

On-Line Monitoring for MSR MC&A

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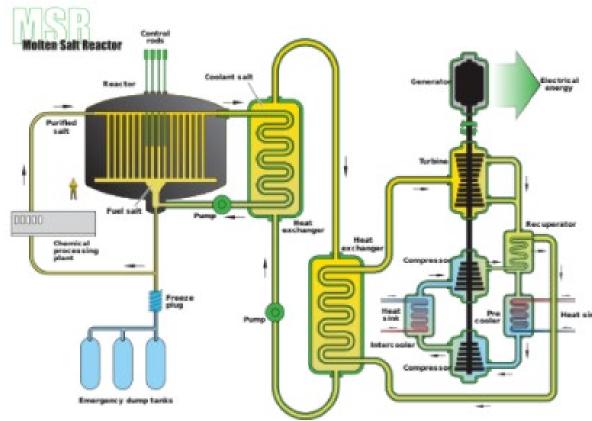
PNNL is operated by Battelle for the U.S. Department of Energy





Motivation

- MSR systems pose unique challenges to MC&A analysis
- Building robust capabilities for inline analysis of the system could provide needed information without opening the system for grab sample collection
- Provide needed information and measurement uncertainty for actinides and other key targets without placing undue burden on the MSR system

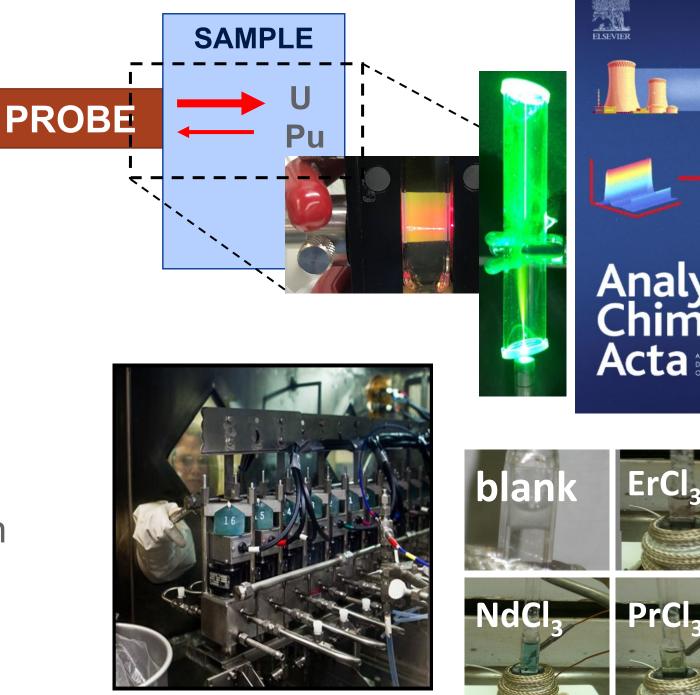


https://en.wikipedia.org/wiki/Molten salt reactor



What On-line Monitoring Provides

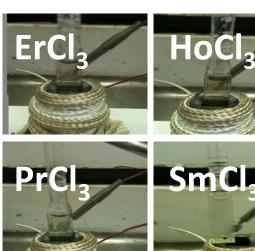
- Fundamental characterization
- Design phase
 - Informed and optimized R&D
- Deployment phase
 - Process optimization
 - Process control
 - Real-time characterization



Tse, P., N.P. F Monitoring

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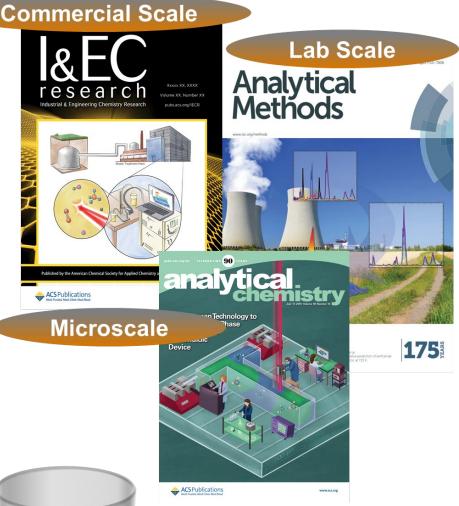




On-line Monitoring for Chemical Characterization: Optical Spectroscopy

- Provides chemical information
 - Identification and quantification
 - Oxidation State
 - Essential information for control of systems
 - Molecular and elemental species
 - Essential information to understand/control separation efficiency or general system behavior
- Fast
- Robust
- Versatile







Liquid



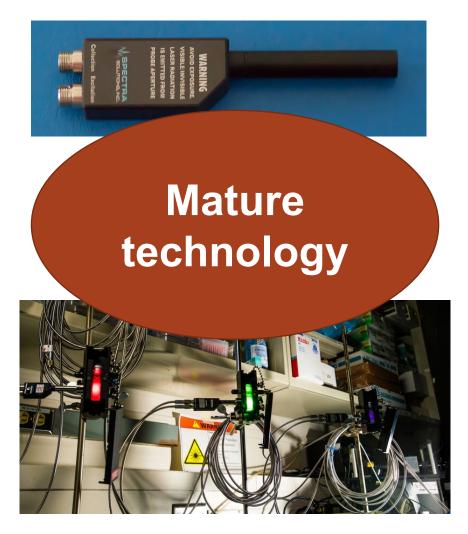


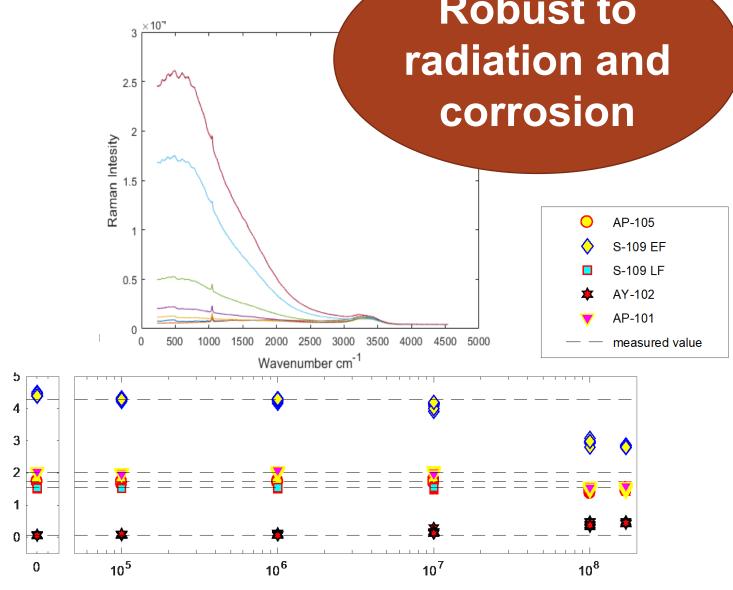
Robust and Mature Capability

3

1

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applied dose, Rad

Robust to





Identifying Needed Areas of Development

- FY20 focus outlined advancement needs
 - Outline of current state of the art
 - Roadmap

 Informed key steps for FY21

Roadmap **Development**

- Identify target analytes and technology needed to monitor species
- Outline current state of the ٠ art and technology gaps for monitoring capabilities
- Plan technology • development roadmap

Phase 3: Large scale testing

- Explore options to test system performance in larger scale system mimicking deployment conditions
- **Optimize design and models**

Phase 1: Laboratory Testing

- **Complete scoping study for** optical fingerprints in target salt system: smallscale
- Design large scale (e.g. immersion probe) interrogation mechanism for system infrastructure
- Test large scale probe response and durability

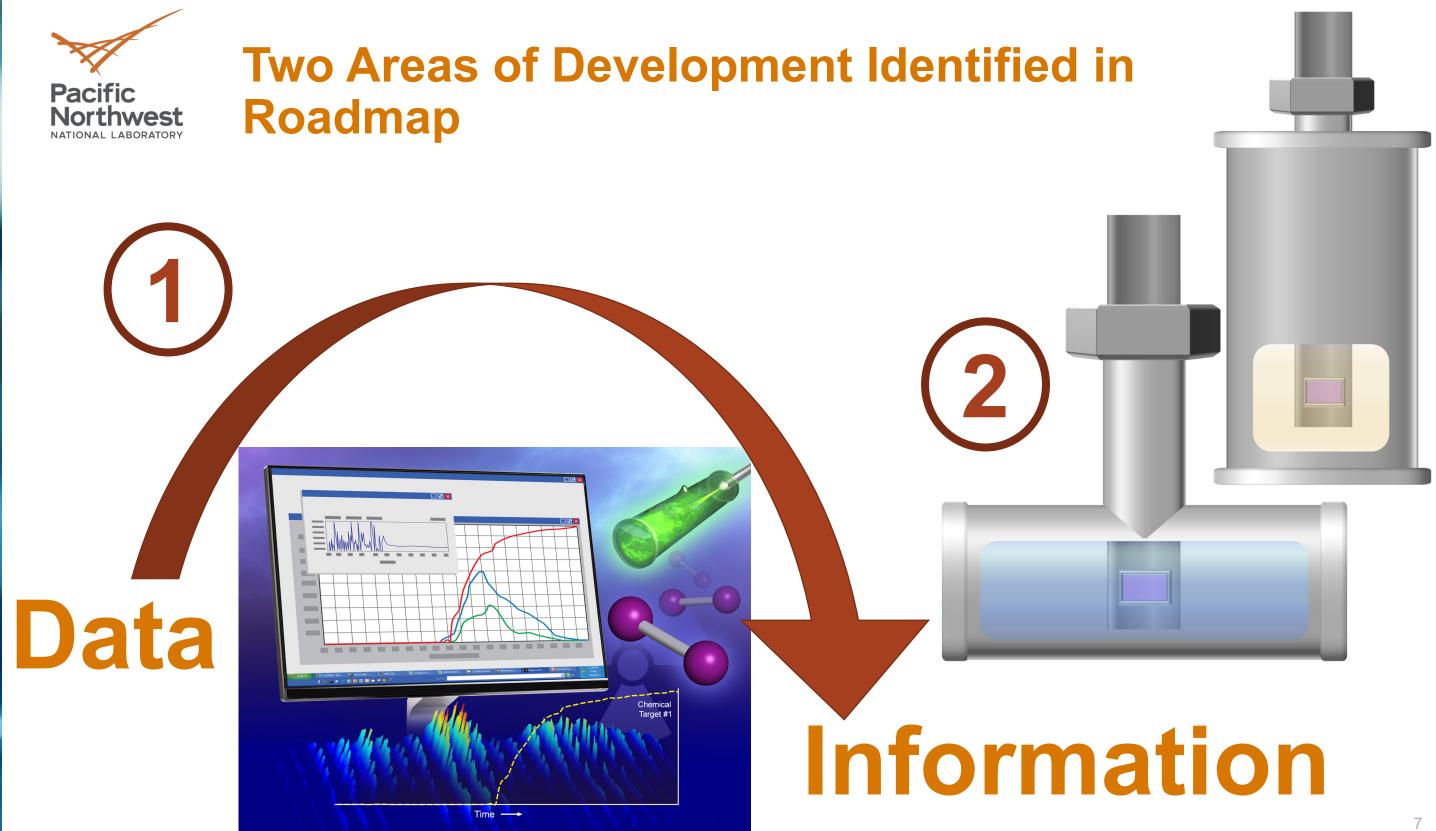
Phase 4: Deployment preparation

Phase 2: Collect training set and build models

- Design training set to capture target and interfering signatures
- **Collect training set**
- **Build chemometric models**
- Validate model performance

Identify QA requirements Assess technology transfer options **Explore approved pathways** to integrate probes







- Demonstration of ability to capture representative target fingerprints
- Exploration of relationship between signal and target concentrations
- Outlining value of approach while continuing to track developing needs

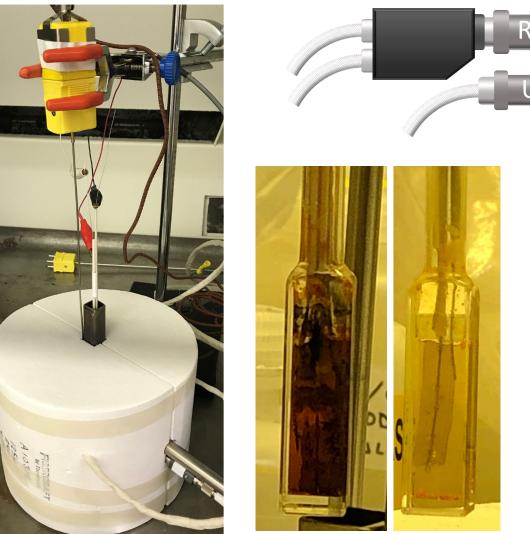
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Small scale

- Utilizing small scale setup
 - Cost effective
 - Time efficient
 - Translates well to anticipated response in larger scale probes
- Utilize

spectroelectrochemistry to control oxidation states and generate "pure" redox spectra Highly efficient scoping and fingerprint collection

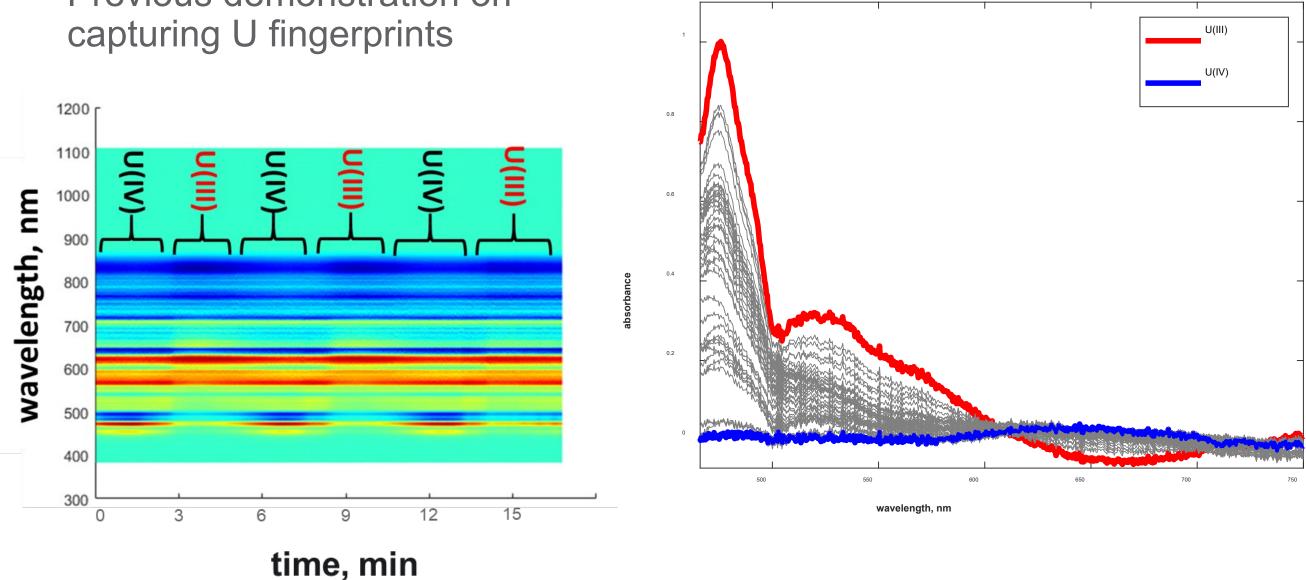




Cuvette Holder



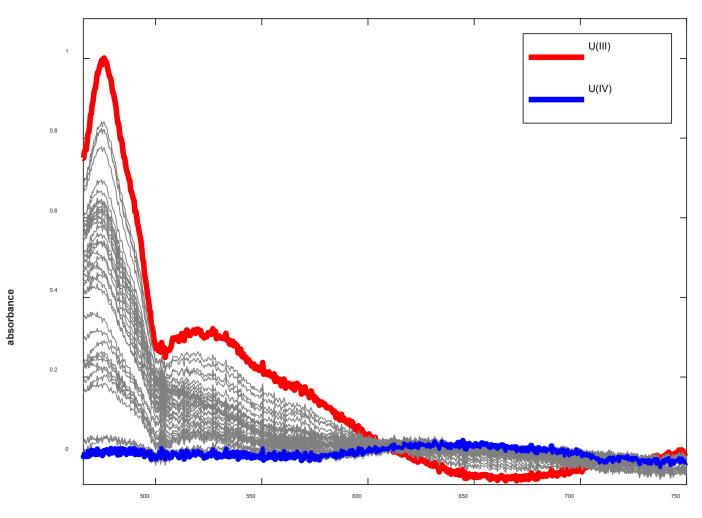
 Previous demonstration on capturing U fingerprints







- Previous demonstration on capturing U fingerprints
- Demonstrated need to improve atmospheric control
- Set initial FY21 focus on setting up inert containment



wavelength, nn





- Final set up of inert containment
- Box feed throughs (long pole of the tent) received and installed
- Furnace and external instrumentation set up











Recent Results Placeholder

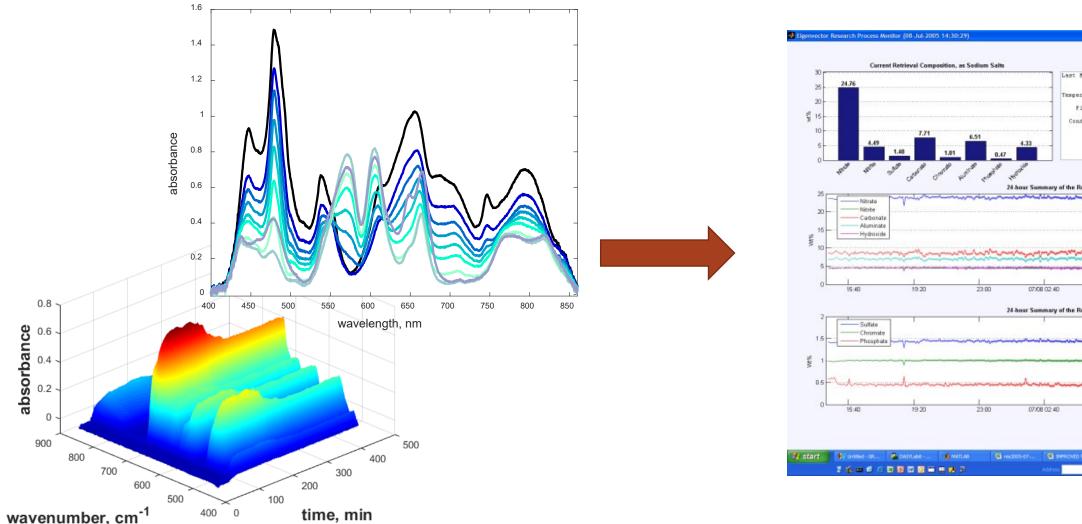




Next steps: Chemometric Modeling for Quantification

Data

Quantification Information

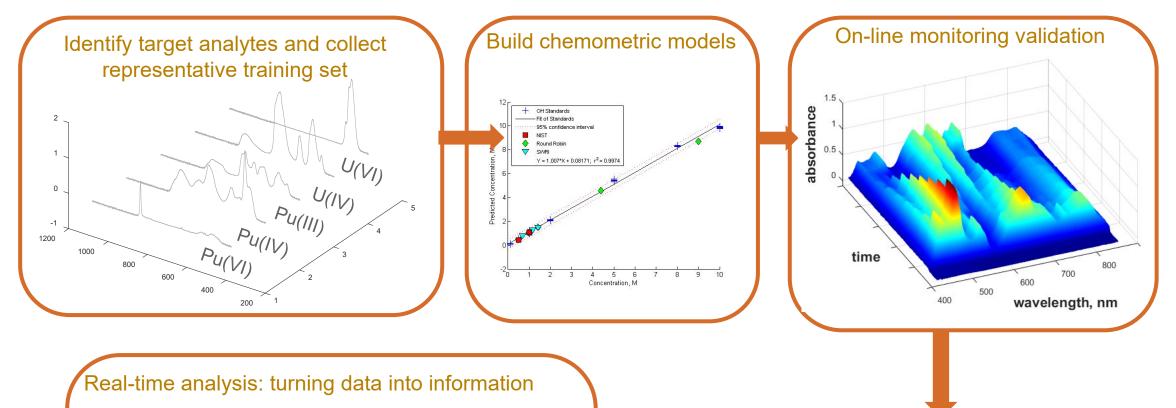


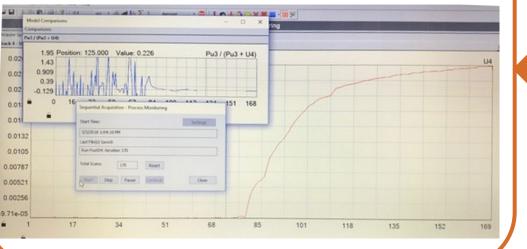
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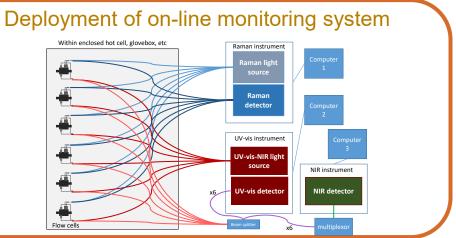
Analytical tool development: An overview of the approach

Pacific

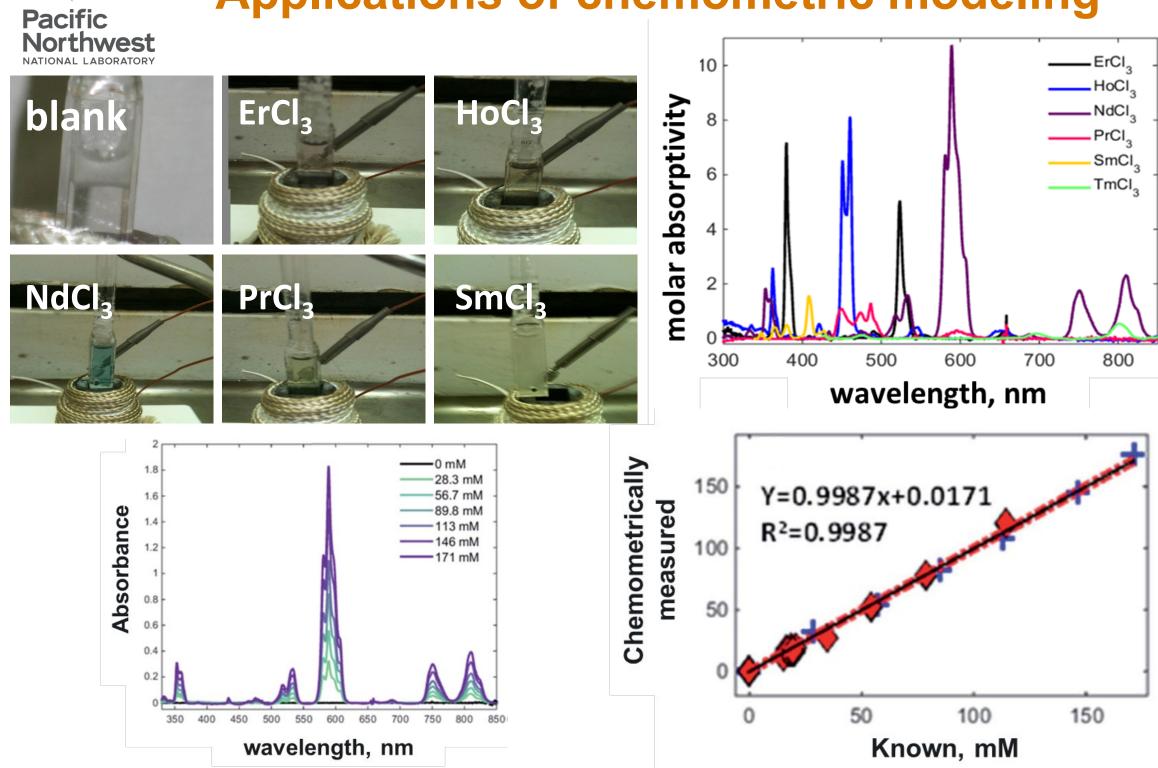
Northwest NATIONAL LABORATORY





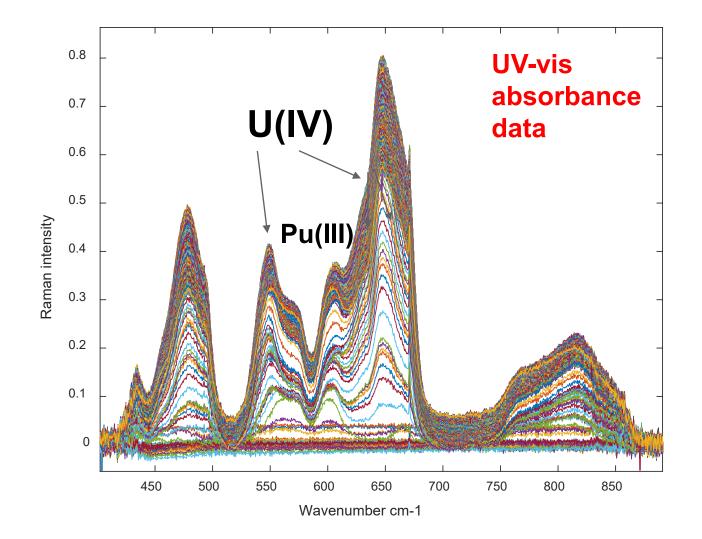






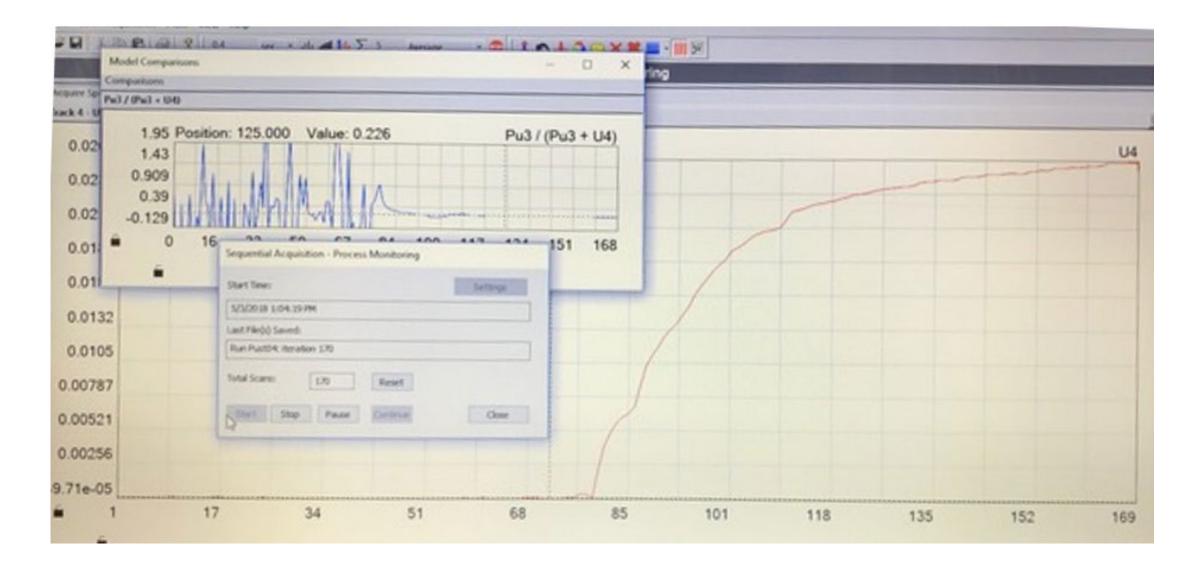
Schroll, Heineman, Lines, Bryan *Anal. Methods*, 2016,8, 7731-7738.





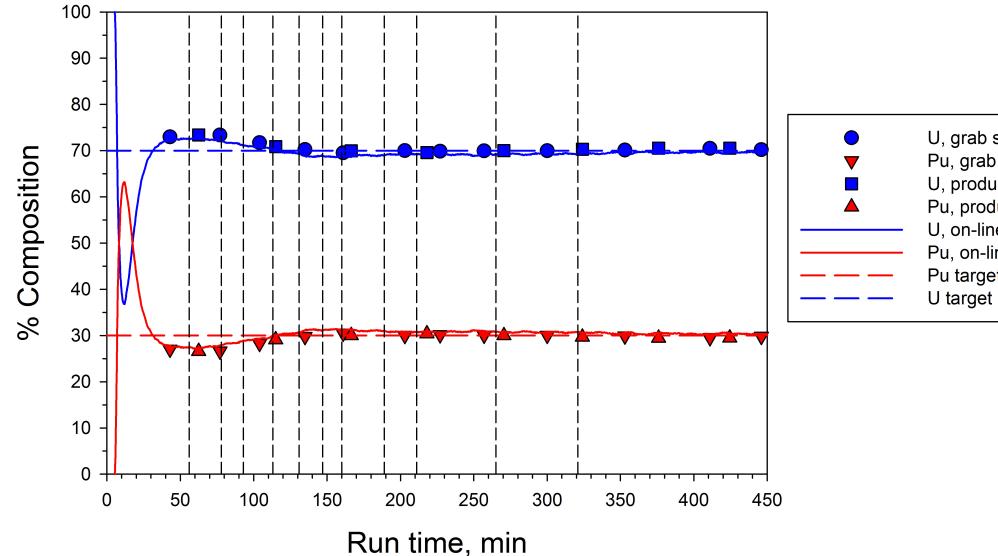








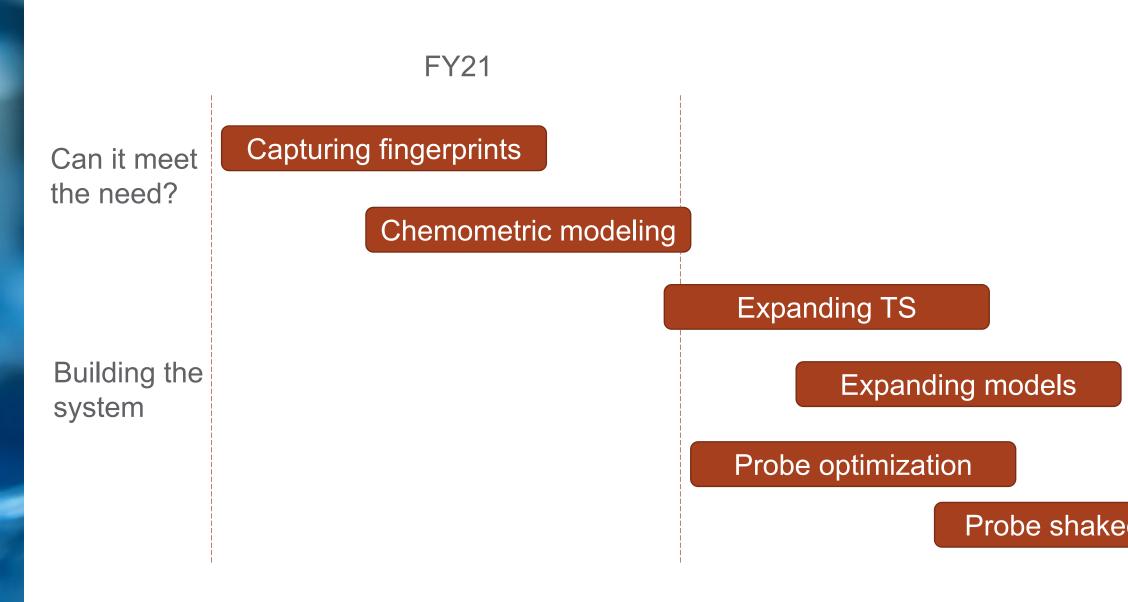






U, grab samples Pu, grab samples U, product bottles Pu, product bottles U, on-line monitor Pu, on-line monitor Pu target





Probe shakedown-loop integration



Key Takeaways

- On-line monitoring is a powerful route to gain *in situ* and real-time characterization of a system
 - Limits or eliminates need to collect grab samples
 - Limits or eliminates need to access closed, atmospheric controlled system
- Building the inline characterization tools can provide a pathway to maintain accountancy
 - Aiming towards approach that is less burdensome to operators
- Optical spectroscopy approaches can provide needed chemical information, and then some
 - Total U concentration
 - U redox ratios, speciation, etc
- PNNL is actively exploring the development, and ultimately commercialization, of these tools



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- PNNL LDRD programs







Thank you

