Project summary

Driven by the insights available from 3D data acquired in real time, the creation of new characterization methods for structural metals has seen explosive growth over the past two decades. Using high flux beams of X-rays (or electrons) and new generations of detectors, we are now able to extract information at higher resolution over larger volumes of material at rates that were only a dream several years ago. The challenge now is to efficiently use these expensive microstructural and micromechanical probes – and the enormous datasets they produce – to better understand existing problems and gain insight into new phenomena that have been previously unreachable.

Although these characterization methods are powerful, current strategies for leveraging them, especially in a multi-modal approach, are almost entirely linear/sequential, with each dataset being used to supplement the shortcomings of the prior technique and involving limited, if any, feedback or iteration between measurements. This status quo has largely arisen from a number of inter-related challenges, including large data volumes, experiment complexity, data complexity, the complexity of material microstructure and behavior, and the complexity of analysis workflows. Taken together, these challenges lead to two distinct pain points: 1) limited interaction with data during *in situ* experiments, compromising data quality, and 2) data analysis becoming a significant bottleneck, with many potentially valuable datasets being archived and never analyzed.

This project will focus on developing new *efficient* experimental and data processing protocols for using high energy synchrotron X-ray diffraction – along with concomitant experimental methods such as electron microscopy and advanced data processing schemes leveraging state-of-the art hardware capabilities as well as modern machine learning methods – to provide the required information in a timely and actionable manner and to create understanding of processes related to plasticity, fatigue crack initiation, phase transformations and fracture. The objectives of the project are to:

- Create new tools to plan optimum data collection strategies
- Create methods for processing data in on-the-fly, as it is collected, to guide critical decisions *during* an *in-situ* experiment
- Develop strategies for reduction of raw data volumes so that scientists can assess data quality and extract desired information efficiently

The methods developed in this project will be implemented at the Cornell High Energy Synchrotron (CHESS) as part of the day-to-day practice and will be made available to other high energy x-ray beamlines around the world. Furthermore, the advancements in data handling realized in this project will enable new experimental, simulation, and data analysis *coupled workflows* that will be demonstrated on the materials science problem of **identifying fatigue-life-limiting microstructural configurations and understanding the evolution of fatigue damage in refractory BCC alloys.**