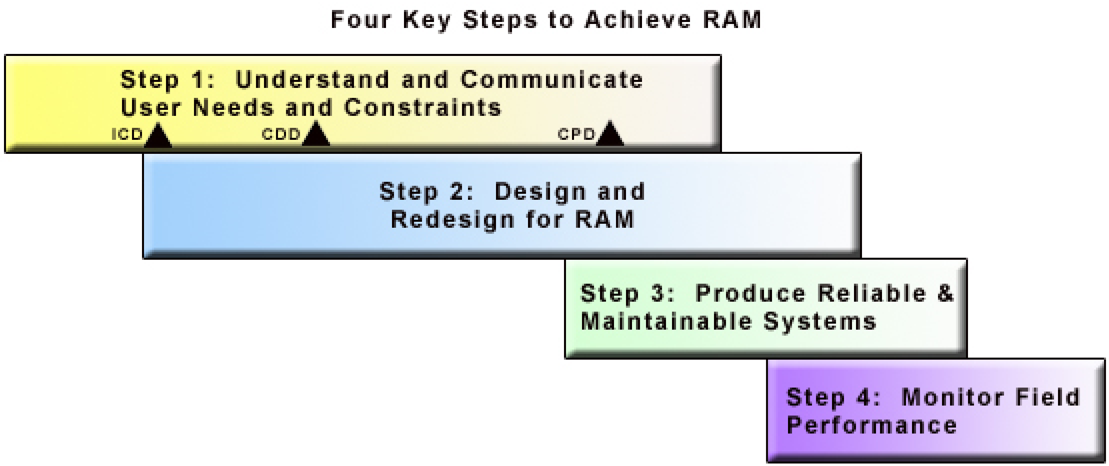
- Poorly defined or unrealistically high RAM requirements.
- Lack of priority on achieving R&M.
- Too little engineering for RAM.
- Among engineering process failures, the following stand out:
  - Failure to design-in reliability early in the development process.
  - Inadequate lower-level testing at component or subcomponent level.
  - Reliance on predictions instead of conducting engineering design analysis.
  - Failure to perform engineering analyses of commercial-off-the-shelf (COTS) equipment.
  - Lack of reliability improvement incentives.
  - Inadequate planning for reliability.
  - Ineffective implementation of reliability growth tasks in improving reliability.
  - Failure to give adequate priority to the importance of integrated diagnostics (ID) design influence on overall maintainability attributes, mission readiness, maintenance concept design, and associated LCC support concepts.
  - Unanticipated complex software integration issues affecting all aspects of RAM.
  - Lack of adequate ID maturation efforts during system integration.
  - Failure to anticipate design integration problems where COTS and/or increment design approaches influence RAM performance.

As the LCL develops the initial product support strategy, understanding why systems fail to achieve RAM will help with risk assessment and developing resulting support strategies.

**Steps to Improving RAM**

Four major steps have been identified as an approach for improving RAM in the RAM Guide as illustrated below.

A key element in the implementation of these steps is the development of a conceptual system model which consists of components, sub-systems, manufacturing processes, and performance requirements. This model is used throughout development to estimate performance and RAM metrics.

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**Long Description**

Four Key Steps to Achieve RAM within DoD 5000 Series Acquisition Management Framework. There are four rectangles representing the four steps.

The length of the rectangle representing Step 1 is slightly less than the length of the rectangle representing Step 2. Step 2 is significantly larger than Step 3. Step 3 is slightly larger than Step 4. The rectangles are stacked in a stair-step manner, with Step 4 on the bottom, Step 3 stacked on Step 4, Step 2 stacked on Step 3, and Step 1 stacked on Step 2.

- Step 1: Understand and communicate user needs and constraints
- Step 2: Design and redesign for RAM
- Step 3: Produce reliable & maintainable systems
- Step 4: Monitor field performance

## Knowledge Review

Which of the below is a characteristic of Validation, Verification, and Accreditation?

- [ ] It is important to ensure quality in manufacturing so that the inherent RAM qualities of the design are not degraded.
- [ ] Improvement and success relies upon understanding and communicating user needs and constraints.
- [ ] It can fail if there is too little engineering or a lack of priority when achieving performance.
- [x] It facilitates multiple benefits and savings from increased synergism and use over time and across activities.

Check Answer

Validation, Verification, and Accreditation **facilitate multiple benefits and savings from increased synergism and use over time and across activities**.

**RAM Assessment**

So, how do you know what level of RAM is being achieved? A RAM assessment is the continuing process of determining the value of the level of RAM being achieved at any point in time. Of course, the ability to make an assessment and the quality of the assessment depends on the information available.

How is an assessment done? Typically, a RAM model is used. It presents a clear picture of functional interdependencies and also provides the framework for developing quantitative product level RAM estimates to guide the design trade-off process. RAM models are useful for:

- Allowing summarization of all factors affecting system RAM.
- Making numerical allocations and assessments.
- Easy identification of single points of failure.
- Evaluating complex redundant configurations.
- Showing all series-parallel and other topological relationships.

**RAM Assessment, Cont.**

RAM models are derived from and traceable to system functional requirements. Inputs to the models may include:

- Comparative analysis
- RAM predictions
- Test data
- Field data
- Customer requirements and use profiles, including mission, threat, operating and support concepts.

Models can vary from relatively simple models to those that go into great detail considering details such as duty cycles, service life limitations, wear out items, varying environments, dormant conditions, human reliability, software, etc. Even simple models can help guide concept and refinement decisions to improve RAM.

In the more detailed models, the calculation of the overall system RAM becomes more complex and difficult to solve analytically. Solutions here are often determined through simulation that entails mimicking some or all of the behavior of a system. Monte Carlo simulation is a simulation technique where the performance of the logical model of the system under analysis is repeatedly evaluated using RAM parameter value from designated probability distributions. Complex systems are relatively easily modeled using this simulation technique and the input algorithms are straightforward.

As an LCL you may or may not be tasked with performing RAM assessments. You will however use the results of the assessment(s) as you develop the initial product support strategy. Understanding RAM and the implications of RAM assessment results will be very helpful to you.

## Reliability Growth Modeling

Another useful application of M&S to improve RAM is reliability growth modeling that provides estimates of the current or projected system reliability performance and estimates of the time required to develop specified levels of reliability. The emphasis of the reliability growth activity is the identification and removal of failure modes. Reliability growth modeling is typically modeled using Duane Model or the Army Material Systems Analysis Activity (AMSAA) Model developed by Dr. Larry Crow. Both models have the same parameters and reliability growth pattern. The estimation for the Duane Model uses a simple regression fit. The AMSAA (Crow) Model, however, utilizes more rigorous statistical procedures with the benefits of confidence intervals, goodness-of-fit tests, and other statistical tools and procedures. The appropriate model should be based on selecting the simplest one that does the required job.

### Comparison of Reliability Growth Models

| | Duane Model | AMSAA (Crow) Model |
|---|---|---|
| **Basis of Model** | Empirical Model | Statistical Model |
| **Confidence Bounds** | Confidence bounds cannot be determined | Confidence bounds can be determined |
| **Trending** | Significance of trend cannot be tested | Significance of trend can be tested |
| **Data Fit** | Least squares fit to the data | Maximum likelihood fit to the data |
| **Popularity/Complexity** | More popular/less complex (simple) | Less popular/more complex |
| **Graphical Representation** | Straight line on log-log paper | Straight line on log-log paper |

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**Long Description**

Comparison of AMSAA (Crow) and Duane Models, from the DoD Guide for Achieving Reliability, Availability, and Maintainability, August 3, 2005. The comparison categories are: Basis of Model; Confidence Bounds; Trending; Data Fit; Popularity/ Complexity; and Graphical Representation. Basis of Model: The Duane Model is empirical. The AMSAA (Crow) Model is statistical. Confidence Bounds: In the Duane Model, confidence bounds cannot be determined. In the AMSAA Model, confidence bounds can be determined. Trending: In the Duane Model, the significance of trend cannot be tested. It can be tested in the AMSAA Model. Data Fit: In the Duane Model, the least squares fit to the data. In the AMSAA Model, maximum likelihood fit to the data. Popularity/ Complexity: The Duane Model is more popular and less complex. The AMSAA Model is less popular and more complex. Graphical Representation: Both models produce straight line on log-log paper.

## The LCL's Active Role in Using Modeling and Simulation to Increase Reliability and Maintainability

As an LCL, you need to actively participate in the modeling and simulation activities of the program. Doing so will help facilitate the development and application of specific models and simulations that can provide insights to the inherent R&M as the system is being developed. It will also serve as M&S tools that can be used throughout the life cycle to assess R&M as the system evolves to fielding.

Insights gained through M&S of R&M can provide useful information that can be used to identify risk areas, correct deficiencies and increase RAM. In addition, the product support strategy can be refined based on the results of the M&S to accommodate the estimates of R&M as they evolve.

## Knowledge Review

What are the three elements of RAM?

- [ ] Reliability, Accuracy, Maintainability
- [x] Reliability, Availability, and Maintainability
- [ ] Reuseability, Availability, and Maintainability
- [ ] Reliability, Availability, and Measurability

Check Answer

**Reliability**, **Availability**, and **Maintainability** are three characteristics of RAM.

## Technical Activities Summary

You have completed Technical Activities and should now be able to:

- Identify the correct technology readiness level.
- Define the types of simulation and the VV&A process.
- Identify modeling and simulation methods and challenges related to improvement of system reliability and maintainability.

## Lesson Completion

You have completed the content for this lesson.

To continue, select another lesson from the Table of Contents on the left.

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