



As one of the largest research and engineering firms in the U.S., SAIC promotes cutting-edge research through its Executive Science & Technology Council (ESTC) publication awards competition. Since 1984, the ESTC has recognized some of the most innovative research and best written technical papers and books by SAIC scientists and engineers. Here are summaries of some winners.

Returning to renewable energy

Before the industrial revolution, mankind directly harnessed the sun, wind, and water for its energy needs. Ironically, we now return to renewable energy sources as the folly of fossil fuels is exposed by heated issues such as global warming. The nation's recent spike in gas prices is another painful reminder of our need to become less dependent on petroleum and fossil fuels.

One promising renewable energy source is geothermal energy, which taps the energy of water heated within the Earth's crust. Geothermal power has tremendous potential, considering the massive heat reservoir inside the Earth. According to the California Energy Commission, geothermal resources generated over three times more electricity in California in 2001 than wind and solar resources combined, totaling five percent of the state's total electrical power generation.

To estimate the recoverable energy from a geothermal reservoir, scientists predict the quantity and thermodynamic state of the water that may be produced by a geothermal well. Because geothermal wells contain a highly turbulent mixture of liquid water and steam, no strictly analytical method exists to calculate well behavior. Scientists instead simulate fluid flow in geothermal systems with computer models that are based on correlations for oil wells. Not surprisingly, the differences between oil and water make petroleum-based simulations unreliable for geothermal systems.

For the first time in the industry, SAIC's Sabodh Garg, John Pritchett, and James Alexander have utilized actual geothermal well data to accurately simulate this

complex fluid dynamics problem. "With the advent of modern well measurement tools, we now have dependable data on which to base our models," states Garg. Using high quality data from over forty flowing wells the researchers explored what is known as the liquid hold-up correlation. "In order to model the fluid flow in a geothermal well, one of the critical tasks is to develop a relationship for the dramatic difference between the liquid and gas velocities," explains Garg. "This relationship is called liquid hold-up correlation."

Applying SAIC's proprietary well-simulation program, WELBOR, the team initially forced simulation results and actual data into agreement by adjusting the liquid hold-up correlation for each well. Then using the liquid hold-up correlation values for all the wells, the team created a generalized liquid hold-up correlation that can be applied to any geothermal well.

After integrating the new liquid hold-up correlation into WELBOR, the forty wells were simulated with excellent agreement between the computed results and measured data. The new liquid hold-up correlation accurately predicts fluid flow in geothermal well bores and will aid in the search for economically recoverable geothermal energy sources.

"A new liquid hold-up correlation for geothermal wells" was published in Volume 33 of *Geothermics*. The research was sponsored by the U.S. Department of Energy, utilizing well data from Unocal Corporation and Caithness Energy.

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VIRTUAL WEAPONS OF MASS DESTRUCTION

At the dawn of the twenty-first century, governments have been forced to fight the physical and psychological terror of weapons of mass destruction (WMD). A counter-offensive in the war against WMD, the computer is used extensively to prevent and mitigate damage. By simulating weapon systems and their effect on targets, computer scientists can predict vulnerabilities while avoiding costly and destructive physical experiments.

A challenging example is the simulation of an underwater explosion, the data from which can be used to protect ships. Many complex physical processes must be modeled: a detonation wave through explosive material, a shock wave into water, the pulsating behavior of gas bubbles (which wreak most of the damage), and the interaction of these shocks with nearby structures. These processes occur over vastly different time scales – from seconds to millionths of a second, making typical numerical models expensive if not impossible, even for today's massively parallel supercomputers. Additionally, the dramatic variation between the properties of the explosive material and water, in both liquid and gas phases, can easily lead to the meaninglessness and collapse of the simulation.

SAIC's Hong Luo and Joseph Baum together with Rainald Löhner have solved this demanding computational fluid dynamics problem in a novel way, applying a method never before used on a problem of this complexity. Rather than explicitly calculating the movement and properties of the entire multi-material flow, which would have been computationally expensive and unstable, the team focused on the interfaces between the different phases of materials. "We do not allow the materials to mix within individual cells of the grid. Pockets of liquid and gaseous water and explosive material are kept distinct by explicitly tracking the interfaces between them," explains Luo. "The bulk of the flow goes along for the ride, which simplifies the computation while making it more robust."

The team specifically tested three variations of the Arbitrary Lagrangian Eulerian (ALE) method, which is typically used to analyze static bodies that interact with fluid. The team adapted the method for their highly volatile multi-material flow problem with excellent results from two of the three ALE schemes. The models achieved sharp resolution along the material interfaces and handled strong property and velocity discontinuities between materials. In addition to successfully modeling a series of underwater explosions, the methods also effectively simulated a supersonic missile over water. Subsequent research will predict damage on structures with more complex geometries, as virtual WMDs will eventually mirror their real-life counterparts.

"On the computation of multi-material flows using ALE formulation" appeared in Volume 194 of *Journal of Computational Physics*. This research was sponsored by the Defense Threat Reduction Agency.

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