# Overview of SMART Initiative


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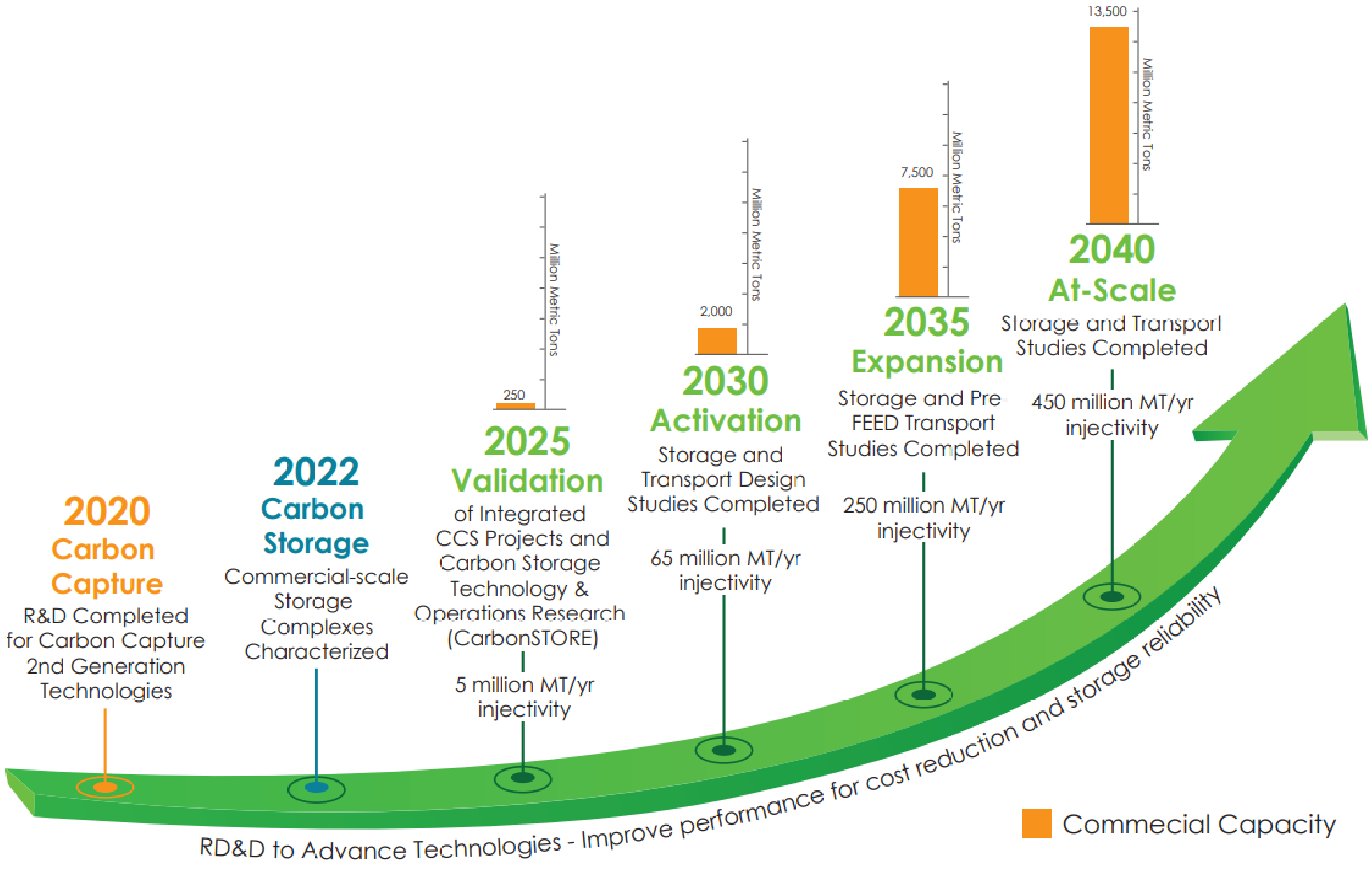
U.S. DEPARTMENT OF ENERGY

NATIONAL ENERGY TECHNOLOGY LABORATORY

# Meeting the CCS Challenge



# $CO_2$ Reduction Targets

NATIONAL ENERGY TECHNOLOGY LABORATORY

- The U.S. Department of Energy (DOE) has announced a commitment from several companies and organizations to reduce their carbon emissions by 50% by 2030 through DOE's Better Climate Challenge.

- Climate Challenge is key to reaching the goal of a net-zero emissions economy by 2050 through an equitable clean energy transition.

- Investments are made for rapid development of large-scale $CO_2$ storage operations. This include 45Q Tax credit for Carbon Sequestration.

# Our Motivation

**Growing momentum for rapid commercial scale deployment of CCS**

- Develop relevant experience / understanding among stakeholders
- Facilitate decision-making process during project planning, permitting, operations

**Traditional analysis involves physics-based models**

- Data interpretation for characterization
- Pre-injection planning and system design
- Observational data integration for operational decision making

**Recent focus on Machine Learning based computationally expedient alternatives**

# SMART Initiative

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

## Technical Team

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

Sandia National Laboratories

Berkeley Lab

Illinois

Phase 2

# SMART - Visualization and Decision Support Platform

## SMART Functionalities

**Real-Time Visualization**
*"CT" for the Subsurface*

**ML-based Rapid Prediction**
*Virtual Learning*

**ML-based Real-Time Forecasting**
*"Advanced Control Room"*

## SMART Decision Support Platform

## SMART Applications

**Virtual Learning to Support Permitting**
**Injection Operational Control**

**Phase 1**
**"Proof of Concept"**

**Phase 2**
**"Development and Validation"**

# Making Better Decisions

Phase 2

***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

❶ Where is the $CO_2$ now?

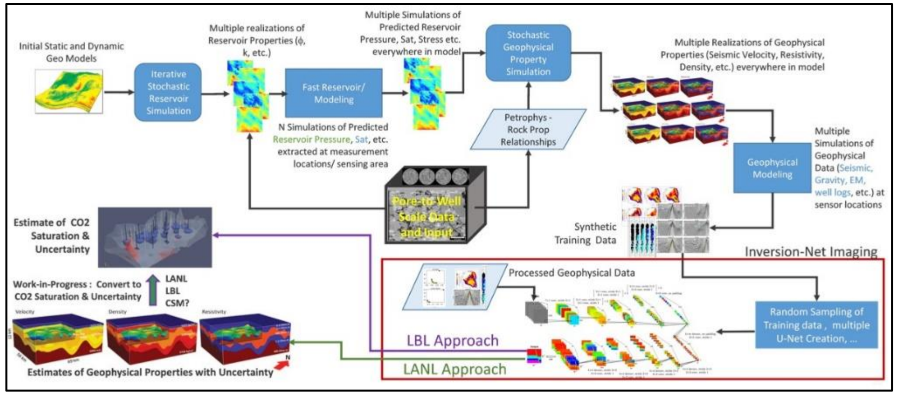
❷ How do I move the $CO_2$ where I want it to be?

❸ Is the project safe?

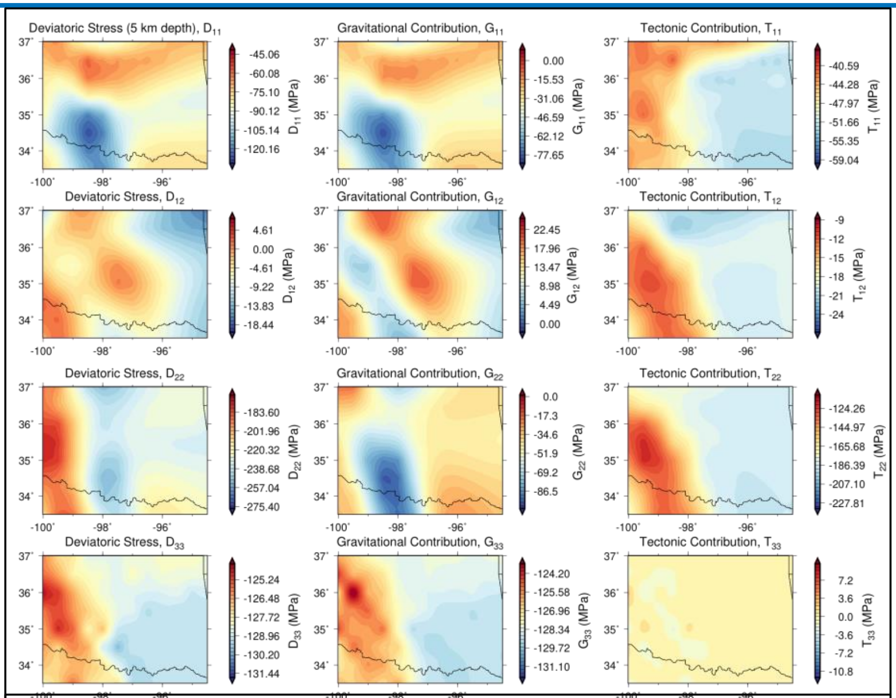
- Will it leak, and if so, where?
- Will it cause induced seismicity?

# PHASE 1 Highlights

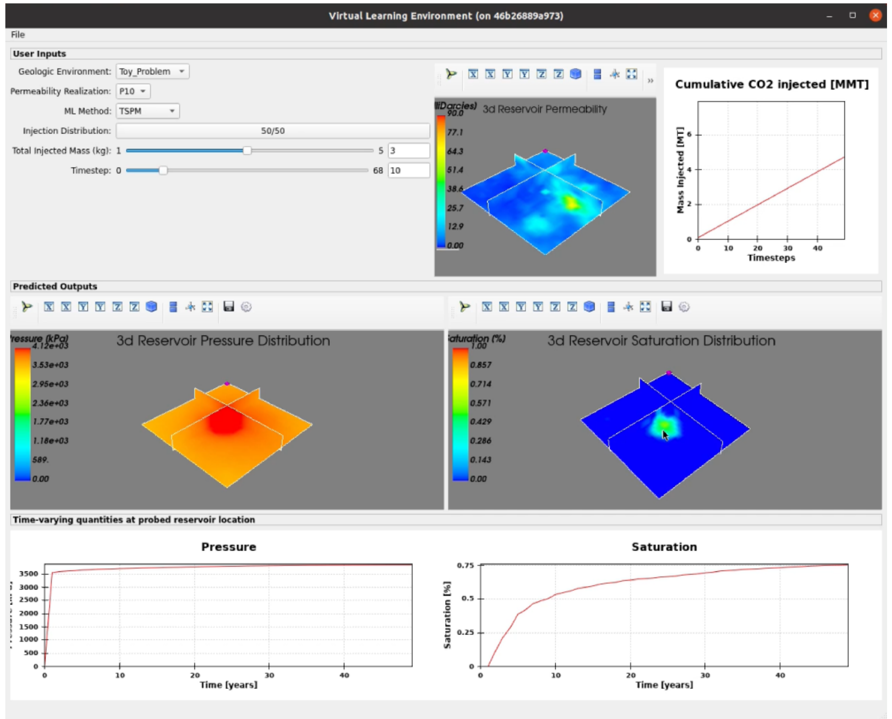
**TASK 2**
**ML-based $CO_2$ satn. from seismic data**



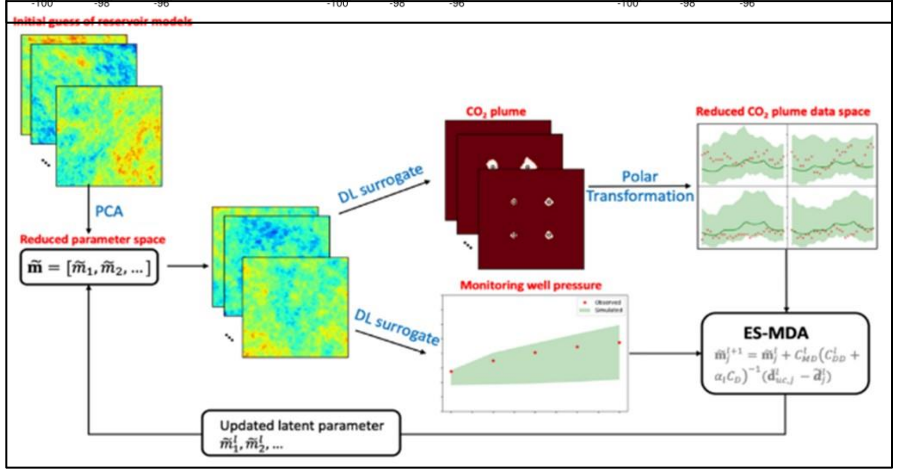

**TASK 3**
**ML-based stress tensor characterization**




**TASK 5**
**VLE**
**Virtual Learning Environment**




**TASK 4**
**ML-based history matching & forecasting**



# Organization of Technical Activities

**Phase 2**

**Task 2**
**Virtual learning to support permitting**

**Task 3**
**Advanced learning and computational methods**

*Field validation of Phase 1 tools and workflows in conjunction with NRAP and EDX4CCS*

**Task 4**
**Site-specific data management & imaging**

**Task 5**
**Site-specific storage reservoir modeling**

**Task 6**
**Site-specific decision support & visualization**

**Task 7**
**Site-specific data curation**

# SMART Phase 2 Framework

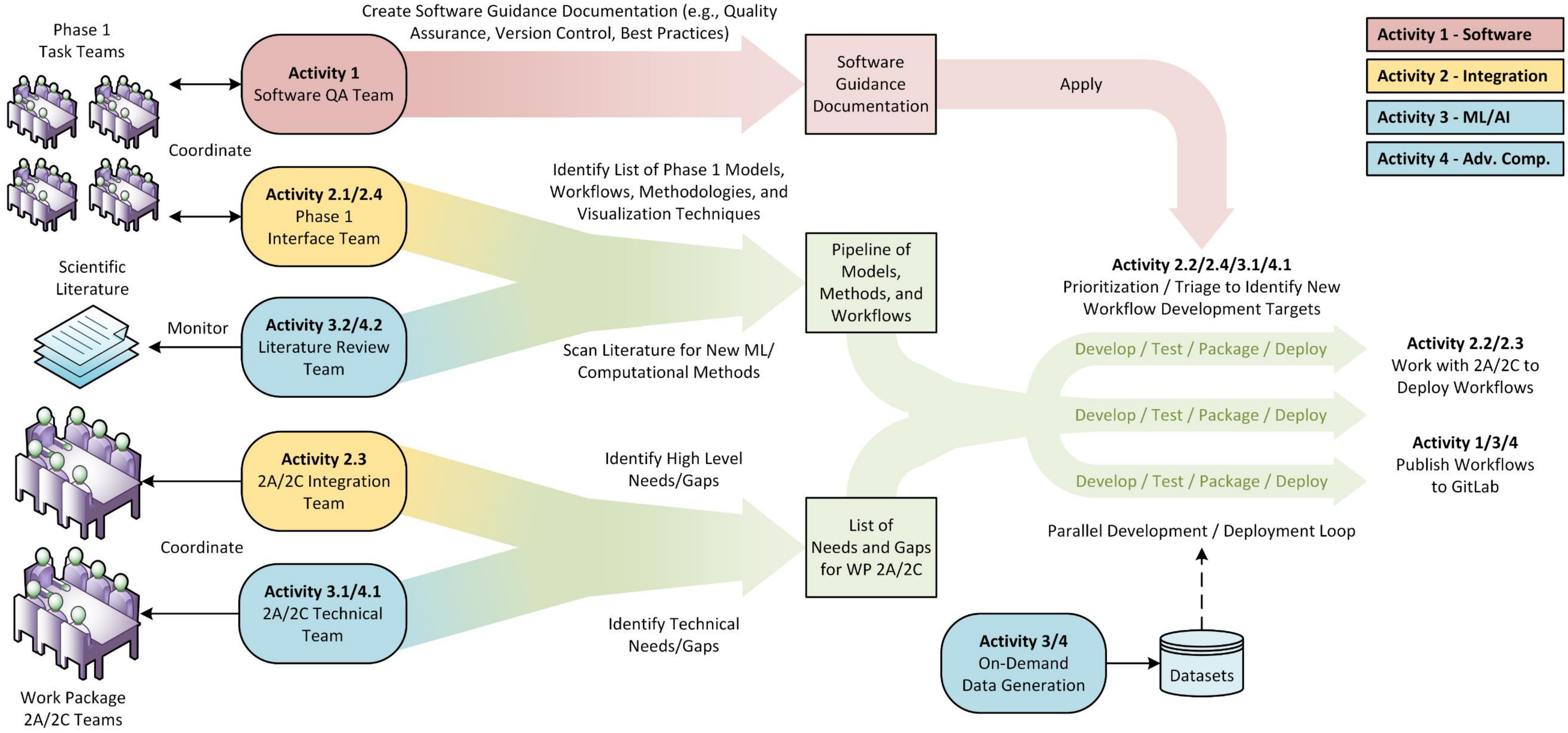
Phase 2

- **WP2A ⇨**
  Demonstrate virtual learning in action to support regulators & stakeholders during permitting
- **WP 2B ⇨**
  *Develop advanced learning and computational methods*
- **WP 2C ⇨**
  Apply ML-assisted workflows for reservoir imaging and modeling from Phase I for field-scale deployment

[Q] New insights / information from ML-assisted workflows – improved communication / ease of use during Class VI permitting? (case study - WY CarbonSAFE)

[Q] (Near) real-time feedback for operational control / optimization - improved system understanding? (case study – IBDP)

# Wiring Diagram – WP 2B – Advanced ML & Comp. Methods



# 2A – Virtual Learning in Action to Support Permitting

**Goal** ⇨ Demonstrate how ML and virtual learning can be used in permitting process:

- Regulators and site developers are key customers
- Work with existing permit application to show added value

**Activity 1: Outreach to Regulators**

Identify how Machine Learning based approaches can help during Class VI permitting process

**Activity 2: Improved Site Characterization**

Demonstrate application of ML-based approaches to improve site-characterization efforts performed during pre-injection phase

**Activity 3: Rapid Forecasting**

Demonstrate how ML-based rapid forecasting can help with pre-injection reservoir management decisions under data uncertainties

**Activity 4: Model Explorer**

Show how visualization platform with ML models can help stakeholders explore key prediction uncertainties that affect injection/storage operations.

**Activity 5: Value of Information and Economic Decisions**

Demonstrate how Machine Learning based approaches can be used to help with value of information using existing Class VI permit application related data/models.

# Wiring Diagram – WP 2A – Virtual Learning for Permitting

## Activity 2: ML-based site characterization

- Improved characterization of faults/fractures
- Predictions of state-of-stress
- Improved permeability estimate

- Geologic realizations

## Activity 3: Rapid Forecasting

Reservoir Simulation Ensembles
- Location of injection wells
- Geological uncertainty
- Well controls

Training Database
- Pressure
- $CO_2$ saturation
- Stress / deformation

Fast-Running ML Surrogates
- Pressure
- Saturation
- Stress

## Activity 4: Model Explorer

Virtual Learning Environment
- AOR (2D, 3D)
- Pressure
- Saturation
- Stress

## Activity 5: VOI

Value of Information
- ML-based methods/workflows to tie static geologic models to fast predictive models with economic analysis (decisions)

## Activity 1: Outreach

Workshop
- Regulatory orgs, Stakeholders
- Feedback

## Raw Static Database

Static Data (WP 2C2)
- Core and Well logs
- Well tests
- Fluid samples
- 3D seismic and passive seismic

Simulation models

Improved characterization data

## New Development

R&D (WP 2B)
- Surrogate models
- Compression methods
- Transfer learning

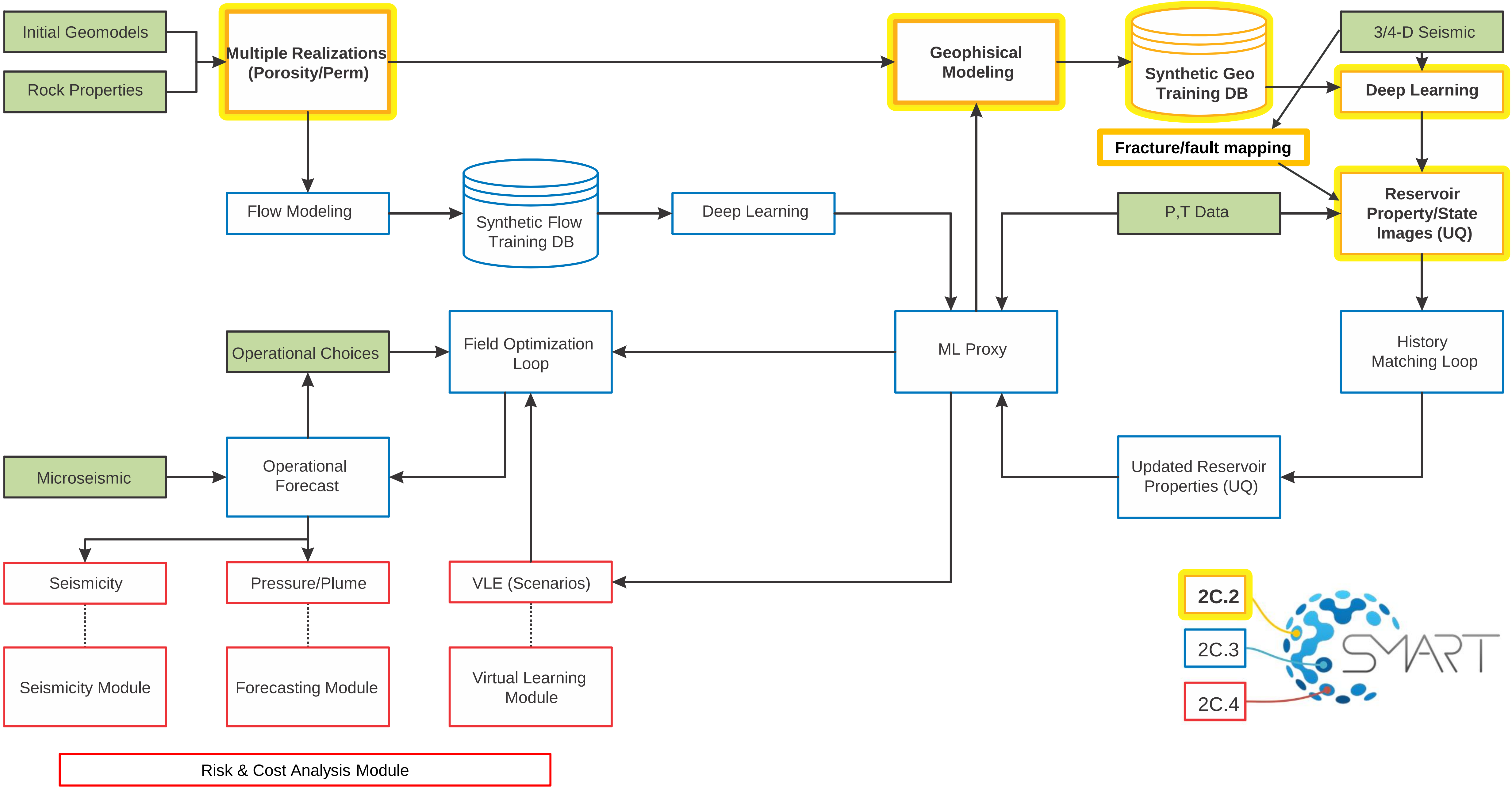
## Visualization

Synergy (WP 2C4)
- VLE Beta version on fact track
- Recommendations

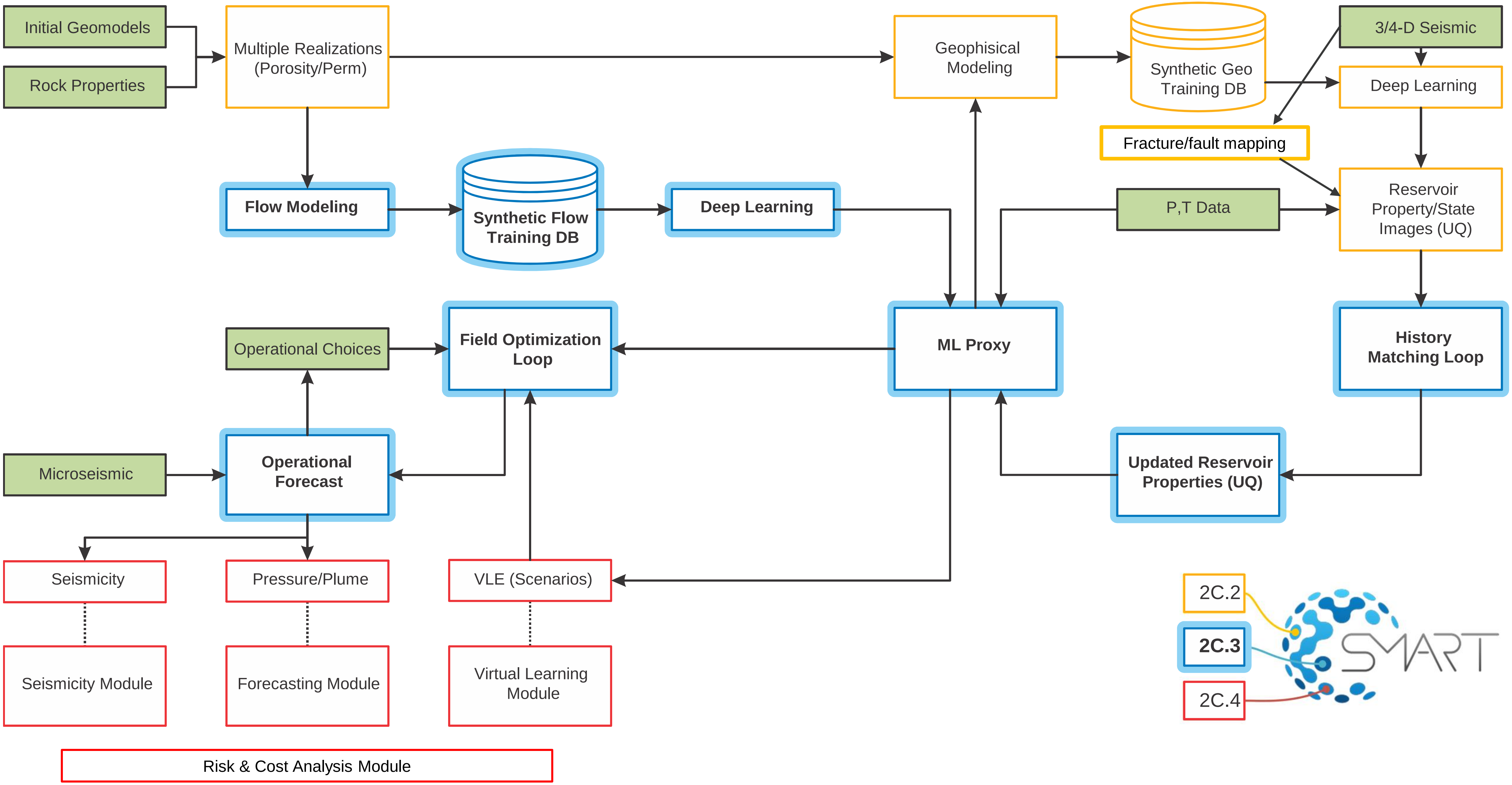
## New Development

Synergy (WP 2C3)
- ML based surrogate models

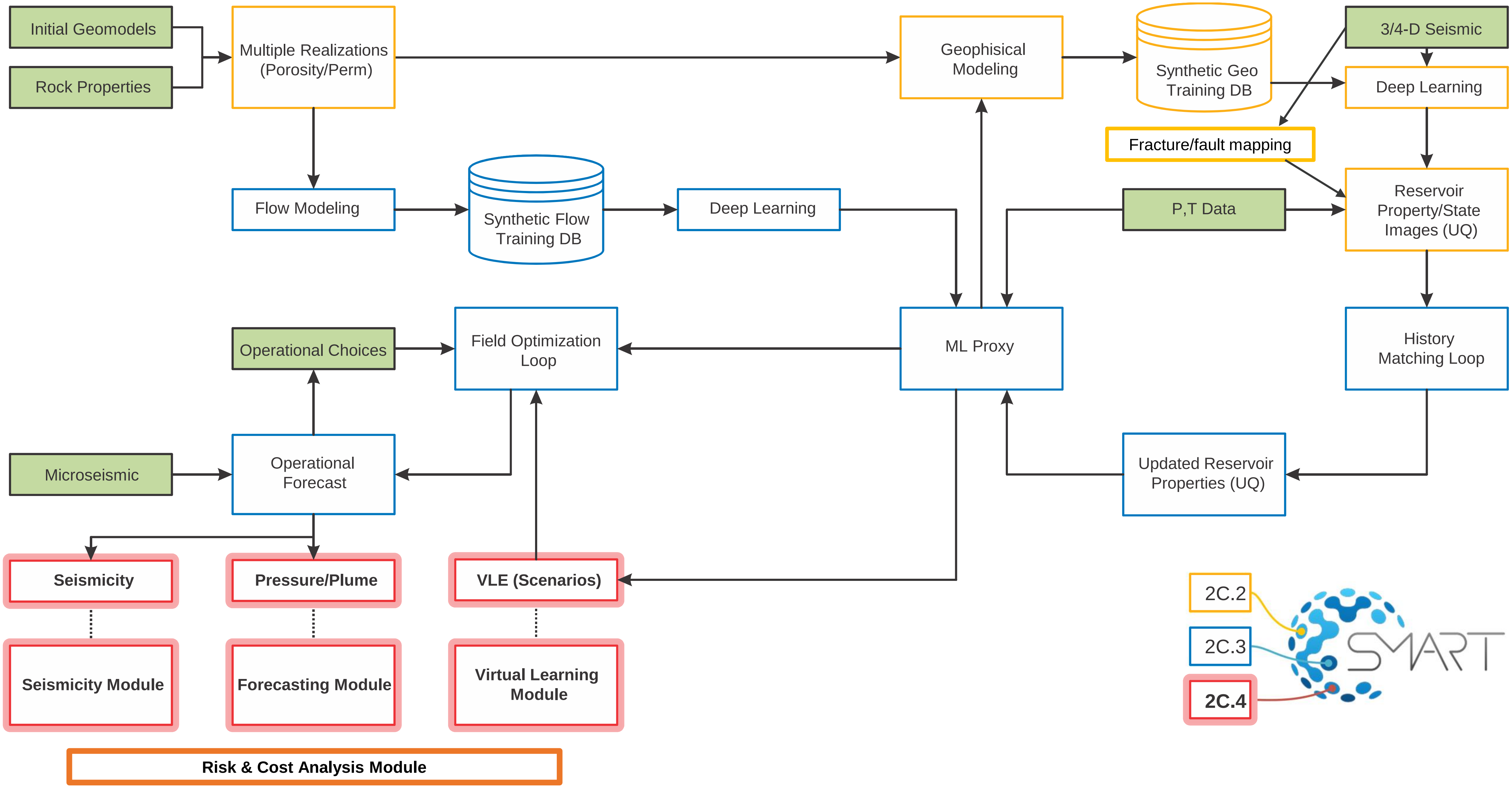
# Wiring Diagram – WP 2C2 – Data Organization & Imaging



# Wiring Diagram – WP 2C3 – Storage Reservoir Modeling

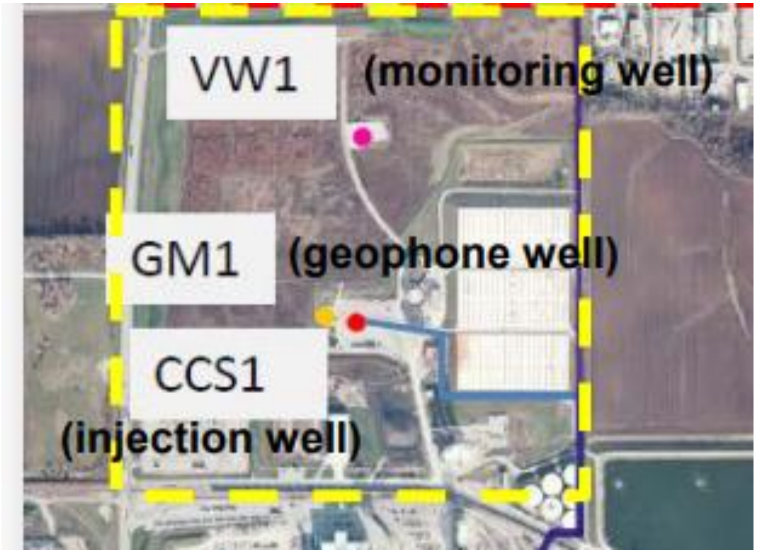


# Wiring Diagram – WP 2C4 – Decision Support & Visualization



# Data Types Available from IBDP for Reservoir Imaging

- **Geologic Models**
  - Static Geologic Model
  - Dynamic Reservoir Model
  - Geomechanical Model
  - Groundwater Model
- **Project Imagery (High and Low Res)**
  - Pre-injection
  - During Injection ( 3 May 2012)
  - Post Injection (30 April 2015)
  - Final (5 Nov 2019)
- **Passive Seismic Events Data**
  - Surface Geophones
  - Downhole Geophones
  - Raw data as well as picked events
- **Active Source Seismic Data**
  - 2D lines
  - 3D Volume
  - 3D VSP
  - 4D volume
  - Raw 3D Data
- **Data Collected From 3 Deep Wells**
  - MWD
  - Core & Sidewall Core
  - Well Tests
  - Geophysical Logs
- **Geochem**
  - Soil $CO_2$ flux and gas
  - Shallow groundwater sampling
  - Deep Fluid Sampling
- **$CO_2$ Injection Monitoring Data**
  - CCS1 Only
    - DTS
    - $CO_2$ Flow
  - CCS1 and VW1
    - $CO_2$ Saturation Logs
    - Temperature Logs
    - T, P



# SMART Presentations

| | |
|---|---|
| 1:15 p.m. - 1:40 p.m. | **Overview of the SMART Initiative**<br>Hema Siriwardane, National Energy Technology Laboratory, and Srikanta Mishra, Battelle Memorial Institute |
| 1:40 p.m. - 2:05 p.m. | **SMART - Advanced Machine Learning and Computational Methods**<br>Jared Schuetter, Battelle Memorial Institute, Alexandre Tartakovsky, University of Illinois, and Chung Shih, National Energy Technology Laboratory |
| 2:05 p.m. - 2:30 p.m. | **SMART - Site Specific Data Organization and Imaging**<br>Joe Morris, Lawrence Livermore National Laboratory, David Alumbaugh, Lawrence Berkeley National Laboratory, and Youzuo Lin, Los Alamos National Laboratory |
| 2:30 p.m. - 2:55 p.m. | **SMART - Site Specific Dynamic Storage Reservoir Modeling**<br>Joshua White, Lawrence Livermore National Laboratory, Hongkyu Yoon, Sandia National Laboratory, and Akhil Datta-Gupta, Texas A&M University |
| 2:55 p.m. - 3:20 p.m. | **SMART - Site Specific Visualization and Decision Support**<br>Diana Bacon, Pacific Northwest National Laboratory, David Morgan, National Energy Technology Laboratory, and Maruti Mudunuru, Pacific Northwest National Laboratory |
| 3:20 p.m. - 3:50 p.m. | BREAK - Ballroom Foyer |

# Concluding Remarks

- SMART motivation, structure, organization, wiring diagrams
- Goal ⇨ Empower various stakeholders with advanced ML and related tools that can accelerate decision-making
- Outcomes of SMART expected to be publicly available
- Each WP will present its key accomplishments from EY22

**Thank you for your attention**