



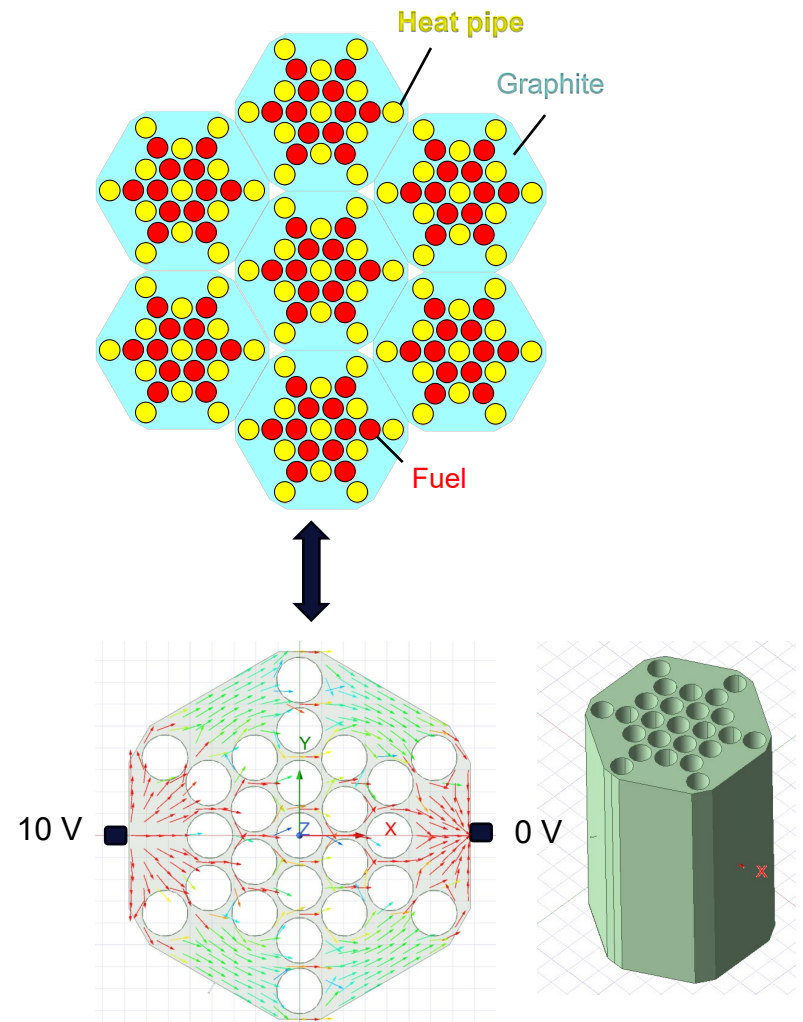
# Non-Visual Techniques for Monitoring Microreactor Components

3-5 March, 2026

**Daniel C. Sweeney**, Anant Raj, Brandon Schreiber,  
Pradeep Ramuhalli, Christian M. Petrie

# Electrical Impedance Tomography for Defect Monitoring in Graphite for Microreactors

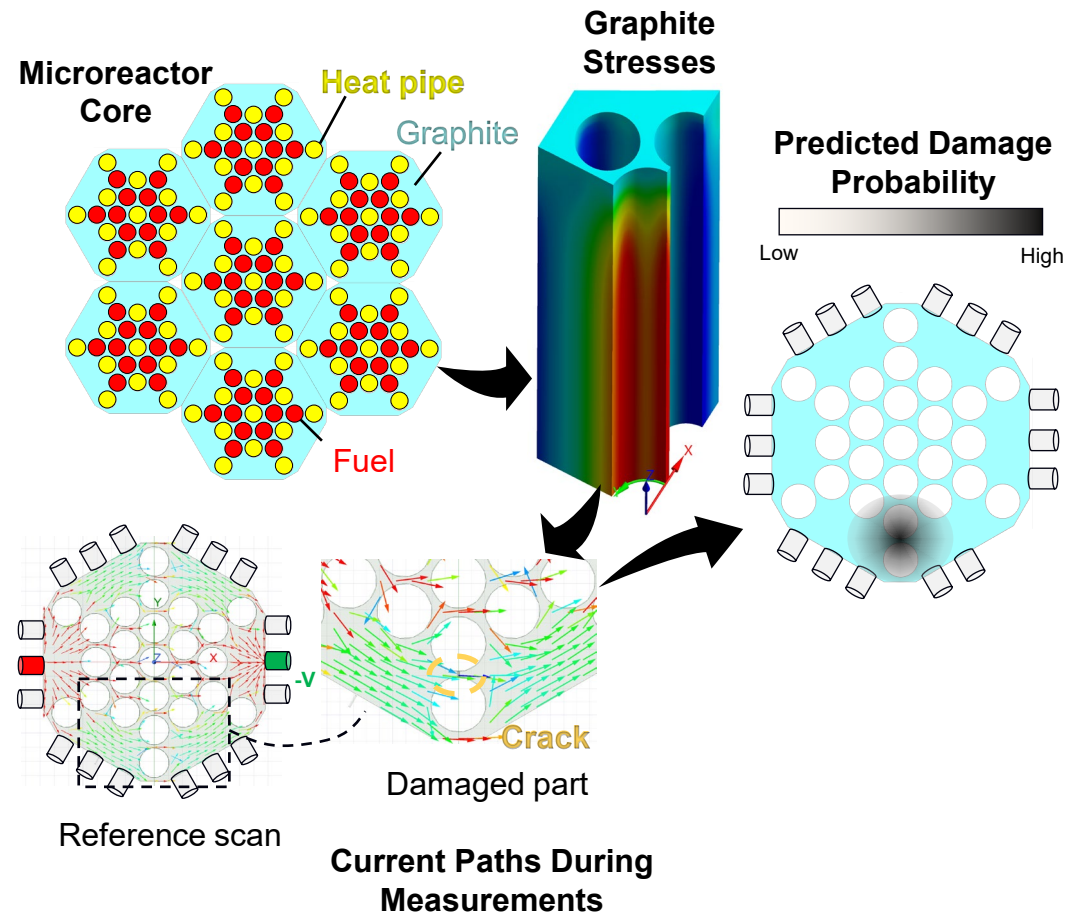
Anant Raj, Brandon Schreiber,  
Pradeep Ramuhalli and Christian M.  
Petrie



(Note: Microreactor design is fictional)

# Localizing damage in graphite microreactor components using models

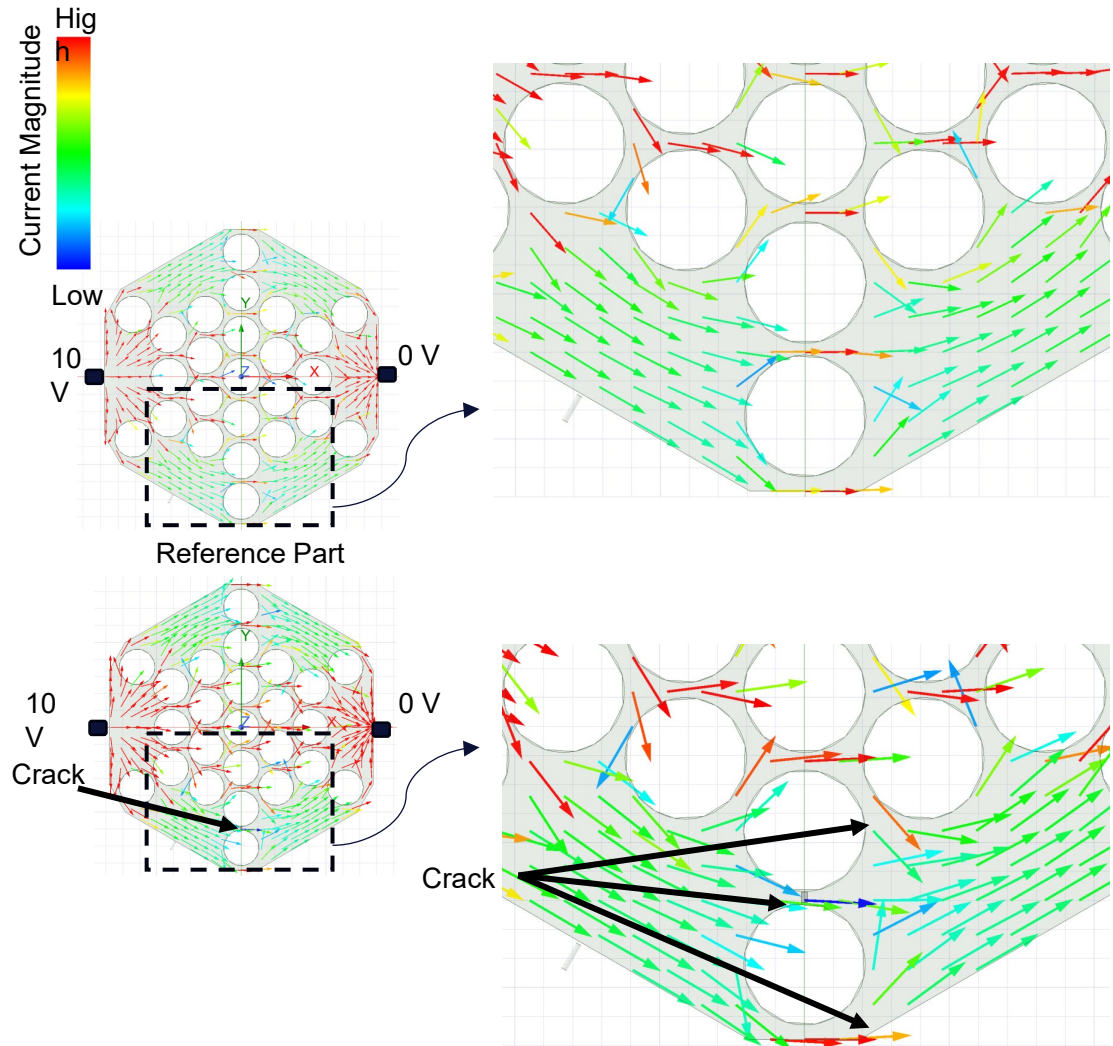
- Electrical impedance tomography (EIT) utilizes boundary measurements to infer internal condition
- Finite element methods (FEM) solve **inverse problems** to identify damaged location based on measured impedances
- **Goal:** Non-destructive evaluation (NDE) technique to identify damaged components during outages



(Note: Microreactor design is fictional)

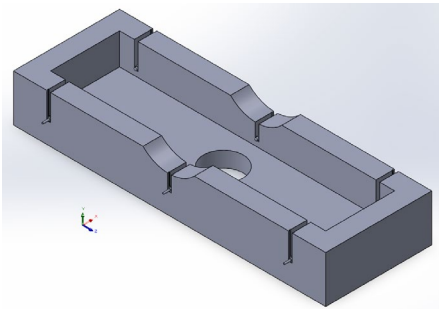
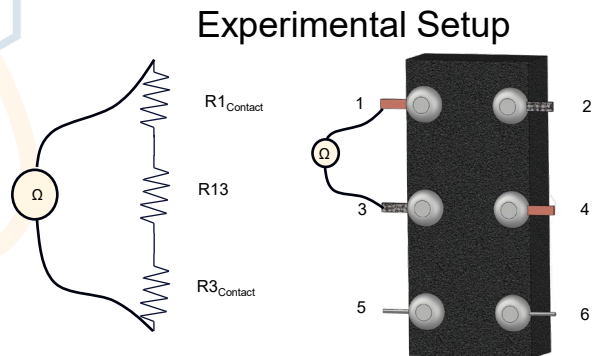
# Crack redirects the current through alternate routes via adjacent slots

- Cracking decreases heat transfer pathways between fuel and heat pipes
- **Concern:** Heat from fuel would have to go to neighboring heat pipes and cause a compounding failure scenario.

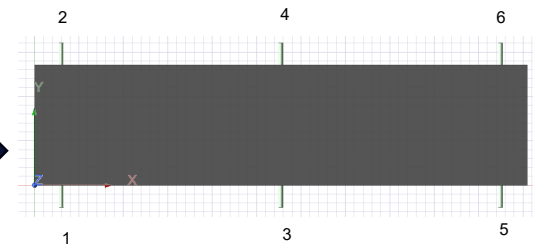


(Note: Microreactor design is fictional)

# EIT analysis was informed using FEM and validated experimentally

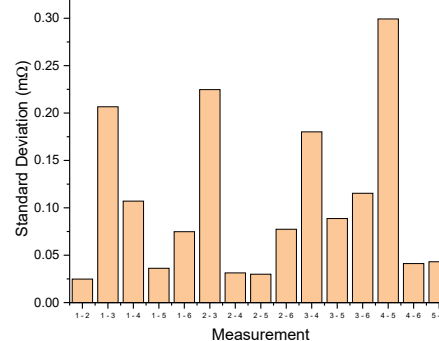


**Equivalent Ansys Model**



Electrode	Contact	~ Contact Resistance (mΩ)
1	Copper	7
2	Fabric	119
3	Fabric	120
4	Copper	17
5	Wire	32
6	Wire	25

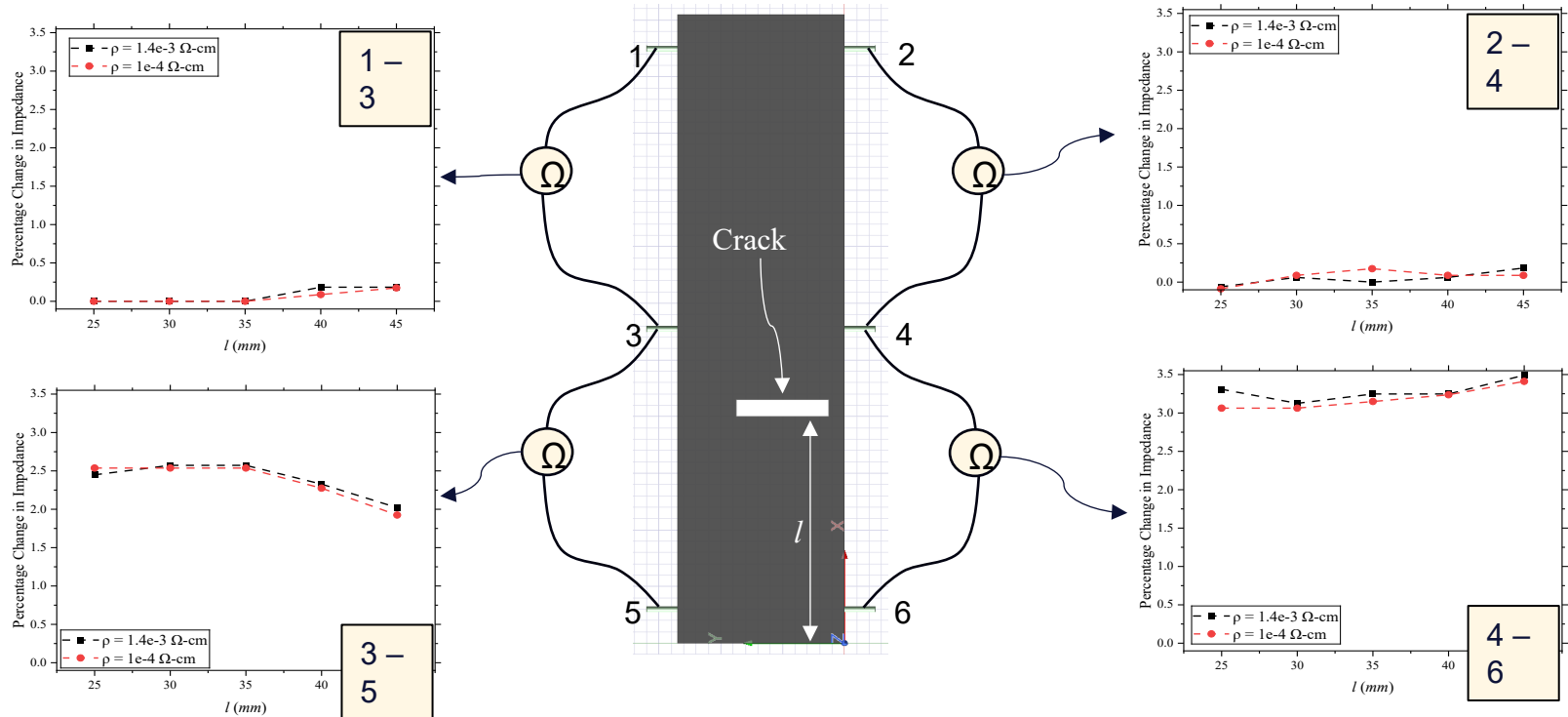
**Measurement Variability without Disconnection**



**Average Impedance Across all Electrodes**

Experiment 17 mΩ  
Simulation 26 mΩ

# Cracks results in change in Impedance across specific electrode pairs about the reference value



# Inverse FEM model is used to extract internal conductivity distribution

Initialize Conductivity Distribution  $\sigma(\mathbf{x})$

Run Forward Model  
 $\nabla \cdot (\sigma \nabla \varphi(\sigma)) = 0$

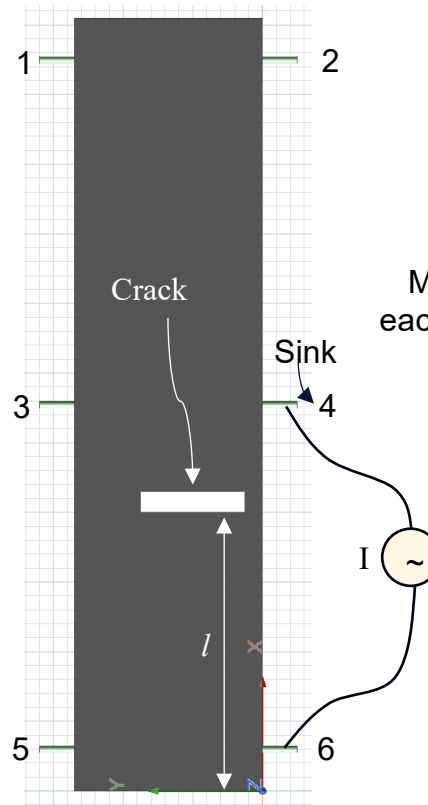
Compute the Predicted Response  $V_P(\sigma_k)$  and mapping with respect to the conductivity

$$J(\sigma) = \frac{\partial V_P(\sigma)}{\partial \sigma}$$

Update the Conductivity Distribution

$$\sigma_{k+1} = \sigma_k + (J^T J + \lambda I)^{-1} J^T (V_0 - V_P(\sigma_k))$$

Liu et al., SoftwareX 7 (2018) 304–308



Apply AC Current Excitation across pairs of Electrodes (Simulation or Experiment)



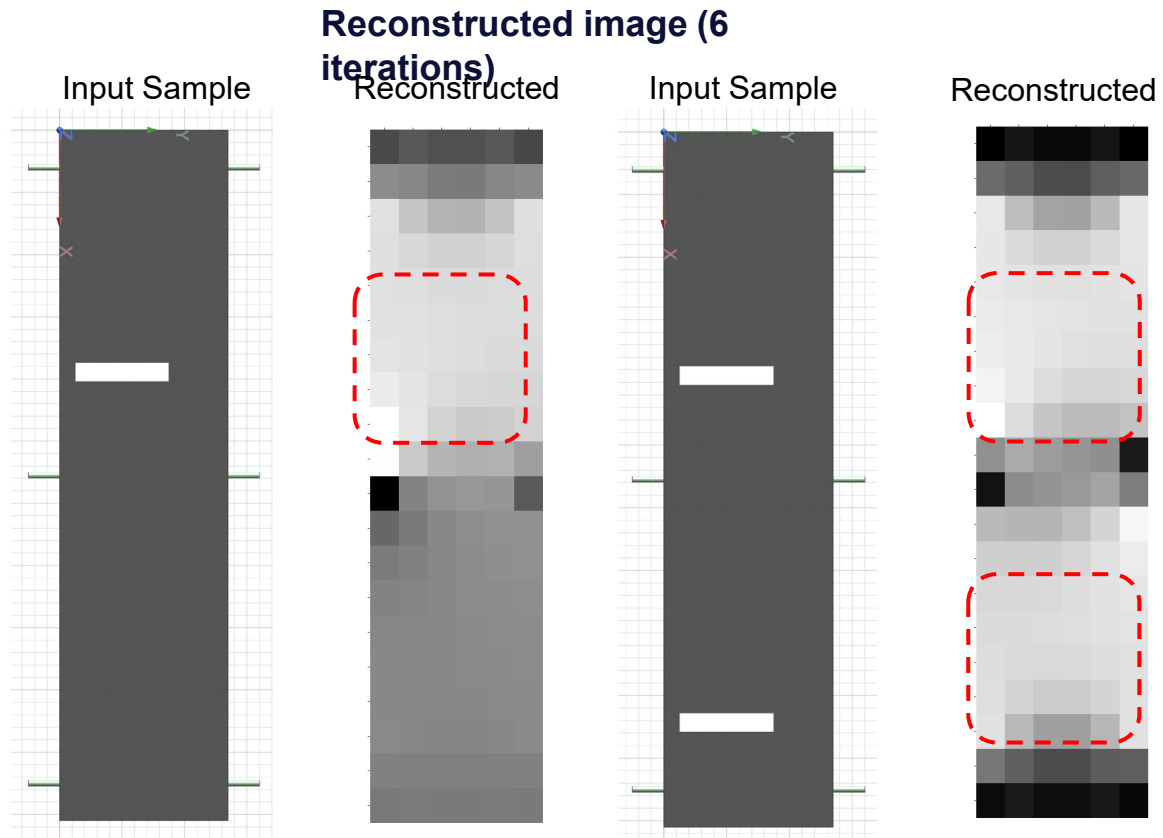
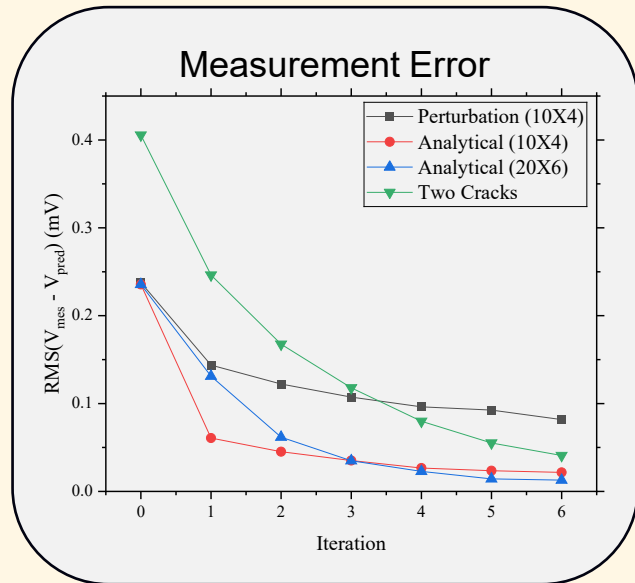
Measure Voltage difference at each Electrode with respect to the current sink.

$$V_0 = \begin{Bmatrix} V_{14} \\ V_{24} \\ V_{34} \\ V_{54} \\ V_{64} \\ \vdots \end{Bmatrix}$$

Analytical Jacobian

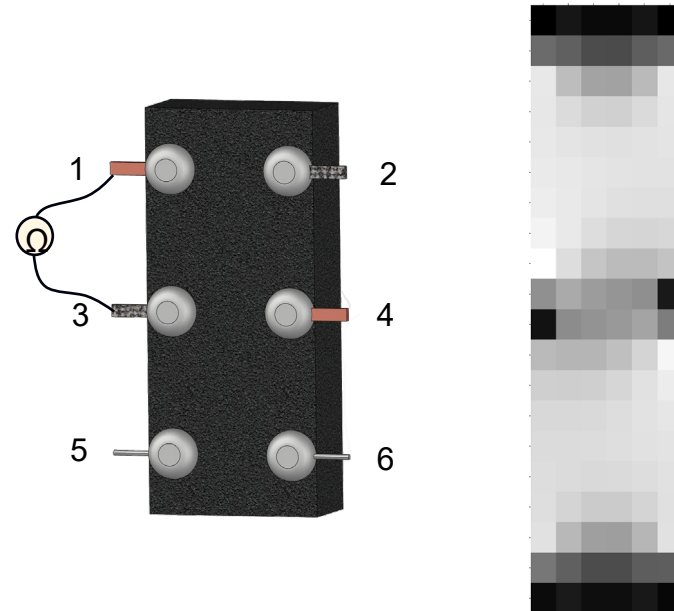
$$J_i^{mn \rightarrow pq}(\sigma) = \frac{-1}{l} \int_{\Omega_i} E_{mn}(\sigma) E_{pq}(\sigma) d\Omega$$

# Conductivity distribution converges and indicates defects



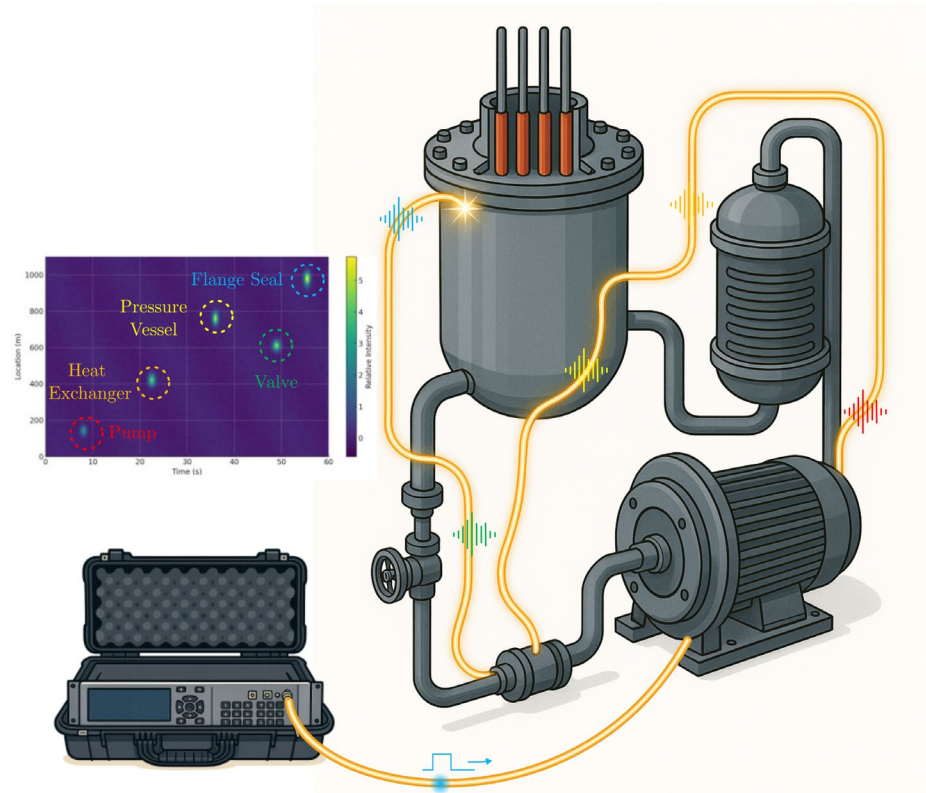
# Summary | Initial results indicate cracks, but further analysis needed to quantify level of crack localization

- Forward and inverse model for EIT developed using Ansys and Python
- Initial results indicate possibility of detecting cracks, while further analysis needed to quantify level of crack localization
- Measurement repeatability in presence of contact resistance presents the main challenge
- Copper tape and copper wire contact with silver epoxy shows promising results
- Measurement variability without disconnection within the range of crack induced impedance increase



# Machine learning-enabled optical fiber-based maintenance monitoring for microreactors

Daniel C. Sweeney

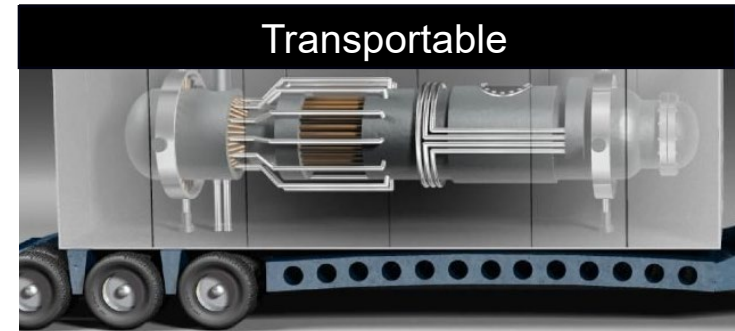
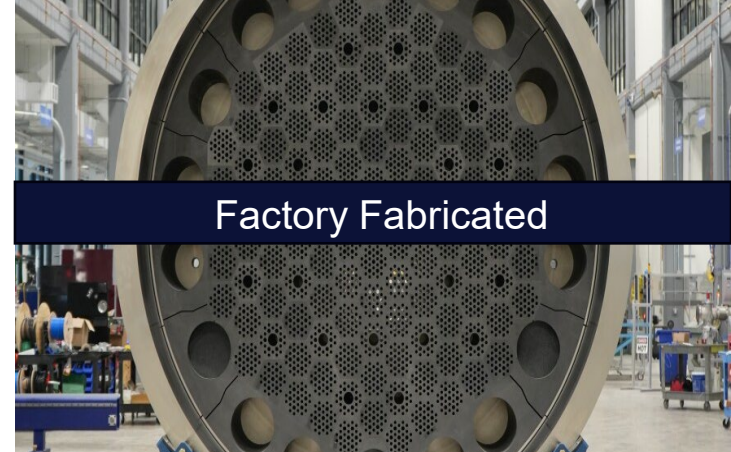


(Note: Microreactor design is fictional)

# Microreactors will be transported to and operated in isolated environments

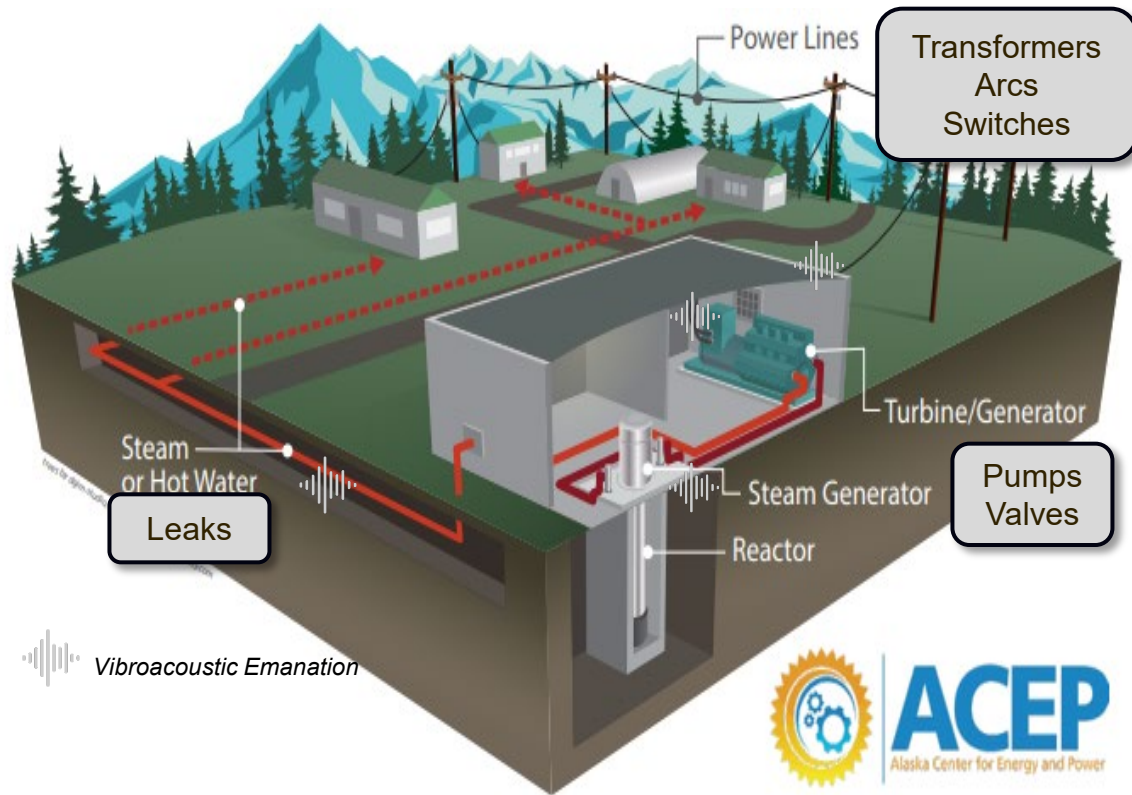
- Small reactors (1-20 MWth) with multi-year operational lifetimes
- Economics greatly rely on reducing maintenance costs (e.g. fewer visual examinations, high reliability)
- Reactors and components assembled in a factory transported via Conex boxes
- Require supporting site-built infrastructure for shielding/containment and energy conversion (pumps, heat exchanges, etc.)

Fraser, Julia. *Next up for nuclear power: small, transportable and made in a factory near Pittsburgh*. 90.5 WESA. 10 Mar 2021  
Arave, Addison. *What are microreactors?*. INL. Accessed 17 Feb 2026.



# Support systems will require maintenance

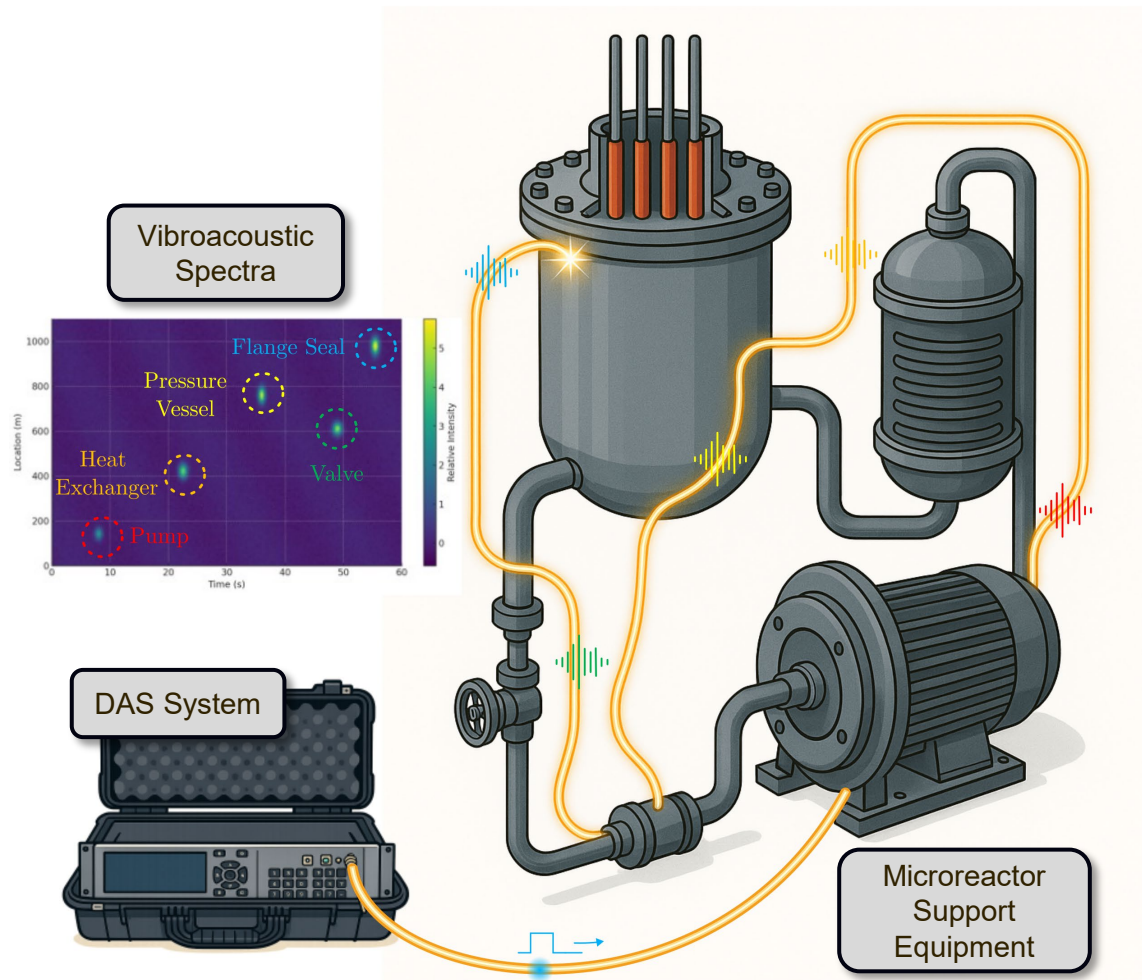
- 5-20+ year operational life will require system maintenance
- Periodic maintenance required
- Component failure modes exhibit acoustic signatures



ACEP. *Small Scale Nuclear Power: an option for Alaska?*, Jan 2021

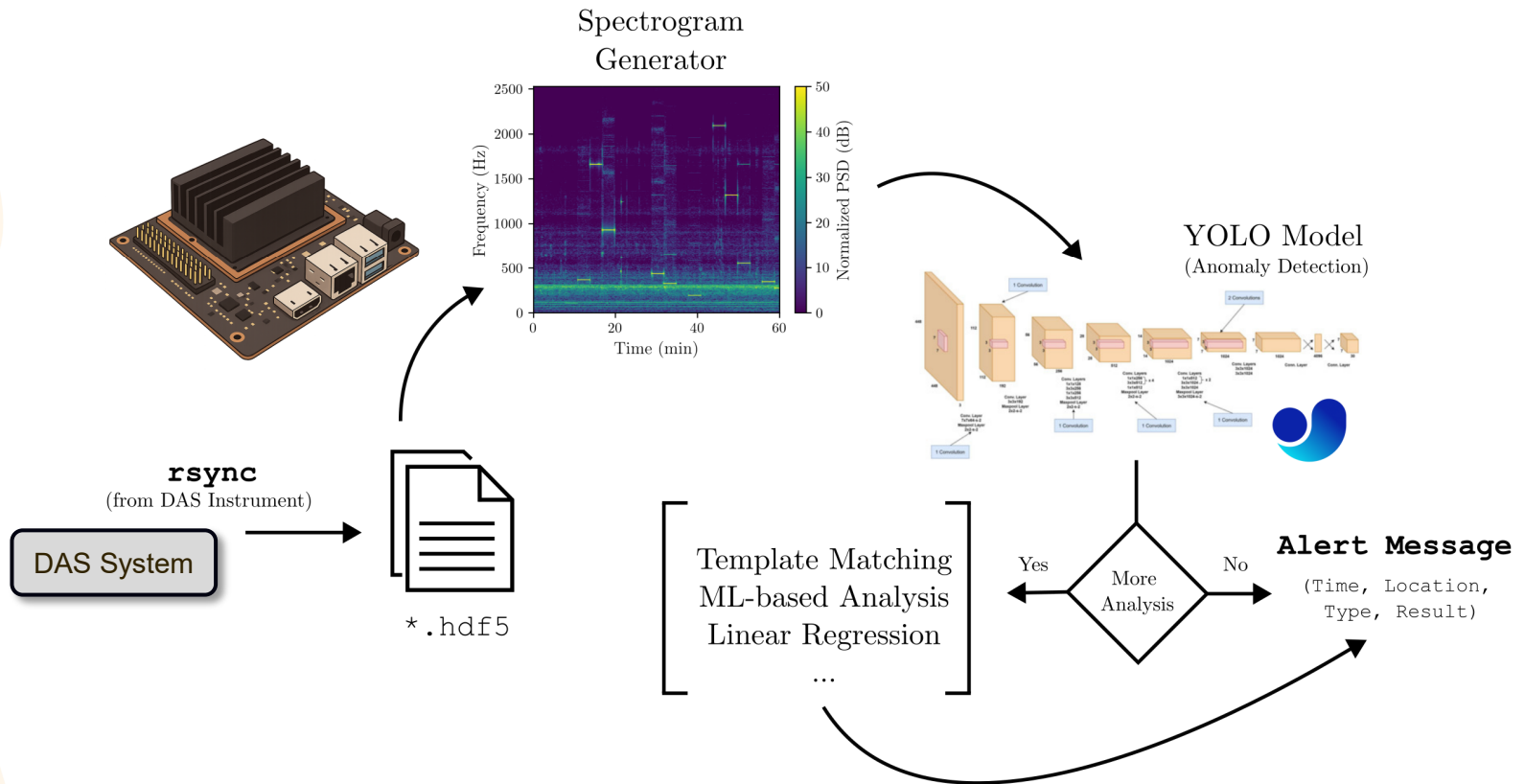
# Distributed optical fiber sensing enables online monitoring

- Distributed acoustic sensing (DAS) monitors vibroacoustic data along an optical fiber
- Bandwidth >1 kHz over 40 km at 5 m spatial resolution
- Vibration spectra from each segment simultaneously





# Vibroacoustic signals are processed as image tensors



# Project on-track for prototype demonstration by end of March

- **Target Demo:** *Online classification of acoustic tones via concert pitch*
  - Pure tones played via a speaker laid on top of a spool of optical fiber
  - Conversion of time-domain data to frequency spectrum
  - ML model adapted for training using `*.npy` files
  - `chron` + `rsync` used to transfer data between DAS system and edge processor.
- **Expected result:** *Print via the terminal the concert pitch as it is played in sequency*
- **Accomplishments:**
  - Reconfigured the DAS system and processor to pass data as its generated
  - Demonstrated use of ML model to classify surrogate and real vibroacoustic spectral data
  - Recorded, cleaned, and segmented training data from DAS system
  - DAS system agnostic architecture
- **Outlook**
  - Software pipeline and ML model operational by end of March
  - Begin acquiring training data from long term installation from test site