Improvements to a Response Surface Thermal Model for Orion Mated to the International Space Station. Stephen W. Miller, NASA Johnson Space Center, Houston, TX 77058, and William Q. Walker, West Texas A&M University, Canyon, TX 79016.

This study is an extension of previous work to evaluate the applicability of Design of Experiments (DOE)/Response Surface Methodology to on-orbit thermal analysis. The goal was to determine if the methodology could produce a Response Surface Equation (RSE) that predicted the thermal model temperature results within ±10°F. An RSE is a polynomial expression that can then be used to predict temperatures for a defined range of factor combinations. Based on suggestions received from the previous work, this study used a model with simpler geometry, considered polynomials up to fifth order, and evaluated orbital temperature variations to establish a minimum and maximum temperature for each component.

A simplified Outer Mold Line (OML) thermal model of the Orion spacecraft was used in this study. The factors chosen were the vehicle's Yaw, Pitch, and Roll (defining the on-orbit attitude), the Beta angle (restricted to positive beta angles from 0 to 75), and the environmental constants (varying from cold to hot). All factors were normalized from their native ranges to a non-dimensional range from -1.0 to 1.0. Twenty-three components from the OML were chosen and the minimum and maximum orbital temperatures were calculated for each to produce forty-six responses for the DOE model. A customized DOE case matrix of 145 analysis cases was developed which used analysis points at the factor corners, mid-points, and center. From this data set, RSE's were developed which consisted of cubic, quartic, and fifth order polynomials. The results presented are for the fifth order RSE.

The RSE results were then evaluated for agreement with the analytical model predictions to produce a $\pm 3\sigma$ error band. Forty of the 46 responses had a $\pm 3\sigma$ value of 10°F or less. Encouraged by this initial success, two additional sets of verification cases were selected. One contained 20 cases, the other 50 cases. These cases were evaluated both with the fifth order RSE and with the analytical model. For the maximum temperature predictions, 12 of the 23 components had all predictions within ±10°F and 17 were within ±20°F. For the minimum temperature predictions, only 4 of the 23 components (the four radiator temperatures), were within the ±10°F goal.

The maximum temperature RSEs were then run through 59,049 screening cases. The RSE predictions were then filtered to find 55 cases that produced the hottest temperatures. These 55 cases were then analyzed using the thermal model and the results compared against the RSE predictions. As noted earlier, 12 of the 23 responses were within ±10°F at 17 within ±20°F. These results demonstrate that if properly formulated, an RSE can provide a reliable, fast temperature prediction. Despite this progress, additional work is needed to determine why the minimum temperatures responses and 6 of the hot temperature responses did not produce reliable RSEs. Recommend focus areas are the model itself (arithmetic vs. diffusion nodes) and seeking consultations with statistical application experts.