Natural Gas Hydrate FWP

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NETL R&IC

U.S. Department of Energy

National Energy Technology Laboratory

Oil & Natural Gas

2020 Integrated Review Webinar

Project Overview

Project Goals:

- Provide the state-of-the-art experimental, modeling, and economic analysis to support planning and execution of long-term field gas production tests, predicting environmental implications and developing long-term projection of US energy asset.
- Provide pertinent, high quality information that benefit the development of geological and numerical models and methods for predicting the behavior of gas hydrates in natural and production conditions.

EY20 Funding: $2.66 M ($2.25 M + $0.41 M Carryover)

Overall Project Performance Dates: 04/01/2020 – 03/31/2021

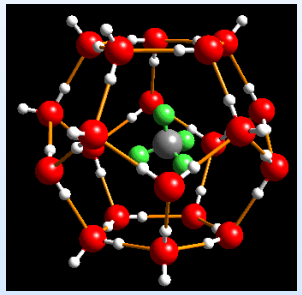
Project Participants:

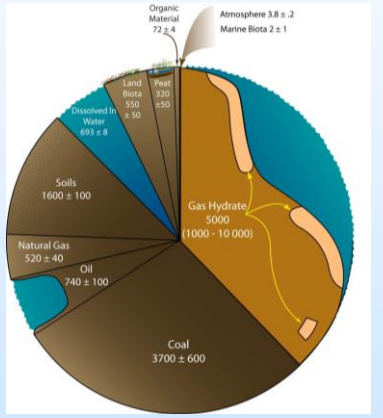
- FE HQ Division Director; Timothy Reinhardt
- FE HQ Project Manager: Gabby Intihar
- NETL Technology Manager: Joseph Stoffa
- NETL Senior Fellow: Grant Bromhal
- NETL Program Manager: Sand Borek
- NETL R&IC TPL: Yongkoo Seol
- NETL R&IC Researchers
- LRST Site Support Researchers
- ORISE Fellows
- Universities: West Virginia Univ., RPI, Georgia Tech, Pitt, Stanford

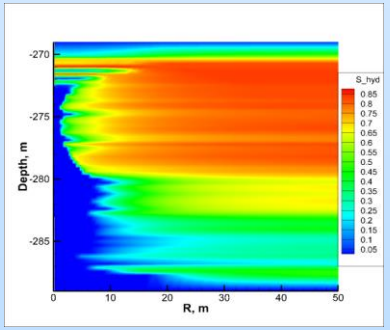
Natural Methane Hydrate

- **Crystalline solid consisting of gas molecules, usually methane, each surrounded by a cage of water molecules**
  - One volume hydrate typically equivalent to 160 volumes methane gas
- **Natural gas hydrate (NGH) is an enormous global storehouse of organic carbon**
  - Estimates of carbon trapped in NGH exceeds that of known coal, oil and gas resources combined
  - Volume of clean, natural gas trapped in NGH could offer significant energy resource
  - CH_4 is >20x's more potent a greenhouse gas than CO_2
- **Large Occurrence at Arctic regions and in Marine sediments**
  - Focused on sandy sediments in permafrost and deep-water for production
- **National Gas Hydrate R&D Program**
  - Resources assessment and confirmation of sustainable gas production
  - Long-term Production testing at Alaska with Japan
  - Pressure coring at GOM

Global assessments indicate a large volume of organic carbon is trapped world-wide in gas hydrates (1000 – 10,000 GT).



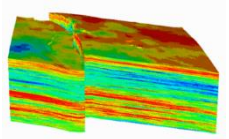




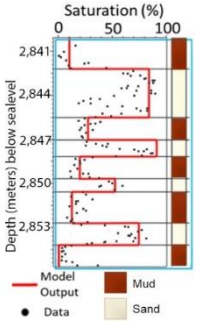
NETL R&IC Hydrate Portfolio

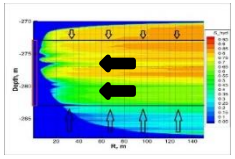
Overarching Goal

- ✓ To promote understanding of intricate **hydro-thermo-mechanical coupled processes** in hydrate systems,
- ✓ To provide key parameters for reservoir simulators of production potential prediction,
- ✓ To advance the **fundamental sciences filling knowledge gaps** for safe and economic exploitation of hydrate deposits.

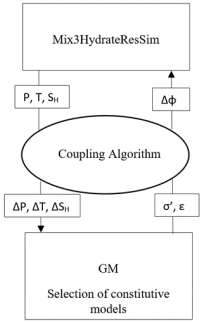


3D Geological Model based on well log and seismic





Production Simulations for operation design support

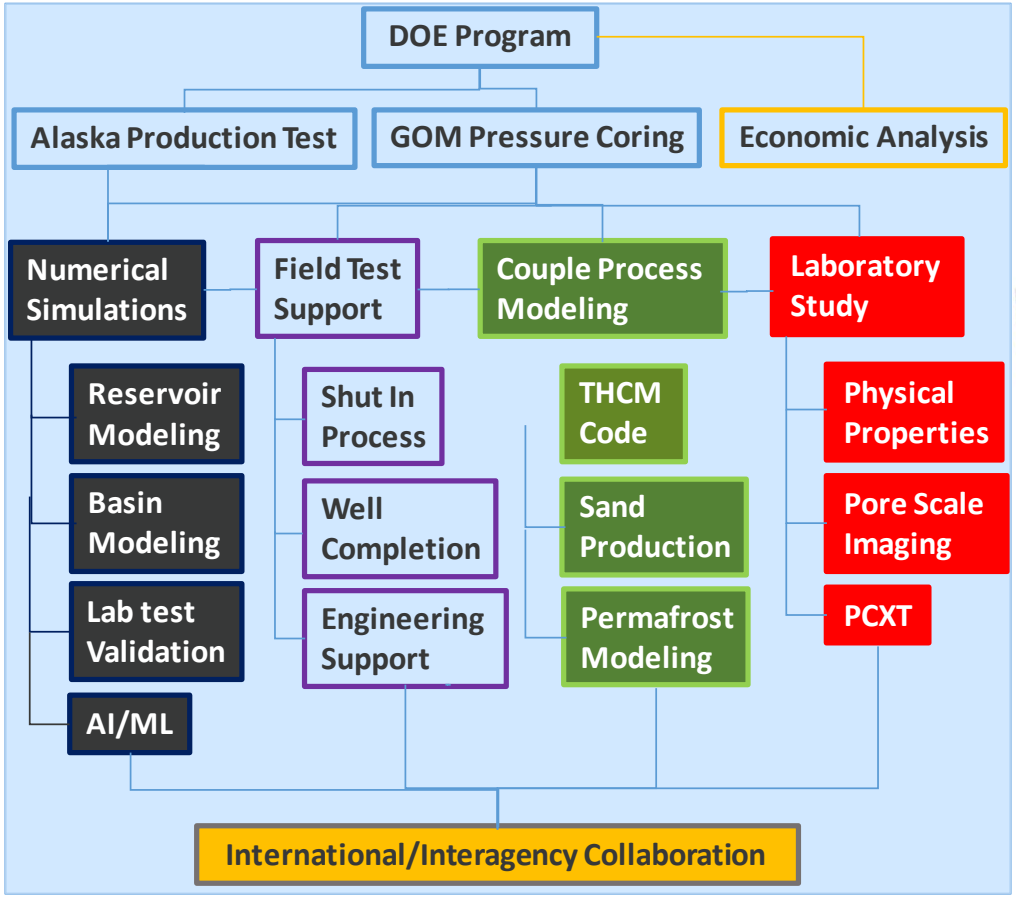


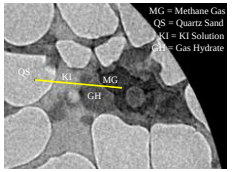
3D Basin Model calibrated on well log and seismic, Distance based sensitivity Analysis

NetworkX
Network Analysis in Python

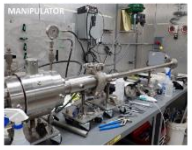
Mix3HRS-GMS: fully coupled THCM code Sand production prediction

GeoData Framework for Hydrate

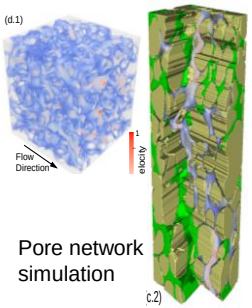




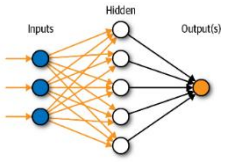
Pore Scale Visualization

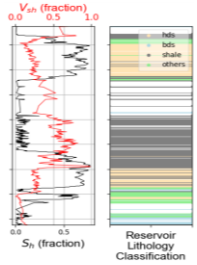


Pressure core handling tool Characterization and Analysis



Pore network simulation





Machine Learning Application Parameter estimation and 3D modeling development

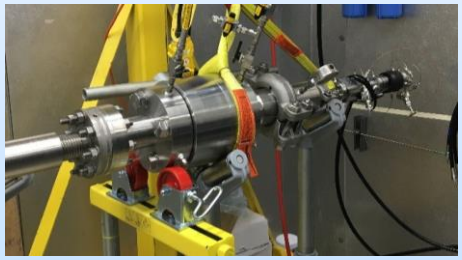
NETL R&IC Hydrate Portfolio

Project Area	Tasks	Goals
Numerical Simulation Supports	• Gas Production Prediction/Code Comparison • Hydrate Accumulation Genesis • 3D Model based on ML and new data framework	• Economical recoverability for short- and long-term gas production and recommendations on planning, execution, and analysis of field production tests
Coupled Processing Modeling	• THCM Code development and Modeling • Sand Production Modeling and Critical State Model • Permafrost Impacts	• NETL's THCM simulator for methane hydrate reservoir modeling
Laboratory Experimental Supports	• Hydrological/Geomechanical Property • Pressure Core Analysis and Tool Development • Multiscale (Core/Pore) Testing and Imaging	• Relevant input for numerical simulations • Fundamental knowledge on gas hydrate and its responses
Field Production Test Supports	• Shut In Procedure/Well Completion Method • Engineering Support	• Engineering support needed for the planning and operation of the ANS production well test
Economic Analysis of Gas Resources	• Gas supply and demand analysis for 2100 timeframe	• perspective on potential need for additional gas supply sources to meet market demand
Interagency and International Collaboration	• Code comparisons, Core Analysis Working Group	

Major Accomplishment

Pressure Core Characterization and Visualization Tools in NETL Gas Hydrate Laboratory

- **Goal**: Characterizing geomechanical and hydrological properties of synthesized and natural hydrate and hydrate bearing sediments under insitu and production condition
- **Challenges**: Experimental complexity associated with hydrate stable pressure and temperature condition, which should be maintained during operation
- **Approach:** A suite of tool set that can manipulate and characterize natural hydrate bearing cores, as well as visualize methane hydrate in natural sediment pores with high resolution at its *in-situ* condition.
- **Results:** The tool set, called PCXT (pressure core characterization and x-ray CT visualization tools) can measure physical properties including permeability, compressibility, and acoustic velocity,
- **Implications**: The tool set will be utilized to analyze pressure cores from Alaska North Slope (2021) and Gulf of Mexico (2022) for physical properties, which will be the key input for numerical reservoir simulation of gas production potential.



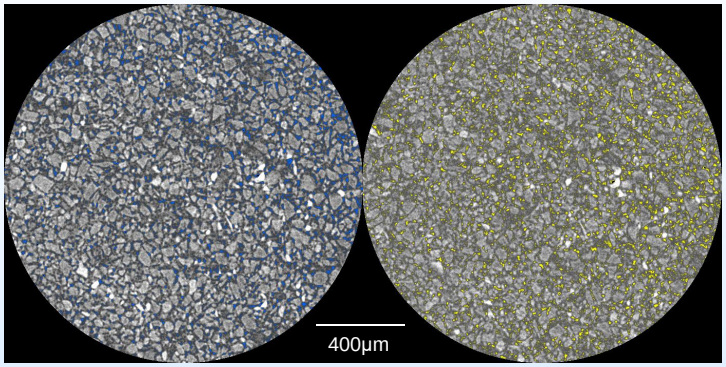
Anisotropic Permeability Cell

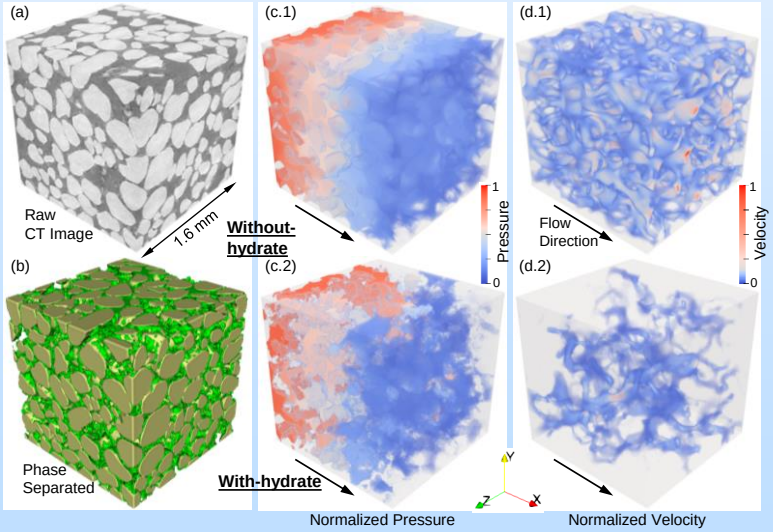
Triaxial Stress Chamber

Major Accomplishment

High Resolution Visualization of Methane Hydrate In Natural Sediments

- **Goal**: Describing the pore habit of methane hydrate in sediment matrices for understanding natural distribution of methane hydrate, methane trace (transport and solidification) in the hydrate stability zone, physical properties of hydrate-bearing sediments, and the associated influence on potential gas production
- **Challenges**: Experimental complexity associated with hydrate stable pressure and temperature condition and similarity in density of methane hydrate and pore fluid
- **Approach:** Pressure-core Characterization and X-ray visualization Tools (PCXT) and the phase-contrast micro-CT technique: develop 3D pore structures of hydrate bearing sediments and analyzed pore-scale fluid flow phenomena ,
- **Implication:** help understand natural distribution of methane hydrate, methane migration in the hydrate stability zone, physical properties of hydrate-bearing sediments, and the associated impact of fluid migration that dominate the potential gas production

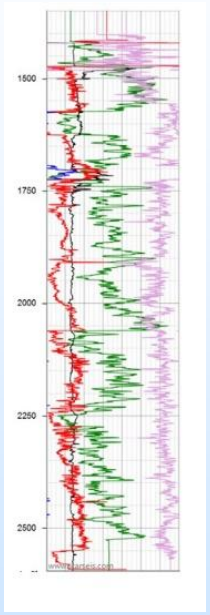


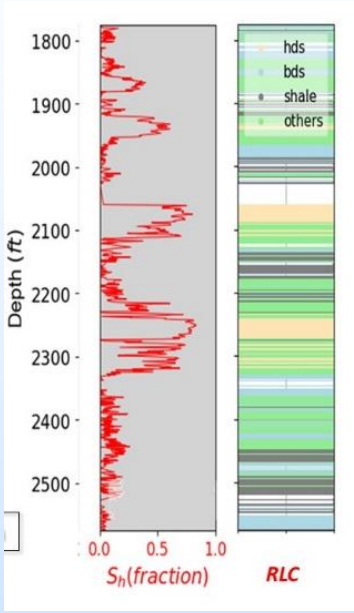


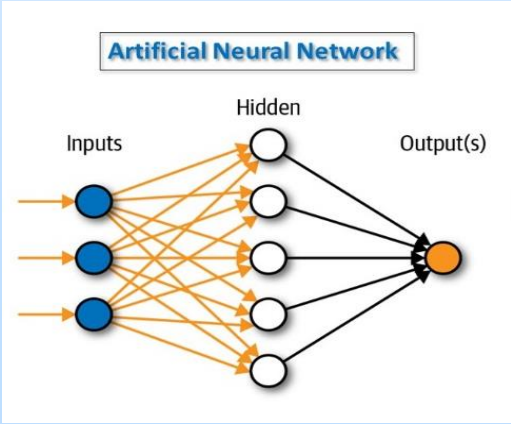
Major Accomplishment

Machine Leaning Applied to Gas Hydrate Reservoir and Basin Characterization

- **Machine Learning Approaches**: Uniquely offer the ability to identify and exploit underlying dependencies between input and target data that are not readily available through physics-driven models
- **Results**: Trained ML models capable of predicting gas hydrate saturation distribution and lithofacies recognition at 84% and 90% accuracy
- **Application of ML techniques in Gas Hydrate Research**:
  - ✓ Spatial and temporal characterization of gas hydrate deposits in permafrost and marine environment using data from pore to basin scales,
  - ✓ Synthesis of existing gas hydrates system knowledge from scientific literature, prediction of reservoir productivity,
  - ✓ Optimization of wellbore design for reservoir performance
- **Implication to DOE Natural Gas Hydrates Program** to obtain high precision data on gas hydrates in their natural environment and under production scenarios that secures future exploration of gas hydrate as future U.S. energy source



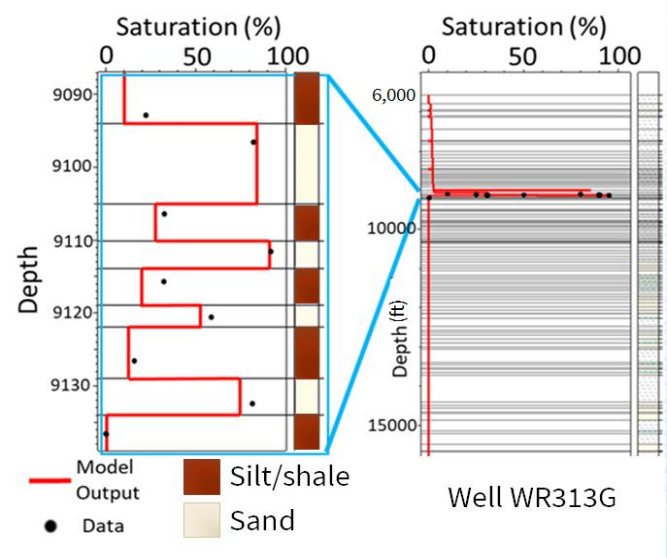


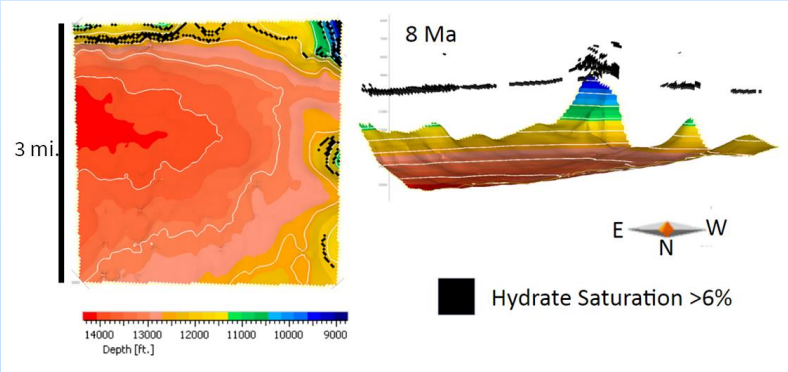


Major Accomplishment

Developed a High Resolution, 3D Basin-Scale Model for Terrebonne Basin

- **Goal**: A quantitative basin and petroleum system model enables the reconstruction of complex Earth basin histories as well as the evolution of the petroleum system fluids while incorporating geology, physics, chemistry, and other dynamic formulas
- **Approach:** Collected 2D seismic (i.e. sub-surface imaging) from the USGS, 3D seismic from WesternGeco/Schlumberger, published literature, and reports from 3 wells drilled in the area of interest to built 3D basin and petroleum system model and to calibrate the pressure, pore space, and gas hydrate saturations of the model
- **Outcome**: High resolution basin model of a gas hydrate petroleum system with 230 layers gridded at a 10 m spacing, 24 million cells, and sensitivity analysis for salt movement, hydrate recycling, faults, and physical properties.
- **Implication:** Understanding hydrate system processes through time and its present properties can lead understand more of the scientific processes driving gas hydrate formation, volumes, and saturations, for this area's energy prospect, but also where to search for gas hydrates next

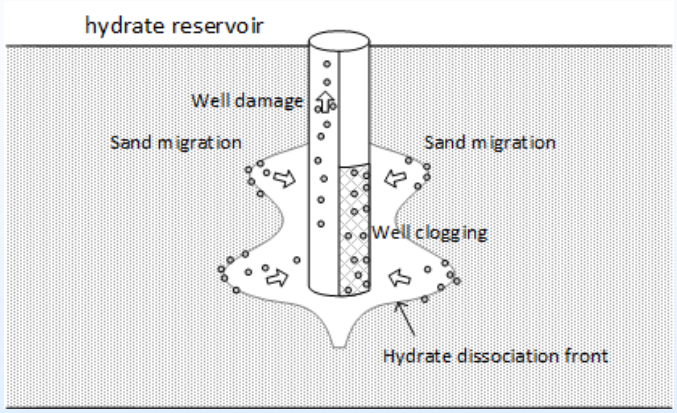


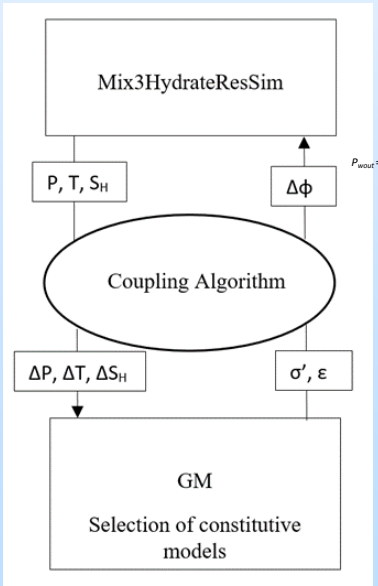


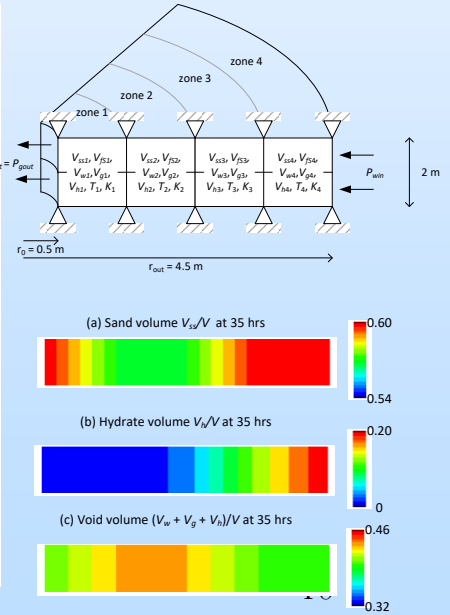
Major Accomplishment

NETL's THCM simulator, Mix3HRS-GM to incorporate Sand Migration Modeling

- **Goal**: NETL's own comprehensive simulator for simulating gas production from hydrate bearing sediment
- **Challenges:** Complex multiphysics processes highly coupled with hydrate formation and dissociation causing temperature change and weakening sediments affecting permeability
- **Approach:** NETL's THCM simulator, Mix3HRS-GM, extended its capability to model sand migration through incorporating sand-water mixture flow and sand mobilization model.
- **Outcome**: Unique simulator to predict the amount of mobilized sands, where they come from, what the consequences are in terms of gas productivity and sediment deformation.
- **Implication:** Results suggest how to mitigate potential adverse effect of sand migration along with gas production and the novel simulator, Mix3HRS-GMS can help the US Department of Energy to unlock the abundant new source of hydrocarbon energy for future generations







Plans for Future Activities

- Numerical Reservoir Simulations: Developing 3D Heterogeneous Model for Alaska Reservoirs
- Pressure Core Characterization and Analysis for Cores from Alaska and GOM
- Fundamental Physical Properties for Layered Hydrate Bearing Sediments
- Parallelization of Mix3HRS-GMS for Full 3D Coupled Process Modeling with Sand Production
- Machine Learning Application to Marine Hydrate System and 3D Geologic Model Development
- Geodata Framework Development for Hydrate System
- Basin Modeling for Alaska Kuparuk Basin
- Continued Engineering Supports for Alaska Production Test
- Studying impacts of gas production on Permafrost

Summary

- **Project Goal:** Support DOE's large field program by providing high quality information that benefit the development of geological and numerical models and methods for predicting the behavior of gas hydrates for long-term US energy asset.
- **Major Accomplishments:** developed capability and capacity for numerical simulations, physical properties assessment, and fundamental knowledges on hydrate and hydrate-bearing sediments
- **Future Actions:** Enhanced and expanded capability and capacity for hydrate research with new tools including pressuring core handling tool sets, ML, and parallelized reservoir simulators to better support DOE's field explorations and expedition

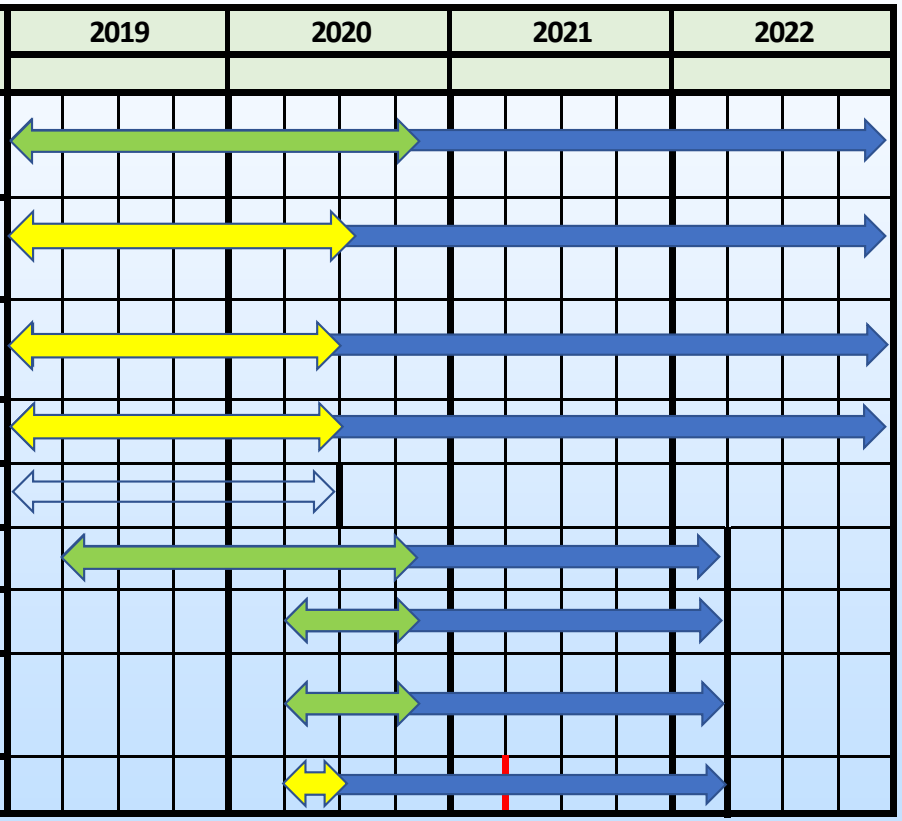
Organization Chart

- NETL Technology Manager: Joseph Stoffa
- Senior Fellow(s): Grant Bromhal
- R&IC TPL(s): Yongkoo Seol
- R&IC PI(s): Yongkoo Seol, Don Remson, Tim Grant,
- FE HQ Division Director: Timothy Reinhardt
- FE HQ Project Manager: Gabby Intihar
- Program Manager: Sandra Borek

Task #	Task Leads	Team Members
Z	Sand Borek	Jeff Ilconich (LRST)
2	Yongkoo Seol	Evgeniy Myshakin (LRST), Gabe Creason (LRST), Nagasree Garapati (WVU), Allegra Scheirer (Stanford), Laura Dafov (Stanford), Zach Burton (Stanford)
3	Yongkoo Seol	Evgeniy Myshakin (LRST), Xuerui Gai (LRST) Shun Uchida (RPI), Jeen-Shang Lin (Pitt)
4	Yongkoo Seol	Jeong Choi (LRST), Karl Jarvis (LRST), Sheng Dai (GT)
5	Yongkoo Seol	Taehyung Park (ORISE), Karl Jarvis (LRST), Bryan Tennent (LRST)
6	Don Remson Tim Grant	Ray Boswell, Jim Kirksey (MESA), Alana Sheriff (MESA)
7	Don Remson Tim Grant	Ray Boswell, Jim Kirksey (MESA), Alana Sheriff (MESA)
8	Yongkoo Seol	Ray Boswell, Jeff Ilconich (LRST) Ryder Scott Subcontractors
9	Yongkoo Seol	Evgeniy Myshakin (LRST), Leebyn Chong (LRST)
10	Yongkoo Seol	Evgeniy Myshakin (LRST), Xuerui Gai (LRST)

Gantt Chart

Task	Task Title for Current Execution Year
2	Numerical Simulations Supports for Reservoir Characterization and Performance Prediction
3	Development of Thermal-Hydro-Chemo-Mechanical Simulator for Methane Hydrate Reservoir Modeling
4	Fundamental Property Characterization of Hydrate-Bearing Sediments
5	Pressure Core Characterization and Analysis
6	Systems Engineering and Analysis
7	Methane Hydrate Well Research
8	Alaskan North Slope Engineering Support
9	Machine Learning Application to Gas Hydrate Systems
10	Permafrost-Gas Hydrate System in Arctic



Go/No-Go TimeFrame

Project Completion

Current Progress as of Oct. 2020 On Schedule Delayed

Completed Planned