Simulation Governance:

Managing Simulation as a Strategic Capability

Dr. Keith Meintjes | CIMdata

As companies drive towards virtual product development and complete digital descriptions of their products and manufacturing systems, simulation becomes increasingly important. A company's actual capability to do simulation well, so it is repeatable, reliable, and robust, can become an important factor in quality, cost and time to market, and overall competitiveness. In this opinion piece, Dr. Keith Meintjes of CIMdata—an internationally recognized authority on Product Lifecycle Management (PLM), proposes that simulation can be demonstrably superior to hardware-based test and development in a number of aspects.

The age of simulation is now about 50 years old. In that half century, aerospace and automotive companies have led the way in applying these tools. Indeed, commercial automobile and airplane OEM companies have achieved impressive levels of capability, and continue to drive the development of simulation tools for ever-more complex products that integrate mechanical design, electrical, software and controls in a concurrent engineering environment. Smaller companies and suppliers to the large OEMs are much less capable.

At CIMdata, we have found that many companies are failing to achieve an effective (optimum) return on their investment in and commitment to simulation.

In this article, we discuss best practices for managing simulation for maximum effectiveness and sustainable success. The key issue, where many companies fail, is to develop confidence in their own capability. This is not simply a technology issue, but one of organization and culture. Despite performing significant levels of virtual performance simulation, many companies do not trust simulation enough to make critical product design decisions because they do not close the loop to calibrate and validate simulation so as to measure or confirm their own capability.

We describe strategies for companies to improve their capability and confidence in their digital or virtual engineering processes.

Introduction

The fastest growing segment of Product Lifecycle Management (PLM) over the past few years has been simulation and analysis. This growth, and the increasing reliance on simulation to support product development decisions, underscores the need for a Governance framework to manage Simulation and Analysis (S&A) as a strategic capability that can be used to validate and optimize design decisions throughout the entire product lifecycle.

Governance is about managing, within an overall enterprise PLM framework, the core engineering approaches to product development. Amid the explosive growth of computer-aided engineering (CAE) and model-based systems engineering (MBSE), this framework embraces and supports product development. S&A Governance[1] is a corporate strategy to manage specific lifecycle processes, solutions, and technologies regardless of how and where they are used in the enterprise.

Fundamentally speaking, governance is a structured way to ensure and nurture technical competence. The focus includes capturing and re-using best practices, standardized work processes, embedded quality assurance, the integration of product development with manufacturing, and collaboration across the extended enterprise over the full product lifecycle.

Getting it done

An effective simulation capability requires delivering three elements:

- Doing the work: applying simulation to product and manufacturing system design
- Providing the required IT resources
- Developing methods and capability in which the organization has confidence

Simulation often remains the province of small groups of highly skilled (and expensive) individuals who consume significant resources in terms of computing hardware, software, and methods and IT support. We have found that many companies are failing to achieve an effective (optimum) return on their investment and commitment to simulation.

Where the problems lie

There is a strong desire to "democratize" simulation, to have it used by a much wider audience. This must be done with great care and planning. While the complexity of the simulation tools can often be hidden, the user must understand the engineering and product issues at hand. Companies that have succeeded in democratizing simulation regard it as an avenue to more capable first time designs. It does not reduce the need for proper product validation. Often, simulation experts are responsible to define the work and develop the tools, and are accountable for the quality and accuracy of the simulations that are done by non-experts.

Simulation often has complex IT requirements involving integration with CAD, PDM and test, and interfaces to high-performance computing resources and large data storage facilities. This is a major factor inhibiting the adoption of simulation at smaller companies. Many solution providers now have capable integrated suites of CAE applications, and these solutions deserve serious consideration. Also, cloud computing may greatly simplify access to simulation resources for smaller companies.

Over time, companies have developed in-depth knowledge and methods to engineer, design and validate their products. Often, there is a culture of physical testing of prototype hardware. Simulation must be applied in a way that is compatible with this hardware-centric engineering development process. This means that simulation procedures should be defined, standardized,

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[1] The term "simulation governance" first appeared in a presentation, "Simulation governance: New technical requirements for software tools in computational solid mechanics" by Barna Szabó and Ricardo Actis, Engineering Software Research and Development Inc., St Louis, Mo. The paper was presented at the International Verification and Validation Workshop in Computational Science at the University of Notre Dame, October 2011.

documented, and followed. Simulation must be made reliable, robust, and repeatable.

Still, many companies fail to develop sufficient confidence in their own capability. This is not simply a technology issue, but one of organization and culture. Companies do not trust simulation to make critical decisions, yet they do not close the loop to calibrate and validate simulation so as to measure or confirm their own capability. They expend appreciable resources on simulation, but are far from obtaining optimum benefits.

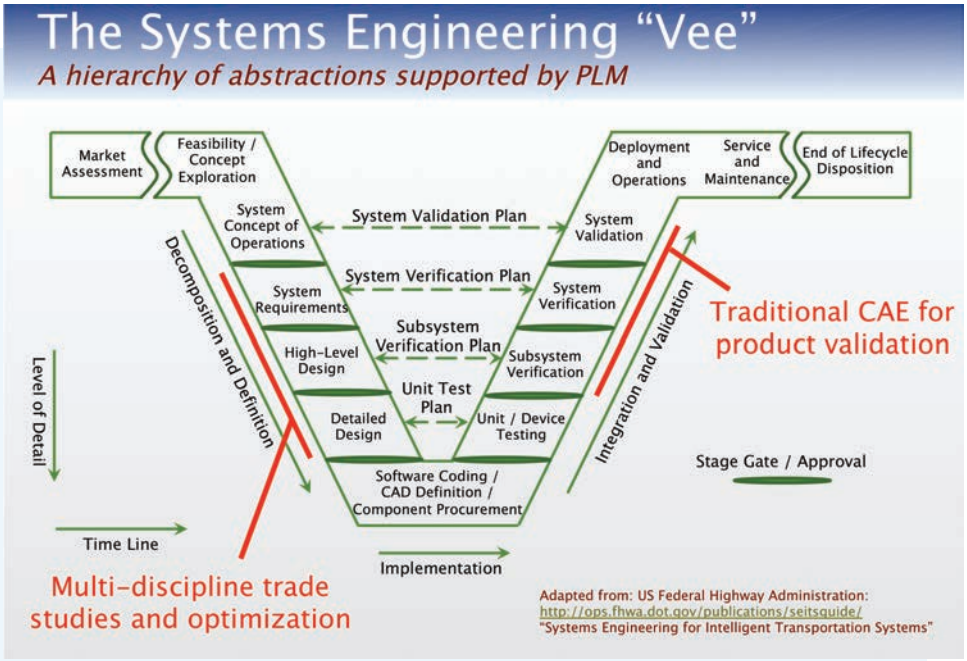

Figure 1: S&A Governance Applies Across the Entire Systems Engineering Vee

Towards improved capability

Balance between test and simulation is required, a continual search for the best way to engineer, develop, manufacture, and validate products. A major powertrain manufacturer requires a signoff from S&A before prototype parts can be ordered. This signoff is an agreement that a test is necessary. They had discovered that 80% of their prototype parts were never tested. Companies also routinely tell us that they have no way to reconcile "as tested" and "as simulated" configurations.

One can propose a capability scale for simulation to support engineering decisions:

- Level 0: Simulation has no capability
- Level 1: Simulation has some capability, but is not useful
- Level 2: Simulation can be used to sort, but not select, alternative designs
- Level 3: Simulation is predictive, but requires physical testing to calibrate models
- Level 4: Simulation is predictive, though validation testing is required
- Level 5: Simulation is predictive, and no validation tests are required
- Level 6: Simulation is more capable than testing and validation (Six sigma, robust design)

This is not a technical issue, but it is a question of the organization's confidence in its own capability. There should be explicit efforts to understand and to improve the capability.

So, a major part of simulation governance is the communication and coordination of an overall strategy across the organization, supported by senior executive management. As noted, the technical capability may be in place but it is not being adequately leveraged and exploited which is why management must be involved.

Note that Level 6 above is a situation where statistical methods can be used to design products with a quality level and speed that could never be accomplished by testing. Such techniques are now routinely used by automotive and commercial aircraft companies.

Simulation Governance

S&A Governance is a strategy that extends across all levels of the organization, which should establish:

- Support for S&A and awareness of its value at the highest levels of corporate management.
- Understanding of the role of S&A, and strategies to democratize S&A by making it available to a much wider audience of people in product development roles.
- An environment to develop and nurture S&A as a strategic competence.
- Integration of S&A as an integral component of a company's product and other lifecycle development processes.
- A rigorous focus on S&A quality, including documented standard work processes, and the verification and validation of S&A as fit for purpose for every case in which it is applied.

But even this is not the whole story. S&A Governance must also address S&A tool license management, CAE model reuse with its challenges of data translation and file interoperability, and verification and validation. The need for effective governance is obvious when one considers all the activities that go into today's S&A workflows. Consider systems engineering and the expanded impact of validation into the left side of the Vee (Figure 1[2]) where it occurs much earlier than in traditional product development processes where S&A is concentrated on the right side of the Vee. It is critical to have a much deeper and formal governance structure in place to assure the continuity of S&A activities as they have earlier impacts on the design and progress from the left to the right side of the Vee process.

[2] Adapted from: US Federal Highway Administration: "Systems Engineering for Intelligent Transportation Systems," http://ops.fhwa.dot.gov/publications/seitsguide/

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Leading companies believe that the adoption of model-based techniques, including simulation, will revolutionize product development. The key is collaboration across disciplines and domains on the left side of the Vee, so that there can be concurrent engineering of mechanical, electrical, controls and software before a commitment to detail product component design in CAD.

There is a potential to use simulation to find more innovative design solutions. The reason is as the cost of a design assessment plummets, engineers are able to explore more of the design space that previously was not economical, uncovering better solutions. The multi-discipline and cross-domain issues become better understood, enabling better decisions earlier in the process. This exploration can include not only engineering decisions for quality and robustness, but also styling (aesthetic design) and features.

Data and process management

In support of S&A Governance, Simulation Data Management captures all of the information required to define the virtual models, conduct simulations and validations, as well as various analysis results from the simulations. S&A models can include everything from low fidelity 1D system models to high fidelity three-dimensional (3D) finite element analysis (FEA), computational fluid dynamics (CFD), and multi-physics analyses.

Key non-geometric data used in simulations such as loads, boundary conditions, performance targets, and material properties is often derived from physical tests and empirical in-service data. This too must be documented and managed along with relevant analysis metadata (e.g., the test or simulation was performed by whom, when, with what specific tools, and for what purpose).

Simulation processes capture repeatable engineering best practices for verification and validation, which spells out how analyses are to be structured, requirements for pre- and post-processing, and system-level computing resources and tools that should be used to conduct specific simulations. Processes can also be defined to orchestrate Design of Experiments (DoE), design optimization, and stochastics (i.e., probability and uncertainty in systems design).

In the past decade, S&A has moved from an engineering validation task ("analyze the design just in case we missed something") to a strategic, up-front role in ensuring that new products will meet or exceed all their requirements and fulfill their customers' expectations prior to production. CAE and related forms of computational or digital modeling have dramatically reduced physical testing, which relies on multiple iterations of costly physical prototypes that are typically created late in the product development lifecycle when changes are more costly to execute. Compared to what can be done with CAE, physical tests are costly, time consuming (typically delaying the development process), and extremely limited in scope. In some industries such as space systems, building and testing complete systems as prototypes is not feasible. The prototype is the first production system and must work correctly the first time it is placed in use.

Meanwhile, many of the CAE specialists who manage this work are nearing or beyond retirement age. As companies downsized and used off-shored engineering, replacing the knowledge of these specialists has proven difficult. This has led to the engineering trend of "democratization," capturing the S&A knowledge base in the PLM software tools themselves and putting customized applications such as templates and wizards into the hands of product engineers, systems engineers and even product designers.

All this complexity underscores the need for S&A governance as an integral part of a comprehensive PLM infrastructure. The goal is to help users and technical support staff to apply their current skills effectively and give them access to best practices from which to develop new ones.

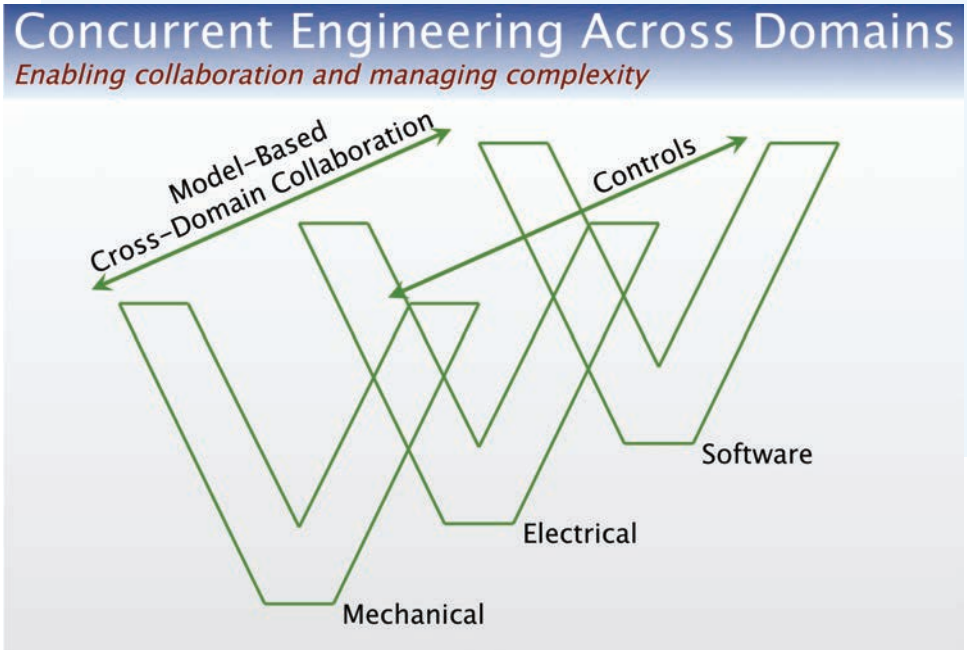

Figure 2: Model-based engineering enables concurrent development across domains

The strongest governance bodies are found in regulated industries.

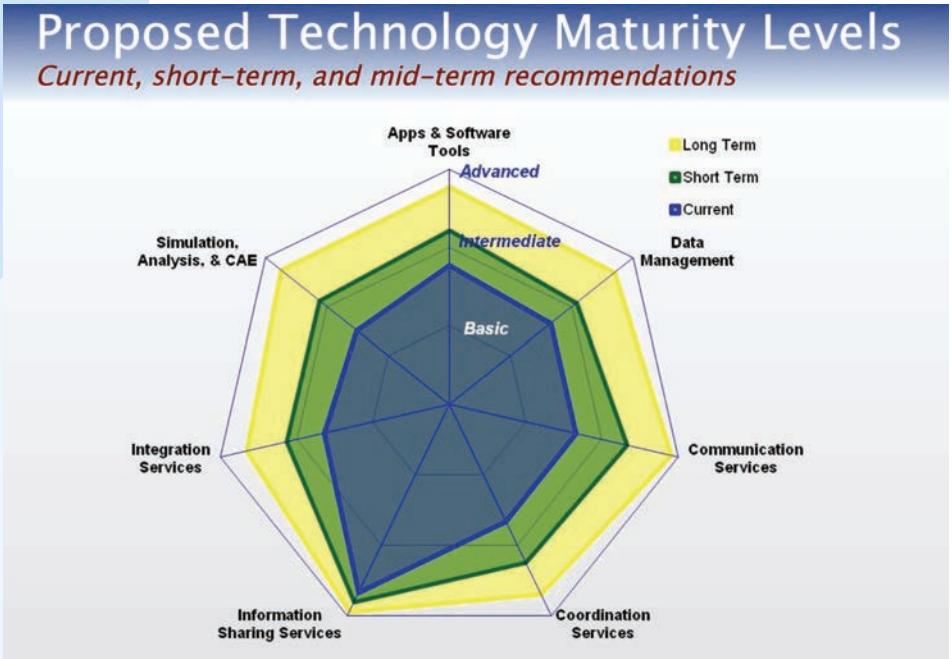

Figure 3: Capability assessments identify gaps and provide a basis for capability improvement

S&A Governance includes:

- Applying maturity models to measure the organization's technological and process capabilities to understand that the S&A processes used are mature. Without understanding maturity, deployment of simulation data management systems is likely to fail. See Figure 3.
- Using maturity assessments to help the organization understand their S&A Governance readiness and pinpoint areas for improvement. Organizationally, readiness means predictability and consistency in everyday tasks. In processes, readiness means "the work gets done" through common methods and shared practices, that routine tasks are scripted, that repetitive tasks are automated, and that the available technology is in the right hands. Ideally, maturity assessments are followed by pilot implementations that foster understanding and substantiate business cases for meaningful change.
- Reconfiguring technology capabilities to bring them closer to S&A users, leveraged by the use of maturity scorecards to evaluate S&A capabilities and to help justify needed improvements.
- Defining repeatable methods and processes to assess accuracy and build confidence in the use of S&A. This confidence can be built into engineering-oriented use cases; these are vital to better understanding user requirements and forge agreements on common methods.
- Insisting on consistently accurate, reliable, and complete data throughout product development.
- Defining, capturing and using best practices both within a company and influenced by competitive assessments should place a continuing emphasis on developing and validating new capabilities that, in turn, leverage improvements in both computer hardware and in application software.

Strong governance is found wherever leaders realize that success is driven by how well the enterprise's information is reused. The strongest governance bodies are found in regulated industries. Sadly, many other efforts in governance are rudimentary and ineffective.

S&A Governance can help make S&A more predictable, consistent, and productive. Without that consistency, S&A organizations usually lack common methods or shared practices. Consequences include poor re-use of S&A results with its many risks (product failures, increased costs and warranty claims, late to market due to engineering changes, etc.), costly duplication of work, and even the purchase of unneeded systems and solutions. S&A Governance is a strategic way for companies to establish a sustainable competitive advantage in innovation, product quality, and time to market.

About the Author

Dr. Keith Meintjes is the Practice Manager for Simulation and Analysis (S&A) at CIMdata—an internationally recognized authority on Product Lifecycle Management (PLM). Dr. Meintjes has over 30 years of experience in the development of simulation tools and in their application to transform product development.

His career spans academia, industry, and consulting, and his achievements include novel methods for combustion simulation, two patents for engine design, strategic planning for the world's largest commercial High Performance Computing facility, and many projects to deploy simulation for product development, manufacturing, and lifecycle management.

Interested in learning more about Simulation Governance?
Keith Meintjes will host panel discussions on this topic at several upcoming NAFEMS events, including:

Simulation & Systems Engineering in the Automotive Industry
March 17th, 2015 | Troy, MI

Simulation & Systems Engineering in the Oil & Gas Industry
April 7th, 2015 | Houston, TX

NAFEMS World Congress 2015
June 21st-24th 2015 | San Diego, CA

Full details can be found at nafems.org