Experiment Automation with a Robot Arm using the Liquids Reflectometer Instrument at the SNS

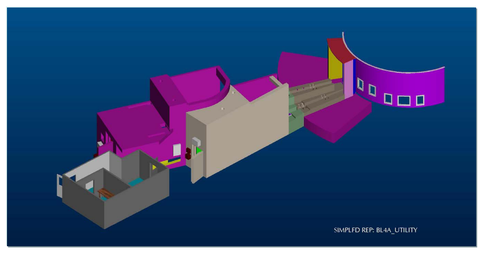
NEUTRON SCIENCES

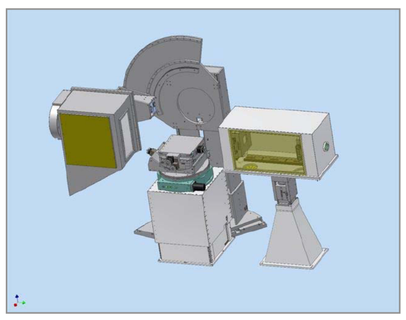
Bogdan Vacaliuc, Piotr A. Zolnierczuk, Madhan Sundaram, Andre A. Parizzi, Candice E. Halbert, Michael C. Hoffmann, Gayle C. Greene, Jim F. Browning and John Francis Ankner

Neutron Sciences Directorate, Oak Ridge National Laboratory, Oak Ridge, Tennessee

The SNS Liquids Reflectometer

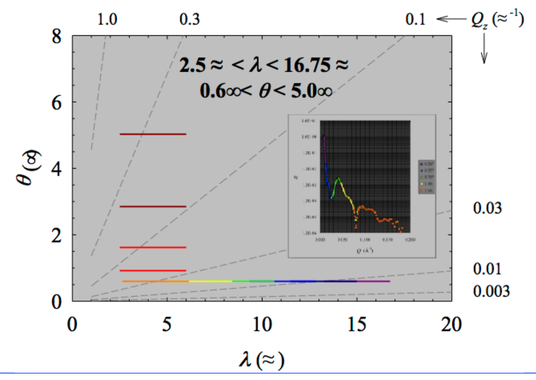
The SNS Liquids Reflectometer is a horizontal-surface unpolarized instrument capable of operating in specular, off specular, and grazing-incident small angle neutron scattering (SANS) geometry.





Operating parameters

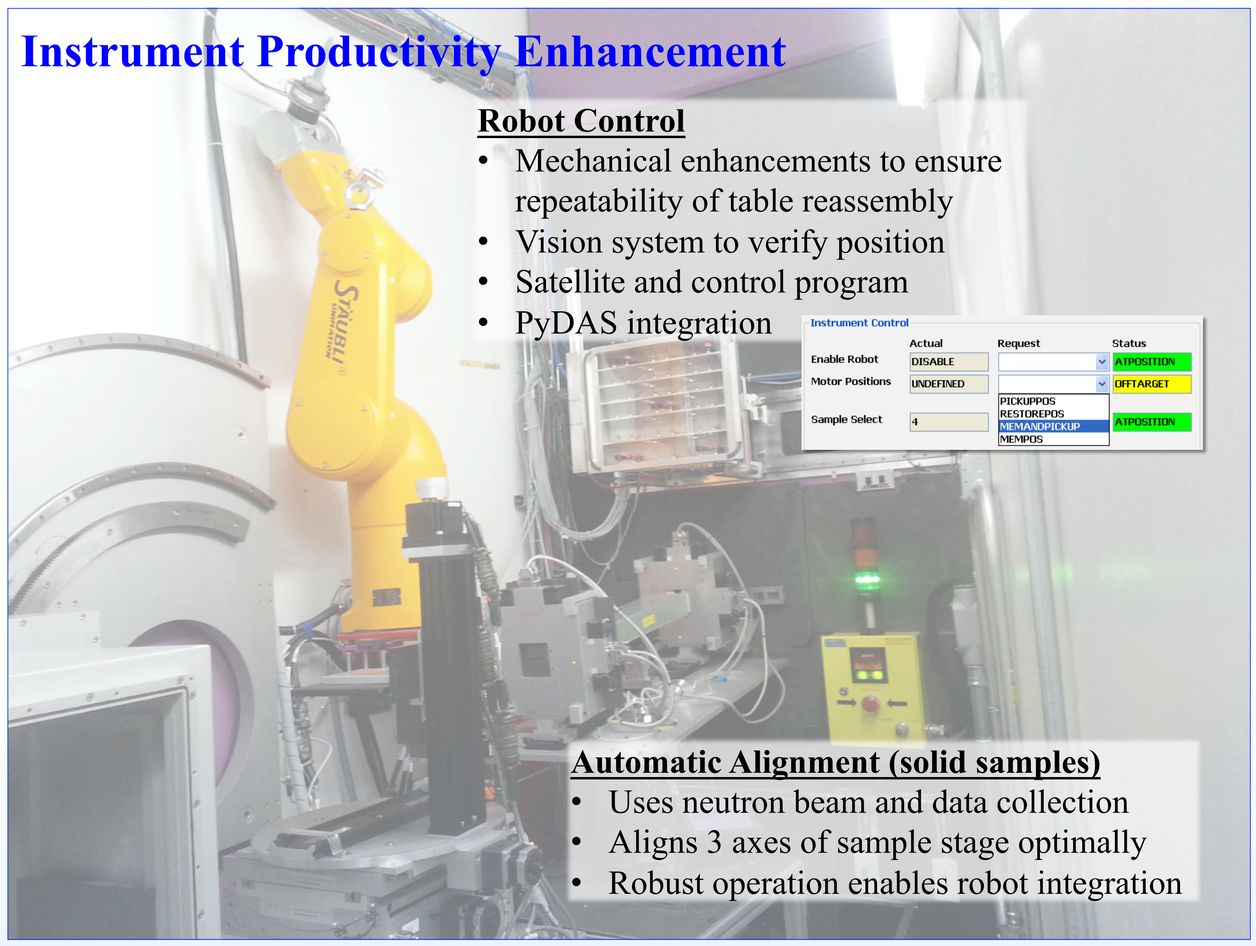
- Wavelength range: 2.5 Å < λ < 17.5 Å
- Operating bandwidth: $\Delta\lambda$ = 3.5 Å
- 2D Position-sensitive detector resolution: 1.3×1.3 mm^2
- Solid-sample Q range: 0.003 Å^{-1} < Q_z < 1.5 Å^{-1}
- Air/liquid Q range: 0.003 Å^{-1} < Q_z < 0.4 Å^{-1}
- Minimum reflectivity (no hydrogen): 5×10^{-8}
- Robotic sample changer with 18 wafer magazine



Productivity Metrics			
Metric	2012-A	2013-A	Notes
Number of neutron runs that could have used the current robotic sample changer	2696	3805	Number of neutron runs that *did* use the robotic sample changer
Number of days used to run experiments	30 days	51 days	
Average energy on target/experiment day	16.98 MWh/day	16.20 MWh/day	*includes* downtime during experiments scheduled and non-scheduled
Average number of runs/energy on target	5.29 runs/MWh	4.61 runs/MWh	
Estimate average MWh used per sample	1.52 MWh/sample	1.76 MWh/sample	based on 8 runs/sample (typical)
Typical time of manual alignment scan	14 min/sample	32 min/sample	Average time of automatic alignment
Energy equivalent spent for alignment	165 kWh/sample	360 kWh/sample	

Future Projections		
	2013-B	
Benchmarked "markers"-based alignment time	12 min/sample	
Energy equivalent estimate using "markers"-based alignment and accelerator at 875 kW	*135 kWh/sample*	
Expected number of runs/energy on target using "markers"-based alignments	*5.29 runs/MWh*	

Instrument Productivity Enhancement



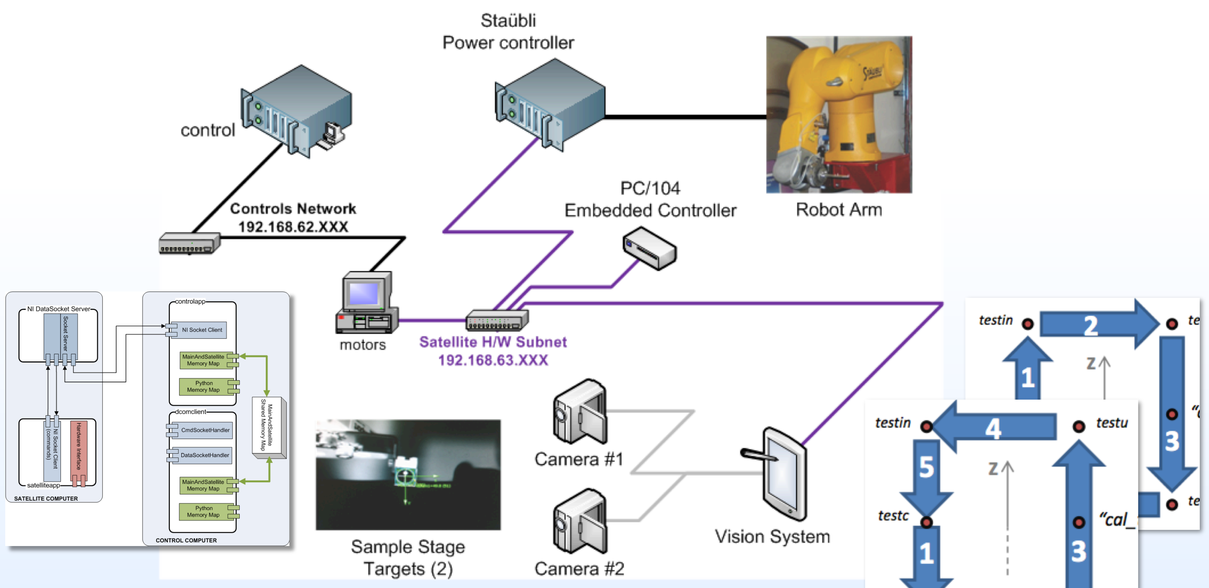
Robot Control

- Mechanical enhancements to ensure repeatability of table reassembly
- Vision system to verify position
- Satellite and control program
- PyDAS integration

Automatic Alignment (solid samples)

- Uses neutron beam and data collection
- Aligns 3 axes of sample stage optimally
- Robust operation enables robot integration

Robot Control Network and System Design



The instrument control network provides access to motor controllers, sample environment control and detector data collection computers.

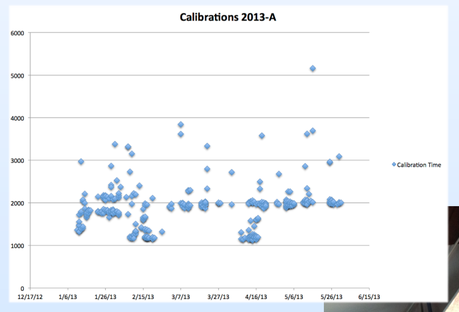
Highlights

- Process variable distribution via NI DataSockets
- Shared memory system on control computer
- Kinematic mount enables sample holders to 'self-align'
- Fundamental 6-point robot motion for pick and put enables operation with sample magazine.

Lessons Learned

Automation

- Initially, instrument operation can become "less efficient" as human-in-the-loop activity is replaced by algorithms
- Detailed timing analysis to identify bottlenecks and resolve them



Vision System

- Consult with vendor FAE during setup
- Protect position-sensitive equipment from bumps

The authors wish to acknowledge valuable contributions made by Lloyd G. Clonts, Xiaodong Tao and Rick Reidel for their original work on the DAS control system. Robert Viola and "Cooper" at Square-One Systems for the design and programming of the robot arm. Brad Lokitz, Juan Pablo Hinestrosa, and Mike Kilbey for being the "first" users of the robotic experiment processing system.

Contacts: John Ankner (anknerjf@ornl.gov), Jim Browning (browningjf@ornl.gov)

Spallation Neutron Source at Oak Ridge National Laboratory, managed by UT-Batelle, LLC for the U.S. Department of Energy under Contract No. DE-AC05-00OR22725.

Acknowledgement