# An Accelerated Creep Testing (ACT) Program for Advanced Creep Resistant Alloys for High Temperature Fossil Energy (FE) Applications

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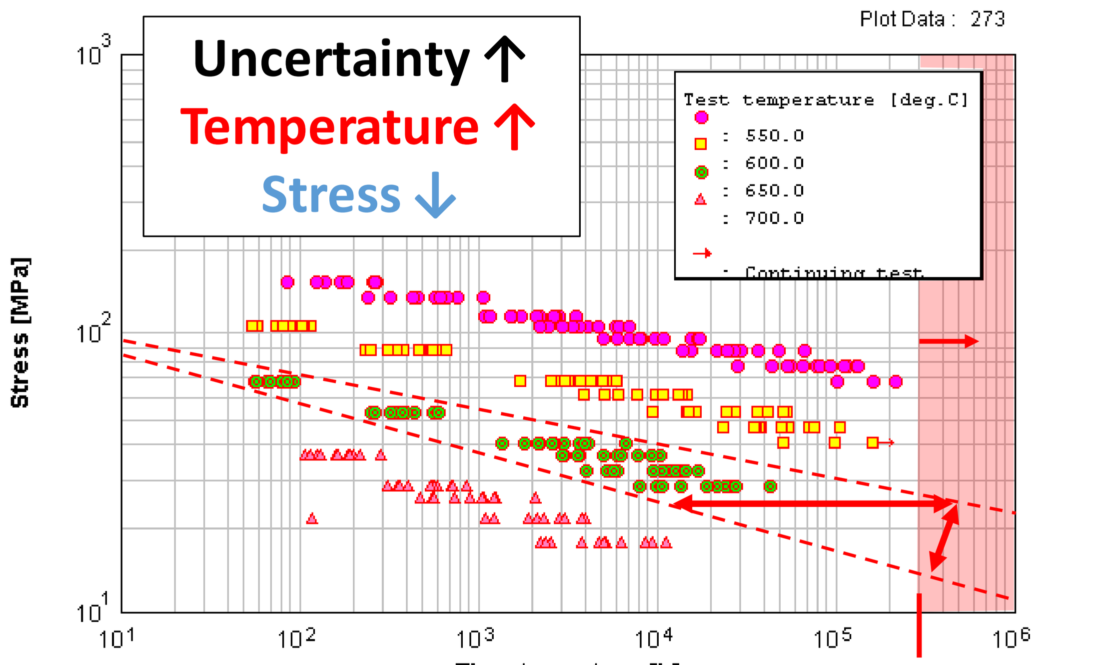
## 1. Motivation

- To increase the efficiency and longevity of fossil energy (FE) power plants, advanced ultrasupercritical (A-USC) power plants are being implemented;
- The A-USC power plants operate for over 10,000 hours at pressures above 4000 psi and temperatures above 1400°F;
- The materials used in these power plants require qualification to withstand these conditions using accelerated creep testing (ACT).

Can we capture this uncertainty in an accelerated manner?



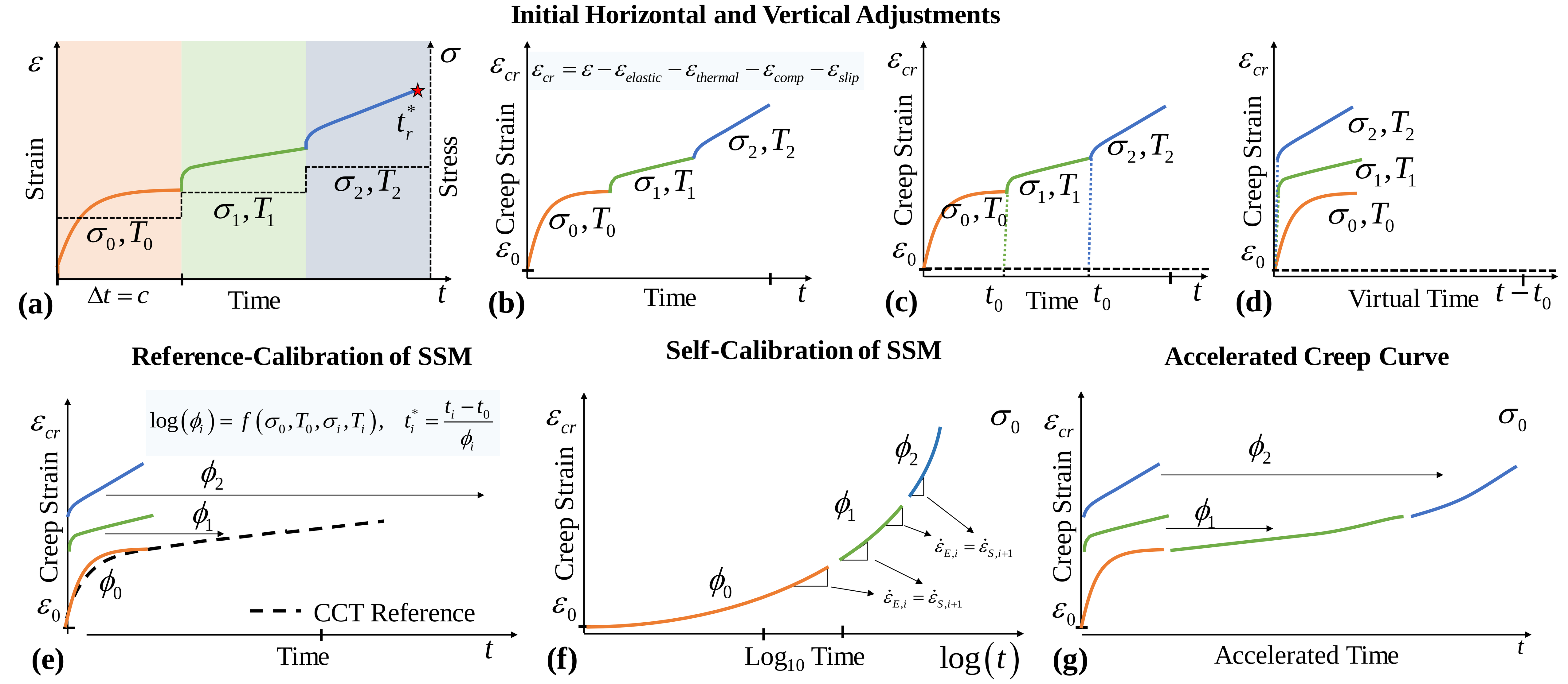

Creep-Rupture of 9Cr-1Mo Tube

Table 1 - Material qualification procedure using Accelerated Creep Testing (ACT)

| Procedure | Advantages | Disadvantage |
|---|---|---|
| **Conventional Creep Test (CCT)** Creep measurements occur at constant stress (in practice constant load) with standard or small punch specimen | • Traditional • Full Creep Deformation Curve • Rupture Life • Simple Equipment | • Destructive • Large Strains • Long Times • Fracture Processes • Major State Changes |
| **Stepped IsoStress Method (SSM) and Stepped IsoThermal Method (SIM)** Creep measurements occur at constant stress that is stepped increased after a fixed interval | • Short Times • Full Creep Deformation Curve • Rupture Curve | • Destructive • Large Strains • Fracture Processes • Major State Changes • Sensitive to Regression Analysis • Advanced Equipment |
| **Stress Relaxation Approach (SRT)** Relaxation measurements occur at constant strain (sometimes constant displacement) near the elastic limit | • Multiple Isotherms of Data • Creep Activation Energy • Non-Destructive • Small Strain • Short Times • No Fracture Processes • Nearly Constant State | • Sensitive to Data Resolution • Sensitive to Numerical Integration Scheme • Does Not Provide Full Creep Deformation Curves • Does Not Provide Rupture • Advanced Equipment |

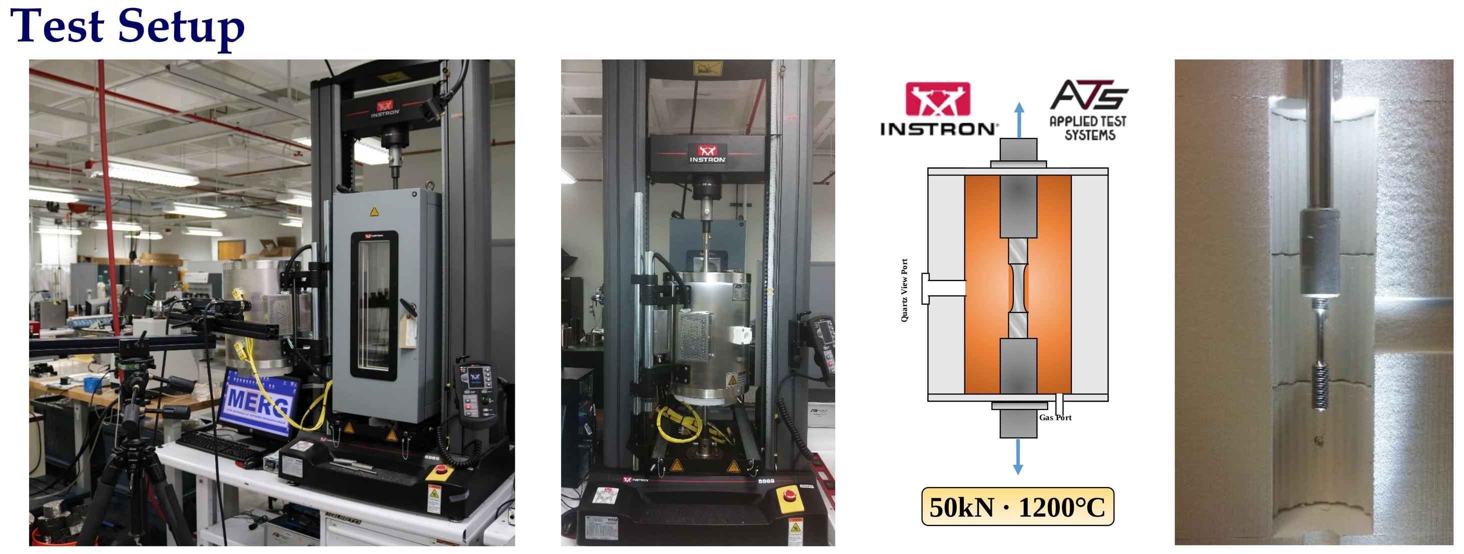
## 2. Systematic Approach to SIM and SSM

The **Research Objective (RO)** of this project is to vet, improve, and test the feasibility of the SIM and SSM accelerated creep tests for metallic materials.



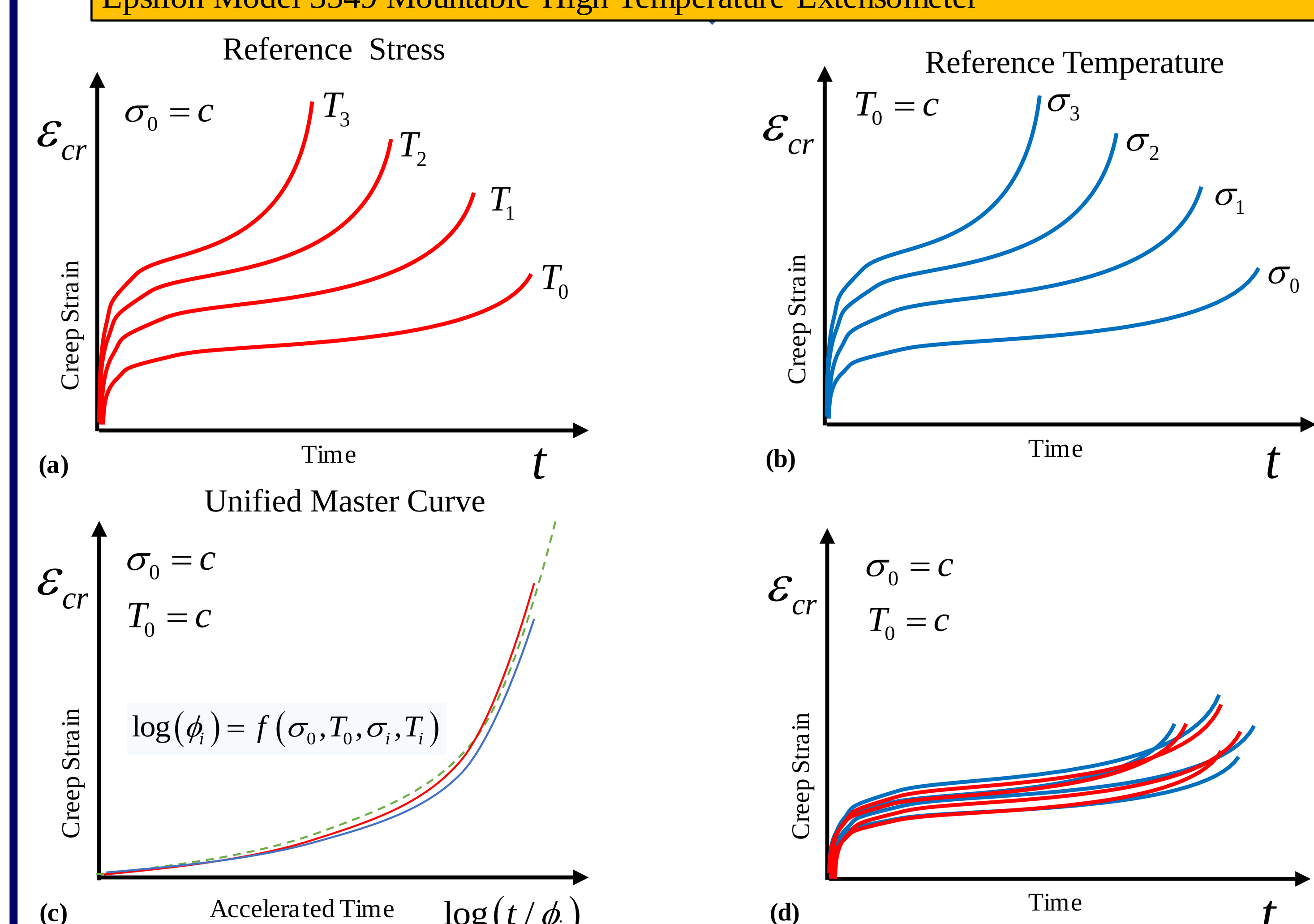

(a) Total Strain-Time Data, (b) Creep Strain Adjustment, (c) Extrapolation to Zero Strain, (d) Virtual Start Time Adjustment, (e) Reference – Calibration, (f) Self – Calibration, (g) Accelerated Creep Curve

## 3. Test Setup



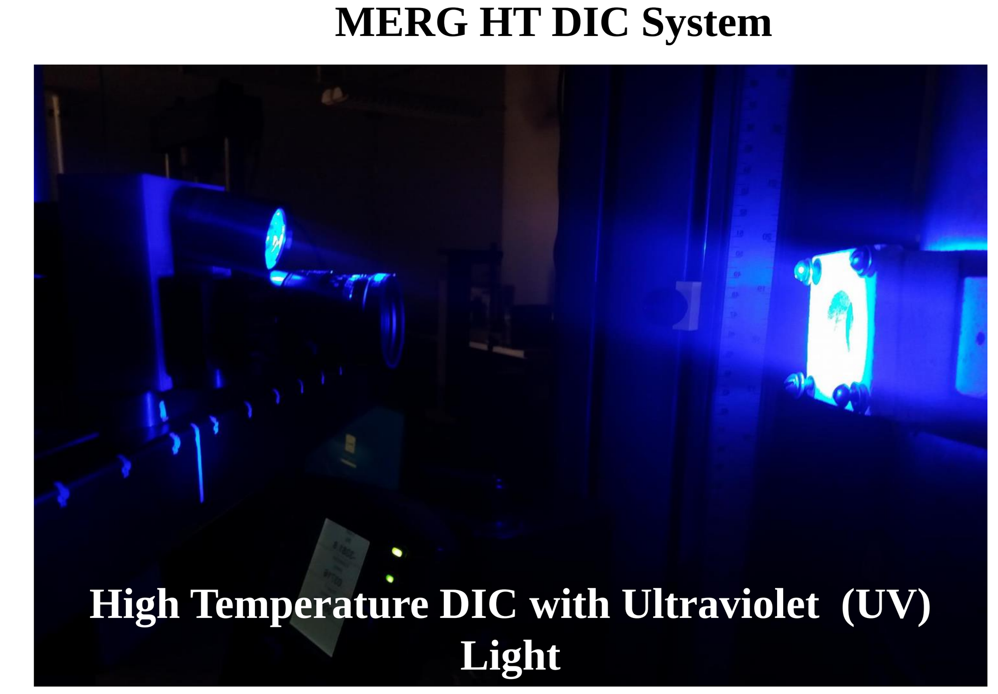

Equipment for SSM

Instron 5969 (50kN capacity)
ATS Series 3120 Split Tube Furnace Ambient up to 1200°C with Watlow PM
Epsilon Model 3549 Mountable High Temperature Extensometer

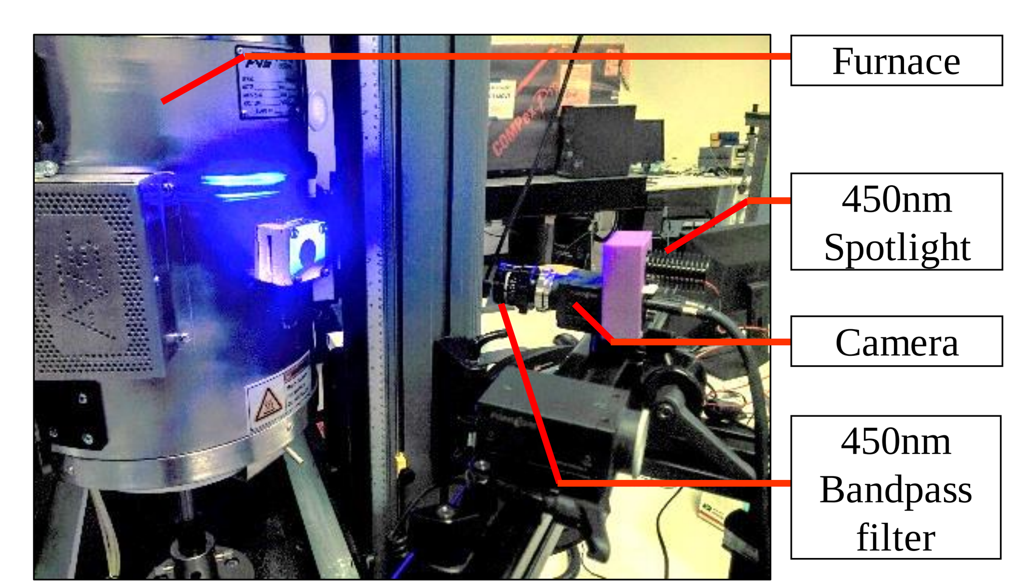


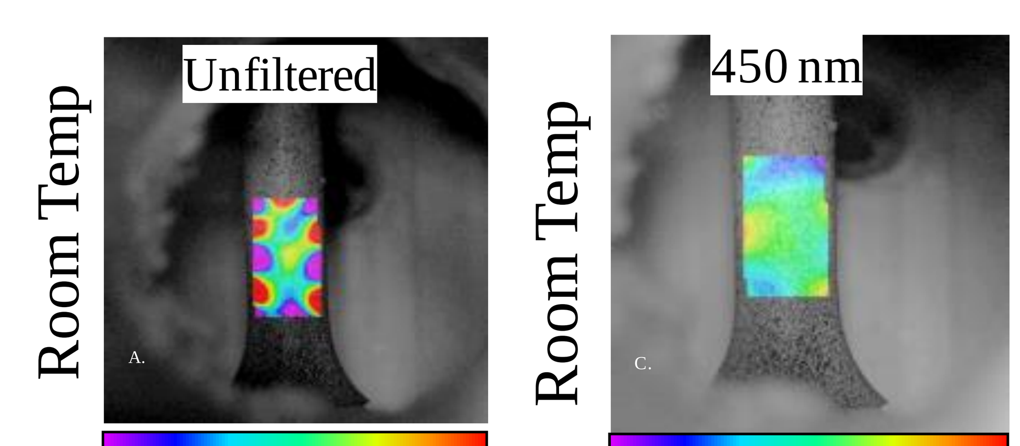

Conventional Creep Tests (CCTs)

MERG HT DIC System



High Temperature DIC with Ultraviolet (UV) Light

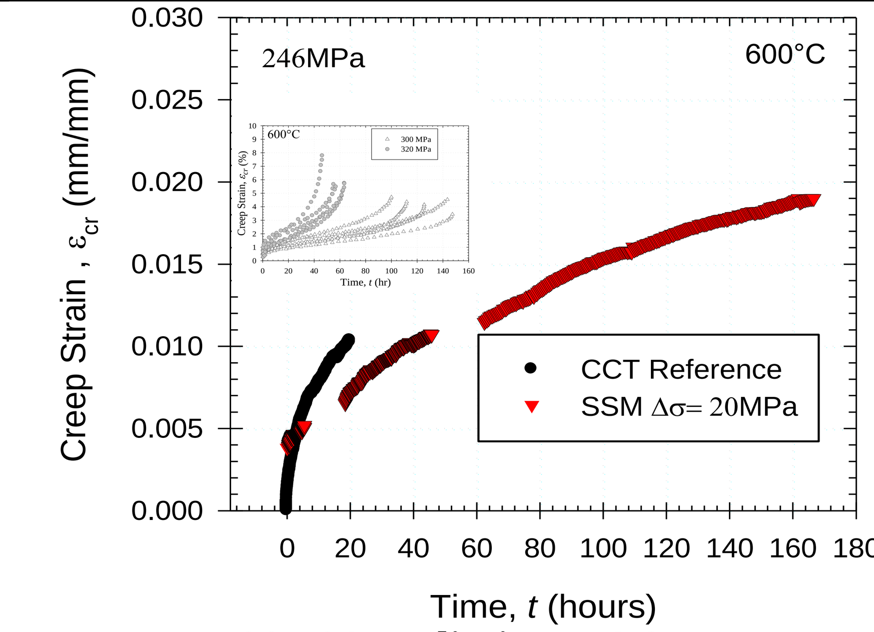



## 4. Test Matrix

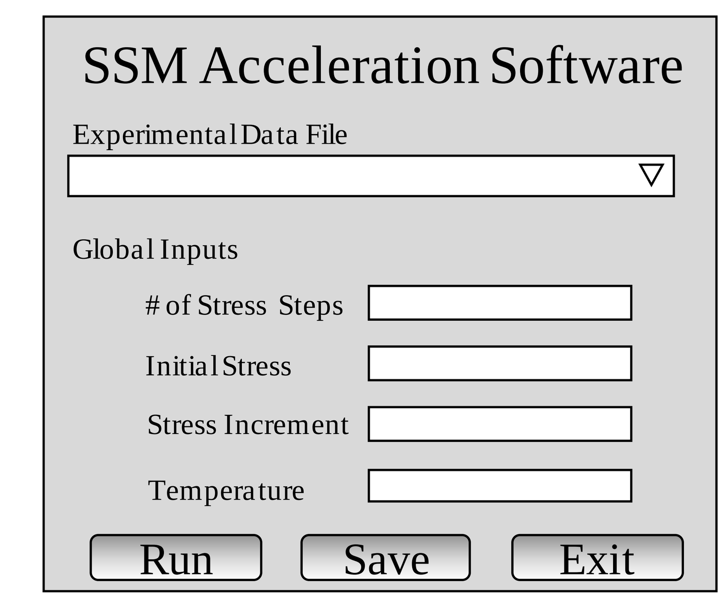
Test 2 – Test-parameter decision matrix for SIM and SSM

| SIM | Maximize Acceleration? |
|---|---|
| $\sigma_0$ | $\sigma_0$ set to the design stress. |
| $T_0$ | $T_0$ set to the design temperature. |
| $\Delta T_0$ | $\Delta T \rightarrow (T_T - T_0)/3$ where $T_T$ is the temperature of the next mechanism transition. |
| $\Delta t$ | $\Delta t \rightarrow 0$ minimizes real time thus maximizes the acceleration. |
| **SSM** | **Maximize Acceleration?** |
| $\sigma_0$ | $\sigma_0$ set to the design stress. |
| $\Delta\sigma_0$ | $\Delta T \rightarrow (\sigma_T - T_0)/3$ where $\sigma_T$ is the stress of the next mechanism transition. |
| $T_0$ | $T_0$ set to the design temperature. |
| $\Delta t$ | $\Delta t \rightarrow 0$ minimizes real time thus maximizes the acceleration. |

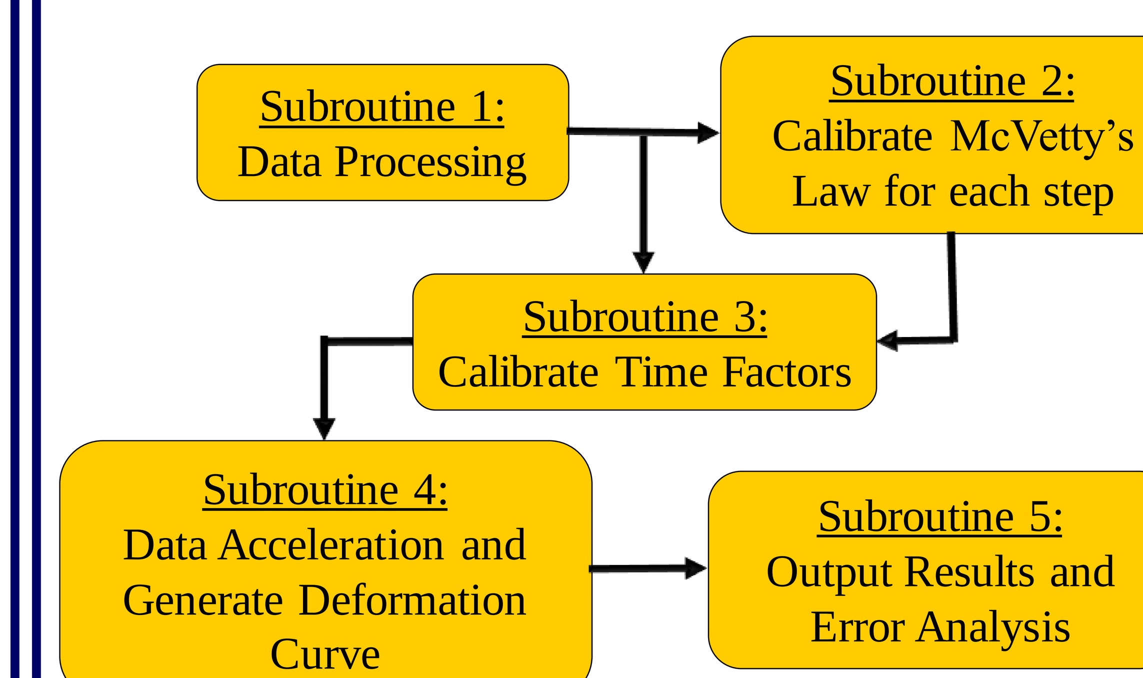



304 SS Preliminary ACT Test

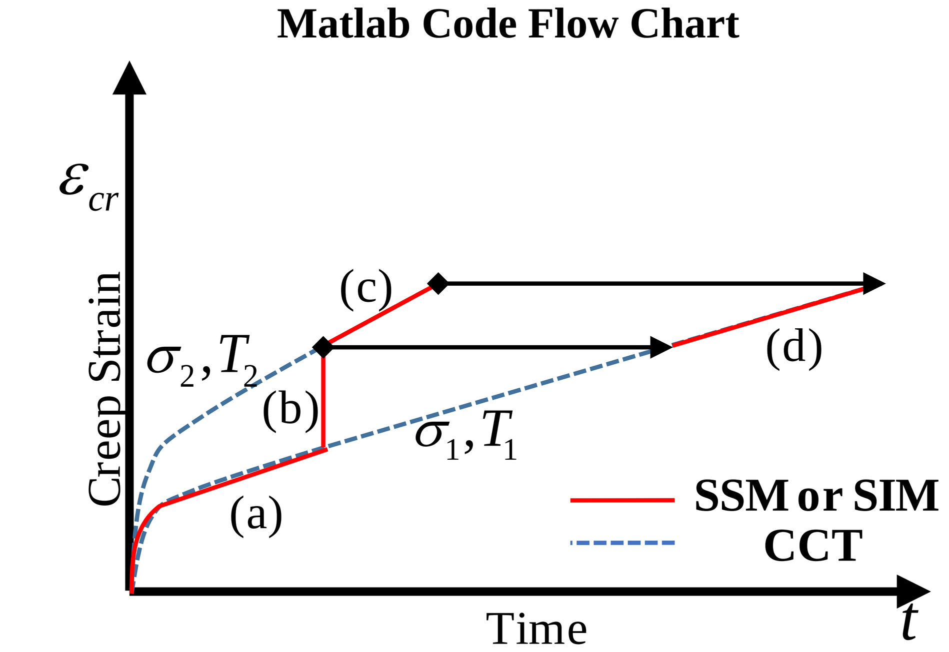
## 5. Acceleration Software




Mock User Interface for the ACT Software




Matlab Code Flow Chart




Time-Temperature-Stress Superposition

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