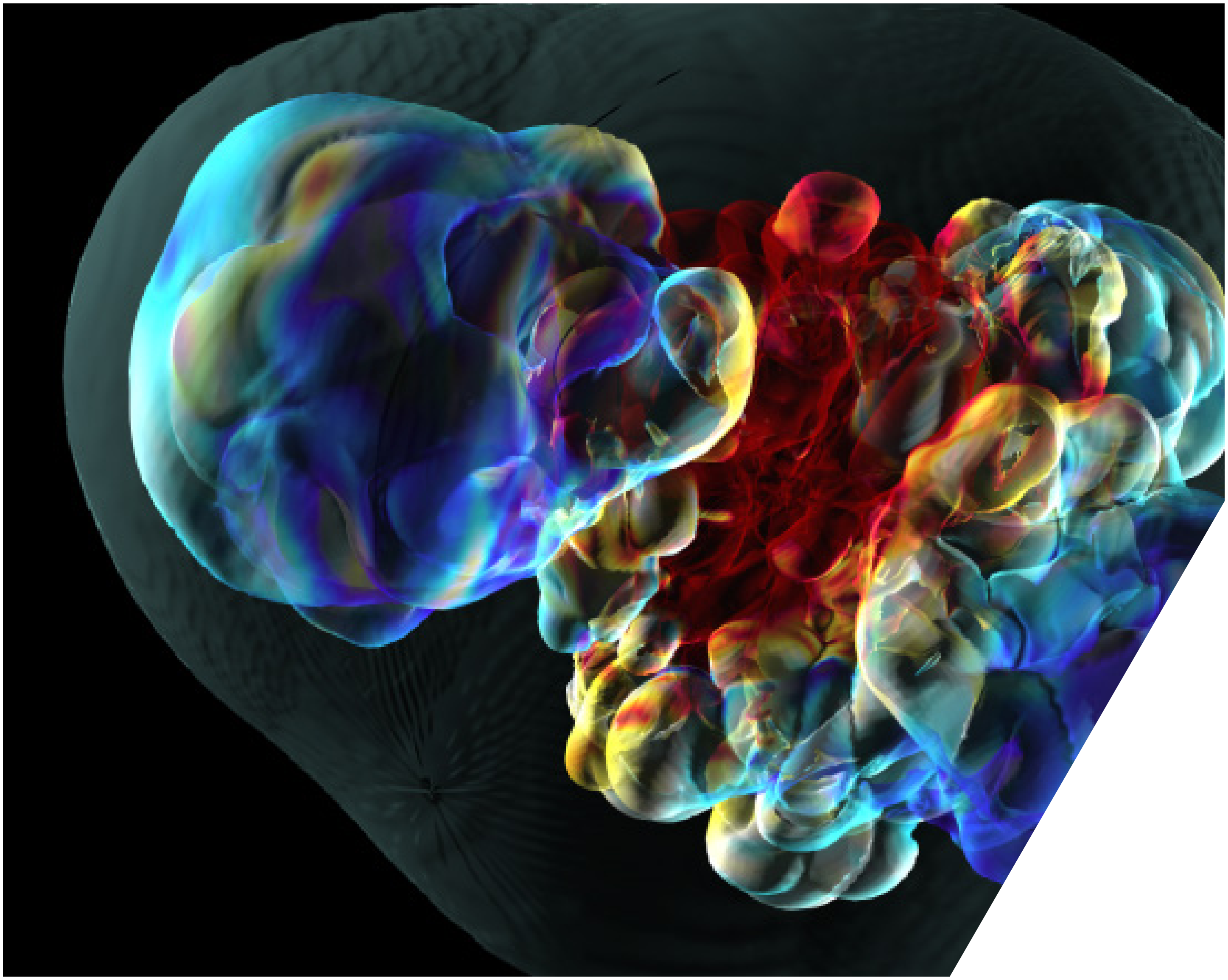
CUSTOMER STORY



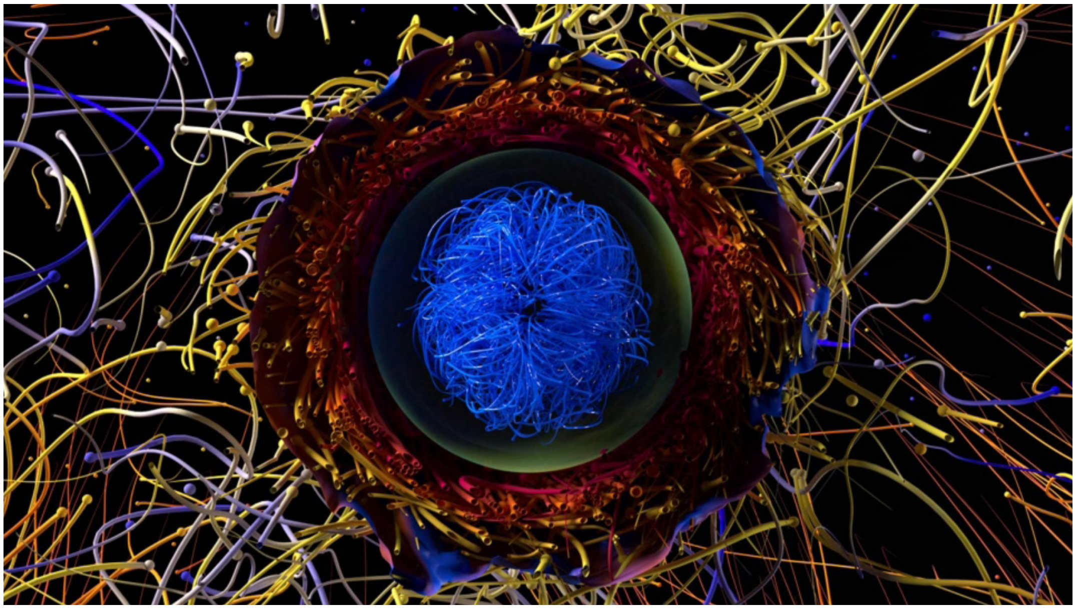
SIMULATING SUPERNOVAS IN 3D

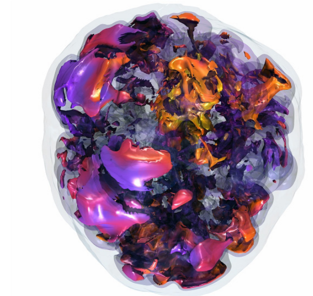
UNIVERSITY RESEARCHERS ADVANCE SPACE SCIENCE WITH ARGONNE HPC RESOURCES

About the Customer

Argonne National Laboratory is a U.S. Department of Energy (DOE) multidisciplinary science and engineering research center, where talented researchers work together to answer the biggest questions facing humanity. The Aurora exascale computer, scheduled to launch at the Argonne Leadership Computing Facility (ALCF) in 2023, will leverage several innovations to support cutting-edge machine learning and data science workloads alongside traditional modeling and simulation. In the run-up to exascale computing with Aurora, Argonne's exascale-era Polaris supercomputer is already enabling advances in a variety of projects.

> Trying to simulate the last seconds in the life of a massive star is a great drama at the confluence of nuclear and particle physics, statistical physics, and the computational arts. Big iron HPC resources such as Polaris and Aurora are central to our ability to simulate this complicated problem.
>
> Adam Burrows, Astrophysicist, Princeton University





PREVIOUS PAGE: Debris distribution from a supernova core explosion

LEFT: Supernova lifecycle from explosion to neutron star birth

TOP RIGHT: Fractured surface of an exploding stellar core

BOTTOM RIGHT: ALCF's Polaris supercomputer

Images are courtesy of Argonne National Laboratory, managed and operated by UChicago Argonne, LLC, for the U.S. Department of Energy

Their Challenge

Everything in our world and beyond is made from a common set of materials — elements — that combine to become the diverse collection of matter all around us. When a star dies, going supernova in a spectacular explosion, it releases massive quantities of these elements. But how and why stars go supernova remains a mystery, and researchers from Princeton University and the University of California, Berkeley are using ALCF supercomputers to **simulate supernovas and the neutron stars and black holes they create**. They're using computing hours awarded as part of the DOE's Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program. "Trying to simulate the last seconds in the life of a massive star is a great drama at the confluence of nuclear and particle physics, statistical physics, and the computational arts," says team leader and Princeton astrophysicist Adam Burrows. Past computer simulations modeling supernovas in one dimension frequently failed, but adding dimensions required a huge increase in computational power because every additional dimension **increased complexity exponentially**.

Our Solution

Burrows' team turned to ALCF's "big iron" computing resources, including the powerful Polaris supercomputer, to enable 3D supernova simulation. The system is boosted by GPUs and equipped with workload orchestration by Altair® PBS Professional®, which automates job scheduling, management, monitoring, and reporting. Efficient workload management is critical for large, complex workloads like these. Enabled by powerful HPC, the researchers have created "the **largest collection of sophisticated 3D supernova simulations ever performed**." The physics behind supernovas include nuclear physics, particle physics, and gravity according to general relativity. Each supernova simulation examines a brief moment leading up to the explosion — around half a second of physical time — and the GPU version of their code on Polaris has allowed the researchers to extend that over 4 seconds in some cases. The project uses the Fornax radiation-hydrodynamics code and simulations that account for highly complicated dynamics like neutrino-matter interactions and turbulence. "It turns out to be a really complicated problem if you do it right," says Burrows. "What we see more accurately in three dimensions is that most of our calculations actually explode. **And this is a new state of affairs**."

Results

Because the 3D models behave the way supernovas behave in space, they bring researchers closer to describing and predicting what really occurs during a supernova explosion. The project's results are a step toward creating a comprehensive standard model of star core collapse and bolstering humanity's fundamental theoretical understanding of supernovas, ultimately advancing efforts to **determine the origin of elements in the universe**. But there's still a lot to learn. The research team will continue to simulate supernovas — on even bigger iron when the Aurora exascale system goes live at ALCF.