Improved Long Term Creep Model for Fossil Energy Power Plants

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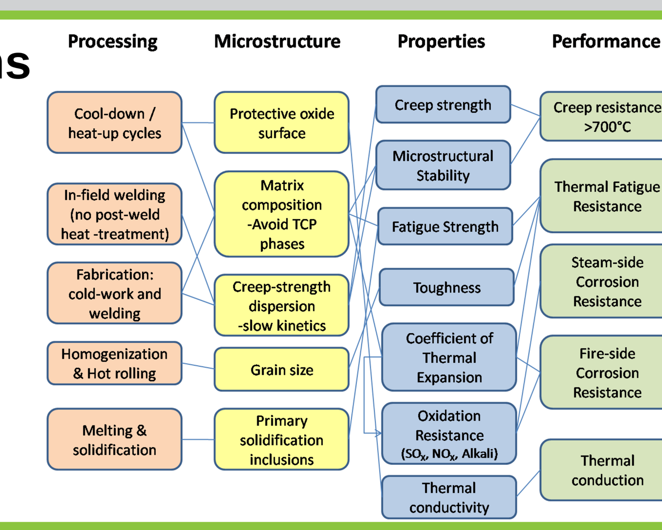
Project Objective

Develop a physics-based creep model as a function of stress, temperature, and microstructure evolution that is capable of predicting long term creep behaviors (~300,000 hrs) of advanced structural alloys of power plant components.

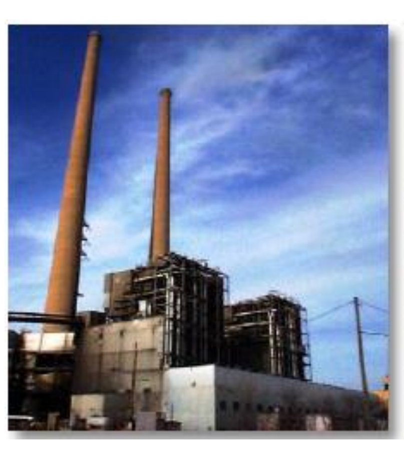
Systems design chart

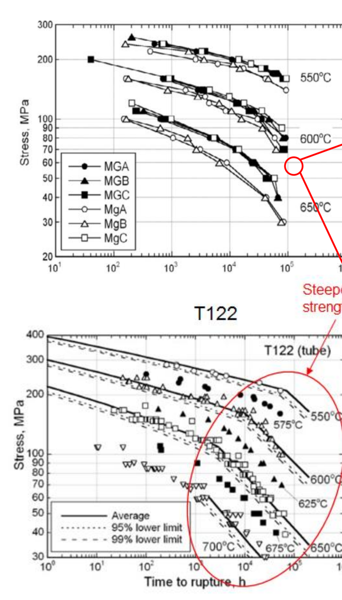


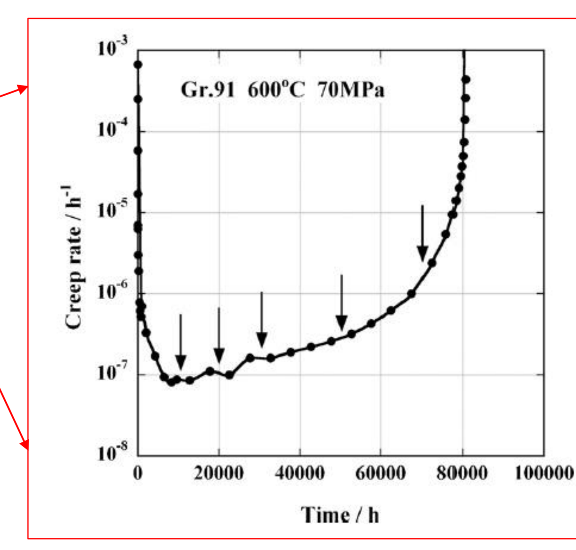
Method and Results

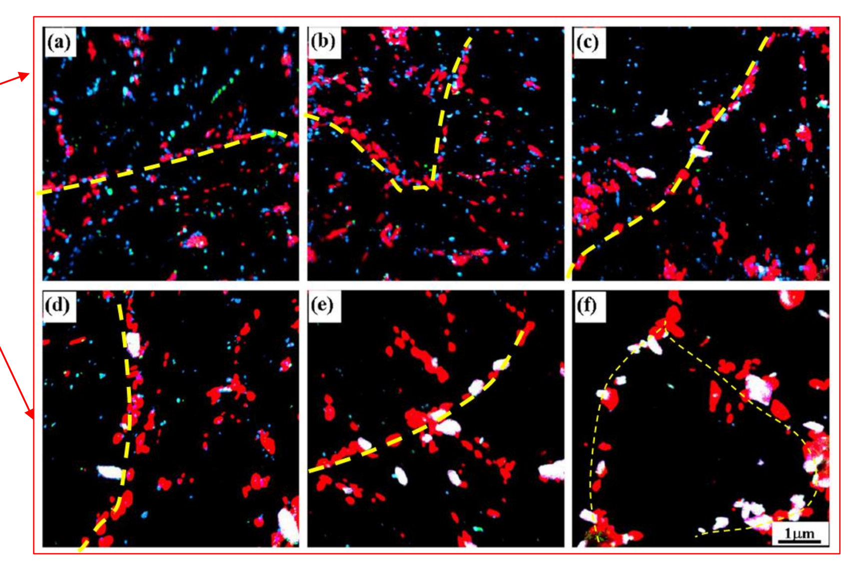
Use Case: Long Term Creep of Grade 91 Ferritic Steel in Fossil Energy Power Plants

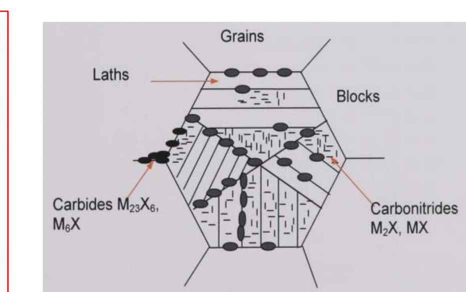
Since the life-time of a power plant can be in excess of 30 years, the qualification of such newly developed materials/ alloys could be as long as the service life required. To enable the deployment of new generation materials for advanced power generation technologies in the future, more efficient, accurate, and user friendly computational methods for long term (to 300,000 hrs. operating life) prediction of materials behavior in fossil energy systems need to be developed.











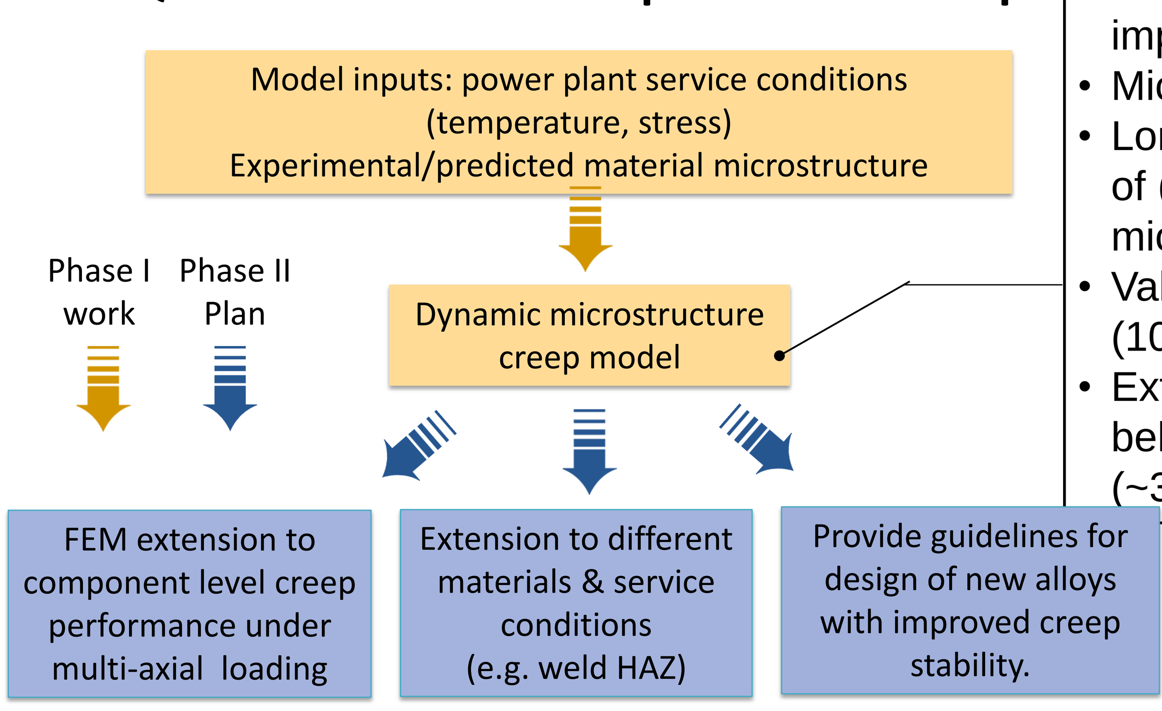
Red $(Fe, Cr)_{23}C_6$
Blue VX
Green NbX
White Z-phase (Cr,V, Nb)N

- Loss of creep strength in long term creep for ferritic steel
- Extrapolation of short-term creep data to long term creep is over-estimating the creep rupture life

The microstructure evolution during long term service is the key of modeling long term creep behavior

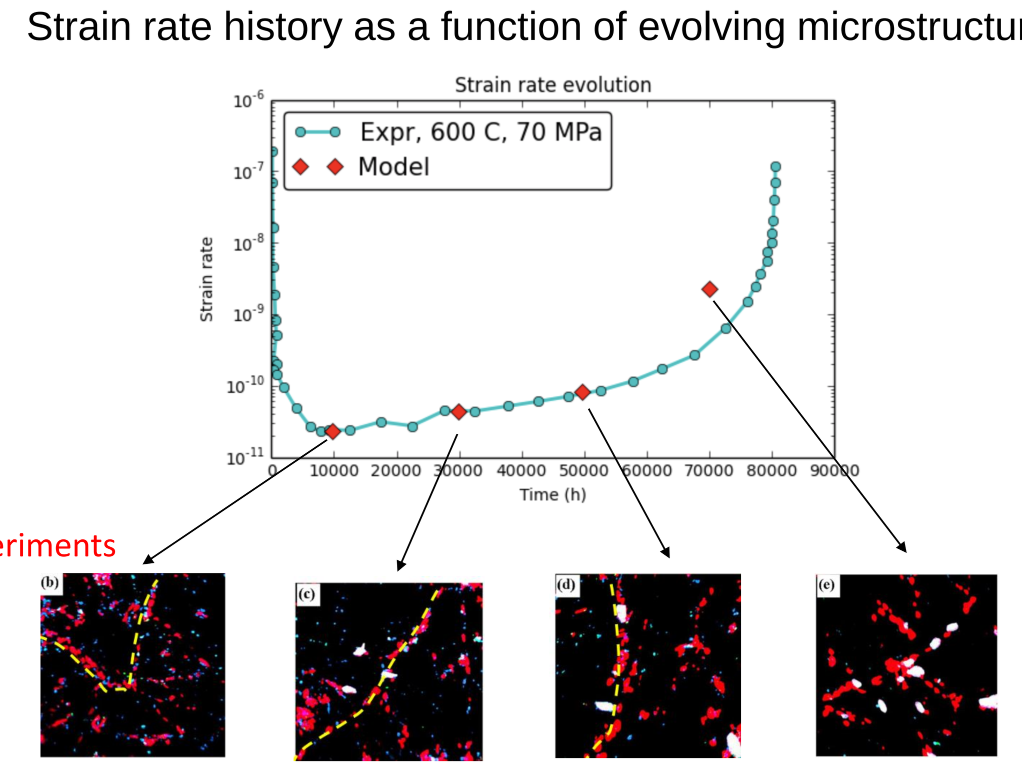
Development of Microstructure-Sensitive Mechanistic Creep Model

QuesTek Model Development Road Map

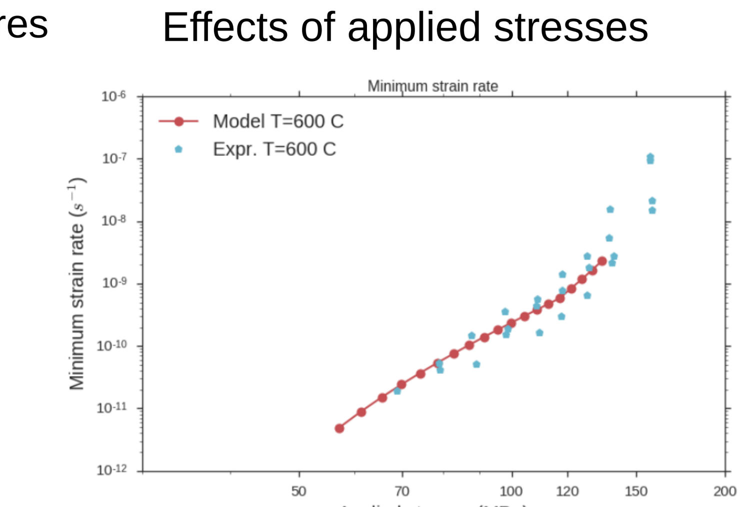


- Fundamental creep mechanisms implemented.
- Microstructure dynamics simulated.
- Long term creep rate as a function of (Temp, stress, initial microstructure).
- Validated with existing creep data (100,000h).
- Extendable to describe creep behavior to greater than 300,000 h (~30 years).

Strain rate history as a function of evolving microstructures

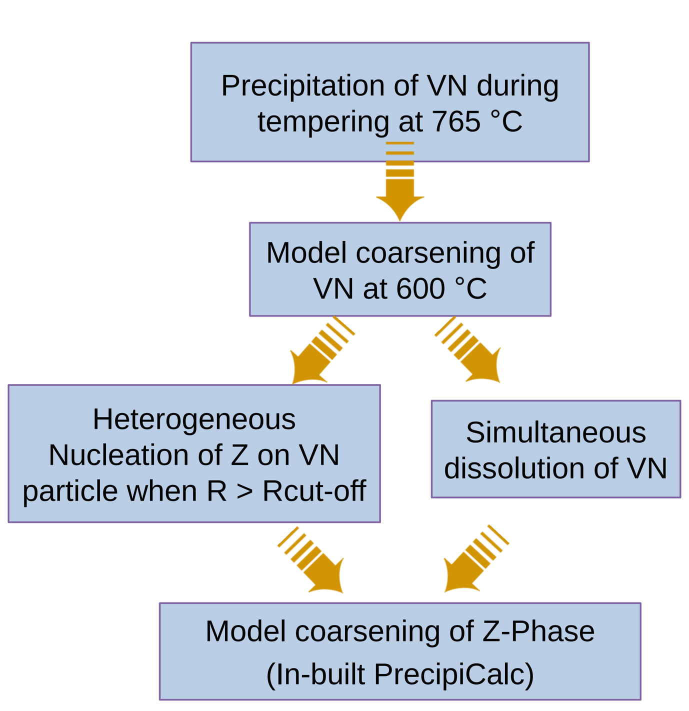


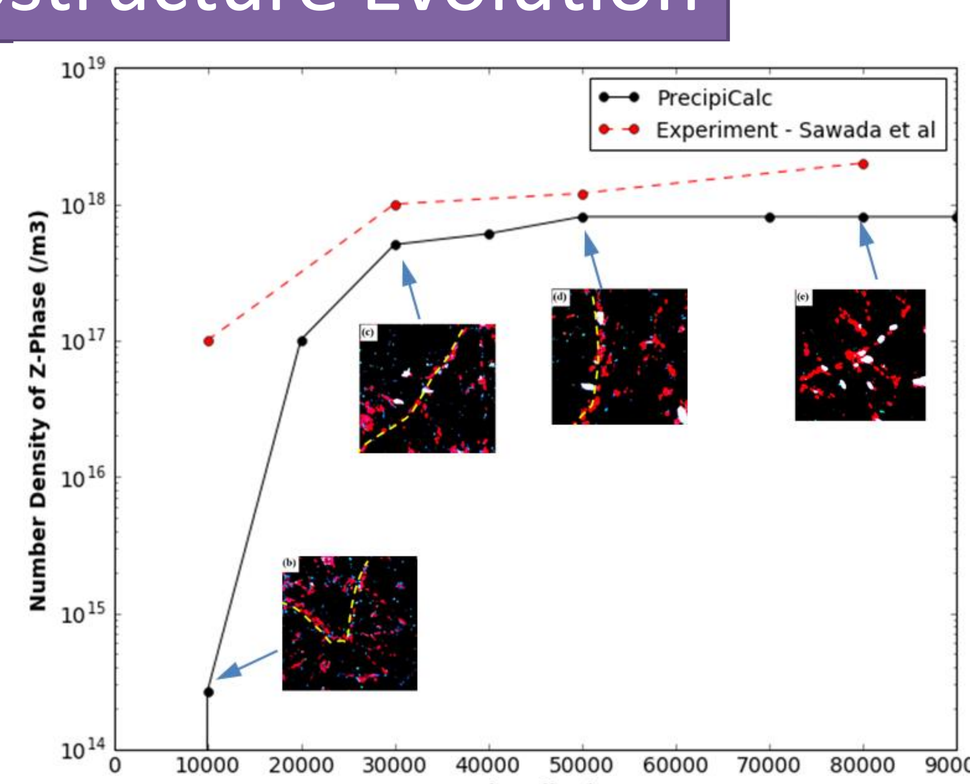
Effects of applied stresses



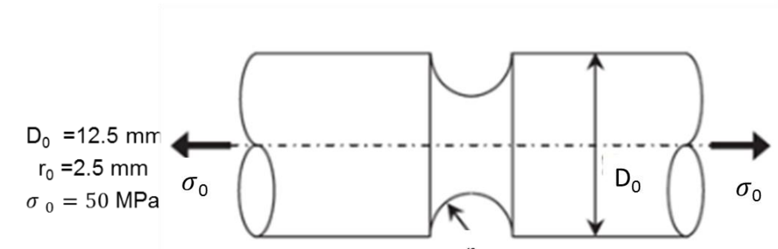
Excellent agreement achieved between model prediction and experimental data (NIMS) indicates fundamental creep mechanisms are properly implemented.

Modeling on Microstructure Evolution

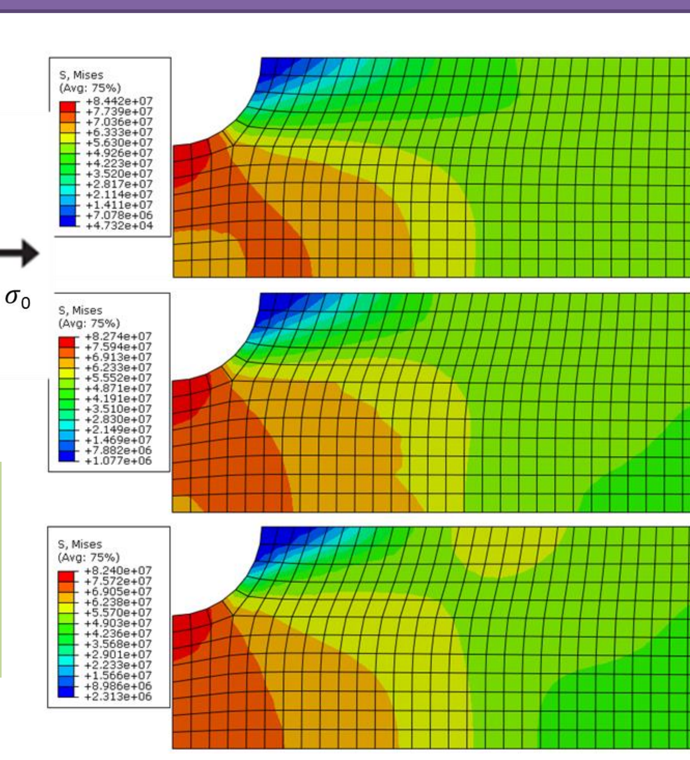


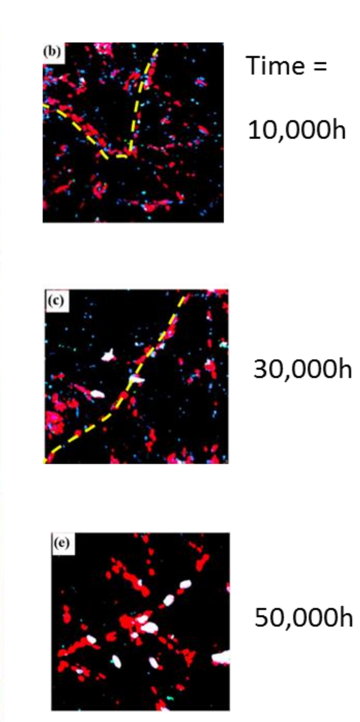


Model Integration in FEM Simulation



FEM simulations can enable structural optimization for new power plant component design





RESEARCH PLANS for Phase II

In summary, in this Phase I SBIR program QuesTek has developed a dynamic microstructure-sensitive creep model to predict the long-term creep behaviors based on the fundamental creep mechanisms. Thermodynamic and kinetic of microstructure evolution during creep has been modeled using QuesTek in-house software package and databases. Phase II efforts will include: (1) Microstructure characterization using LEAP experiments; (2) Extension of microstructure modeling capabilities using *PrecipiCalc*®; (3) Extension of creep models to weldments/heat affected zone (HAZ) in 9-12% Cr ferritic steel; (4) Component-level FEM simulation using base and weldment materials, which will enable structural optimization with improved creep performance and elongated creep life.