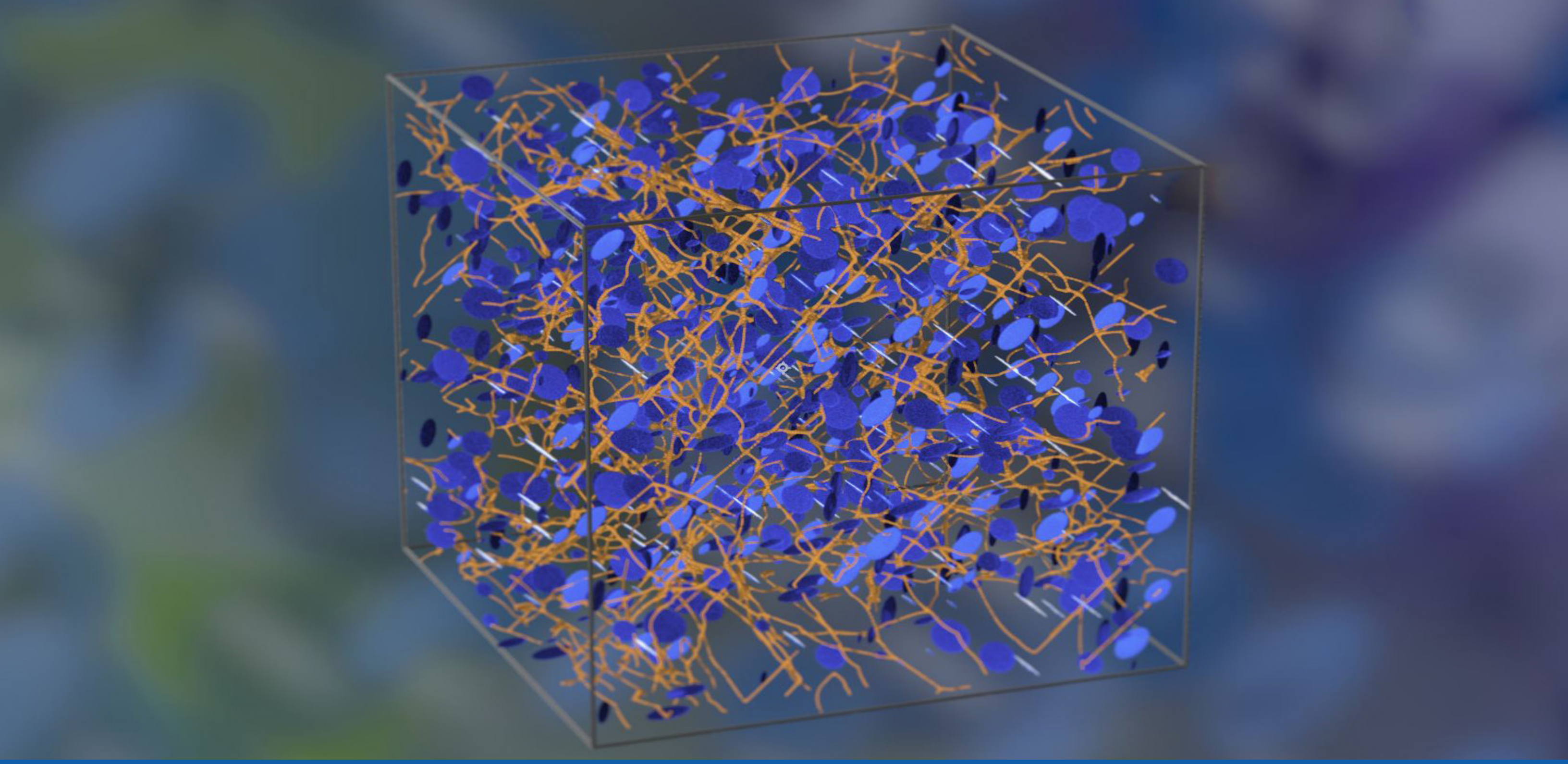


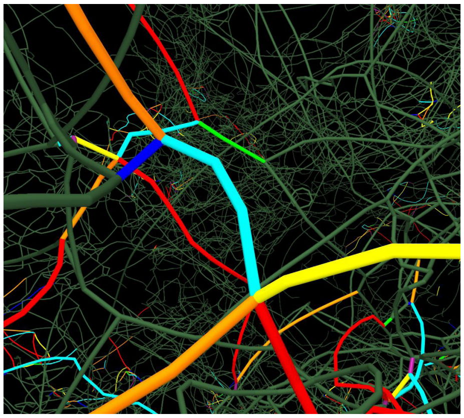
Reducing Development Time of New Lightweight Materials

Livermore is working with industry partners to develop methods for predicting the behavior of new materials.

Computers Speed Progress

Developing strong, lightweight materials for automotive and aerospace applications would significantly reduce fuel consumption and costs. However, it often takes years to develop and characterize new materials. Typically, researchers hypothesize new material constituents, manufacture the material, and then subject it to a series of tests to determine its properties. Livermore researchers help accelerate this process using novel computational techniques on advanced supercomputers to predict—ahead of fabrication—the properties of new candidate materials. These computational methods allow materials experts to perform "virtual" experiments on variations of the constituents and design a material that meets desired performance specifications.

An industrial consortium called Lightweight Innovation for Tomorrow (LIFT), which includes several major aerospace companies, was interested in replacing heavy titanium alloys in aircraft engine turbine blades with a new lighter alloy. They first selected aluminum as a lightweight material, but aluminum did not exhibit the strength of titanium. LIFT realized that by adding lithium precipitates to the aluminum matrix they would strengthen the resulting alloy. Using ParaDiS, modeling software developed at Livermore, the consortium decided to computationally test this idea as a faster way to vet the concept. In a project funded by the Department of Energy's High Performance Computing for Manufacturing (HPC4Mfg) Program, Livermore researchers worked with LIFT to computationally predict the strength of the aluminum–lithium alloy as a function of the percentage of lithium precipitates.



This ParaDiS model simulates a network of dislocation lines within the structure of a material.

Predicting Alloy Strength

Engineers typically determine if a part, such as a turbine fan blade, can survive the stresses incurred during operation by simulating its response to stress using a computational technique known as the finite element method. In particular, engineers want to know how the material, or alloy, used to make the part deforms under stress. Dislocations, which are

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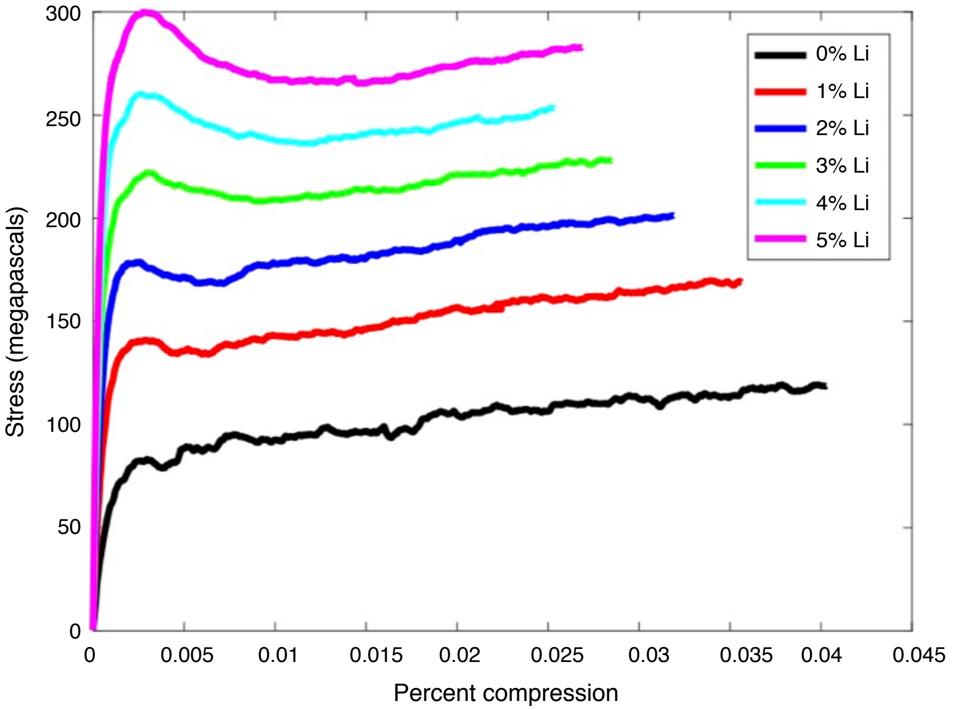
defects in a material's internal structure, play a key role in such an analysis.

ParaDiS enables researchers to predict a material's stress-compression response based on the movement of dislocation lines (and their interactions) through the material as compression is increased. At each physical point in the part being tested, a corresponding constitutive model improved by ParaDiS can accurately represent the alloy's response to external loads.

Impurities or precipitates in the structure's lattice inhibit the motion of the dislocation lines and cause them to multiply. For the aluminum–lithium alloy, Livermore researchers and LIFT extended the capabilities of ParaDiS to model the interactions between these dislocation lines and lithium precipitates.

The model results allowed the team to determine how the dislocation lines moved through the aluminum–lithium alloy and around the lithium precipitates. ParaDiS showed them that when the dislocation lines multiplied, dislocation density increased—and the alloy's strength increased as a result. Numerical results of the simulations showed the relationship between the percentage of lithium precipitates in the material and the material's strength. For example, it predicted that the yield strength of a 5 percent lithium–aluminum alloy exhibits a 3 times higher yield strength than a 1 percent lithium–aluminum alloy.



This chart shows the stress–compression response of aluminum–lithium alloys as a function of the percentage of Li precipitates in the aluminum matrix.

Such analyses help LIFT aerospace engineers determine if the new material will meet the strength specifications needed for replacement parts.

Cost-Effective Replacement for Titanium Parts

Ultimately, the new alloy could replace the more expensive and heavier titanium hubs for turbine blades in aircraft engines. Nearly 50 million liters of fuel ($26 million) could be saved per year industry-wide. Researchers are continuing to expand their predictive capabilities for future materials development. Later work will consider different alloys and polycrystalline materials.

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