1 Executive Summary

The goal of the Center for Simulation of Advanced Rockets (CSAR) is the detailed, whole-system simulation of solid propellant rockets from first principles 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 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.

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) encouraged the University of Illinois at Urbana-Champaign (UIUC) to establish CSAR 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/NNSA 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 our mission.

We focus on the reusable solid rocket motor (RSRM) of the NASA Space Transportation System, better known as the Space Shuttle, as its long-term simulation vehicle. The RSRM is a well-established commercial rocket, is globally recognized, and most importantly, design data and propellant configurations are available. The Center has a Space Act Agreement with NASA in place to share data and simulation results. Several smaller scale rockets are also simulated to provide validation data for CSAR codes. Simulations that include full geometric and materials complexity require a sequence of incremental developments—in engineering science, computer science, and systems integration—over an extended period of time.

From the outset, our emphasis has been on system integration rather than separate threads of development that eventually come together at some point in the future. Rapid exploration of critical system integration issues demanded the use of simplified—but fully integrated—models and interfaces initially, followed by successively refined models and interfaces as experience was gained. CSAR staff have designed and implemented a fully integrated code that includes characterization of various burn scenarios and the onset of potential component failures. Refined multiscale component models and advanced system integration concepts based on lessons learned from this effort constitute the key features in our ongoing research. Use of the simulation code to explore scientific and engineering issues in complex fluid-structure interactions is a major focus for the new program.

More than 100 UIUC faculty, students, and researchers currently contribute to the success of the Center. An External Advisory Board provides critical guidance in rocket simulation and computational science. The DOE-supplied budget has been sufficient to maintain an aggressive research program. In addition, the University of Illinois has provided funds for ancillary research expenditures, computer workstations, and facility renovation. Center personnel have traveled widely to explore rocket science and technology, identify technical collaborators, describe the ASCI/ASAP program, and establish relationships among Center investigators, DOE/NNSA DP scientists, and industry leaders.