



SMART Visualization and Decision Support Platform

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

Task-6 team (PNNL, LLNL, and NETL)

Presenters:

- Maruti Mudunuru (PNNL)
- Chris Sherman (LLNL)
- Patrick Wingo (NETL)



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ENERGY



Acknowledgments and disclaimers

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Outline of the talk

- Part-1: SMART platform (~5-6 minutes by Maruti Mudunuru)
 - Overview of the Platform and its ecosystem
 - EY24 early win
 - Platform's user-interface
 - Integration of key SMART modules into the Platform
- Part-2: STRIVE package -- SMART Tools Rapid Visualization Environment (~5-6 minutes by Chris Sherman)
 - Overview of STRIVE -- Modern-looking, flexible, fast, and efficient user interface
 - Benefits of using STRIVE
 - Platform, ORION, and VLE user-interfaces
 - Impact – How will the SMART modules/platform utilizing STRIVE help the CCS industry?

Part-1: SMART Visualization and Decision Support Platform

Task-6 (EY23 and on-going EY24): Key Developers, Contributors, and Participants – PNNL, LLNL, NETL

POCs

- Maruti Mudunuru
- Chris Sherman
- Hema Siriwardane

Key developers and contributors

- Patrick Wingo
- Eusebius Kutsienyo
- Alex Hanna
- Ashton Kirol
- Wenjing Wang
- Veronika Vasykivska
- Kolawole Bello
- David He
- *Mathew Harris*
- *Ivani Patel*
- *Armando Sanchez*

Other contributors

- Derek Vikara
- David Morgan
- Diana Bacon
- Gavin Liu

Part-1: SMART multiverse (end-to-end): Piecing everything together

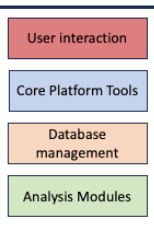
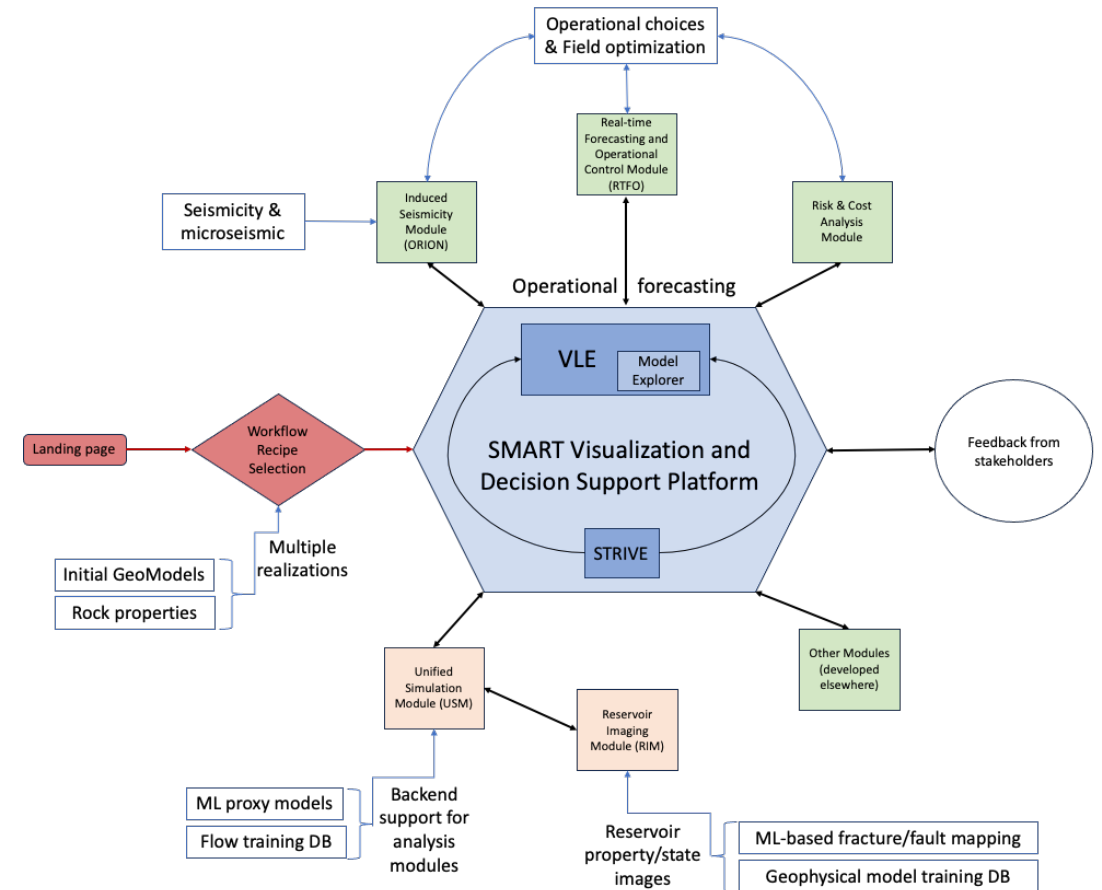
- Key terminology

- SMART Platform

- SMART visualization and decision support platform
- **STRIVE interface** allows to develop consistent look and formatting for SMART modules

- SMART Modules

- USM, ORION, RTFO,
- VLE, ModelExplorer
- Risk and Cost Analysis



Version-1 (EY23): Hub-and-spoke figure of SMART platform

Part-1: EY24 Early win – SMART platform's graphical user interface

Welcome to the SMART Platform

Wiring Diagram
Integrated SMART Network
Workflow and Tools

ORION
Explore induced Seismicity factors
Workflow and Tools

VIRGO
Forecasting simulation processes.
Workflow and Tools

Workflow Recipes
Explore different workflow recipes.
Workflow and Tools

ModelExplorer
Class VI permitting analysis.
Workflow and Tools

RIM
Reservoir Imaging Model
Workflow and Tools

Risk Analysis
Operational risks and costs.
Workflow and Tools

RTFO
Forecast and Operation Control.
Workflow and Tools

TALES
Economic and Liability Evaluation
Workflow and Tools

Legacy Code
Predictions of simulation processes.
Workflow and Tools

Other Simulators
Pressure, Saturation, and AorT Evaluation
Workflow and Tools

Other Modules
Analytical-based GCS Estimation
Workflow and Tools



Part-1: EY24 Early win – SMART modules integration into overall platform (video)

Welcome to the SMART Platform

Wiring Diagram

Integrated SMART Network

Workflow and Tools

ORION

Explore Induced Seismicity factors

Workflow and Tools

VLE

Forecasting simulation processes

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Workflow Recipes

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Operational risks and costs

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RTFO

Forecast and Operation Control

Workflow and Tools

TALES

Economic and Liability Evaluation

Workflow and Tools

Legacy Code

Predictions from legacy code

Workflow and Tools

Other Simulators

Numerical and Analytical base
GCS developed elsewhere

Workflow and Tools

Other Modules

Analytical-based GCS Estimation
Developed elsewhere

Workflow and Tools

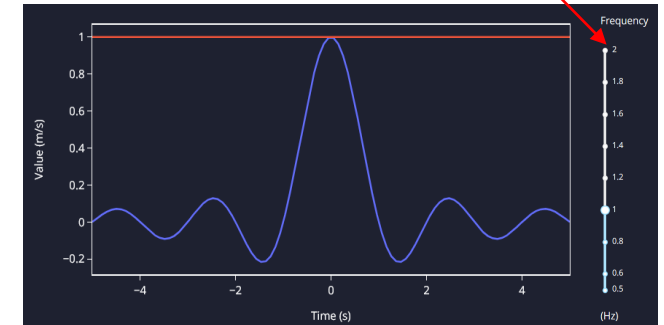
Institutional Disclaimers Displayed on Every Page



Part-2: STRIVE – SMART Tools Rapid Visualization Environment Package

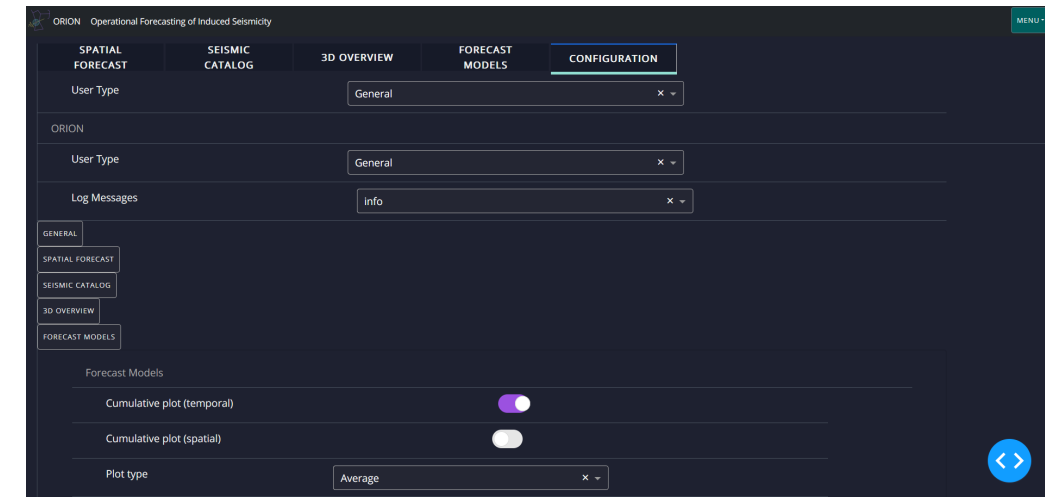
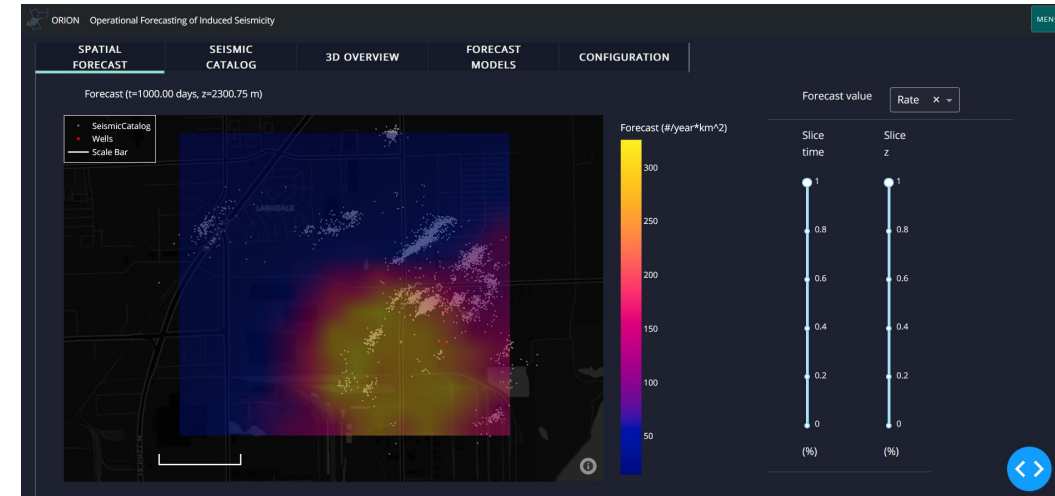
- **STRIVE provides tools for building a modern-looking, flexible, and efficient GUI in Python**
- **To implement STRIVE a user/developer needs to:**
 - Use the provided object base class
 - Write simple API instructions to create figures, widgets
 - STRIVE parses these objects and creates the GUI at run-time
- **This approach provides these benefits:**
 - Simplifies the development process
 - Minimizes redundant code
 - Potential to target multiple front-end engines
 - Approach was adapted from the previous ORION GUI framework, which used Tkinter
- **Current front-end selection: Plotly/Dash**
 - Browser-based and scalable
 - Can be hosted on the cloud or the user's desktop

```
class Example(data_manager_base.DataManagerBase):  
  
    def set_class_options(self, **kwargs):  
        self.name = 'Child'  
        self.float_value = 1.0  
  
    def set_gui_options(self, **kwargs):  
        self.gui_elements['float_value'] = {  
            'element_type': 'entry',  
            'label': 'Frequency',  
            'position': [0, 0],  
            'units': '(Hz)'  
        }  
}
```



Part-2: STRIVE-based ORION user-interface

- **ORION serves as the Induced Seismicity Module for Platform**
- **Key inputs:**
 - Observed seismic activity
 - Pressure model
 - Geologic model
- **Outputs:**
 - Independent seismic forecast models that are based off different physical assumptions, statistics, and ML (in development)
 - An ensemble seismic forecast
 - Visualizations to assist end-users understanding of seismic activity / risks



Part-2: STRIVE-based Virtual Learning Environment (VLE) Module

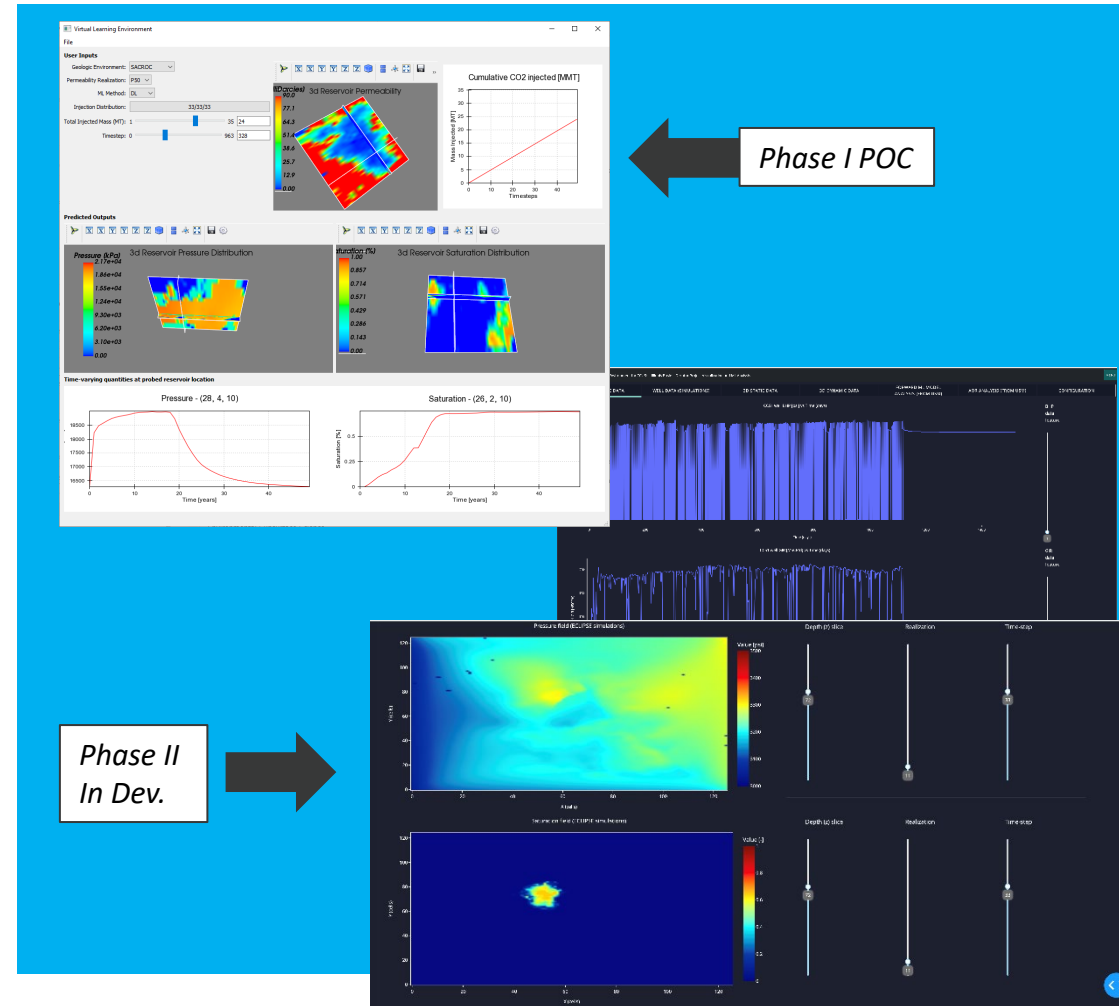
The **Virtual Learning Environment (VLE)** is an exploratory module which uses ML predictions to rapidly inform an end user of how a given reservoir simulation would likely change in response to altered inputs (i.e., “What-if” scenarios)

Phase II development utilizing STRIVE progress includes:

- Encompass Phase I behavior
 - Explore *predicted* changes in pressure and saturation over time given injection rate and permeability profile
 - Additional framing data (AoR) is integrated
 - ML model analysis and visualizations
- Be migrated to an online environment
- Import ML data from Unified Simulation Module (USM)
- Exploring the during and post-injection scenarios

Benefit to CCS industry:

- **Virtual learning:** Computer-based experiential learning environment to improve field development and monitoring strategies
- **Real-time visualization:** Visuals of key subsurface features and flows by exploiting ML to substantially increase speed and enhance detail

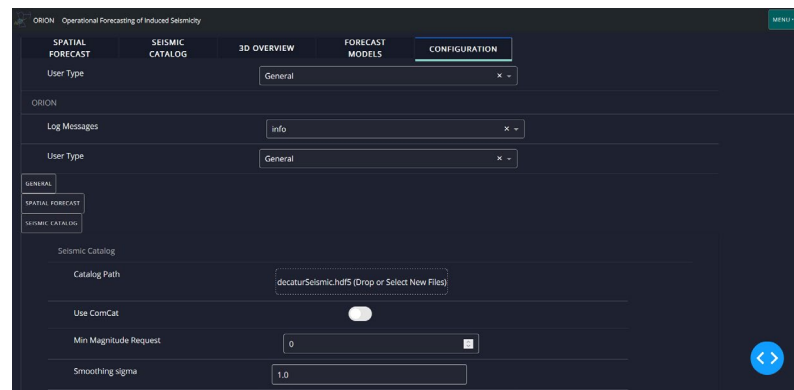
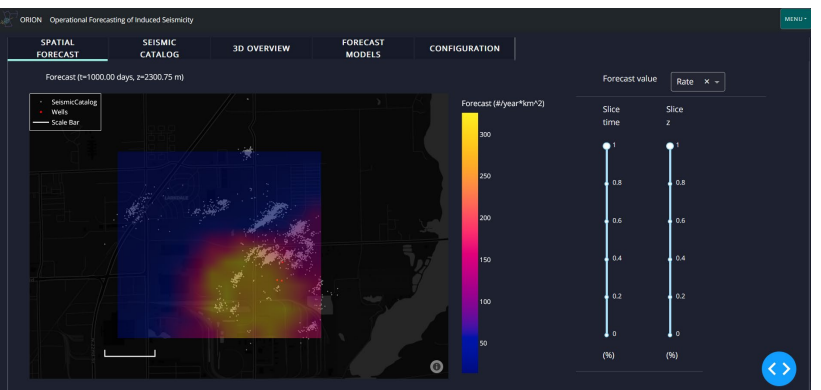
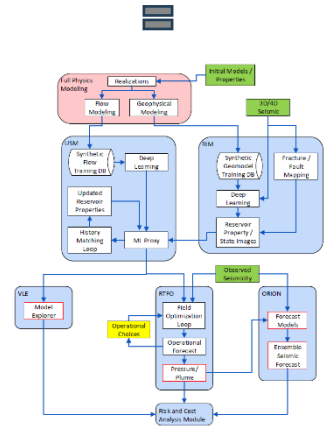
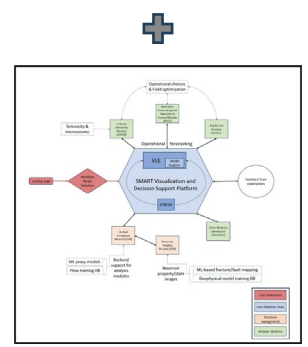


Conclusion – Impact of SMART platform & its modules to CCS Industry

- SMART platform + STRIVE will help us rapidly create, test, and deploy tools developed under SMART
- By design, tools can be tailored to the end-user’s needs and level of expertise
- Figure indicates how a recipe could be used to map the platform to a target workflow

Example Recipe:

1. [USM] Parse results from a FMM-based pressure model
2. [USM] Convert model to VTK and interpolate onto a regular 4D grid
3. [DATA] Send the pressure model from USM to ORION
4. [ORION] Load a second pressure model (in ORION’s preferred .hdf5 format)
5. [ORION] Load seismic data from a local catalog
6. [ORION] Build a seismic forecast and ensemble model
7. ...





Live-demos and posters on SMART platform & its modules

- Live-demos and posters of SMART tools
 - SMART Tools Rapid Visualization Environment (STRIVE) Package – Chris Sherman
 - Operational FoRecastIng Of INduced Seismicity (ORION) – Kayla Kroll and Chris Sherman
 - Model Explorer module – Ashton Kirol and Ivani Patel
 - Real-time Forecasting and Operational Control (RTFO) module – Alex Hanna
 - Virtual Learning Environment (VLE) Module – Maruti Mudunuru
 - Unified Simulation Module (USM) – Wenjing Wang
 - Engineering Economics Module (TALES) – Dave Morgan
 - SMART platform (EY24 early win) – Eusebius Kutsienyo

Questions?

Thank you!

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