Satellite-forming impact simulations: past, present, and funded future

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In 2001, we began to simulate satellite-forming asteroid impacts as part of a three-year project funded by NASA's Intelligent Systems (IS) program. At first glance, "Intelligent Systems" seems an unusual home for such research. The primary goal of the IS project was to determine whether state-of-the-art Artificial Intelligence (AI) techniques could speed up the "understanding" of non-chaotic numerical simulations.

The runtime of each 100,000-particle impact simulation described by Durda et al (Icarus **170,** 243-257 and Icarus **186,** 498-516) varied from hours to months. We ran a coarse grid of 160 simulations as ground-truth, to understand the landscape, i.e. determine which combinations of 3-D impact parameters (relative size, velocity, and speed) produce the desired populations of binary asteroids - either SMATS or EEBs (see Durda abstract). Completing the suite of runs required over six months on a 16-node Beowulf cluster at JPL. Using AI techniques, we hoped to reduce the overall run-time in half - or better - while improving the resolution of the results.

Within the IS project, the main purpose of the 160-run grid of simulations was to benchmark the results of the AI techniques. Our algorithms require each run to be "graded", and for convenience, we eventually opted to use a grading formula based upon the size-frequency distribution of the impact remnants rather than the production of SMATS and EEBs. At that point, the goals of the IS project and the satellite formation research diverged.

Presently, we continue to simulate satellite formation under other projects. We are completing a 4-D grid of ~100 Kuiper Belt impact simulations to study whether low-velocity, icy impacts produce SMATS and EEBs as prolifically as Basalt asteroid impacts. Recent N-body code extensions by Derek Richardson, SPH support from Erik Asphaug, and a new, local 18-CPU Opteron cluster allow us to study target/remnant shapes, sizes, rotations, and thermal properties.

Over the next two years, we intend to revisit our AI heritage. We believe that improved AI algorithms can learn the best combinations of satellite-producing impact parameters 10x faster than dumb-grid techniques. Achieving this high level of efficiency requires us to tighten the focus of our grading tools, enhance our AI processes, and use better visualization tools. The challenges ahead are substantial, as are the potential benefits to runners of non-chaotic numerical simulations.