SMART Initiative

Science-informed Machine Learning to Accelerate Real Time (SMART) Decisions in Subsurface Applications

Grant S. Bromhal
National Energy Technology Laboratory (NETL)
Senior Fellow, Geological and Environmental Systems

Carbon Management and Oil and Gas Research Project Review Meeting
August 4, 2021

U.S. DEPARTMENT OF ENERGY

NATIONAL ENERGY TECHNOLOGY LABORATORY

SMART Initiative

Science-informed **M**achine Learning to **A**ccelerate **R**eal **T**ime (SMART) Decisions in Subsurface Applications

Real-Time Visualization
"CT" for the Subsurface

Rapid Prediction
Virtual Learning

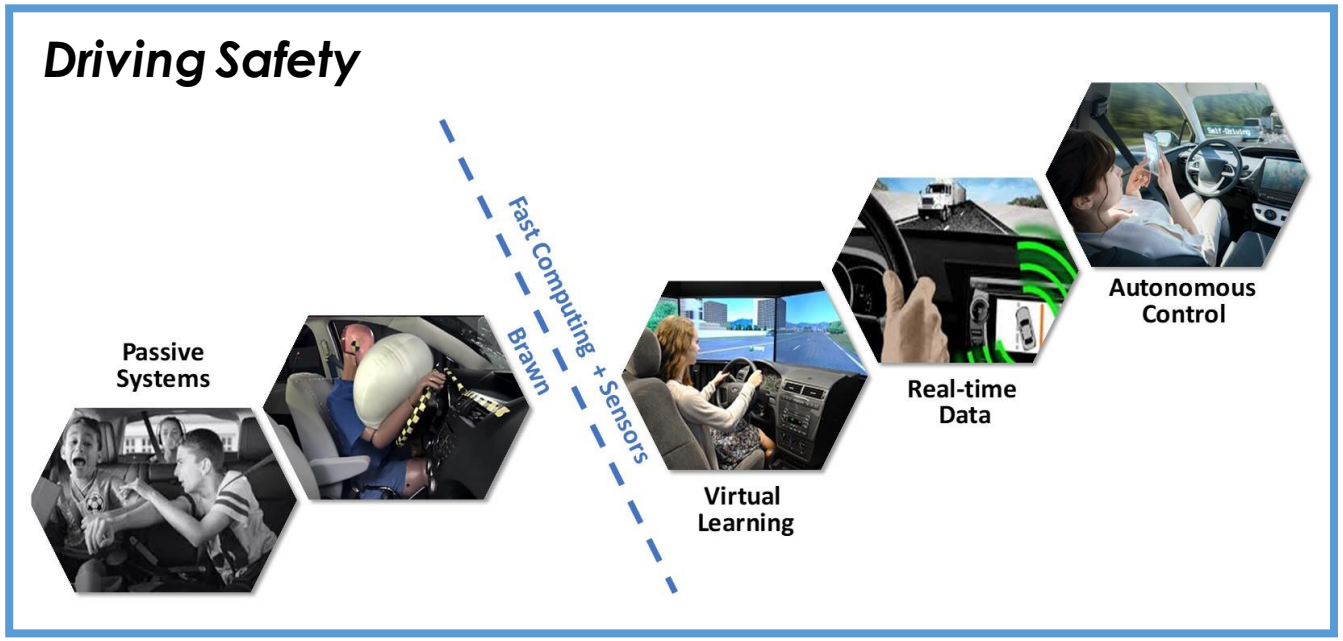
Real-Time Forecasting
"Advanced Control Room"

Transforming decisions through **clear vision** of the present and future subsurface.

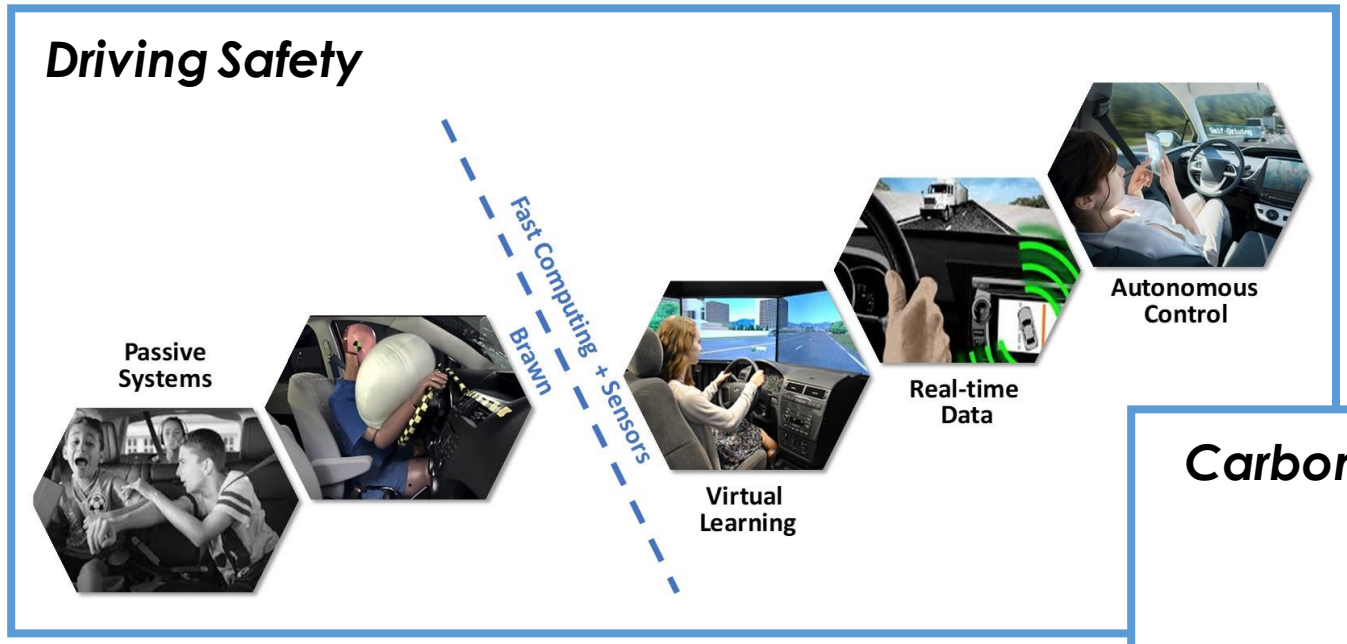
Technical Team

Carnegie Mellon University
Los Alamos National Laboratory
NETL National Energy Technology Laboratory
BATTELLE
EERC University of North Dakota
FACT
Lawrence Livermore National Laboratory
Colorado School of Mines
Oak Ridge National Laboratory
PennState
The University of Utah
Pacific Northwest National Laboratory
Bureau of Economic Geology
Texas A&M
Sandia National Laboratories
Berkeley Lab
Illinois

Transformational Experience



Transformational Capability

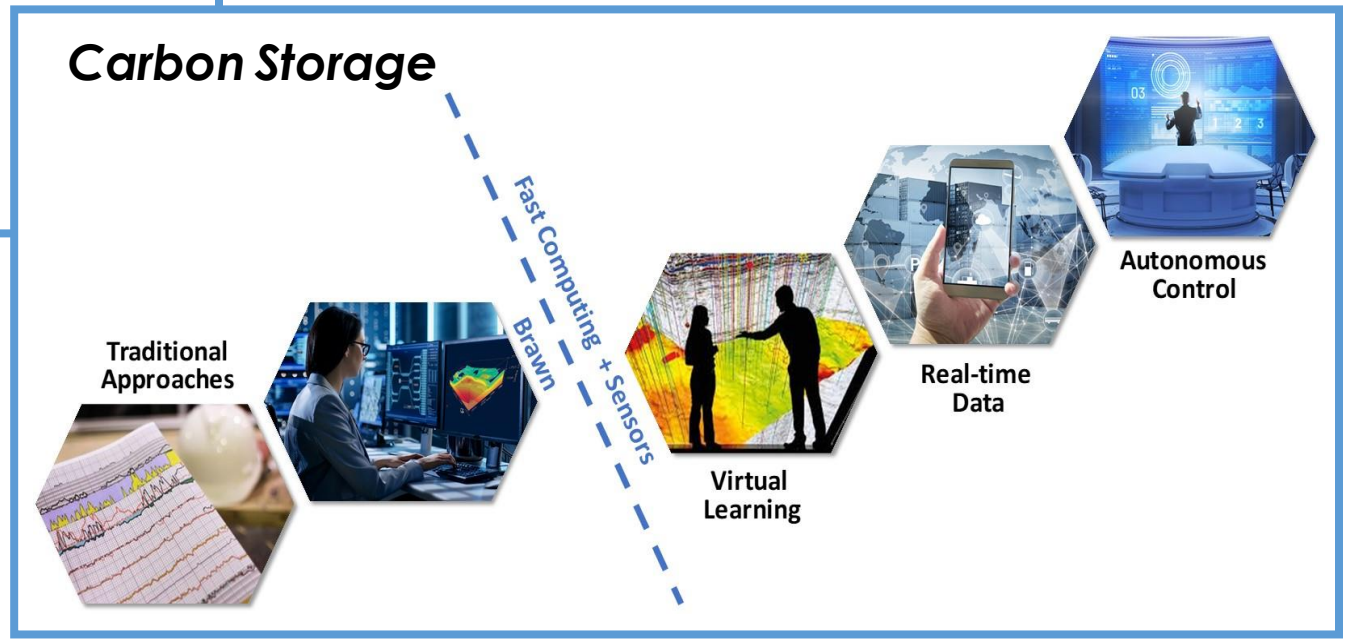


Pattern Recognition

Autonomous Monitoring

Virtual Reality Learning

Autonomous Control



Confluence of Data, Computational Capability, and Machine Learning

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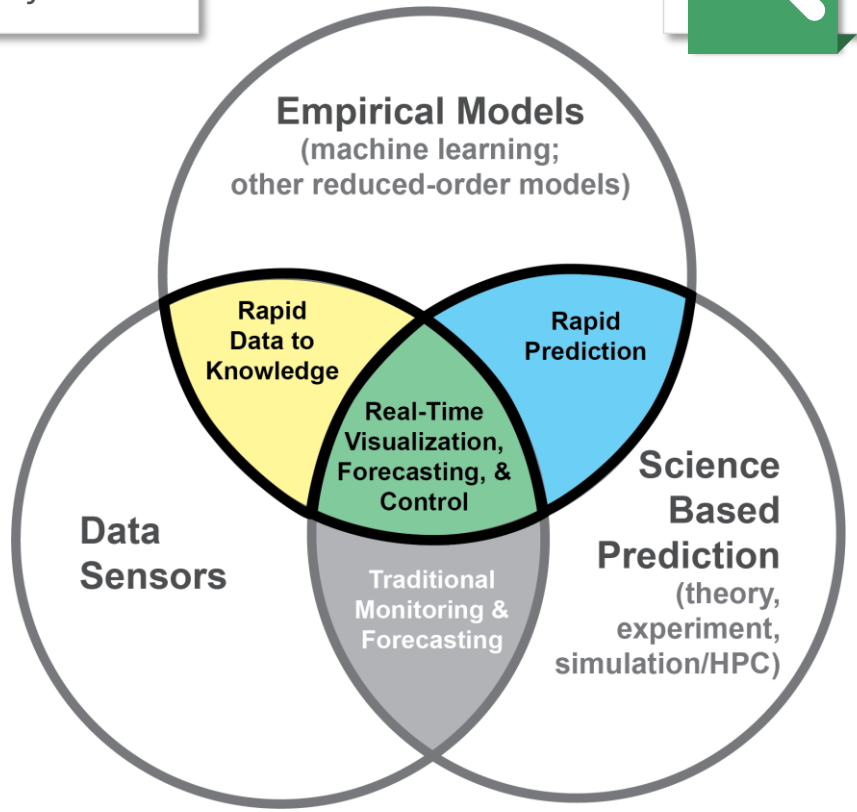

Rapid Data to Knowledge
Autonomous Monitoring

Rapid Prediction
Virtual Learning

SMART Initiative

FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29

PHASE 1

"Proof of Concept"

PHASE 2

"Development and Validation"

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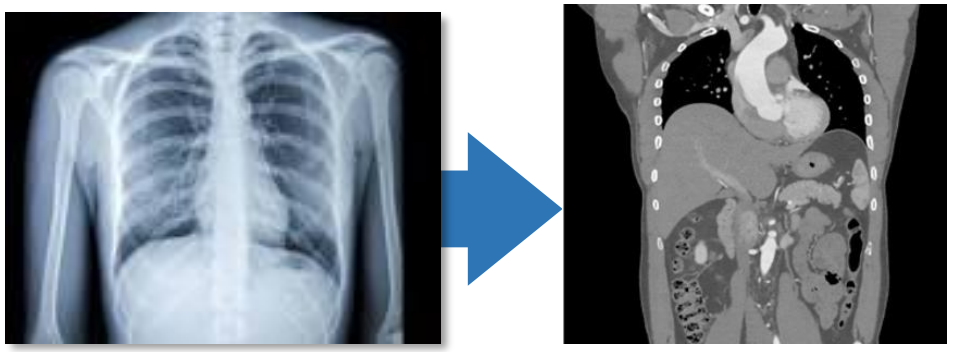

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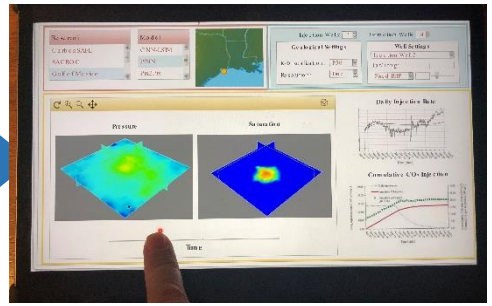


Making Better Decisions

Transforming *decisions through* ***clear vision*** *of the present and future subsurface.*

Decision-makers

Project Engineers

Regulators

High-level Executives

Landowners/Public

Phases

Site/Field Selection

Permitting

Development

Operations

Closure

Questions

Is the project safe?

- Will it leak, and if so, where?
- Will it cause induced seismicity?

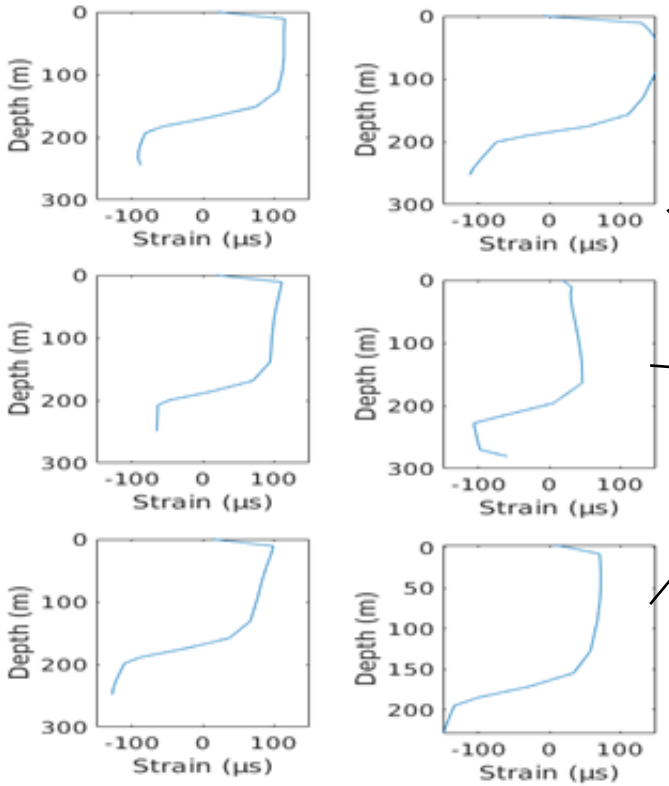
Where is the CO_2 now?

Where should I locate the wells?

Is the project safe?

Rapid detection of possible hazards reduces project risk

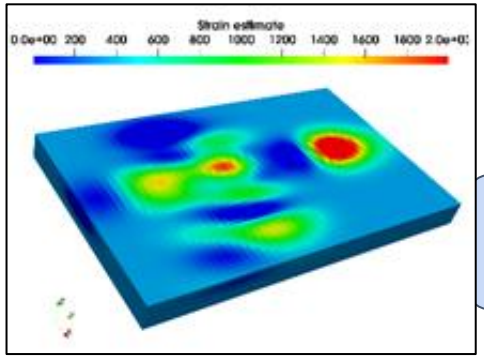
Input: Field data in near real-time



Trained ML models

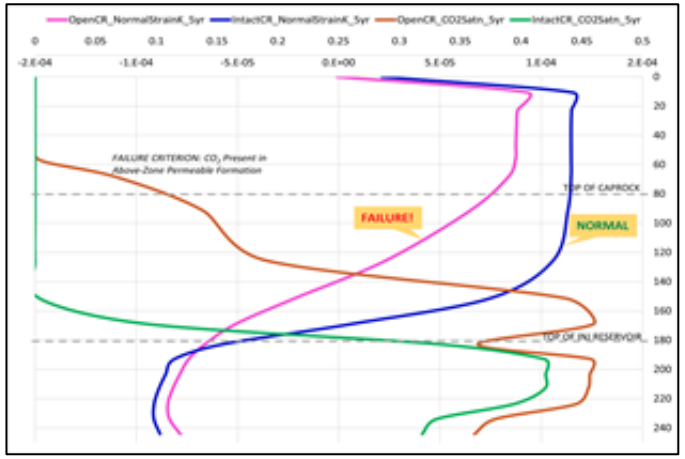
Implementation

Strain distribution X days after start of injection



1. Deep Learning + Kriging for rapid spatiotemporal prediction and visualization

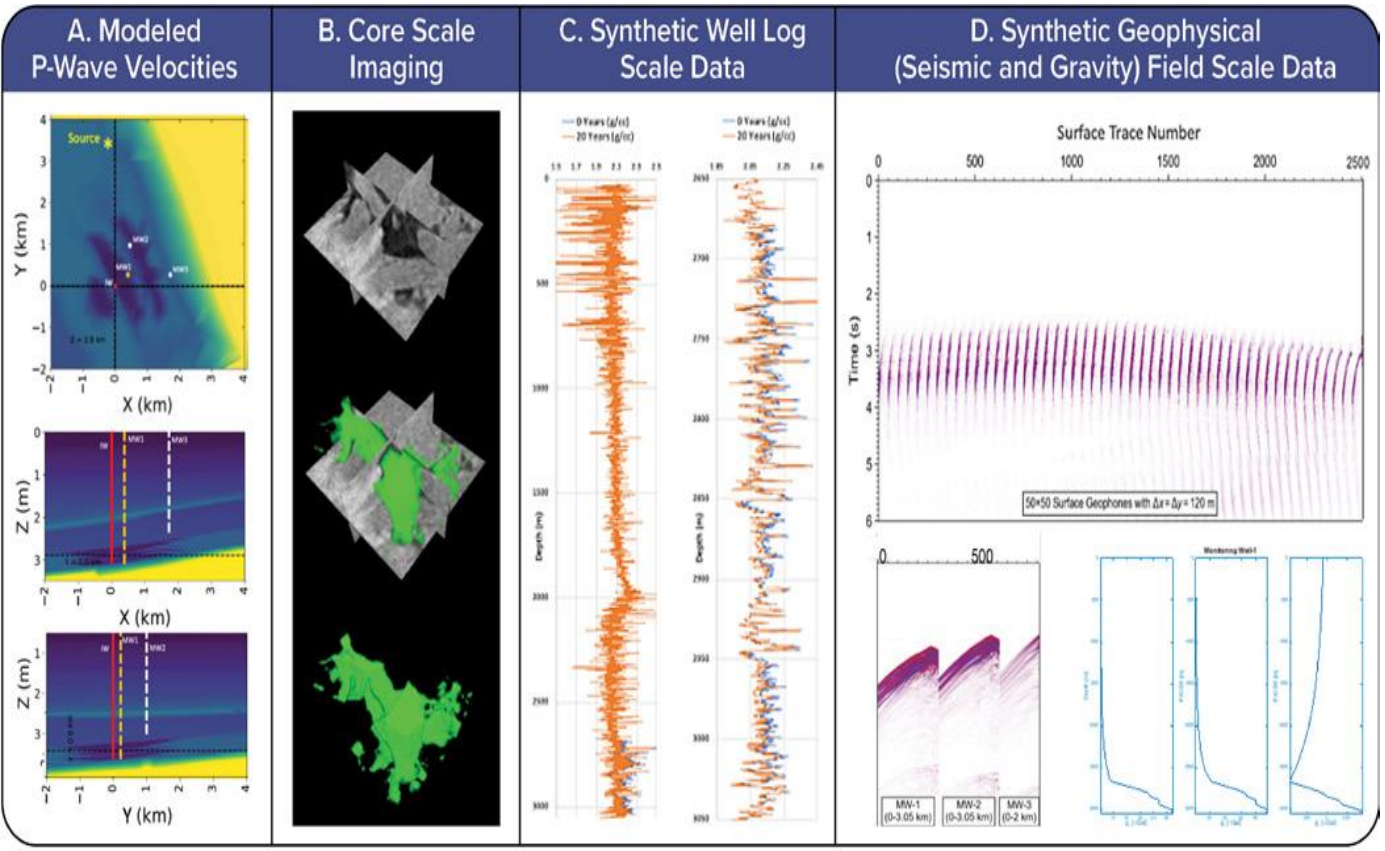
Normal vs. abnormal behaviour detection



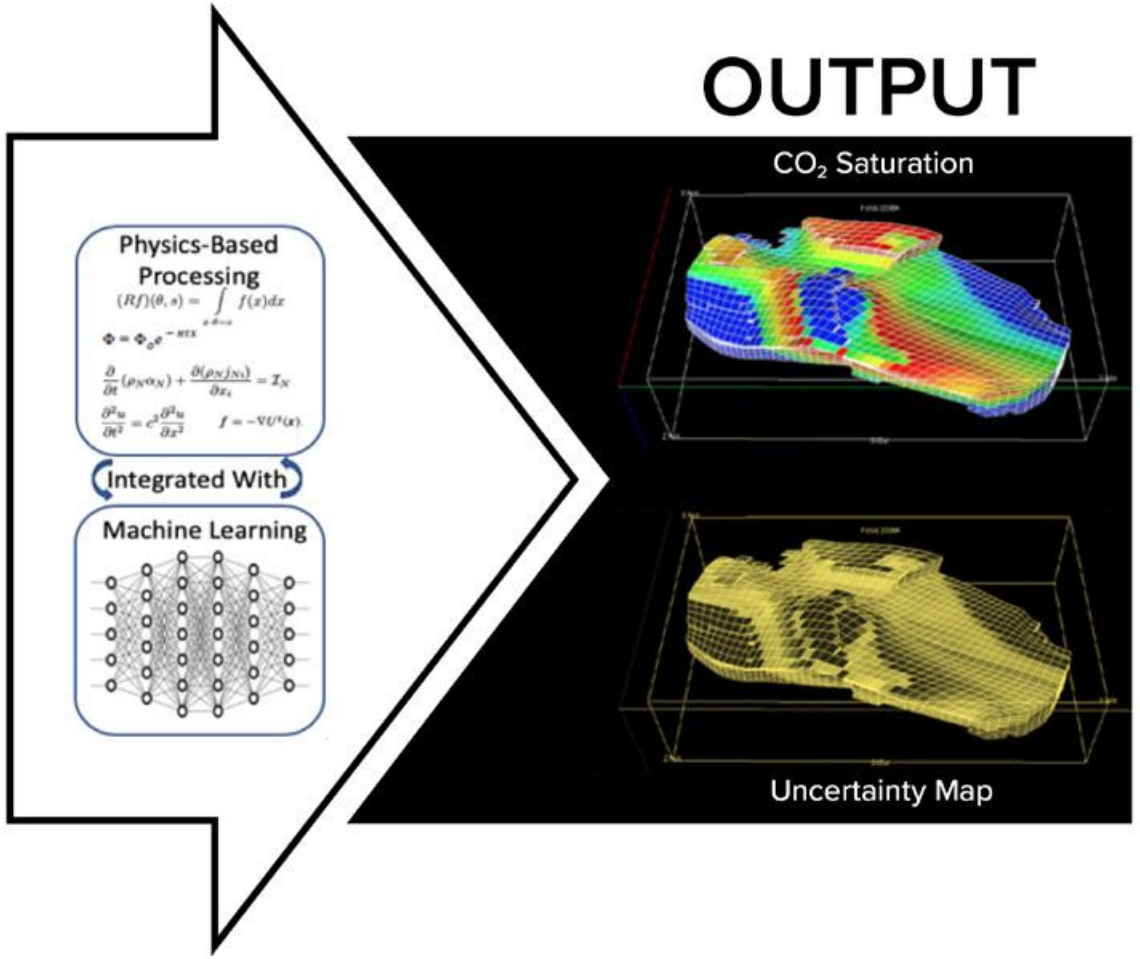
2. ML-based feature recognition and anomaly detection

Where is the CO_2 now?

Quick updating of CO_2 plume location addresses many questions

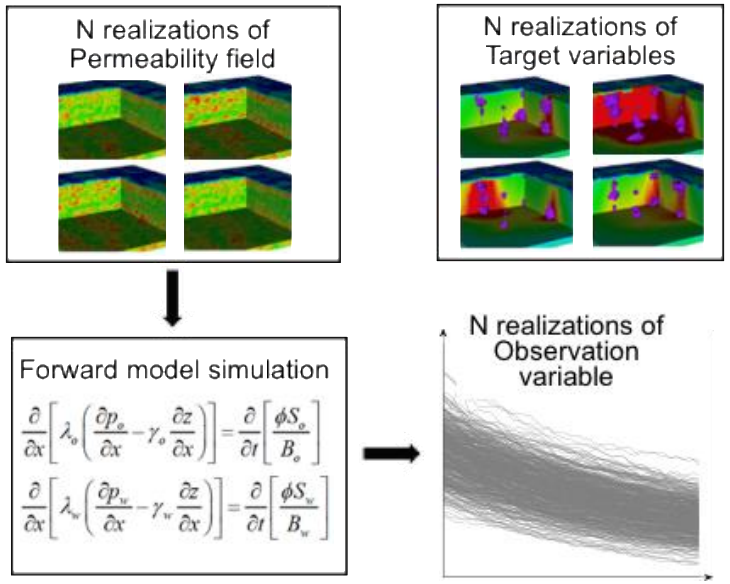


Comprehensive synthetic data sets for realistic site across several scales



Integrating simulations and data to inform decisions

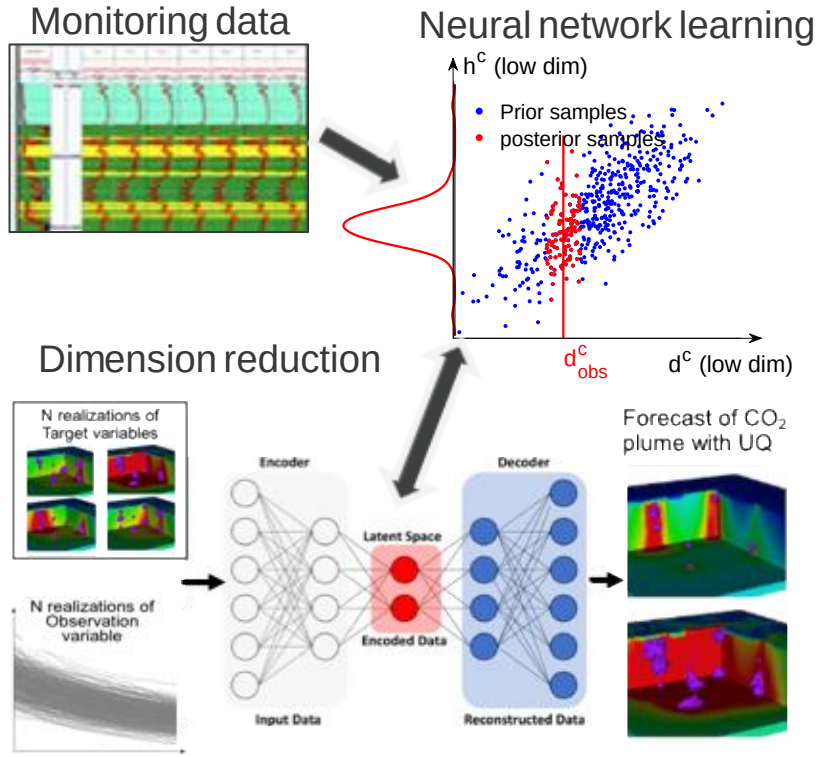
Reservoir simulations



Offline simulation

- Fully parallel
- Time: one forward model run
- Considers various uncertainty

Machine Learning (ML)



Online learning

- ML techniques (dimension reduction and BNN learning)
- Time: mins and robust solution

Deploy

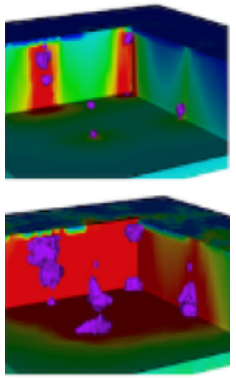
Observations

↓

Trained ML model

↓

Forecast with uncertainty

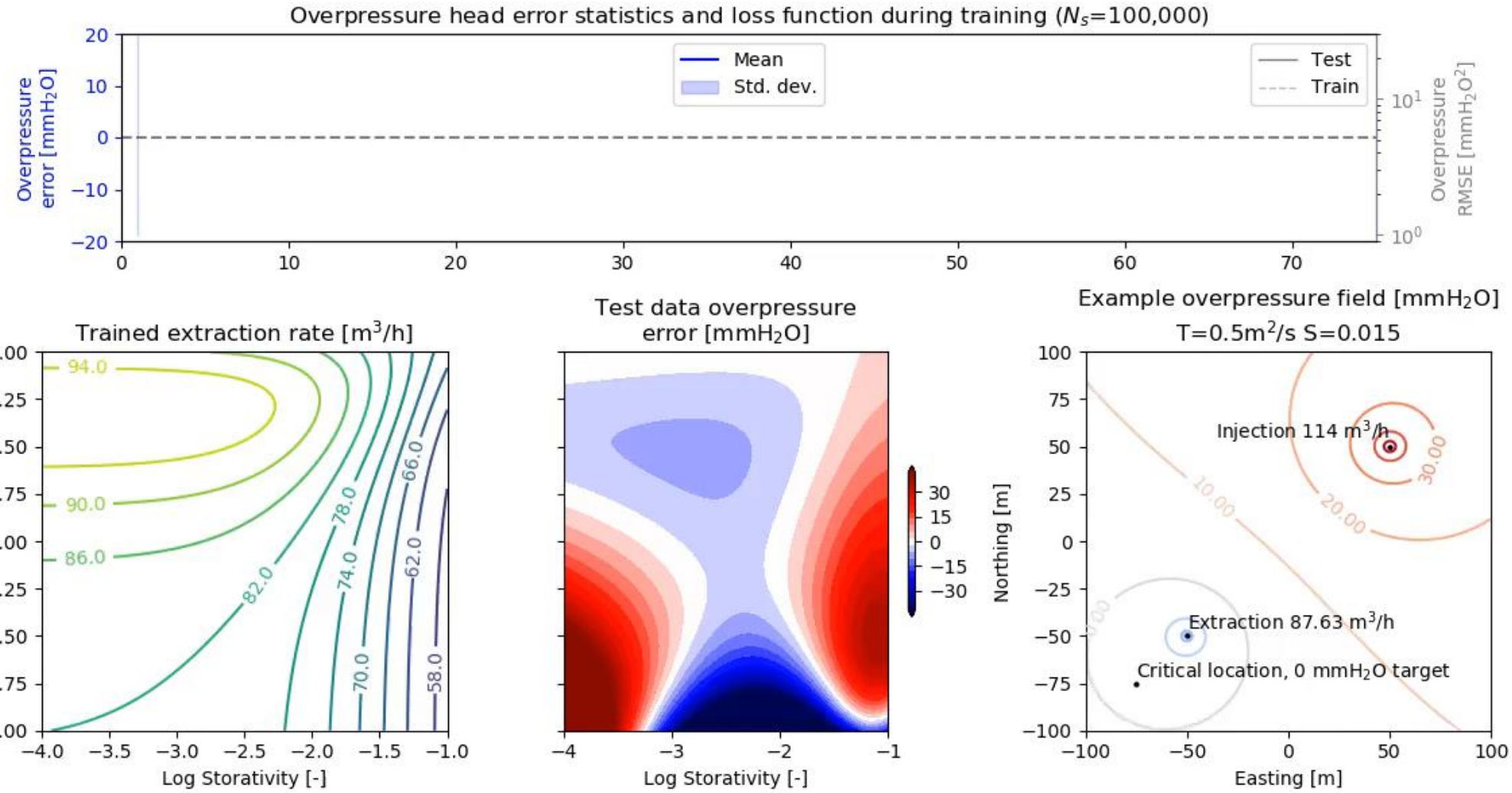


5year

10year

Deploy an automated and real-time forecast framework

Addressing risk and uncertainty

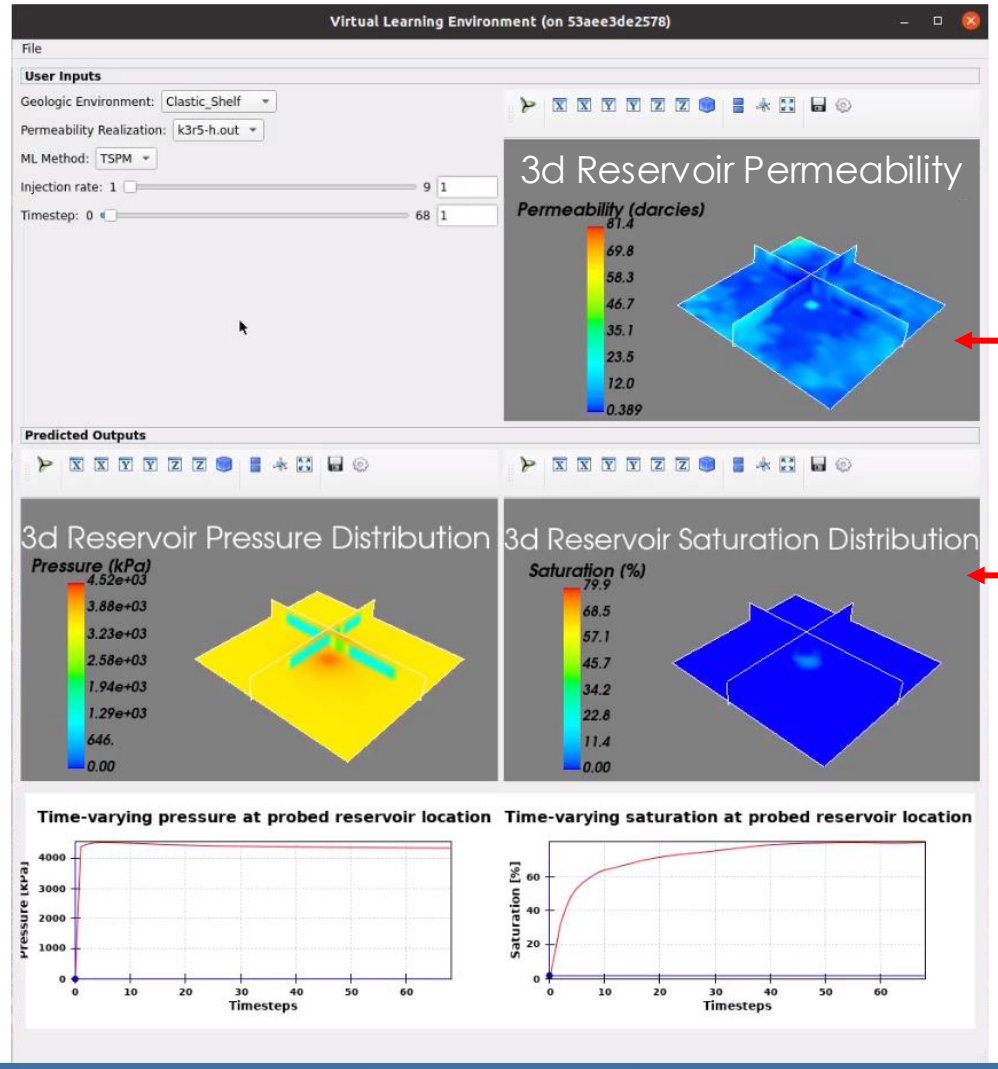


Virtual Learning Tool

Can we rapidly develop experience among CCS stakeholders to facilitate rapid & safe deployment of large-scale geologic CO_2 storage?

Enable a Virtual Learning Environment (VLE):

- for testing strategies to optimize reservoir development
- to evaluate management & monitoring options prior to field activities
- enabling non-experts to explore and learn how the systems work



Interactively gain intuitive understanding of CO_2 storage site behavior by:

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Manipulating inputs &

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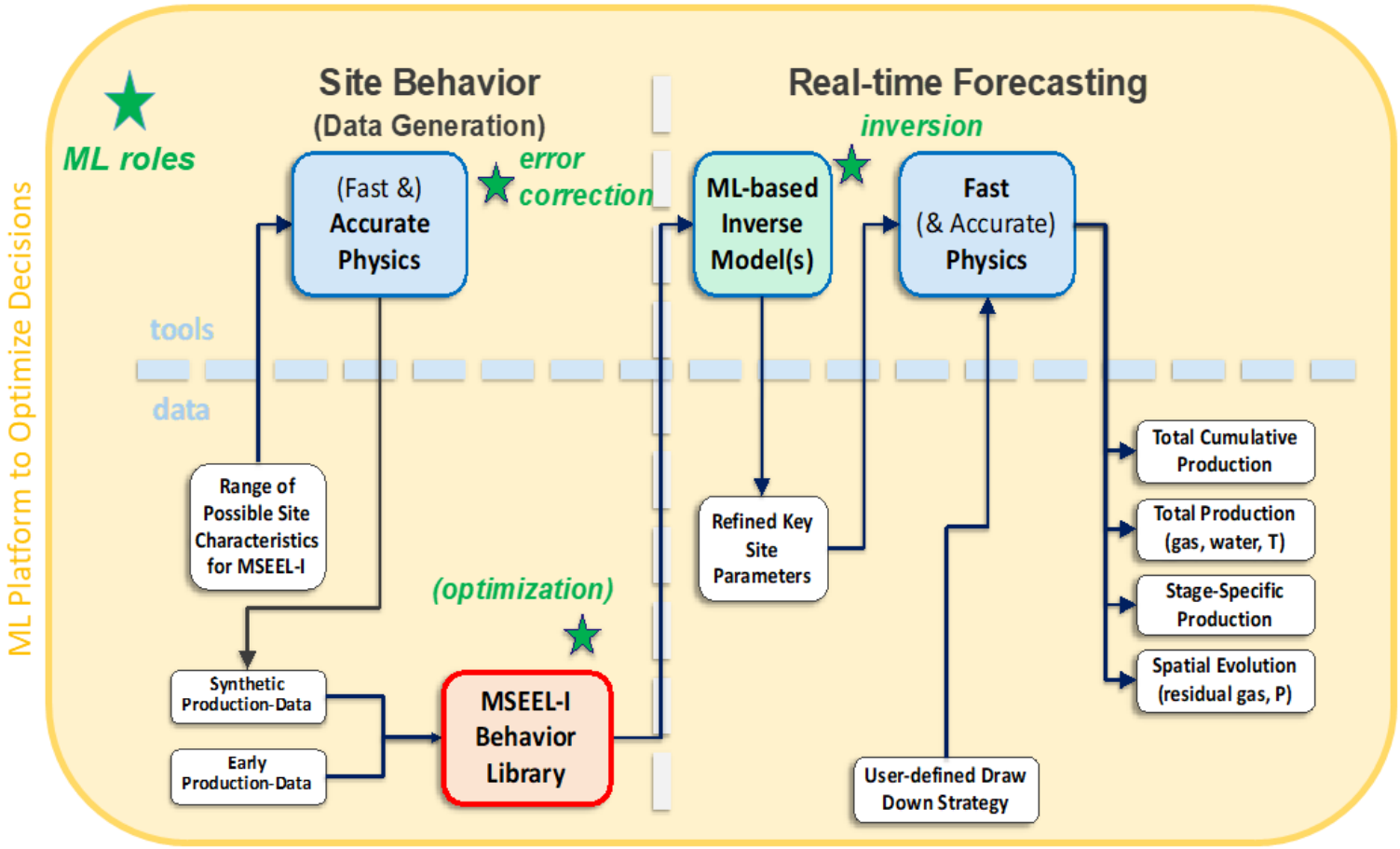
Exploring Outputs

Work with operators to enable real-time predictions

MSEEL DOE Field Site



DOE NAMES PHASE 1 WINNERS IN SMART VISUALIZATION PLATFORM PRIZE CHALLENGE

August 02, 2021

- **Red Volta Visualization Platform**. Submitted by Charles Tanzini and Trevor Nicholson of Raleigh, North Carolina. The developers report that the design and architecture of their platform enables a scalable, multi-user and cross-platform solution. Red Volta's design allows it to be deployed in standalone mode on a dedicated workstation or as a web application that can be used remotely by operators in the field.
- **Subsurface XR**. Submitted by Alexander Zimmerman, an American student studying geo-resources and materials engineering in Germany. Subsurface XR will apply state-of-the-art game engine and mixed reality technology to provide users with an app they can run on any device to visualize and intuitively interact with geoscientific datasets and models in 3D.
- **GeoDeck**. Submitted by PetroLern LLC of Brookhaven, Georgia. GeoDeck is a web-based application. GeoDeck will make the interaction between scientific variables and their spatial and temporal dimensions straightforward and intuitive, using virtual reality (VR) and augmented reality (AR). Developers claim the ultimate immersive experience is only possible by means of VR and AR. The software is designed to accommodate extended reality integration on the web.
- **RocVision**. Submitted by Illinois Rocstar LLC of Champaign, Illinois. The RocVision subsurface visualization system is an advanced 3D platform for exploring subsurface data. RocVision allows a user to explore 3D spatial and temporal data with methods used by geoscientists. The final RocVision product will support geoscience workflows in subsurface science while providing advanced 3D, 2D and data processing features, using VR and AR.

Summary

- **Proof of Concept Phase nearly complete (December)**
- **Developing transformational approaches to enable real-time visualization, real-time forecasting, and virtual learning**
- **Focus is NOT on building new models to replace reservoir simulators at early project stages, but rather to create tools that use existing models/knowledge with data to enable better decisions**
- **Addressing issues:**
  - data formatting and standardization,
  - integrating multiple data streams,
  - testing and training new algorithms for specific use
- **Phase II will focus on site-specific development and validation of SMART tools and approaches, in partnership with operators and other users**

Upcoming presentations

- **August Carbon Management and Oil and Gas Program Review Meetings**
  - Four presentations on SMART Carbon Management (Tasks 2-5) on the afternoon of Friday, August 6, from 1:40-3:10 pm ET
  - Two presentations on SMART Oil and Gas (Tasks 6-7) on Monday, August 23 at 4:20-5:00 pm ET.

Thank You!

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Berkeley Lab

Questions?

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