

# **Topic 4: Storage Monitoring**

## **Introduction – Tip Meckel**

**Mission Innovation workshop**

**Trondheim, Norway**

**June 19-20, 2019**



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# Outline

- **Review of 2017 Report: Accelerating Breakthrough Innovation in CCUS**
  - **Priority Research Directions**
  - **Scientific Challenges Identified**
- **Example rubrics & framing considerations**



# Panel S2: Monitoring, Verification, and Performance Metrics

Panel Leads: Ziqiui Xue (JPN) and Jonathan Pearce (UK)

- Advances in monitoring are needed to enable storage performance verification at a higher level of certainty, both during and following injection operations.
- Areas where basic research could lead to critical improvements include:
  - sensor and tracer technology
  - remote monitoring
  - joint inversion methods for geophysical data
  - optimized design of monitoring and information systems

# PRDs identified for Monitoring, Verification and Performance Metrics

- S-4: Developing **Smart Convergence Monitoring** to Demonstrate Containment and Enable Storage **Site Closure**
- S-5: Realizing **Smart Monitoring** to Assess Anomalies and Provide Assurance

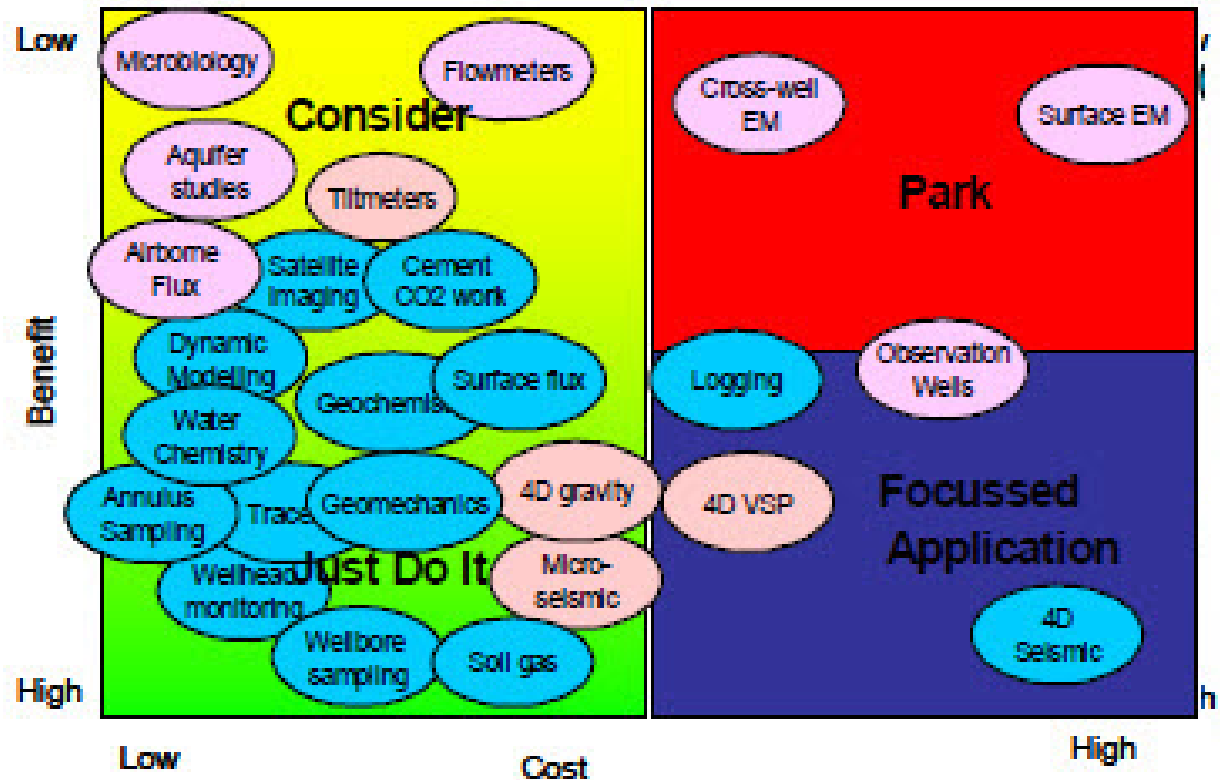
# Monitoring Panel Report - Scientific Challenges Identified

- Transforming far-field monitoring with new tools to directly measure state variables
- Smart monitoring in the far-field
- Improving methodologies for monitoring plans
- Improving interpretation and use of large, complex data sets
- Assessing anomalies and providing assurance – location, attribution, quantification

# IEAGHG CO<sub>2</sub> Monitoring Tools (2010; Online tool also) IJGGC Special Issue (2015) Lots of BPM

Mathieson et al., 2010

			deep	shallow	Plume location / migration	Fine scale processes	Leakage	Quantification	
Seismic		3D/4D surface seismic							
		Time lapse 2D surface seismic							
		Multi-component surface seismic							
	Acoustic imaging	Boomer/sparker profiling							
		High resolution acoustic imaging							
	Well based	Micro-seismic monitoring							
		4D cross-hole seismic							
4D vertical seismic profiling									
Sonar bathymetry		Sidescan sonar							
		Multi beam echo sounding							
Gravimetry		Time lapse surface gravimetry							
		Time lapse well gravimetry							
Electric/electromagnetic		Surface EM							
		Seabottom EM							
		Crosshole EM							
		Permanent borehole EM							
		Crosshole ERT							
		Electric spontaneous potential							
Geochemical	Fluids	Down-hole /Springs							
		Marine							
	Gases	Atmosphere	Bubble stream chemistry						
				Short closed path (NDIRs & IR)					
				Short open path (IR diode lasers)					
			Long open path (IR diode lasers)						
			Eddy covariance						
		Soil gas	Gas flux						
		Gas concentrations							
Ecosystems		Ecosystems studies							
Remote sensing		Airborne hyperspectral imaging							
		Satellite interferometry							
		Airborne EM							
Others		Geophysical logs							
		Downhole Pressure / temperature							



# Monitoring

- **WHY/WHO:** Operations, Regulatory, Public
- **WHAT:** Property/State, Tools, Technology
  - Quantification precision & limitations
- **HOW:** Strategy; FOAK or routine.
- **WHERE:** Near/far field; Shallow/deep;
- **WHEN:** Risk profile, Active/passive
  
- Transparency
- Cost effective (not same as inexpensive)
- Integration (consistency)
- Evolution of strategies, techniques and technologies.
- Verify conformance, predict future performance (model matching) & repeat = assurance!

# Closing gaps for deployment and industrial opportunities: Where should we look for innovation in monitoring?

- Two camps:
  - ‘We have what we need, it just needs to be better’ (high TRL)
  - ‘The better/best tool is still out there, just need to find it’ (low TRL)
  
- The brain
- The computer
- The lab
- The field
  
- **Other fields:** oilfield, robotics (AUV), computing, medical, materials, data management, pattern recognition
  - **CCS Technology Ambassadors?**



# THANK YOU



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# EPA's Suggested Outline for MRV Plans

1. Facility Information
2. Project Description
3. Delineation of the monitoring areas
4. Evaluation of Leakage Pathways
5. Detection, Verification and Quantification of Leakage
6. Determination of Expected Baselines
7. Site Specific Modifications to the Mass Balance Equation
8. Estimated Schedule for implementation of MRV plan
9. Quality Assurance Program
10. Records Retention
11. Appendices

**Multiple  
examples of  
active project  
compliance**

Source: U.S. EPA, Office of Air and Radiation, "General Technical Support Document for Injection and Geologic Sequestration of Carbon Dioxide: Subparts RR and UU – Greenhouse Gas Reporting Program," November 2010.