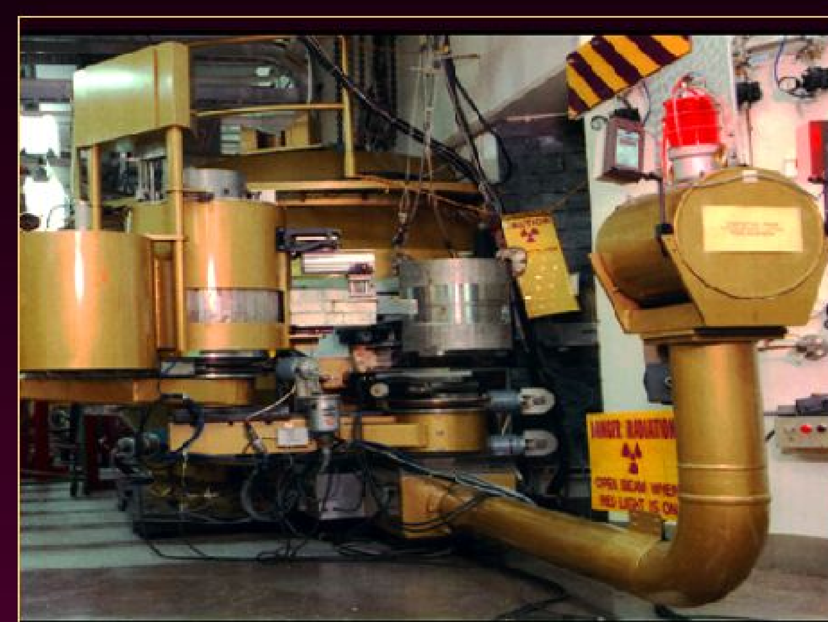
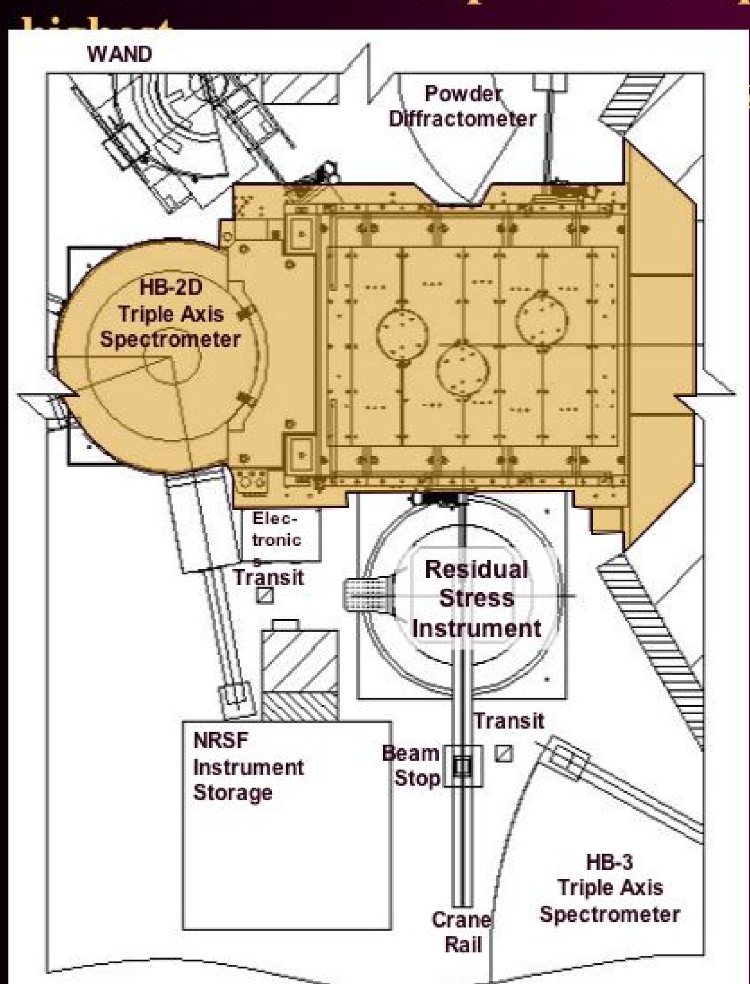
A Second Generation Neutron Residual Stress Mapping Facility (NRSF)

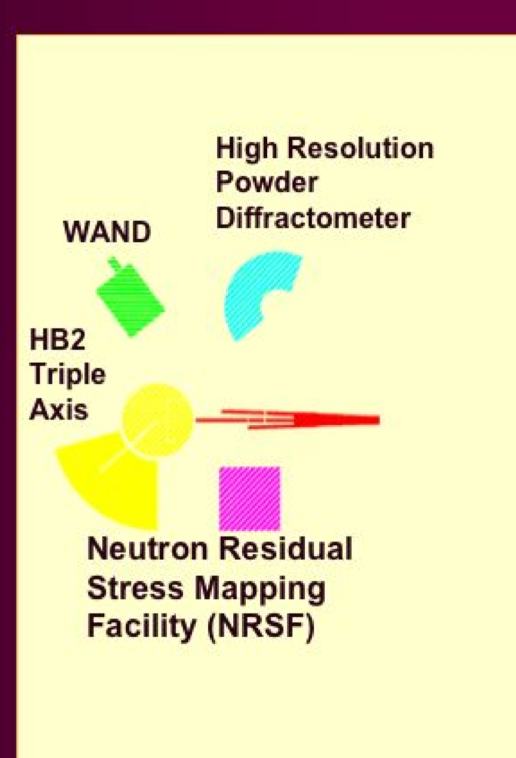
Background – First Generation Neutron Residual Stress Mapping Facility



The Neutron Residual Stress Facility (NRSF) at the High Flux Isotope Reactor (HFIR) has been operated within the DOE sponsored High Temperature Materials Laboratory (HTML) User Program since 1994. The NRSF shared the old inelastic scattering spectrometer on the HB-2 beam line at HFIR with only 60% of the beam time available for strain mapping studies. Yet, NRSF was shown to be one of the best instruments for neutron strain mapping.

In 2000, HFIR was shut down for replacement and improvements to the Be reflector, beam tubes, shutters and instruments. HFIR renewed operation at 85 MW in January 2002 along with the reactor upgrade DOE is also upgrading the neutron optics, shielding and scattering instruments – including NRSF. The combined neutronic upgrades and novel neutron monochromator will increase flux on the specimen to approximately 10^8 n/cm^2/s making NRSF the highest flux research instrument in the world for ...s and strain gradients ... high precision goniometers have been purchased, one with large XYZ mapping stages and a 5 PSD detector array. The other goniometer is a large Kappa instrument for strain tensor and highly textured specimen studies.





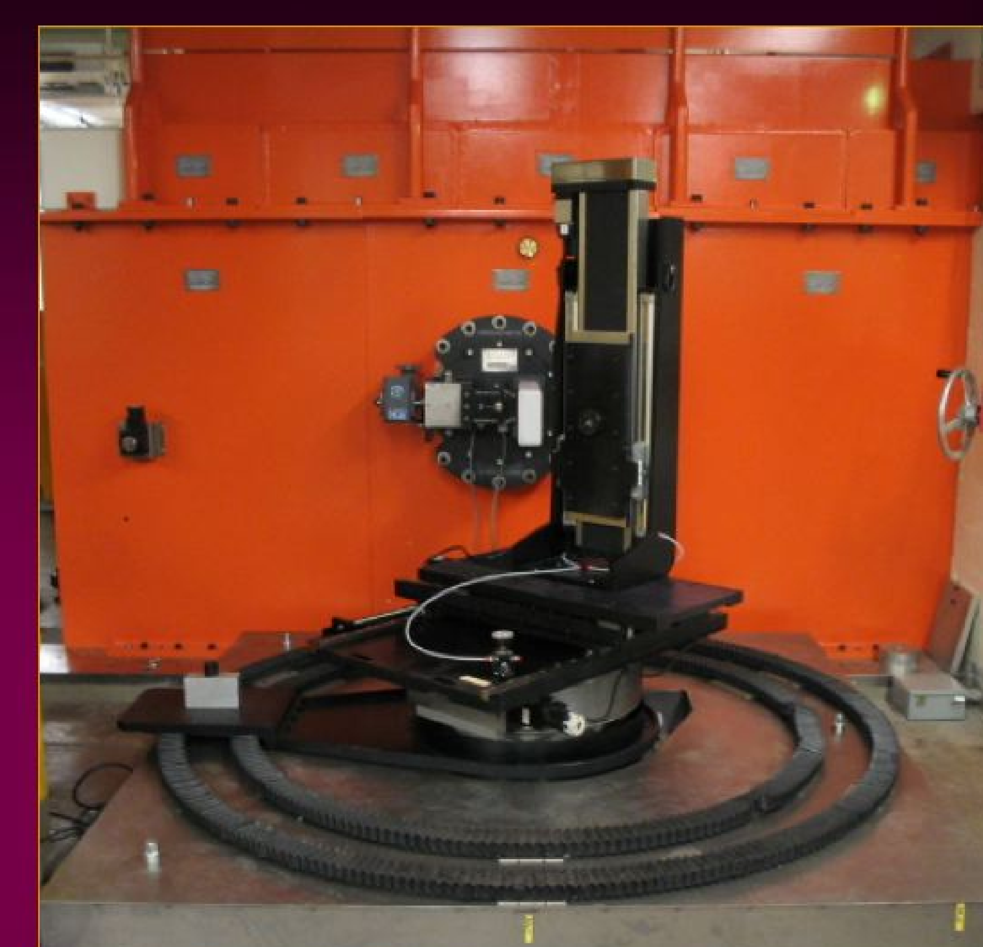
New NRSF Instrument Design Goals

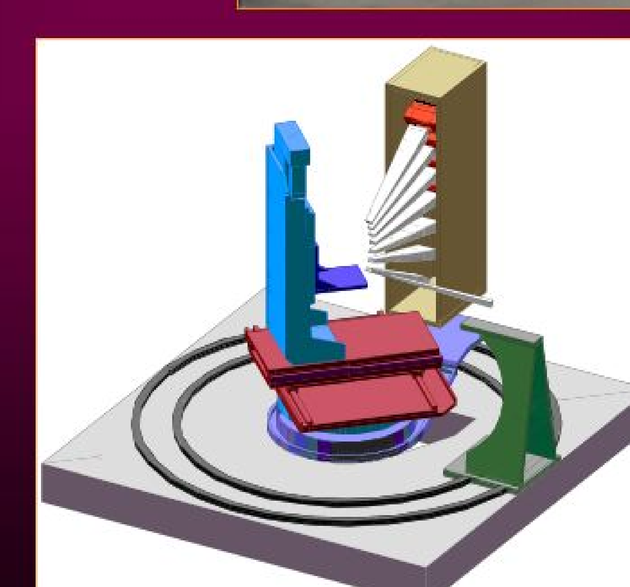
- Capacity to measure wide range of specimens
  - Small research specimens (e.g. rivets)
  - Large industrial specimens (e.g. engine blocks)
  - Single crystals and samples with “large” individual grains
- Multiple wavelengths
  - Studies various materials (Fe, SS, Al, Be,….)
  - Measurements of strains for multiple (hkl)
- Moderate FWHM resolution (0.3-0.4°)
- Working 2Θ range of 70° to 110°
- Precision of measurement to 0.002° 2Θ or better
- High flux in small area
  - Achieve >10x flux using novel monochromator
- Utilize multiple PSD detectors
- Cubic and match stick sampling volumes from ~0.5 to 10 mm3

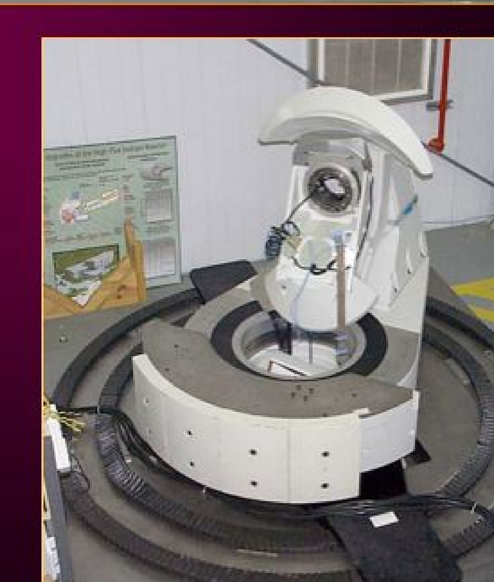
Large XYZ and Kappa Goniometers Extend Capabilities at NRSF

- Mechanically rigid, reproducible positioning
- 2θ accuracy ~ 0.001°
- Ω accuracy ~ 0.003°
- X & Z-stages = 400 mm
  Y-stage = 200 mm
  Precision = 0.01 mm
- 200 kg load on XY
- 50 kg load capacity on Z
- 5 kg load capacity on Kappa
- Increased beam to sample stage distance
- Large platform for use of accessories
  - bottom loading Z-stage
  - chi-phi goniometer
  - load frames
  - process simulation

Large XYZ – Strain Mapping







Novel Neutron Monochromator Provides Flux of ~10^8 n/cm^2/sec

- Designed and built by Univ. of Missouri
- Design constraints:
  - HB-2 constrains $2\theta_M$ to 88° (fixed take-off)
  - Gauge volume definition requires: $70° < 2\theta_S < 110°$
- Dual monochromators: each singly bent Si wafers
  - One with Si[110] orientation to be used for Si(331) reflection;
  - Second with 12° offset of the surface normal from the [100] direction toward the [011] direction to be used for Si(311), Si(400) and Si(511) reflections.
- Double focusing: vertical and horizontal
  - Variable horizontal curvature for minimum FWHM at every $2\Theta_S$
- Discrete wavelengths selected with various hkl’s

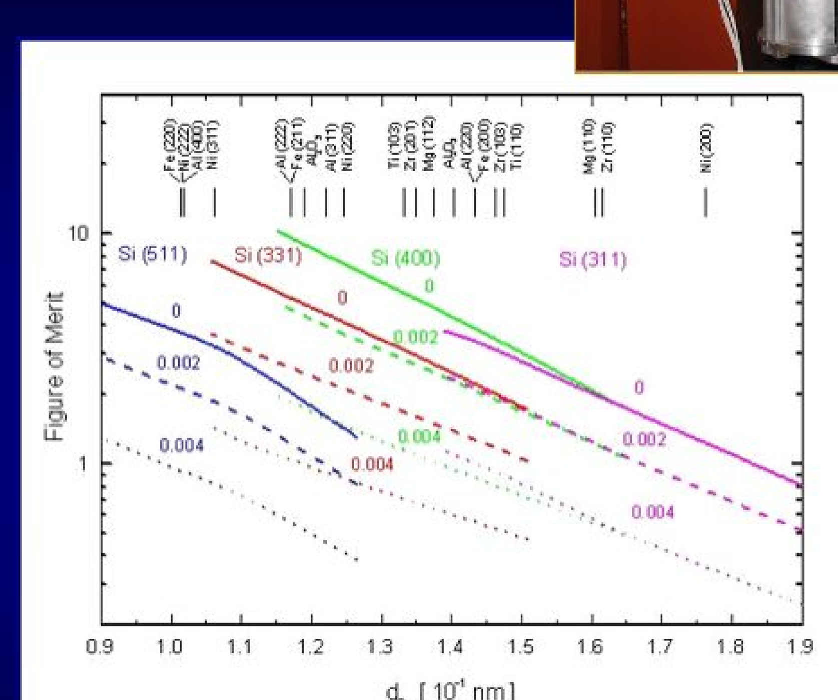


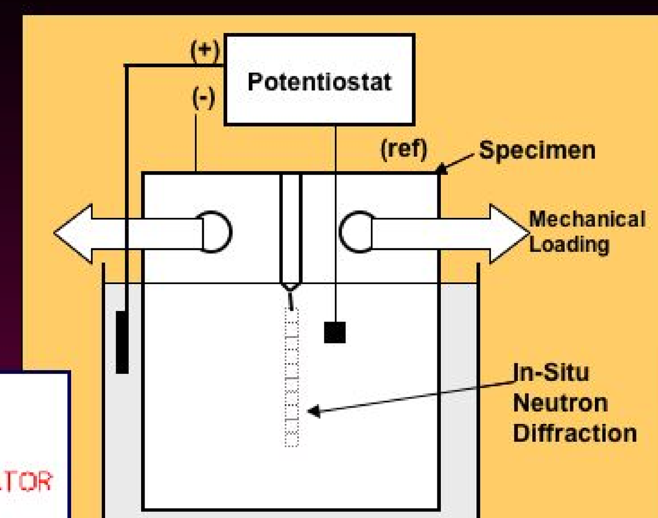
Figure of Merit reference: Si(331) bulk crystal unit. Three values of sample microstrain modeled: 0, $2x10^{-3}$, $4x10^{-3}$. Interplanar spacings frequently used in strain measurement are indicated at top of figure.

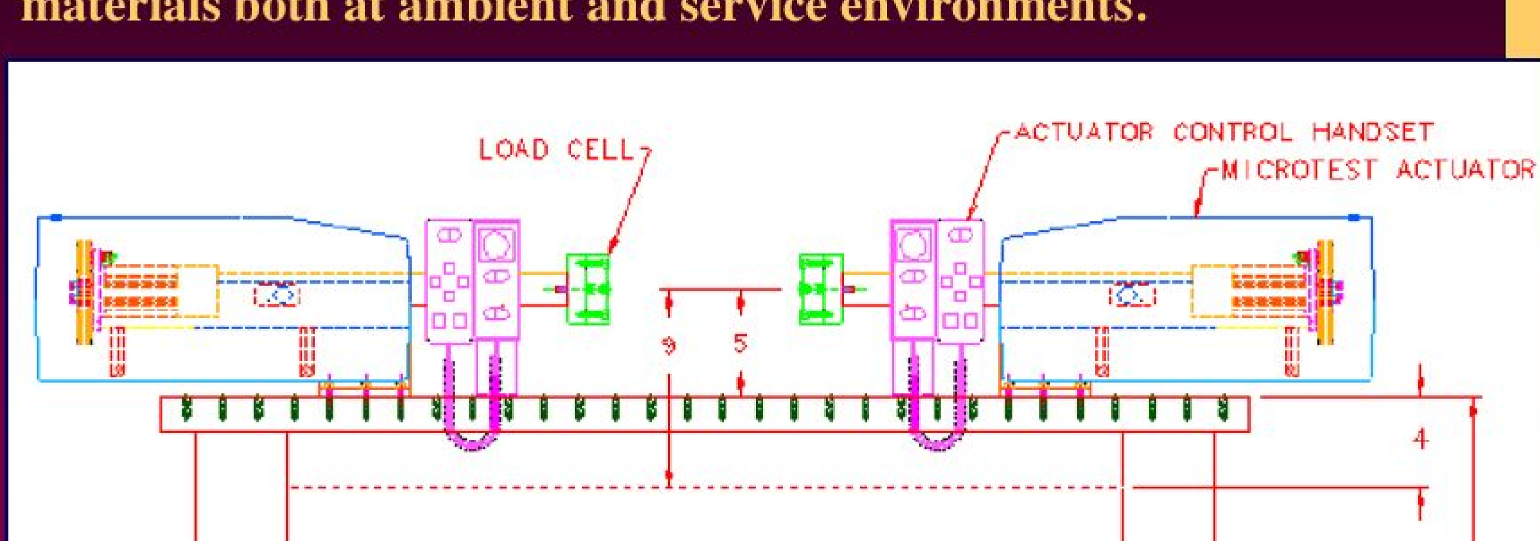
The Scientific and Technical Opportunities

- Stresses in small structures
  - Near notches, crack tips, and laminate layers - in situ and under loads
  - Joining studies (ceramic to metal brazes, laser, friction stir and ultrasonic welds)
  - Local deformation (e.g. aircraft rivets & holes)
  - High stress gradients (e.g. nitrided surfaces)
- Dynamic measurements
  - Functional ceramics - e.g. piezoelectric and electrostrictive ceramics f(V & P)
  - Synchronization with strobe - e.g. meshing gears, running engines, ….
  - Transient changes in phases, temperature, and stress with location - e.g. recharging of batteries, real time welding, shape memory devices, reaction kinetics, ….
  - Materials process simulations
- Boundary conditions & validation of computational materials models
  - FEM of deformation processes - e.g. Al extrusions, rolling, bending, forging, …
- Materials engineering
  - Monitoring in situ stress relief
  - Induction hardening, carburizing, and nitriding research and application
  - Single crystal superalloy blades (simulated service conditions)

Planned Addition –

In-situ mechanical testing with environmental cells will contribute to developing theoretical models for the load/temperature/atmosphere/time response of advanced materials both at ambient and service environments.





2nd sample geometry

G031027-CH