PROJECT SUMMARY

In this SBIR project, CFD Research Corporation (CFDRC) teamed with the University of Michigan (UM) to develop an efficient and high-fidelity computational aerthermodynamics tool to predict the aerothermal environment around ablation-cooled hypersonic re-entry vehicles. All advanced physics models will be implemented in a modular manner to facilitate their coupling to LeMANS/MOPAR, or other code(s) of interest to NASA Ames. In Phase I, the CFDRC-UM team successfully established feasibility by demonstrating the coupled LeMANS-radiation code for the IRV-2 reentry vehicle and the Stardust sample return capsule. Further, the coupled LeMANS-MOPAR code was validated for the Passive Nosetip Technology (PANT) experiment. The radiation code implemented and coupled to LeMANS in Phase I is based on solving the radiative transfer equation (RTE) using the Modified Differential Approximation (MDA). The accuracy of the hybrid MDA method in both optically thick and optically thin media has been conclusively demonstrated. It was found that MDA is accurate over at least three orders of magnitude variation in optical thickness, thereby demonstrating the feasibility of the method and making it an attractive choice to simulate radiative transport in scenarios where the optical thickness of the medium may vary significantly. The coupling framework between LeMANS and the MDA-based radiation code was also successfully developed in Phase I, although only a "loose" coupling was implemented in Phase I. Both for IRV-2 and Stardust, the predicted surface radiative fluxes and the divergence of radiative fluxes showed the proper qualitative trends. Quantitative comparisons will be feasible in Phase II after extending the radiation code to non-gray gases. The PANT experiment data were used to validate the coupled LeMANS-MOPAR code. Reasonable agreement was found between the experimental and numerical data, and we believe that the comparison will improve with the advanced ablation-related models to be implemented in the prospective Phase II project.

In Phase II, the primary focus is to advance the flow and ablation modeling capabilities of the LeMANS/MOPAR codes by including innovative models for: (1) Non-equilibrium surface thermochemistry; (2) Non-equilibrium pyrolysis chemistry; (3) Volumetric ablation model to investigate the porosity, tortuosity, and oxidation of the char layer; and (4) Non-gray, non-equilibrium radiation. All models will be implemented in a modular manner so as to facilitate easy coupling to a code of interest to NASA such as DPLR.