Incremental Quantification of VV&A "Levels" for Integrated Management of Modeling & Simulation Tools

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Abstract

The NASA Exploration Program needs a tailored Verification, Validation and Accreditation (VV&A) approach, wherein the required VV&A, or "confidence level", of many small linked analysis models and tools are incrementally correlated with the data confidence and accuracy required at each program development stage. We call this approach "incremental quantification of VV&A levels". This approach is one component of a new NASA program for "integrated management" of Modeling and Simulation (M&S) tools. This paper will describe the conceptual framework for this new approach, illustrating the correlated and incremental linkage between program risks arising from the use of data from a tool and the corresponding confidence evaluation of that tool's capability to provide the required data.

1. Engineering Risk Drives Confidence Need

NASA's vision for space exploration encompasses a broad range of human and robotic missions, including the Moon, Mars, and destinations beyond. This endeavor will require the usage of Modeling and Simulations (M&S) to perform analyses; validate requirements; evaluate designs, hardware, and software implementation and interfaces; and support element and system integration. NASA uses a comprehensive set of M&S tools to support both technical and programmatic decisions across multiple organizations, at multiple levels throughout the system development lifecycle.

As the risk associated with an incorrect decision increases, the greater the need for confidence in the tools that support that decision. Each decision has an associated risk. Incorrect decisions can lead to catastrophic mission failure or suboptimal design. Simulations used to support decisions inherit the risks associated with the incorrect decision. For this reason, NASA manages risks considering the quality, credibility, and applicability of simulations used to support significant decisions.

NASA measures risk in terms of the likelihood of the occurrence of an unfavorable event and the severity of the consequences given that the event occurs. Likelihood and Consequence form the axis of the 5X5 matrix shown in the leftmost portion of Figure 1.0-1, Risk Confidence Dependency. If it is very unlikely that NASA will make an incorrect decision or if the consequences of an incorrect decision are low, the risk inherited by the use of a simulation is low. Conversely, if there is a greater likelihood of an incorrect decision based on a simulation or the consequences of that incorrect decision are severe, the risks are high. The more "risky"- or more correctly stated, critical – a decision is, the more confidence NASA needs in the data supporting the decision. Simply put and in the simulation providing that data. Therefore, engineering risk drives the need for data confidence.

Data confidence arises from M&S tool confidence and the M&S tool user or analyst confidence as shown in the rightmost portion of Figure 1. This paper deals with measuring the M&S tool confidence achieved through VV&A.

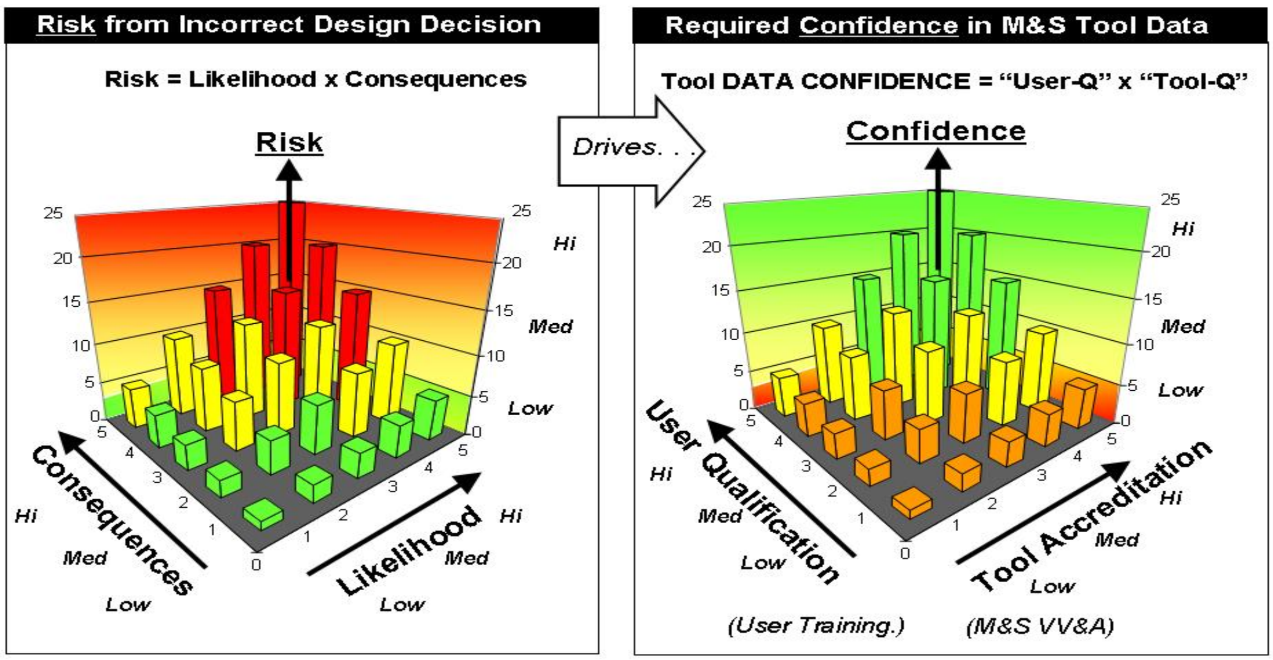

Figure 1. Risk Confidence Dependency

2. Quantification of Confidence

The challenge for VV&A is using the correct parameters to quantify the confidence needed for a given simulation.

Another of the author's papers, entitled "A Characterization Taxonomy for Integrated Management of Modeling and Simulation Tools", introduced a method to compartmentalize simulations to facilitate planning and analysis. The characteristics presented in that paper divide into those that aid in differentiating simulations and those that contribute to the user's confidence in the simulation results, as shown in Figure 2, Simulation Characteristics.

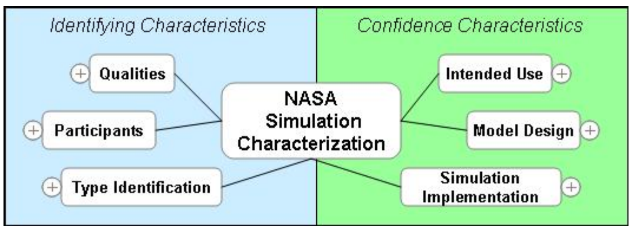

Figure 2. Simulation Characteristics

The most important of the confidence building characteristics are those related to the intended use. Many problems arise from using a simulation outside of its intended domain. Therefore, the needed domain as well as the domains of the available candidate simulations must be accurately characterized. For example, it may not be sufficient to know that a simulation covers the avionics of a crewed vehicle unless it is also known that the simulation includes the needed Martian environment and that it may be used for conceptual analysis.

Figure 3, Intended Use Characteristics shows the breakout of those discriminates. Intended use is a strong criterion, usually resulting in a "Go/No-Go" determination. With the exception of closely spaced alternatives, a simulation should be intended for the purpose that analyst needs. NASA simulations are used for a variety of purposes: during different portions of a project, for various space systems, in several environments, and for many types of spacecraft.

Disciplines covered, which the figure does not show to conserve space, include System Engineering & Integration, Safety & Mission Assurance, Systems Analysis, Cost Engineering, Operations, Risk, RAM, Requirements Allocation, Costing, Safety, Computer, Software & Automation, Aerosciences & Flight Mechanics, Command, Control & Communications, Human Centered, Power Systems, Propulsion and Fluidics, Robotics, Structural, Mechanical, Materials and Manufacturing Each discipline has a unique perspective on the other characteristics. A simulation may be intended for any compartment.

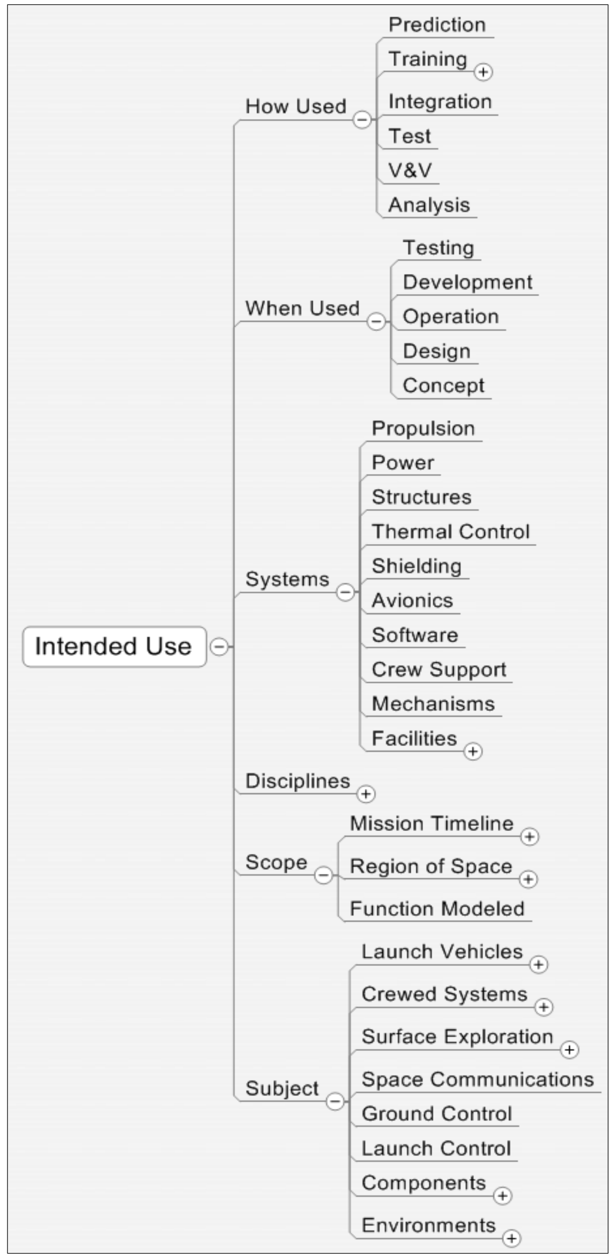

Figure 3. Intended Use Characteristics

Given that the simulation actually does what is needed, the next questions relate to how well the model is designed. Conceptual Modeling is a critical phase in simulation development. The degree to which this process is successful largely determines the quality of the simulation. Figure 4, Model Design Characteristics shows the modeling categories. These characteristics have a continuum of values.

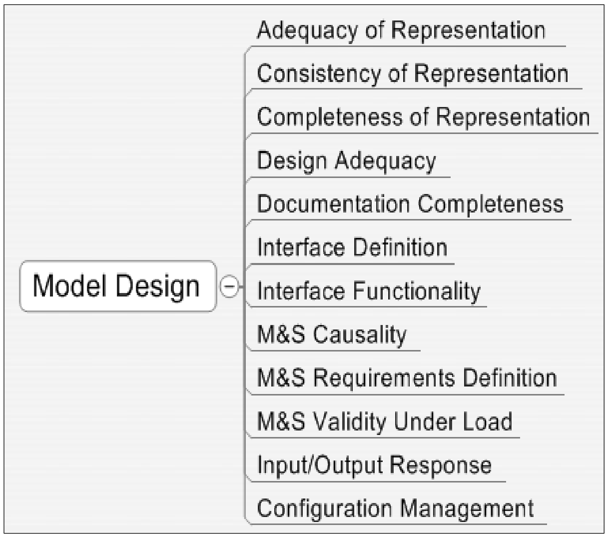

Figure 4. Model Design Characteristics

Figure 5 Simulation Implementation Characteristics shows the final set of confidence parameters. Once the modeling design phase has produced requirements for implementation, most simulations today are implemented in software – as general-purpose programming language, a COTS analysis tool, or a simulation development package. Therefore, implementation characteristics share many of the features of software quality and software verification and validation. They measure the quality of the underlying software used to realize the simulation.

In an accompanying presentation, the authors deal with quantification of these characteristics to obtain metrics that measure both the quality and applicability of a simulation for a given application.

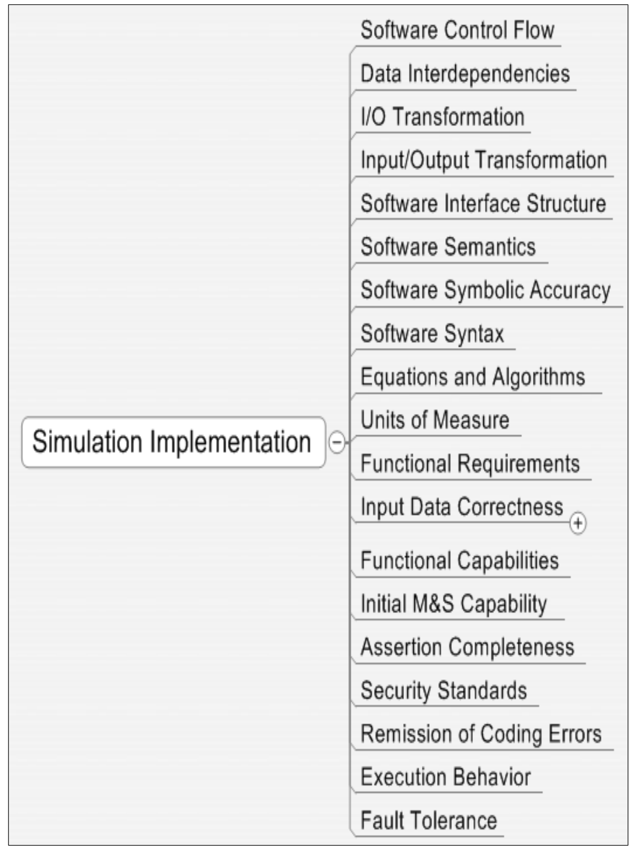

Figure 5. Simulation Implementation Characteristics

3. Incremental VV&A

Ideally, NASA would perform VV&A fully on all M&S tools. Unfortunately, NASA is not equipped with the resources required to accredit all simulations to their highest level. Even by restricting VV&A activities to only those simulations that support mission critical design decisions, NASA cannot fully accredit those simulations within the aggressive Design Analysis Cycles (DACs) mandated by the program. Fortunately, the DACs themselves allow for increasingly complete analysis of designs. Therefore, it is possible for NASA to accept simulations of lower confidence with the understanding that they will gain confidence as they mature and as they complete VV&A in future DACs.

By quantifying the required simulation confidence, NASA will be able to select the appropriate level of VV&A for each simulation at each phase of the program. This “Managed Investment” approach assures that NASA gains the required confidence with the minimal cost.

Figure 6, Using the VV&A Metrics Scale to Plan and Track Simulation Development and Use, shows the progression of confidence across the DACs as a partial result of completing VV&A activities. The vertical arrow at the left represents the significance of a decision based on simulation data and, consequently, the correlated risk due to an incorrect decision, ranging from unimportant to critical. The vertical arrow to its immediate right represents the corresponding need for confidence in the data.

The middle portion of the figure, labeled “M&S METRIC Scale for VV&A Levels & M&S Tool Quality”, shows the appropriate level of VV&A that produces the required confidence in the simulation data given user competence. As the figure shows, NASA currently anticipates applying VV&A to only the more critical simulations. The VV&A that will be applied divides into low, medium, and high categories. NASA needs a way to quantify VV&A activities that produce corresponding confidence in simulations.

The next region to the right labeled, “PLAN For Data Confidence due to Decision Significance” shows application of confidence bounds to one simulation. The color-coded bars show the acceptable range while the dots show a specific measured value. The portion of the figure to the left shows how the increments in confidence progress during the program. Each DAC review presents NASA with an opportunity to apply increasingly stringent rigor to both simulation quality and user qualifications.

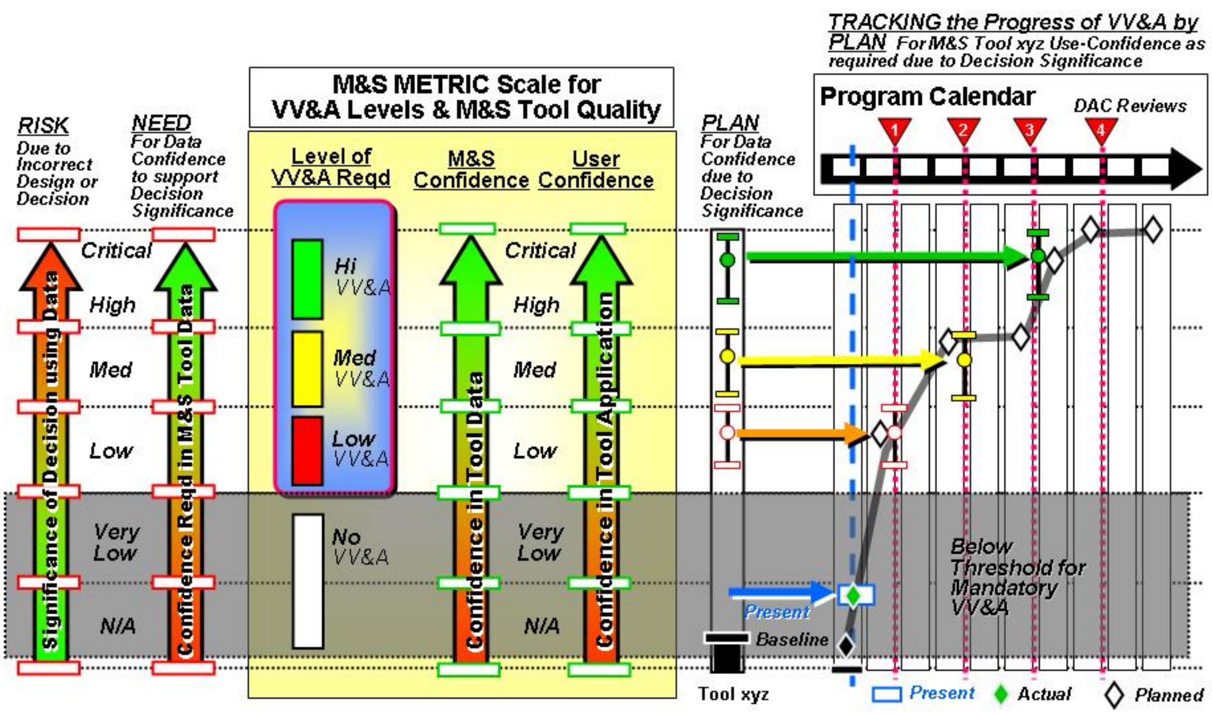

Figure 6. Using the VV&A Metrics Scale to Plan and Track Simulation Development and Use

4. Program Objectives

As NASA learns the process for quantifying incremental VV&A for one simulation, it can apply the lessons learned across the M&S tools used in space exploration program as shown in Figure 7, Incremental VV&A Applied to an Entire Program. The objective for a single simulation is to meet the required increment of confidence at each program milestone as shown in the left panel. When we have developed a reliable metric for tool confidence, program managers will be able to determine the overall confidence in all the designs by comparing a simple parameter, M&S confidence. The program objective is to increase the M&S confidence to a sufficient level across all critical simulations at the appropriate program milestones. .

NASA needs an approach to evaluate its M&S tools. Ideally, NASA would have the resources to fully perform VV&A on all its M&S tools. However, given limited resources, NASA must prioritize the evaluation of those tools that support the decisions that carry the most risk.

Incremental VV&A allows NASA to accomplish this objective. Incremental VV&A also allows for the application of lessons learned across the program so that there can be greater confidence in all tool applications. This new method provides greater management insight into the status of the integrated M&S suite of tools .

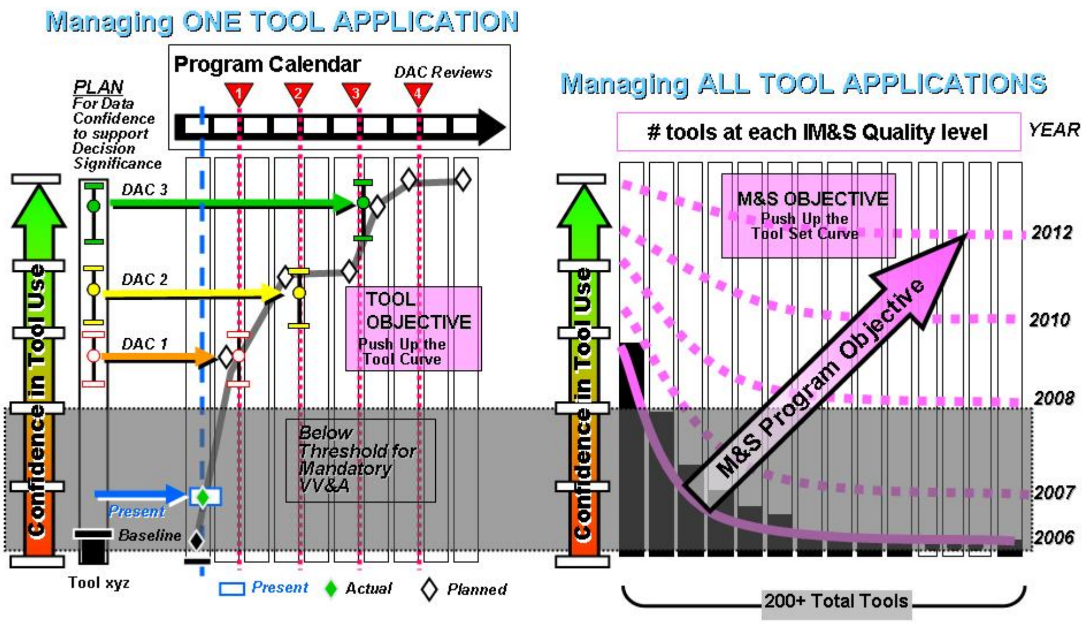

Figure 7. Incremental VV&A Applied to an Entire Program

Author Biographies

LISA CAINE is a Systems Engineer with AEgis Technologies Group in Huntsville, Alabama. She supports the Exploration Mission Space Directorate (ESMD) Integrated Modeling and Simulation (IM&S) VV&A Program. Ms. Caine earned a BS degree in Engineering and Information Systems from Michigan State University and a Masters in Project Management from Keller Graduate School of Management in Chicago. She was also recently awarded the Project Management Professional certification through the Project Management Institute (PMI).

BOBBY HARTWAY is a Senior Research Scientist with AEgis Technologies Group in Huntsville, Alabama. He has developed a new paradigm for simulation characterization and requirements development for space and defense systems. He is using this paradigm to support NASA's activities for integrated management of modeling and simulation.

DANNY THOMAS is a Senior Research Scientist with AEgis Technologies Group in Huntsville, Alabama. He is supporting NASA's effort to institute consistent management practices for simulation development and use. He has developed simulations for space and defense.

JOE HALE is currently Lead for the Exploration Systems Mission Directorate's Integrated Modeling and Simulation Verification, Validation, and Accreditation activity. Prior to that, he was the Lead Systems Engineer for the Next Generation Launch Technologies' Advanced Engineering Environment. Much of his prior work at MSFC was as a Human Factors Engineer, working various projects, including Spacelab and the International Space Station. He spent five years as Team Lead for the Human Engineering and Analysis Team. Mr. Hale is a Certified Human Factors Professional (CHFP) (Board of Certification in Professional Ergonomics), is a founding member and first president of the Tennessee Valley Chapter of the Human Factors and Ergonomics Society (HFES).