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On-Line Monitoring for MSR MC&A

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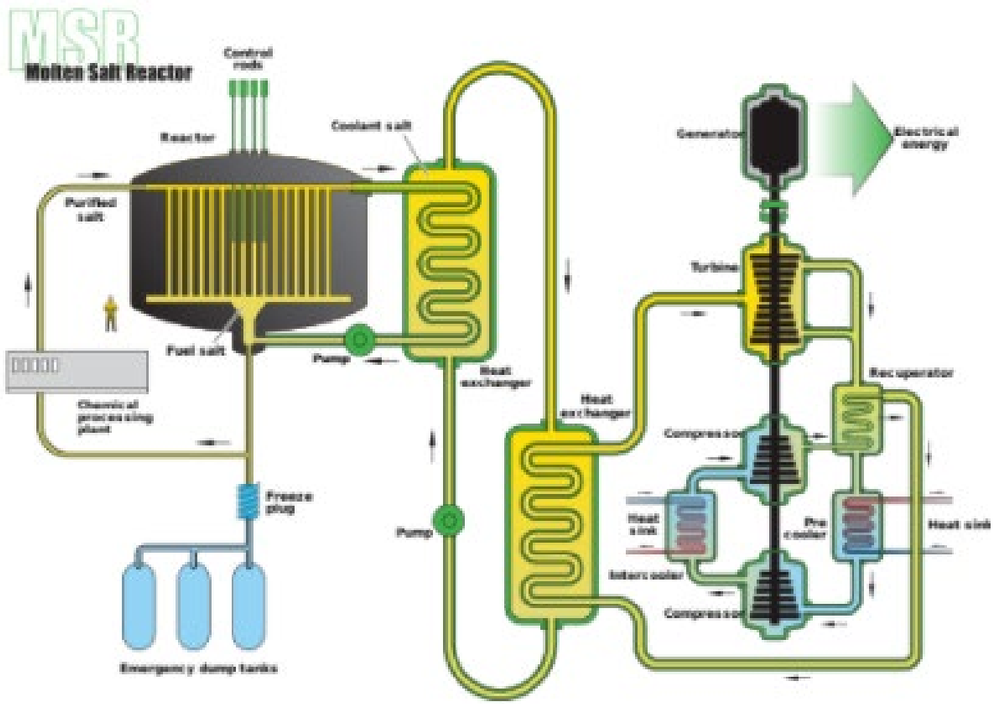
U.S. DEPARTMENT OF ENERGY BATTELLE

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

Motivation

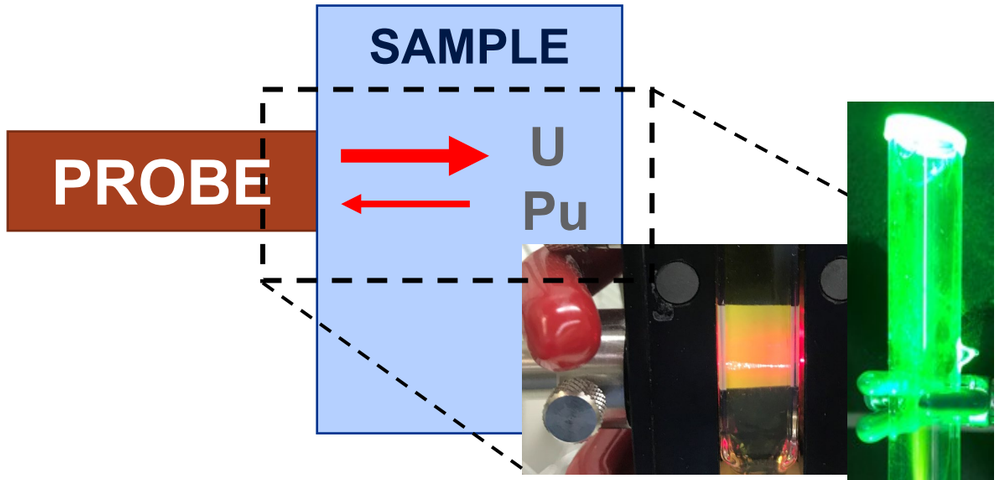
- MSR systems pose unique challenges to MC&A analysis
- Building robust capabilities for in-line analysis of the system could provide needed information without opening the system for grab sample collection
- **Provide needed information and measurement uncertainty for actinides and other key targets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

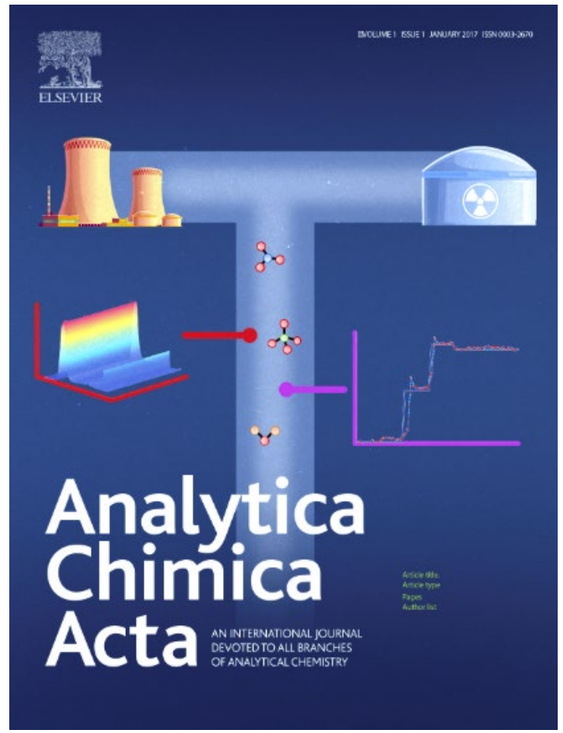


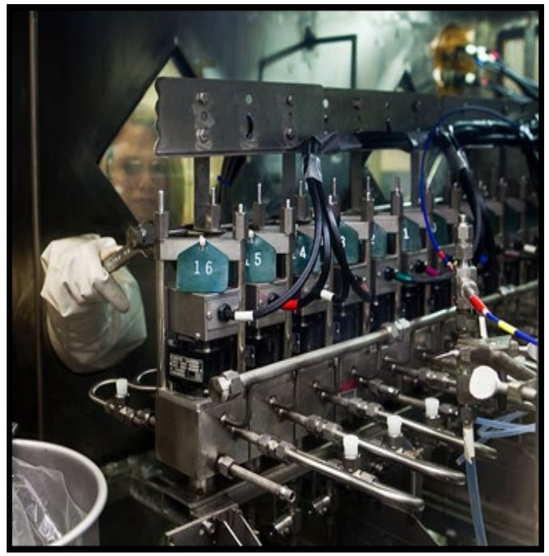
https://en.wikipedia.org/wiki/Molten_salt_reactor

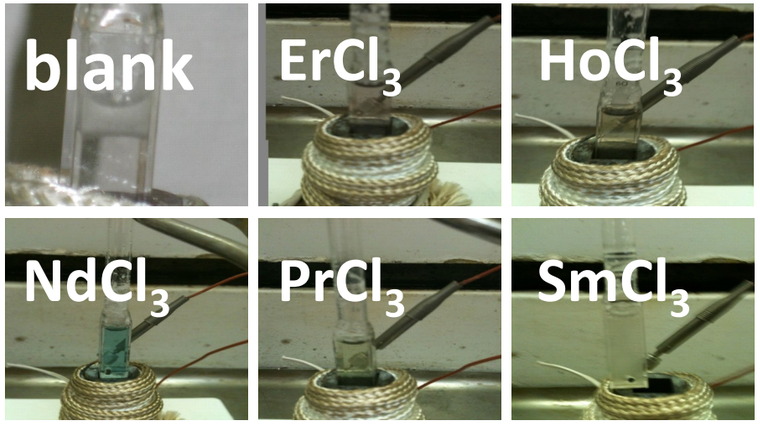
What On-line Monitoring Provides

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





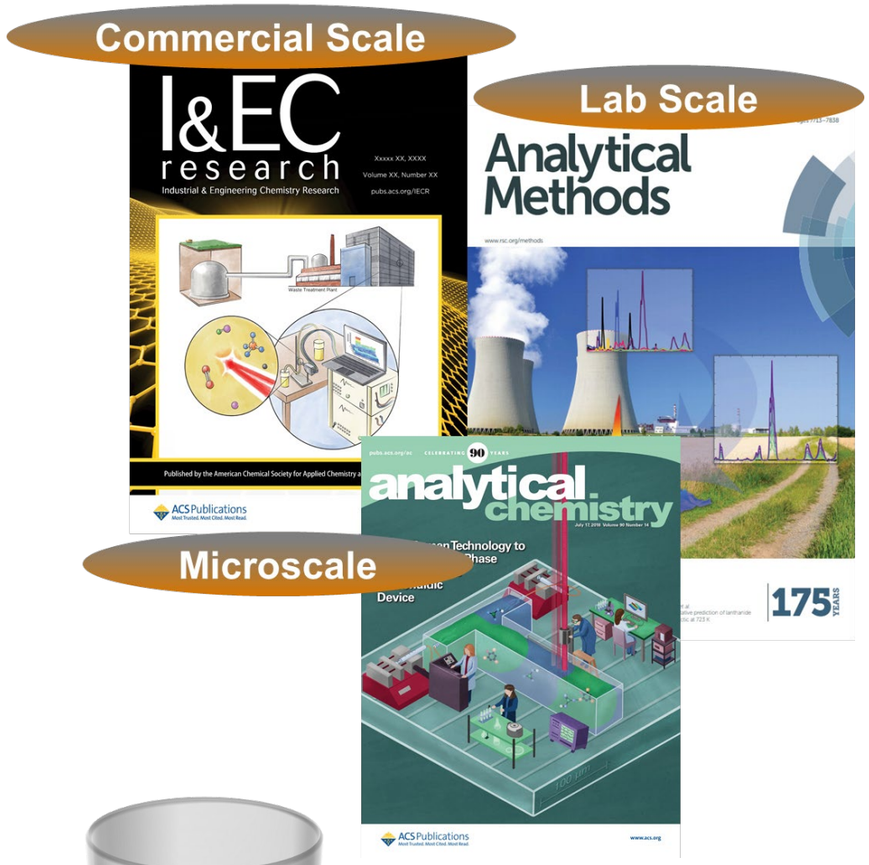




Tse, P., N.P. Bessen, S.A. Bryan, A. M. Lines, J.C. Shafer. "Review of On-line and Near Real Time Spectroscopic Monitoring of Processes Relevant to Nuclear Material Management" ***Analytica Chimica Acta***, 2020, 1107:1-13,

On-line Monitoring for Chemical Characterization: Optical Spectroscopy

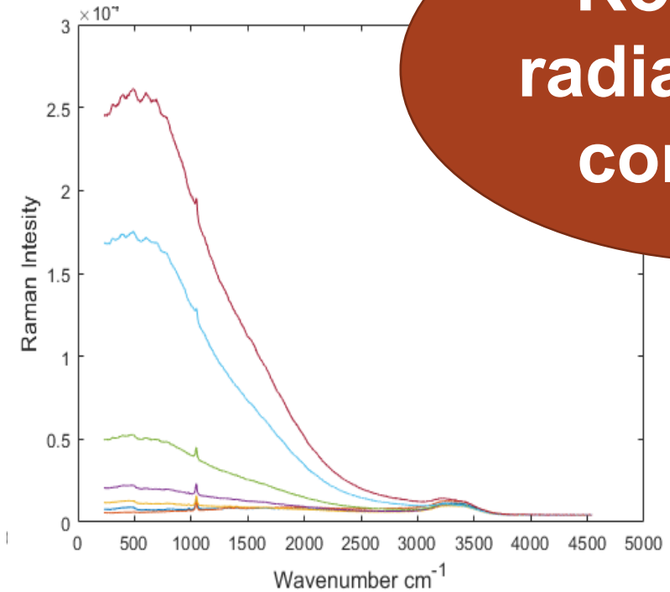
- Provides chemical information
  - Identification and quantification
  - Oxidation State
    - Essential information for control of systems
  - Molecular and elemental species
    - Essential information to understand/control separation efficiency or general system behavior
- Fast
- Robust
- Versatile

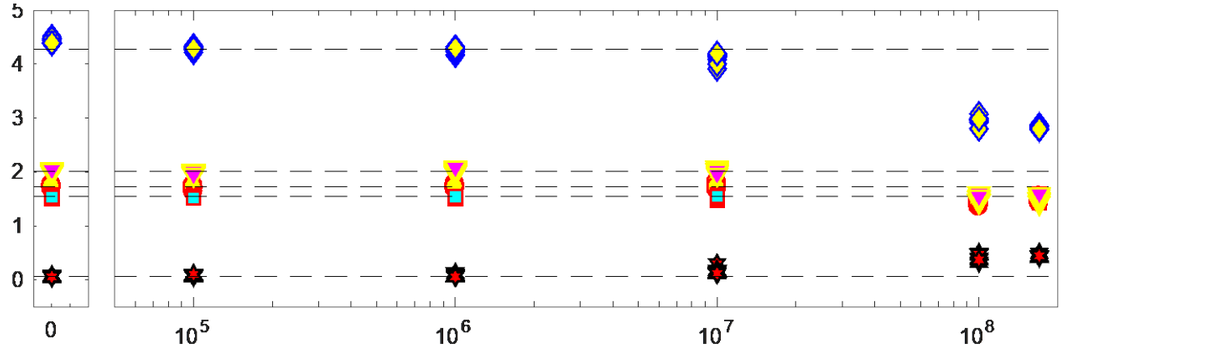


Robust and Mature Capability

Mature technology

Robust to radiation and corrosion

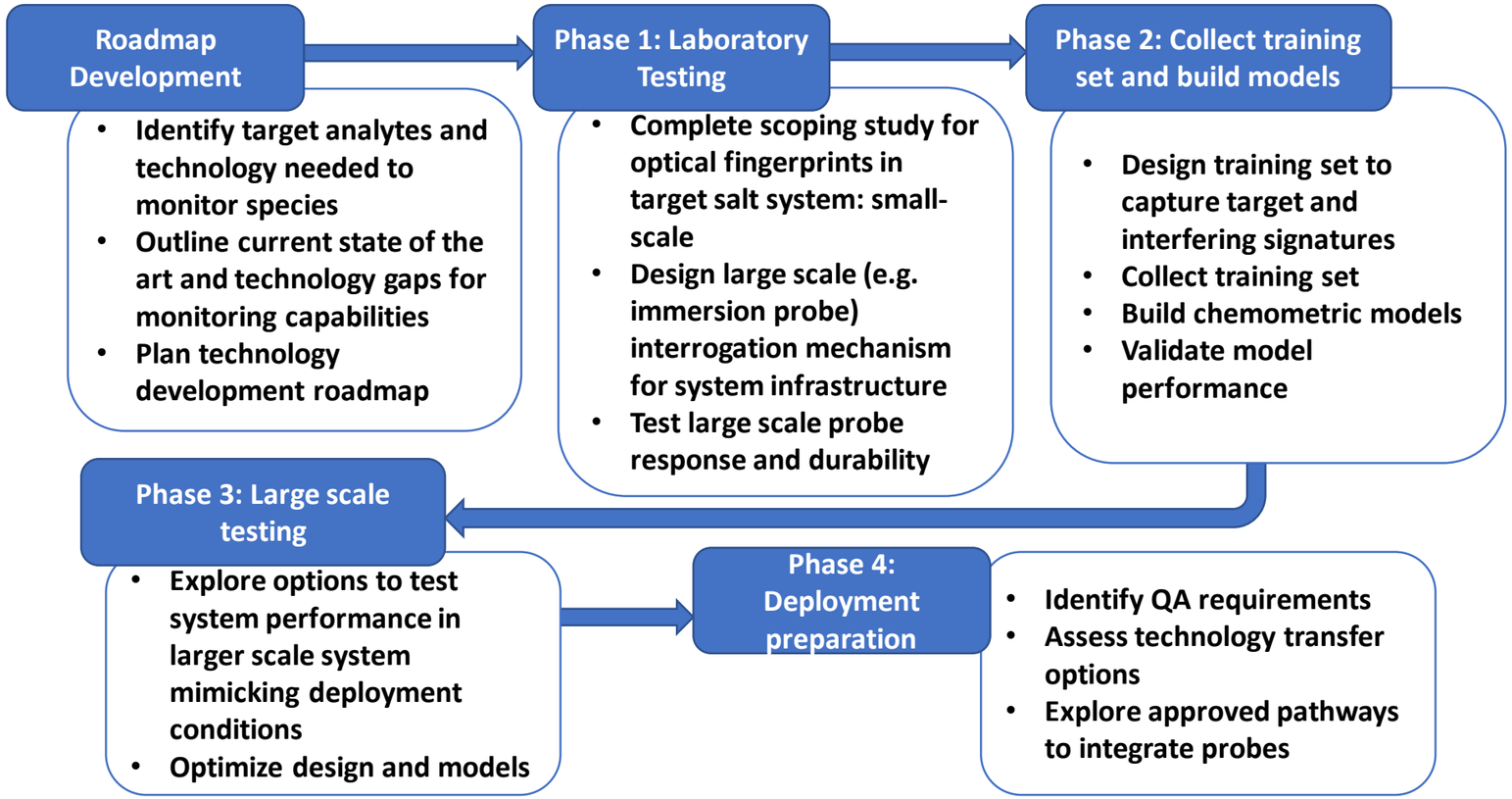




applied dose, Rad

Identifying Needed Areas of Development

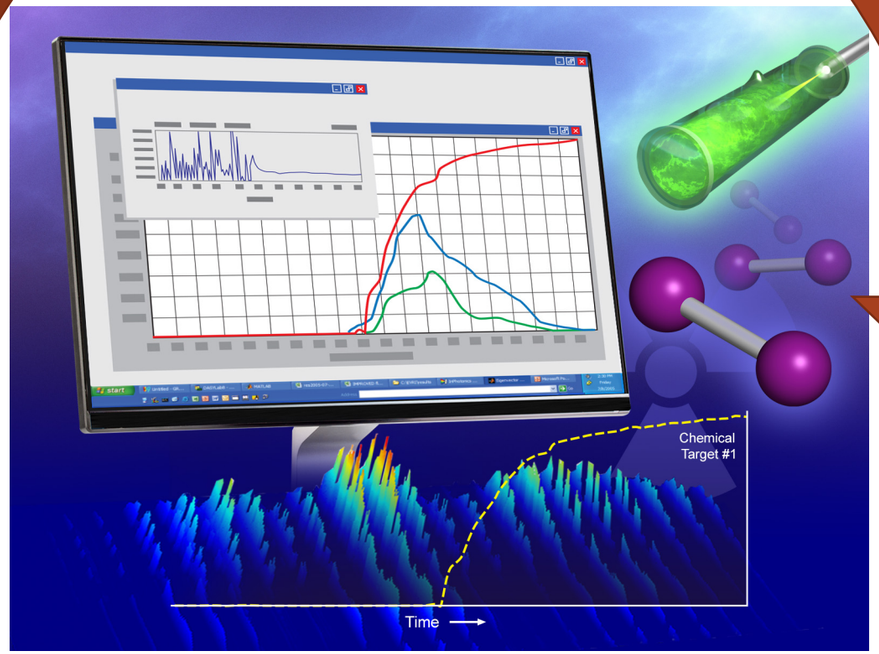
- FY20 focus outlined advancement needs
  - Outline of current state of the art
  - Roadmap
- Informed key steps for FY21



Two Areas of Development Identified in Roadmap

1

Data



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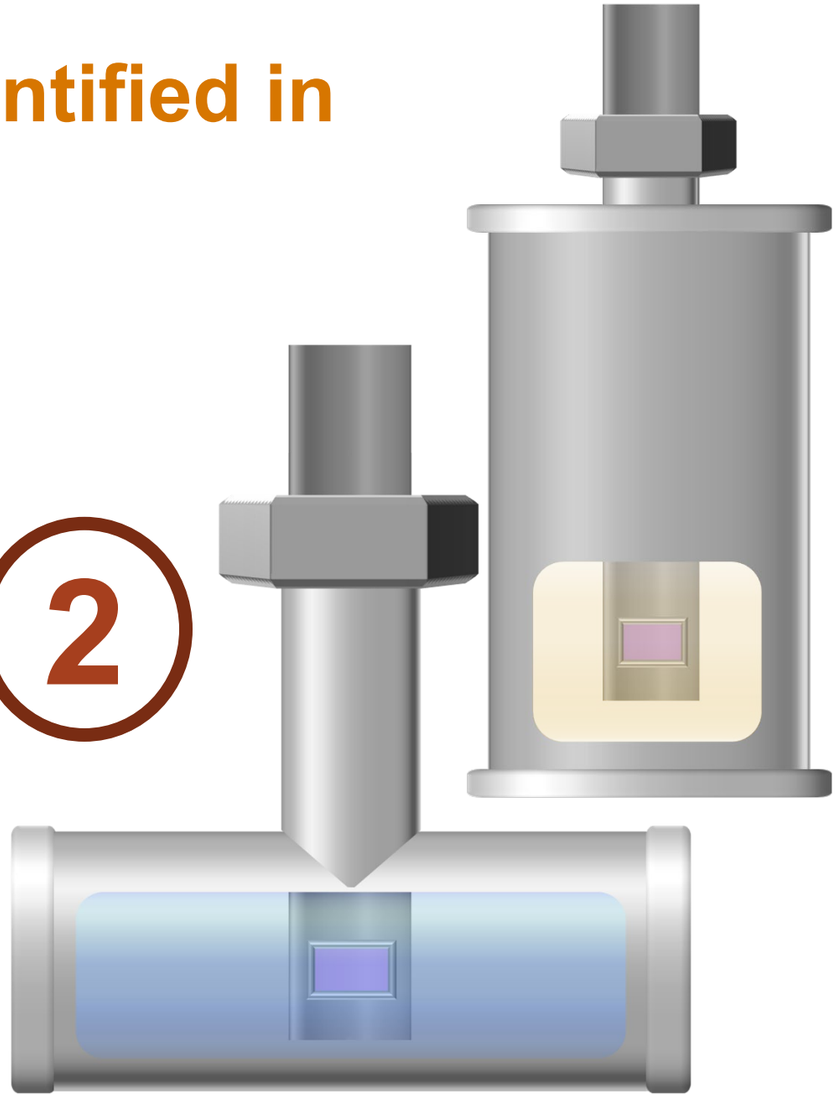


Information

FY21 progress:
A Focus on Data Analysis

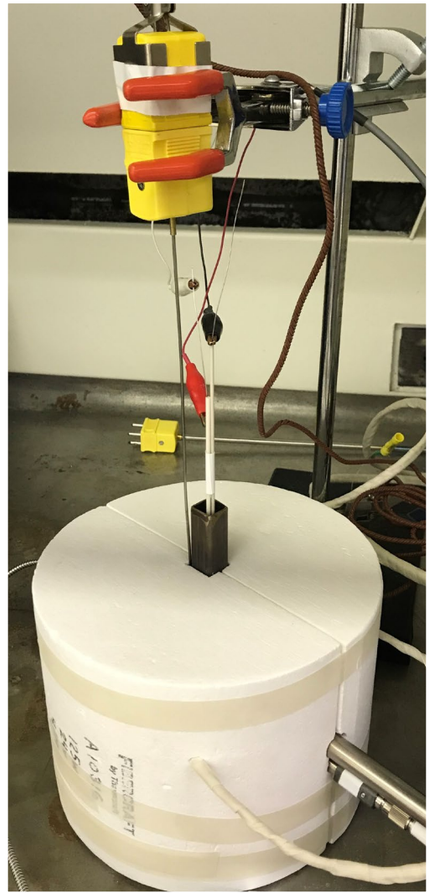
- Demonstration of ability to capture representative target fingerprints
- Exploration of relationship between signal and target concentrations
- Outlining value of approach while continuing to track developing needs

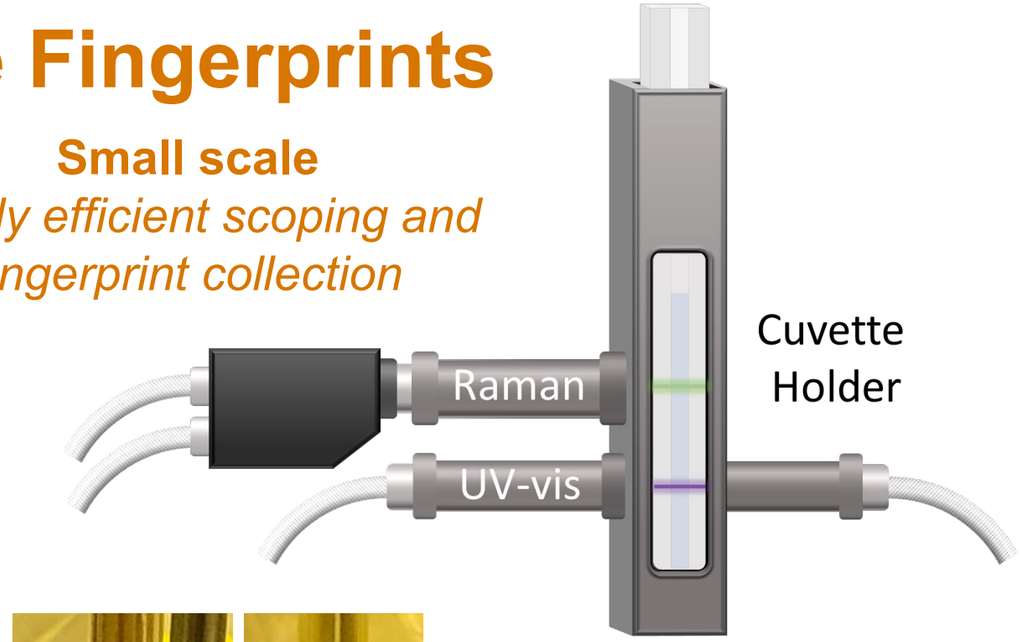
Capturing Representative Fingerprints

- 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

Small scale

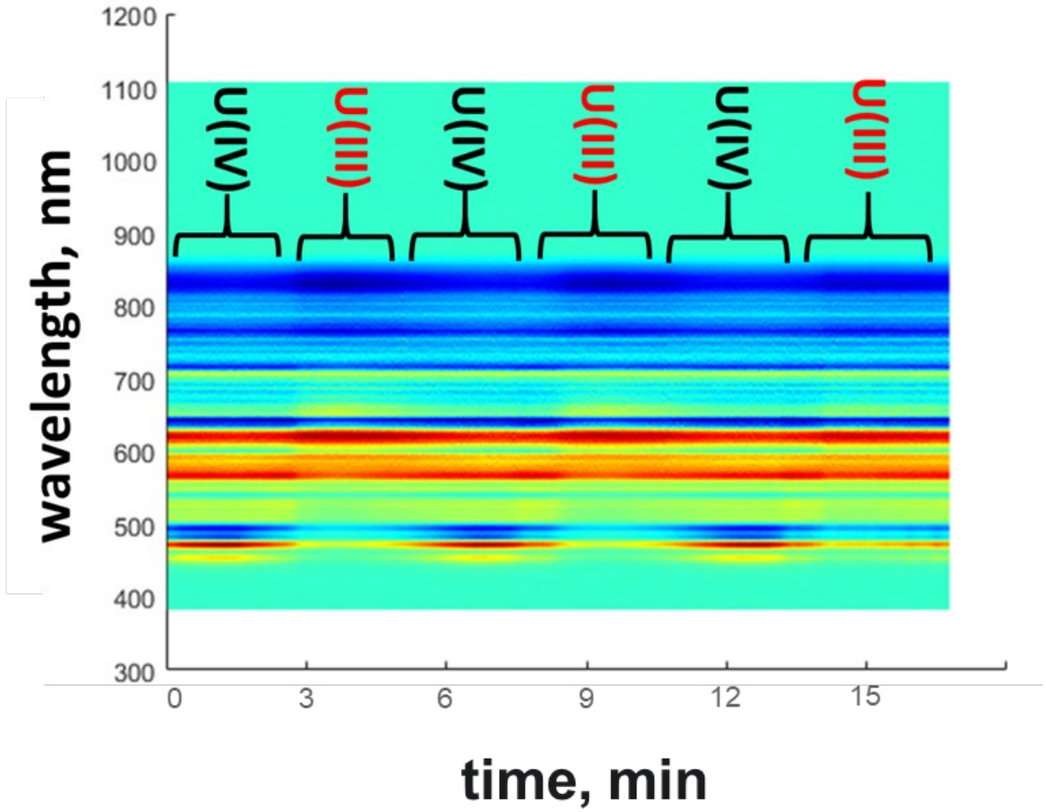
Highly efficient scoping and fingerprint collection

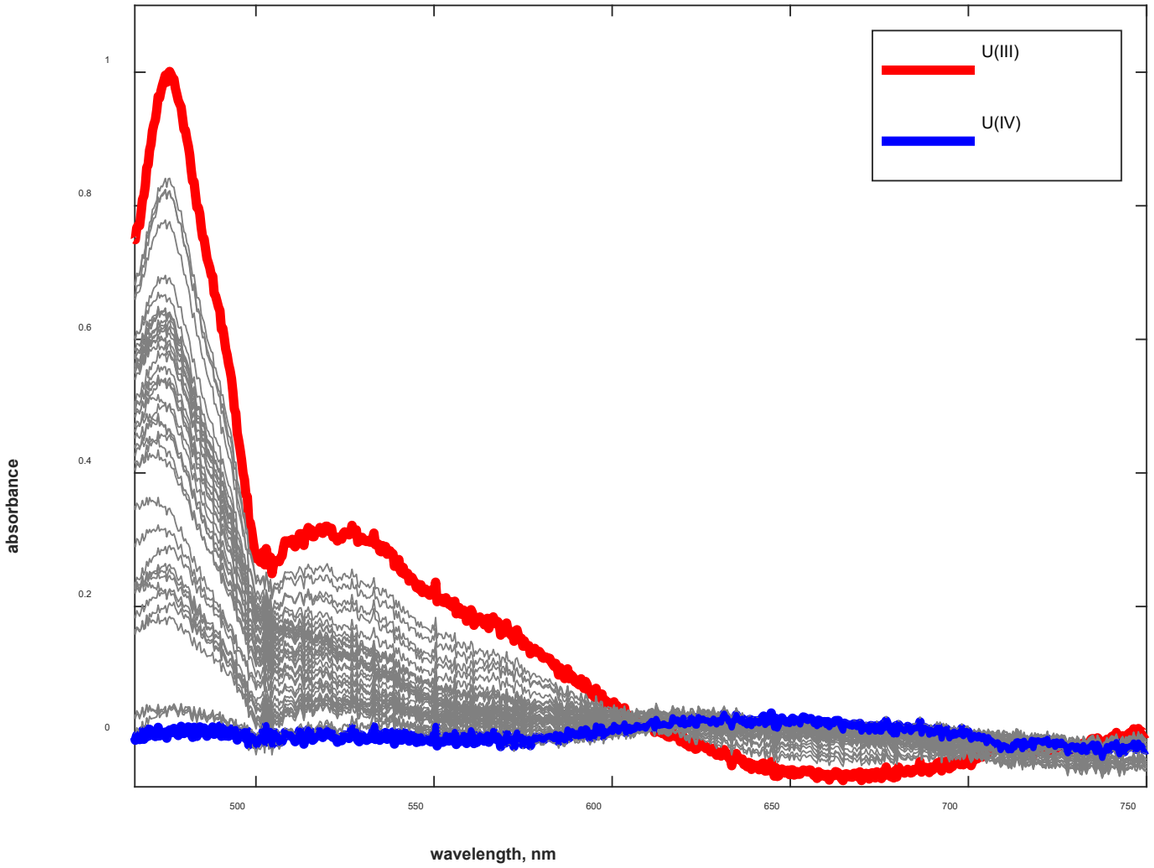




Capturing Representative Fingerprints

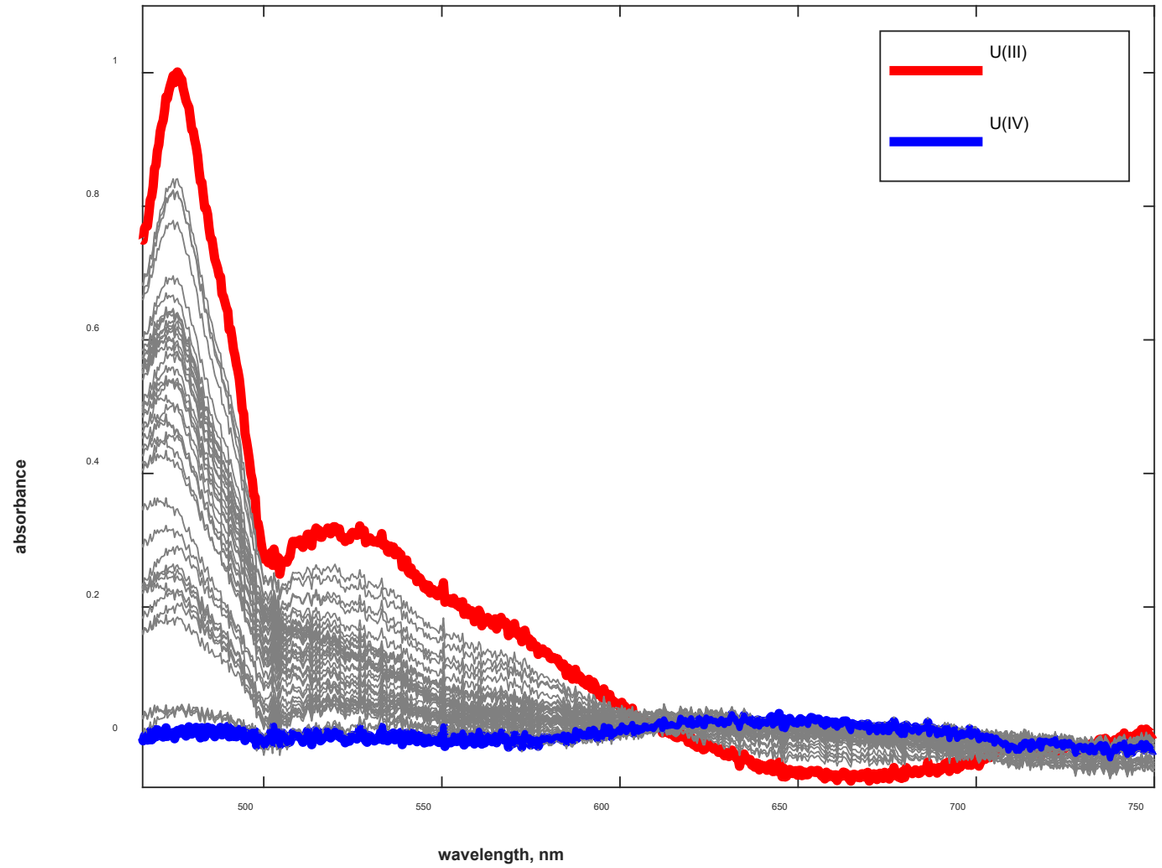
- Previous demonstration on capturing U fingerprints





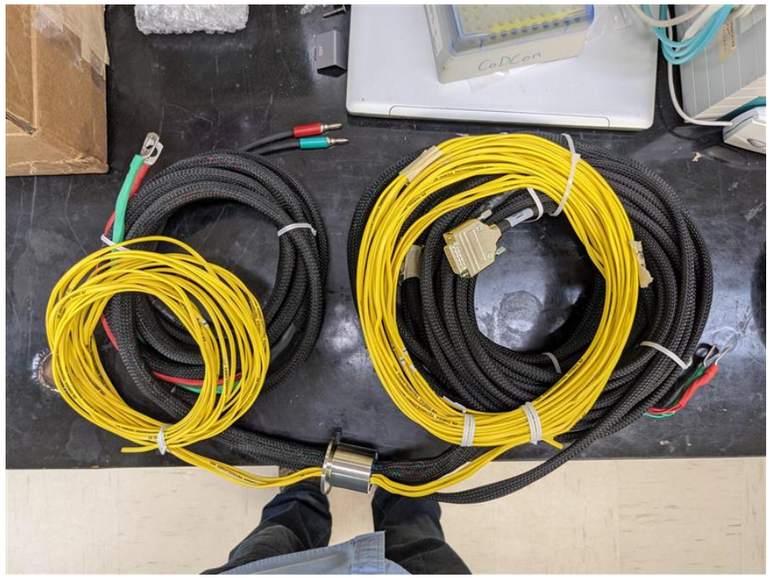
Capturing Representative Fingerprints

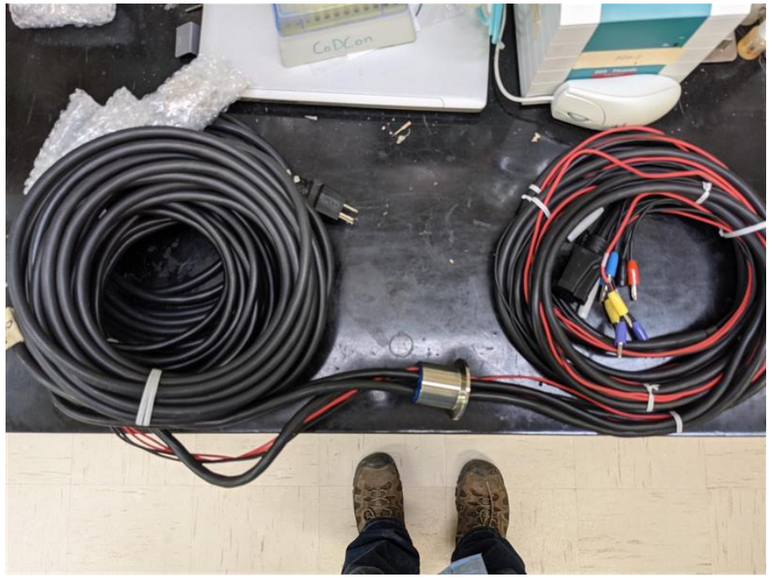
- Previous demonstration on capturing U fingerprints
- Demonstrated need to improve atmospheric control
- Set initial FY21 focus on setting up inert containment



Capturing Representative Fingerprints

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



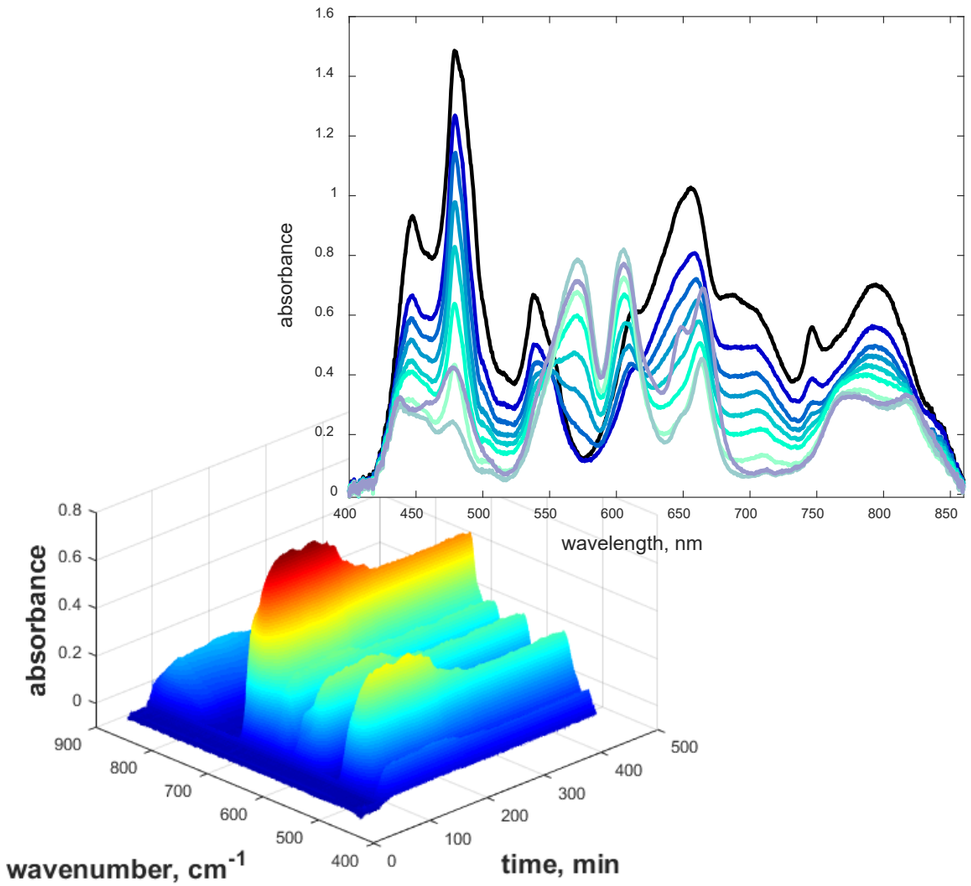


Capturing Representative Fingerprints

Recent Results Placeholder

Next steps:
Chemometric Modeling for Quantification

Data



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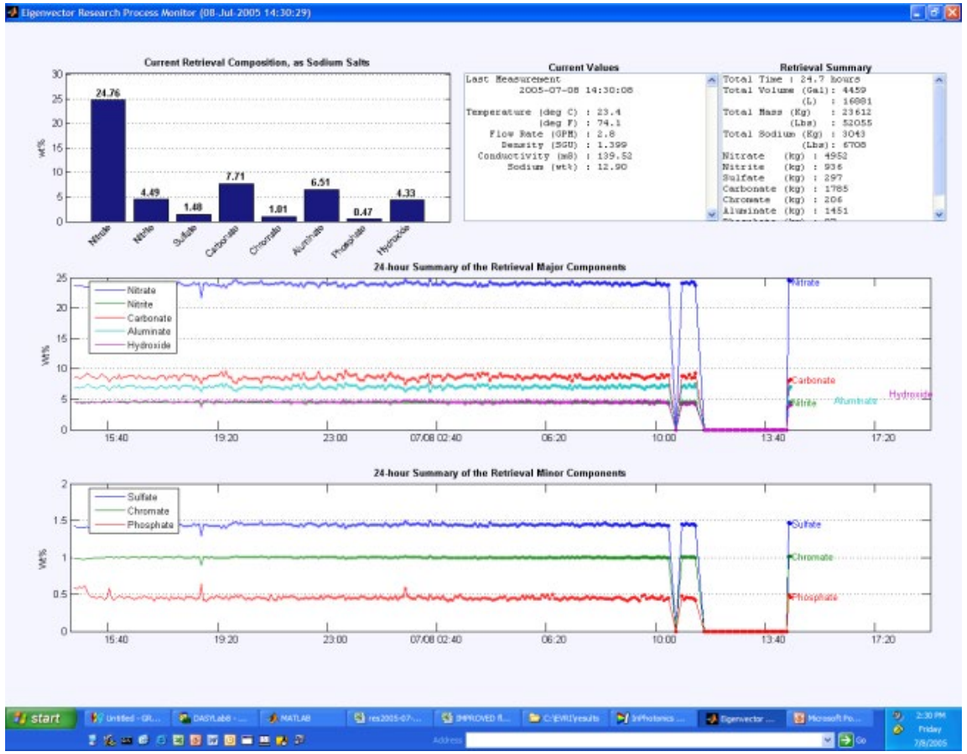
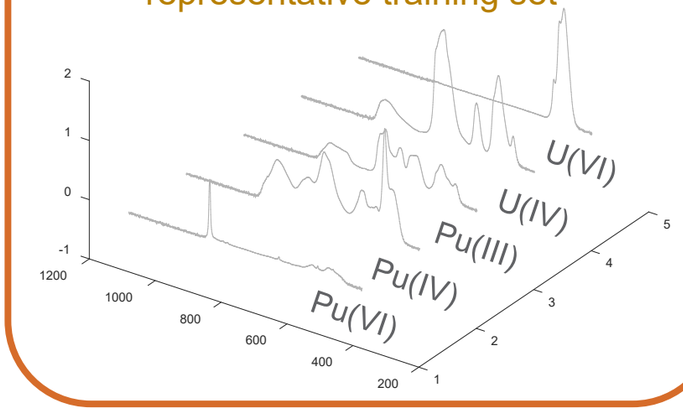
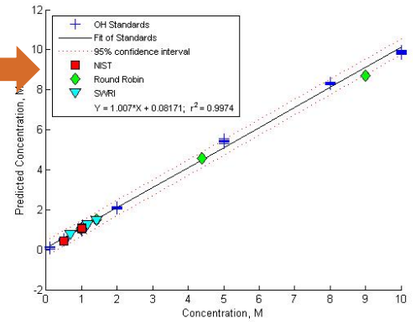


Analytical tool development: An overview of the approach

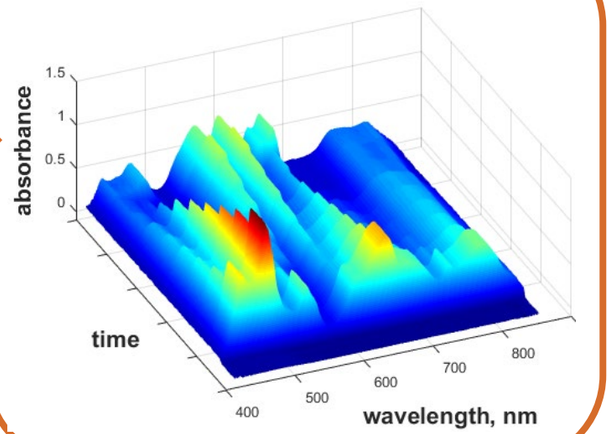
Identify target analytes and collect representative training set



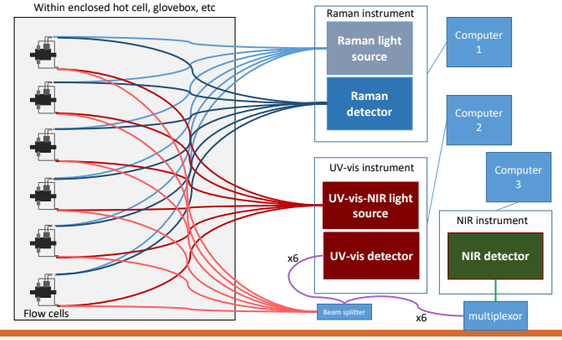
Build chemometric models



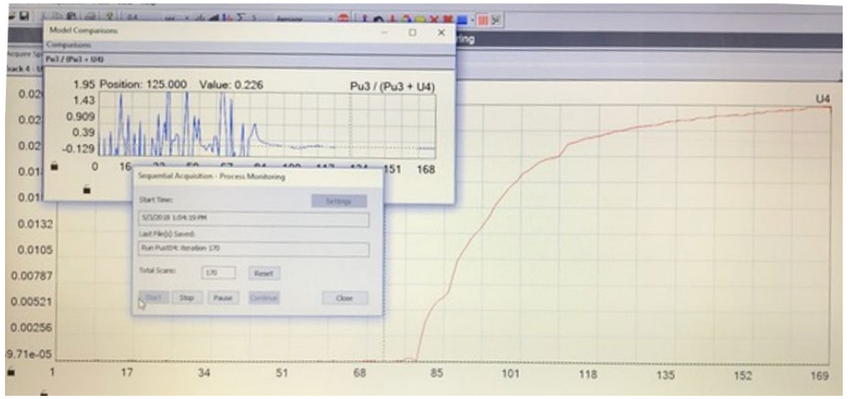
On-line monitoring validation



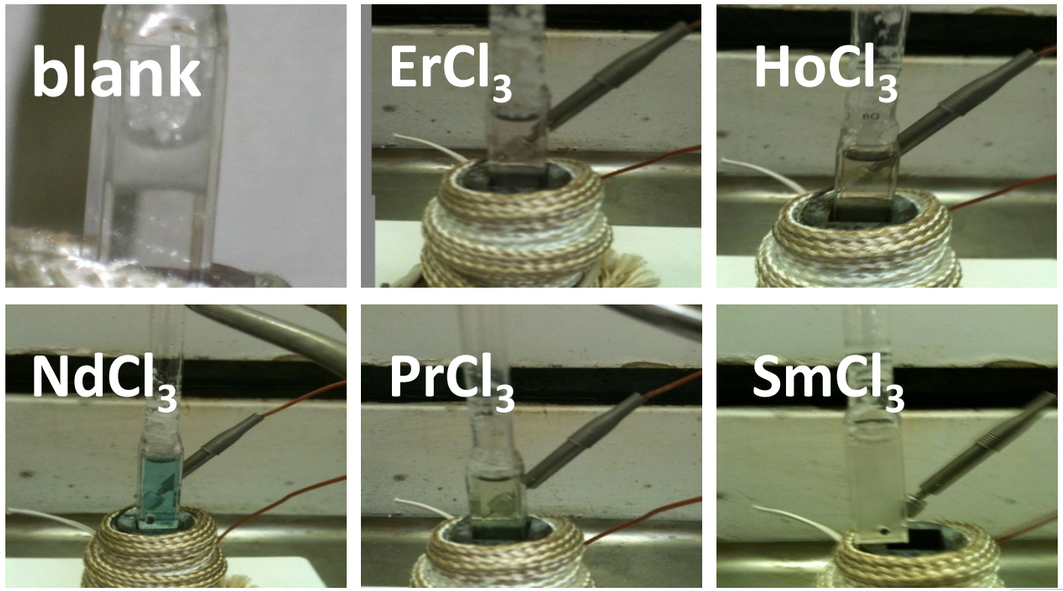
Deployment of on-line monitoring system

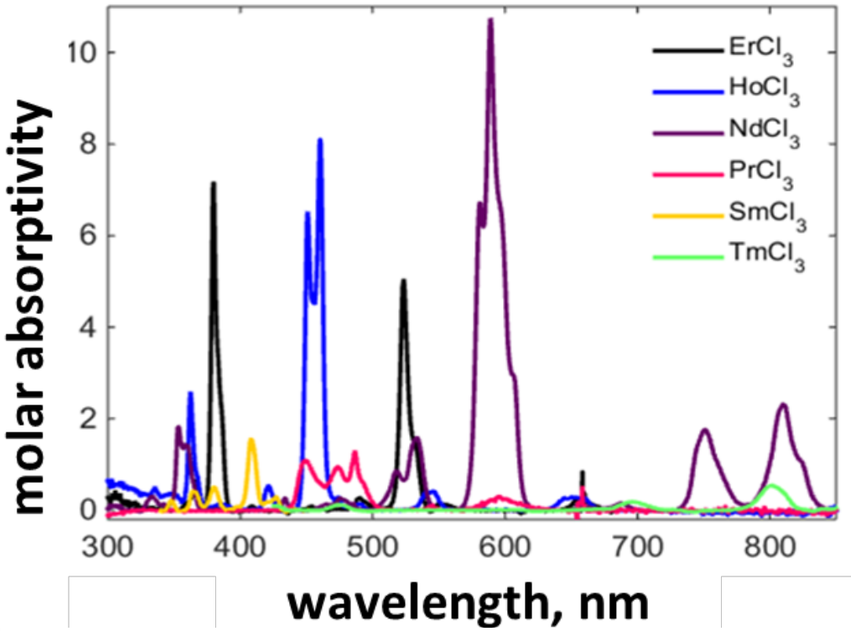


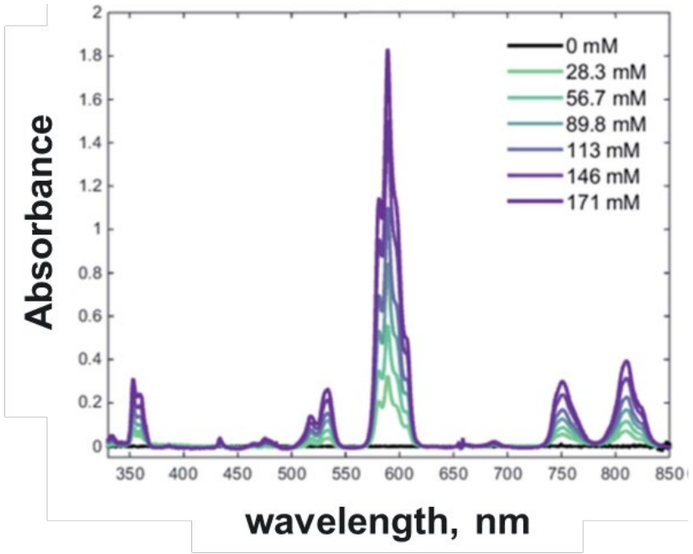
Real-time analysis: turning data into information

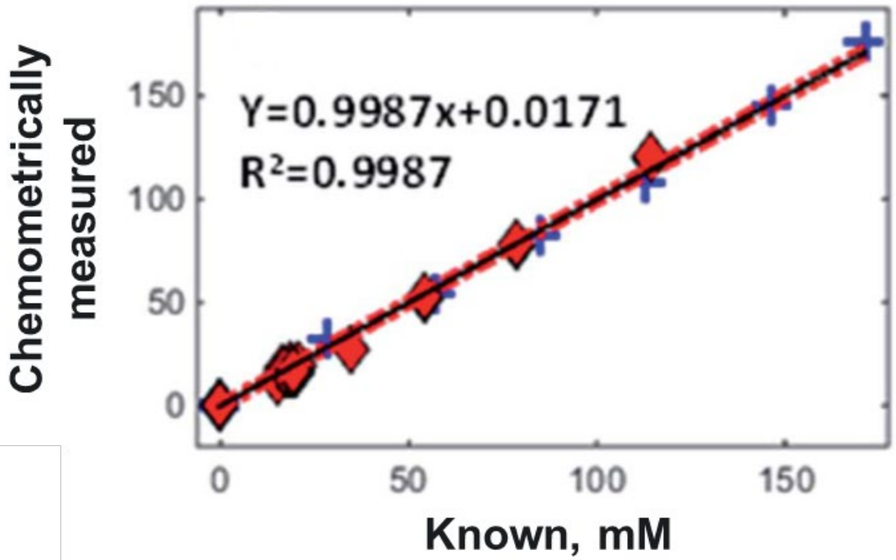


Analytical tool development: Applications of chemometric modeling









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

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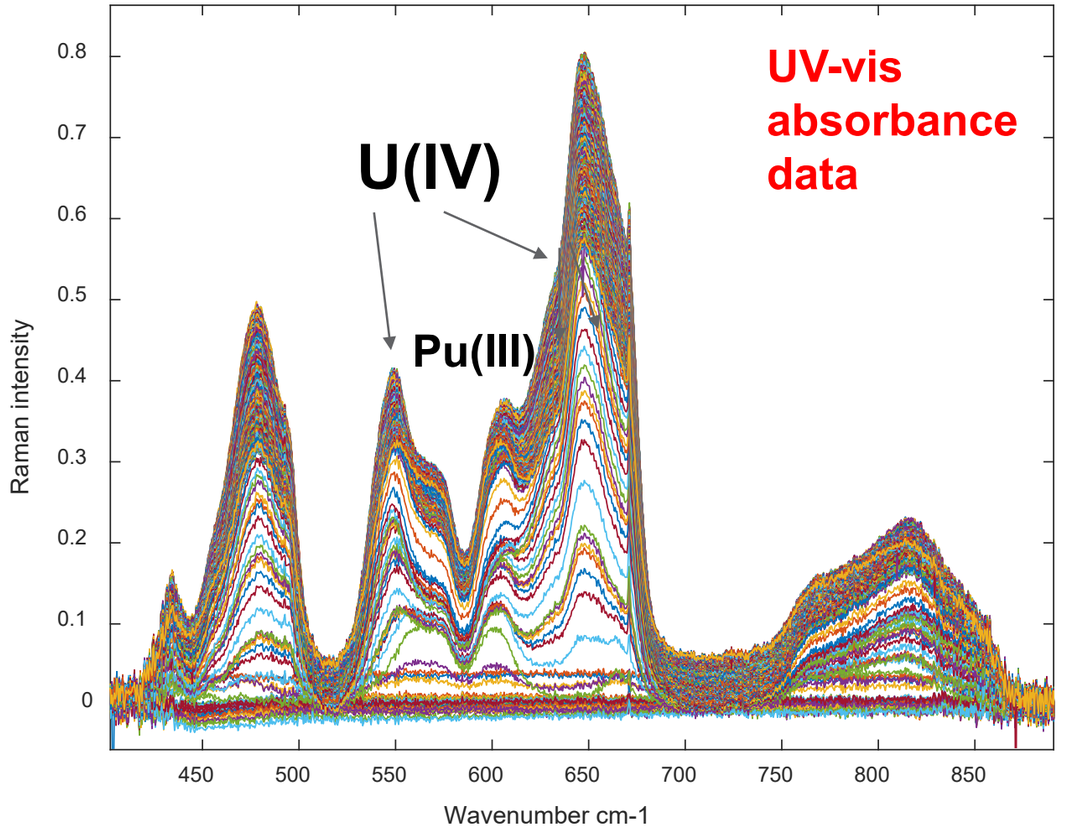

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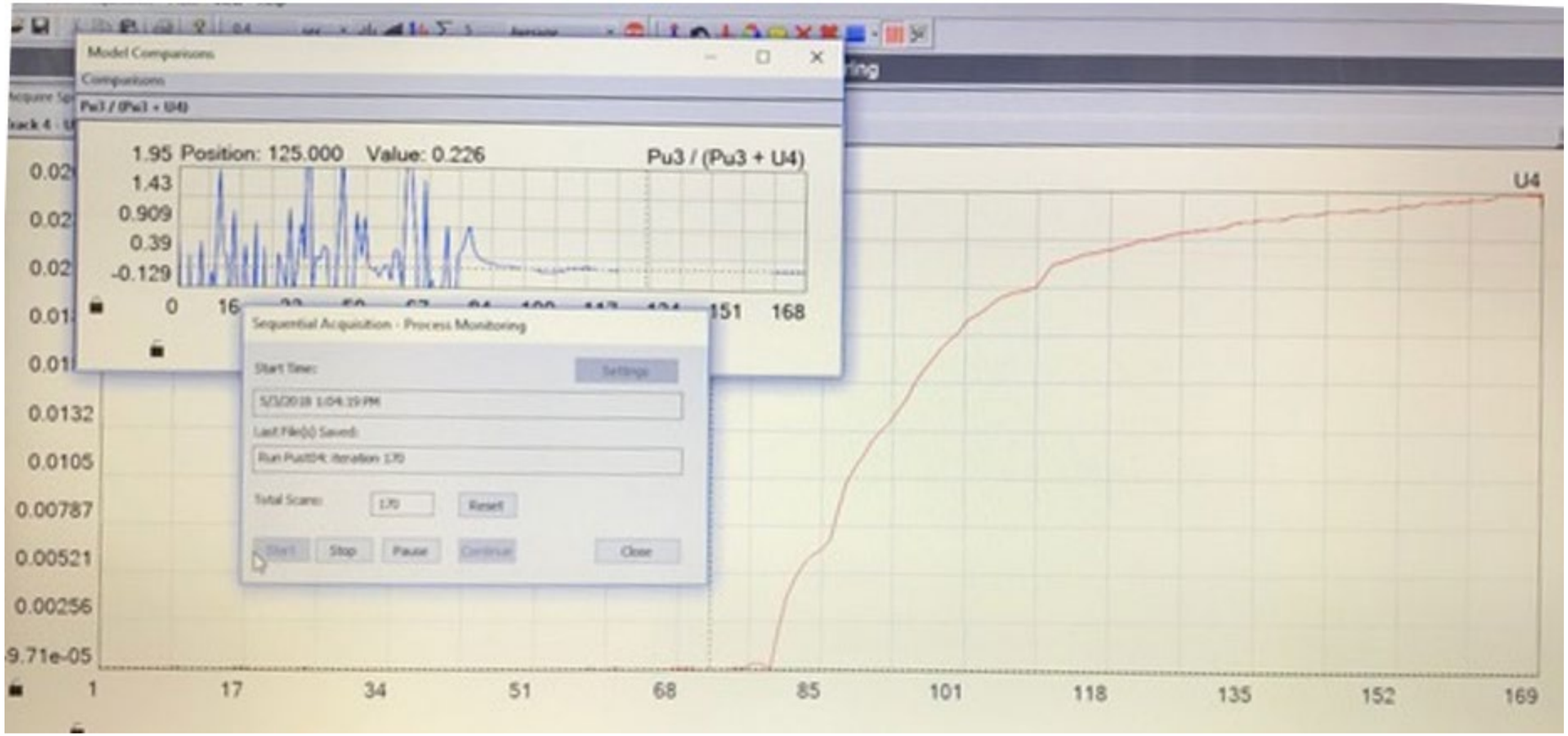

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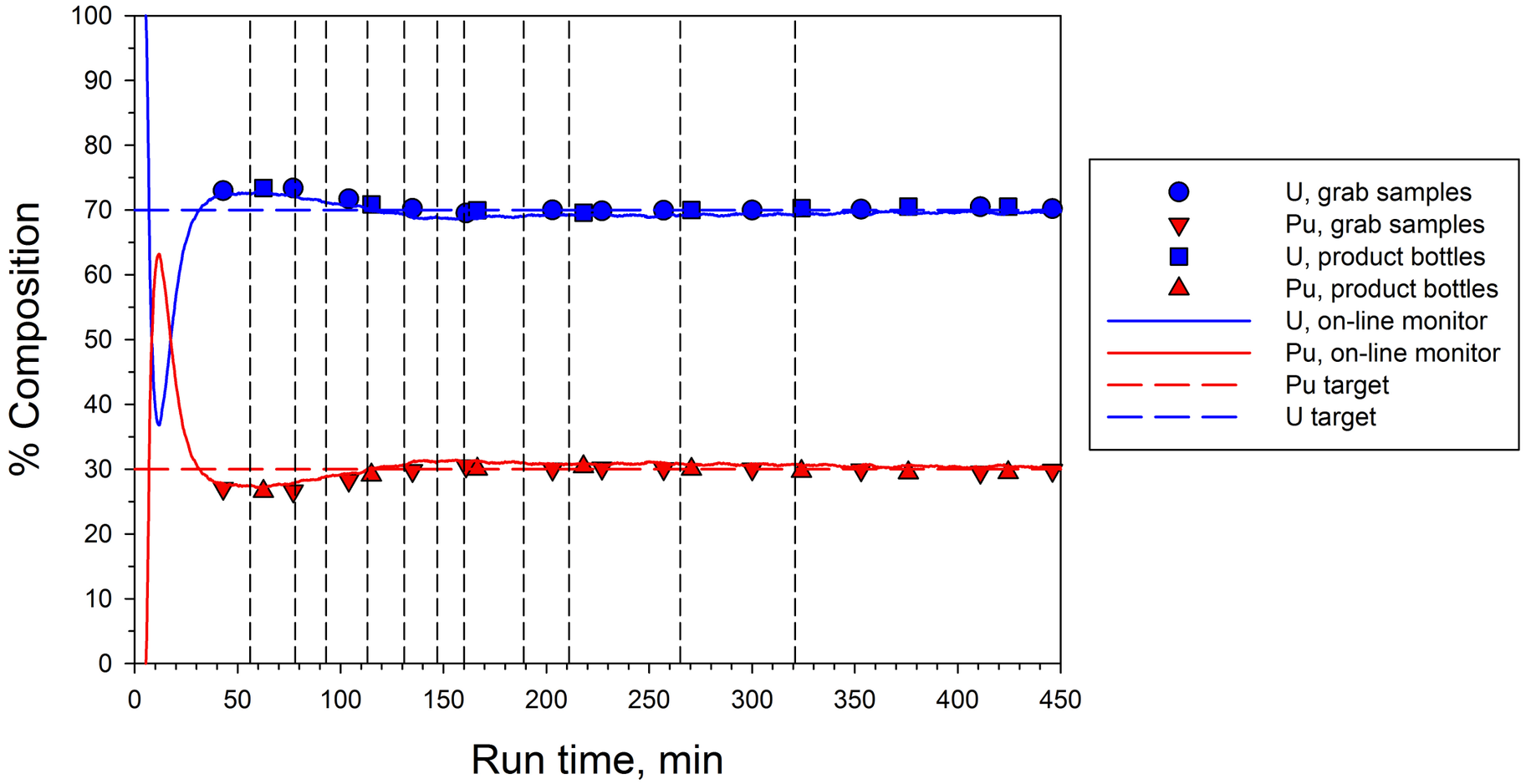
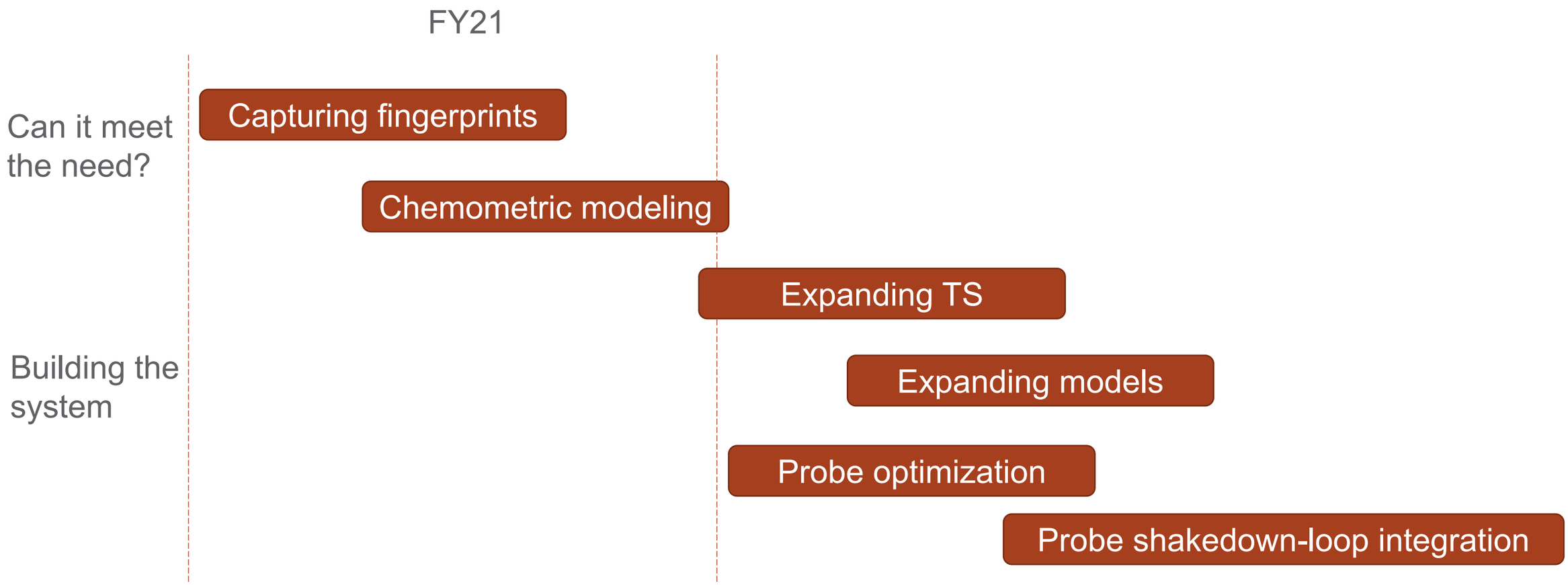


CoDCon Run3.JNB

Target timeline



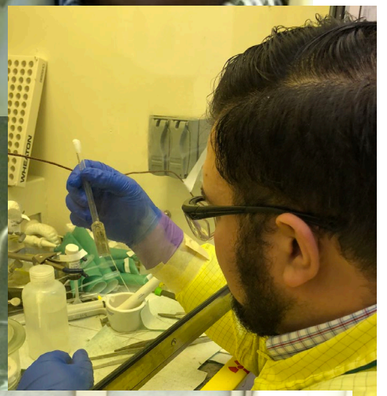
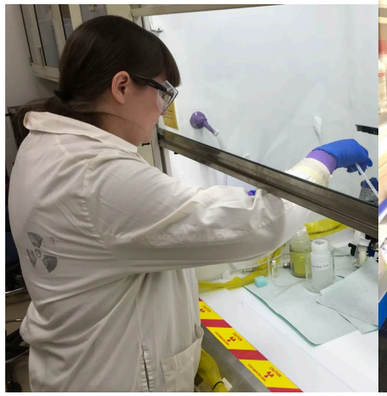
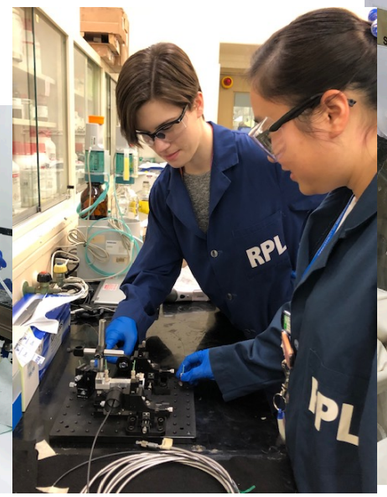
Key Takeaways

- 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

Acknowledgements

- U.S. Department of Energy, Office of Nuclear Energy
- Small Business Innovative Research (SBIR) Grant, Office of Science (SC); collaboration with Spectra Solutions Inc.
- PNNL LDRD programs

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Thank you