Bayesian Inference and the Effects of Varying Uncertainty Models in Charring Ablator Calibration and Uncertainty Quantification Problems

Przemyslaw Rostkowski[a], Jeremie Meurisse[b], Nagi Mansour[b], Marco Panesi[a]

[a]*Department of Aerospace Engineering, University of Illinois at Urbana-Champaign, Urbana, IL-61801, USA*
[b]*NASA Ames Research Center, Mountain View, CA-94035, USA*

Abstract

The Mars Science Laboratory vehicle utilized a heat shield constructed from NASA's Phenolic-Impregnated Carbon Ablator material to protect the main structure from the high enthalpy environment encountered during hypersonic atmospheric entry. During the vehicle's descent through Martian atmosphere, multiple thermocouples embedded within the heat shield captured in-depth material temperature data that allow for studies to be conducted on current material response reconstruction tools. In the present work, material temperature data obtained from thermocouples within the MISP-4 plug are utilized in the calibration of TACOT model parameters in conjunction with NASA's Porous material Analysis Toolbox (PATO) through Bayesian inference where uncertainty due to parametric, modeling, and experimental sources is simultaneously quantified. Prior to the study, a sensitivity analysis is performed through computation of the robust Sobol indices in an effort to study the relationship between input space and model response and to reduce the dimensionality of the statistical inverse problem. The Bayesian inference methodology necessitates an a-priori choice to be made for the uncertainty model for which numerous possibilities are available. Across most works, however, only basic additive or multiplicative models are utilized with pre-defined magnitudes of uncertainty based on a-priori knowledge or to-be-calibrated multipliers of static covariance matrix structures. The present effort explores the effects of informed uncertainty models, ones with temporal dependence that are simultaneously calibrated through Bayesian inference, on calibrated results for parameters that make up the uncertain input space.

Keywords: Bayesian Inference, Sensitivity Analysis, Calibration, Uncertainty Quantification, Charring, Ablator, PICA, TACOT, PATO, Mars Science Laboratory, MSL

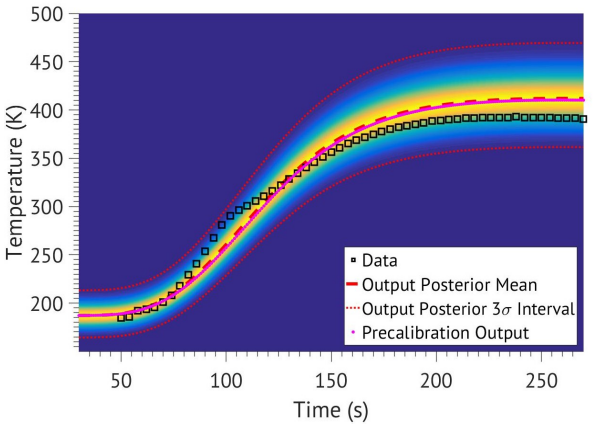

Figure 1: Results using a scalar, temporal and spatial independent multiplicative error uncertainty model for TC-3 of MISP-4 plug.

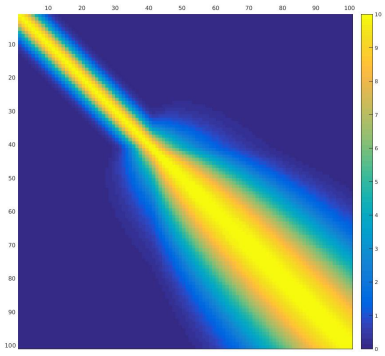

Figure 2: Realization of one of the uncertainty covariance matrix structures with temporal correlation in this study.

Email addresses: rstkwsk2@illinois.edu (Przemyslaw Rostkowski), jeremie.b.meurisse@nasa.gov (Jeremie Meurisse), nagi.n.mansour@nasa.gov (Nagi Mansour), mpanesi@illinois.edu (Marco Panesi)