1. Executive Summary

In response to the scientific and technological needs of the U. S. Department of Energy posed by the Accelerated Strategic Computing Initiative/Academic Strategic Alliances Program (ASCI/ASAP), the University of Illinois at Urbana-Champaign (UIUC) established the Center for Simulation of Advanced Rockets in September 1997. The outstanding quality of the faculty and staff, facilities, and research infrastructure offered by UIUC have enabled a unique partnership among university researchers and the DOE Defense Program laboratories to advance the state of the art in computational simulation of complex systems. State, regional, and university resources are also supporting the program, and an experienced research team is fulfilling the mission of the Center.

The goal of the Center for Simulation of Advanced Rockets (CSAR) is the detailed, whole-system simulation of solid propellant rockets under both normal and abnormal operating conditions. The design of solid propellant rockets is a sophisticated technological problem requiring expertise in diverse subdisciplines, including the ignition and combustion of composite energetic materials; the solid mechanics of the propellant, case, insulation, and nozzle; the fluid dynamics of the interior flow and exhaust plume; the shock physics and quantum chemistry of energetic materials, the aging and damage of components; and the analysis of various potential failure modes. These problems are characterized by very high energy densities, extremely diverse length and time scales, complex interfaces, and reactive, turbulent, and multiphase flows.

Solid propellant rockets perform the “heavy lifting” in the aerospace industry, providing the immense thrust required to launch large payloads into Earth orbit or into outer space. CSAR has chosen the solid rocket boosters (SRB) of the NASA Space Transportation System, better known as the Space Shuttle, as the simulation vehicle. The Shuttle SRB is a well-established commercial rocket, is globally recognized, and most importantly, design data and propellant configurations are available.

In the first year of the research program, we have completed a simplified version of an integrated rocket simulation code that provided invaluable experience in system integration (GEN0). The ongoing implementation of the fully integrated simulation code (GEN1), expected to be operational in Years 2-3, will provide a simplified characterization of various burn scenarios and the onset of potential component failures. The GEN1 code employs macroscopic models for the separate components to enable a strong, near-term focus on the definition and resolution of system integration issues. Refined, multiscale component models and advanced system integration concepts, based on lessons learned from GEN1, constitute the key features in the second-generation code (GEN2) targeted for Years 4-5.

An experienced management and advisory team has been assembled to provide effective leadership and focus for the Center. The budget has been adequate to maintain an aggressive research program during the first contract year. In addition to funds provided by the DOE, the University of Illinois has provided needed support for both research expenditures, computer workstations, and facility renovation. Center personnel traveled extensively in the first year of the ASAP program and were involved in a large number of technical and informational meetings. These included meetings intended to explore rocket science and technology, identify technical collaborators, describe the ASCI/ASAP program, and establish relationships among Center investigators, DOE DP lab scientists, and industry leaders.