Risk-Informed Design & Decision Making

risk reduction through verification, validation, and uncertainty quantification

Computational modeling plays a critical role in the assessment of performance, safety, and reliability for complex, high-consequence engineering systems. The Validation and Uncertainty Quantification department at Sandia National Laboratories enables engineering designers and decision makers to understand and improve the credibility of computer simulations for a wide variety of complex systems.

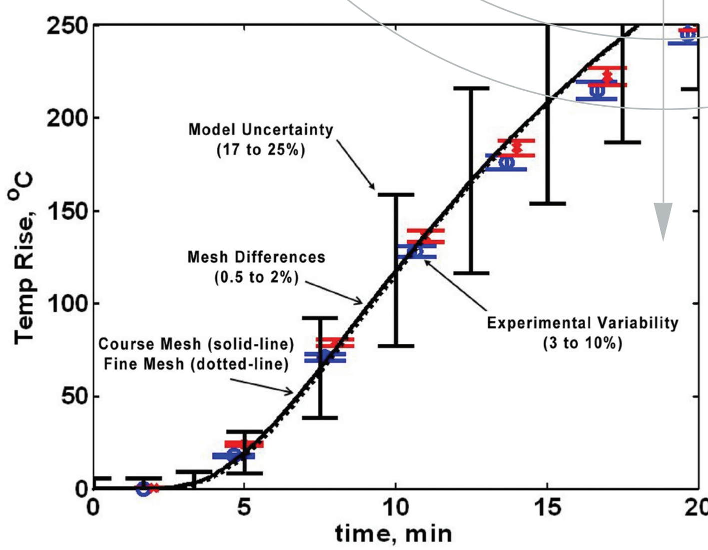
Sandia's Validation and Uncertainty Quantification (V&UQ) Department was formed as part of the National Nuclear Security Administration's (NNSA) Advanced Simulation and Computing (ASC) Program. ASC simulation capabilities are used to analyze and predict the performance, safety, and reliability of nuclear weapons and weapon components over an extraordinary range of normal, abnormal, and hostile environments. We address these high-consequence national security applications using computational tools ranging from desktop PCs up to massively parallel supercomputers.

The unique mission of the V&UQ department is the research, development, and application of mathematical and experimental techniques to assess the credibility of physics-based computational simulations. The multi-disciplinary V&UQ team, experienced in simulation and experimentation, draws from a wide range of disciplines: fluid dynamics, solid and structural mechanics, heat transfer, numerical methods, optimization, statistics, and risk assessment.

Risk-Informed Decisions

Risk-informed decision making is a process that accounts for uncertainty in both experimental data and simulation data when making engineering design and qualification decisions. This process is founded on Sandia's verification and validation activities which quantify all sources of uncertainty via rigorous comparisons between simulation data, theoretical predictions, and experimental data.

Verification determines whether a computational model accurately represents the conceptual-mathematical model of a physical process, and that the computational model is solved correctly. This requires an exacting knowledge of models and their numerical approximations when implemented into codes. Software quality engineering (SQE) practices and numerical error estimation methods are an integral part of verification.



Quantifying the accuracy of model simulations involves comparison with experimental data while considering model uncertainty, model numerics (mesh), and experimental variability and uncertainty.

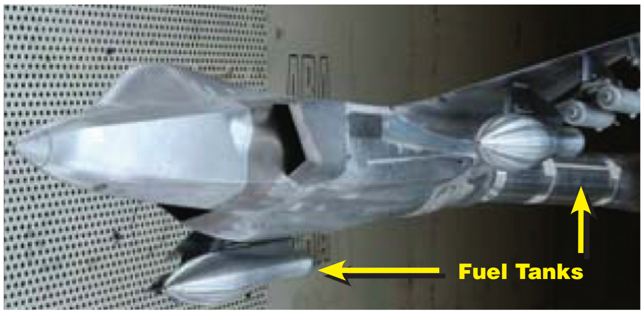
Validation determines, quantitatively, the degree of agreement between experimental data and simulation data, including their respective uncertainties. Validation activities cover a wide range of spatial and temporal time scales ranging from basic material response tests to full-scale system tests.

Uncertainty quantification is a key element of validation and it encompasses a broad range of mathematical and statistical analysis methods. These analysis tools can be used to (1) focus and prioritize research and development expenditures, (2) mitigate risk through exploration of system design alternatives, (3) optimize products and process in the presence of both uncertain and variable parameters, and (4) support risk-informed decision making based on statistically-quantified data.

The combination of verification, validation, and uncertainty quantification establishes credibility in our computational models, which are then employed in making high-consequence risk-informed decisions.

Risk-Informed Design

Risk-informed design couples sensitivity analysis and uncertainty quantification methods with numerical optimization techniques to design complex engineering systems that are robust and reliable.



This wind tunnel model of F-35 features optimized external fuel tanks.

Lockheed Martin recently collaborated with Sandia to design the external fuel tanks for the F-35 Joint Strike Fighter. Lockheed Martin engineers coupled their high-fidelity computational fluid dynamics software with Sandia's DAKOTA parametric analysis and optimization software to create a risk-informed design of the F-35 fuel tank shape. The aerodynamic performance of the optimized tank was demonstrated in wind tunnel tests.

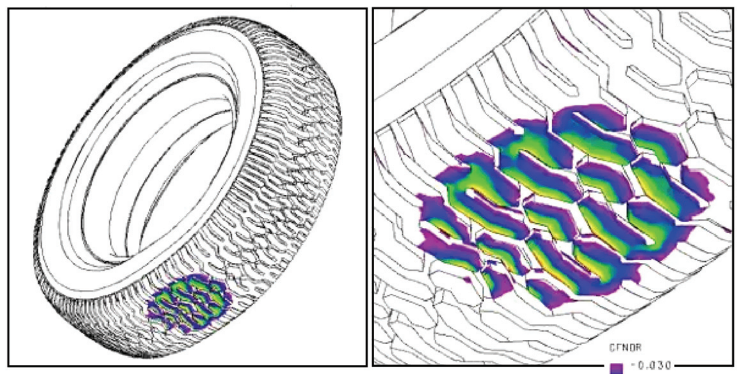
A joint effort between Sandia and the Goodyear Tire & Rubber Company to more accurately simulate tire performance has provided Goodyear with improved design capabilities. These efforts include the numerical optimization of a tire design to maximize tire-wear performance through footprint indicators.

Capabilities

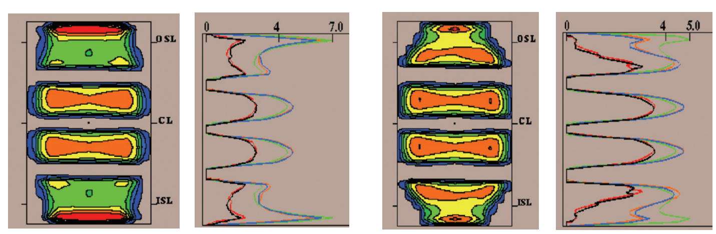
Sandia has taken a leadership role in a number of research and application areas relating to verification of computer codes and numerical solutions, validation of computational models, and uncertainty estimation of computational predictive capability. Continuing efforts include:

- Software quality assurance methods
- Verification of computer codes using analytical and manufactured solutions
- Error estimation of numerical methods
- Design and execution of physical experiments for model validation
- Design of hierarchical validation experiments for assessing predictive extrapolation of computational models
- Probabilistic risk assessment and interpretation of uncertainty
- Newly developed methods for dealing with large epistemic uncertainties
- Advanced optimization and sensitivity analysis algorithms

These core capabilities enable a more credible use of modeling and simulation for a broad spectrum of applications.



Original and optimized tire footprints where the pressure variance and maximum footprint pressure were significantly reduced, thereby leading theoretically to improved wear characteristics.



Original **Optimized**

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