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The Role of V&V in Total Prediction Uncertainty

CHRISTOPHER ROY, Aerospace and Ocean Engineering Department, Virginia Tech

Computational Fluid Dynamics (CFD) simulations are frequently used for decision making in scientific and engineering systems. However, the accuracy and reliability of CFD simulations is often poorly understood. There are three sources of uncertainty in CFD predictions: uncertainty in model inputs, uncertainty due to numerical errors, and uncertainty due to modeling errors. When model input uncertainties are stochastic, they are appropriately described by precise probability distributions, and their effects on output quantities are often determined by standard techniques. In general, not all inputs have precisely specified probability distributions. In such cases, different techniques, such as segregated uncertainty propagation, are needed to propagate mixed aleatory and epistemic uncertainty. Verification and Validation (V&V) address the processes used to estimate uncertainties due to numerical errors and modeling errors, respectively. During Verification, one estimates the numerical errors in a simulation. This estimation process leads one to treat these as uncertainties; however, they are not random (aleatory) uncertainties, but are instead lack of knowledge (epistemic) uncertainties. During Validation, one estimates the errors due to model form. This process usually involves comparison of nondeterministic outcomes from simulation and experiment the estimation process leads us to treat the modeling errors as uncertainties. Finally, estimating the total prediction uncertainty requires that all three sources be accounted for: input uncertainty (via uncertainty propagation), numerical uncertainty (via Verification), and model form uncertainty (via Validation).