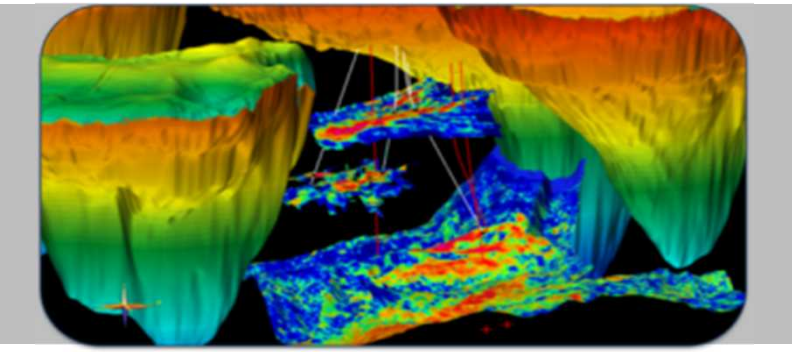
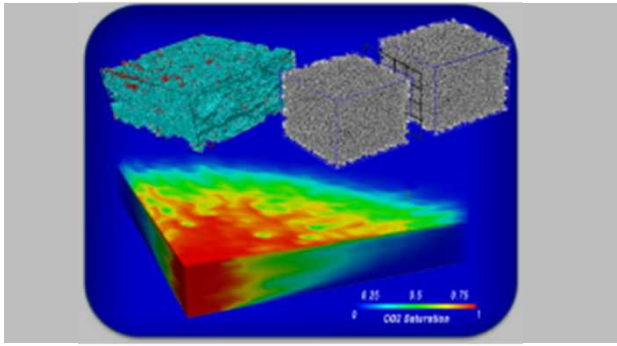
SAND2014-17137PE

Exceptional service in the national interest

Sandia National Laboratories





Opportunity for Earth Sciences at National Laboratories: DOE Crosscut Subsurface Technology "Tech Team" and National Laboratory Big Idea Summit: Subsurface Technologies

Marianne Walck

August 29,2014

U.S. DEPARTMENT OF ENERGY

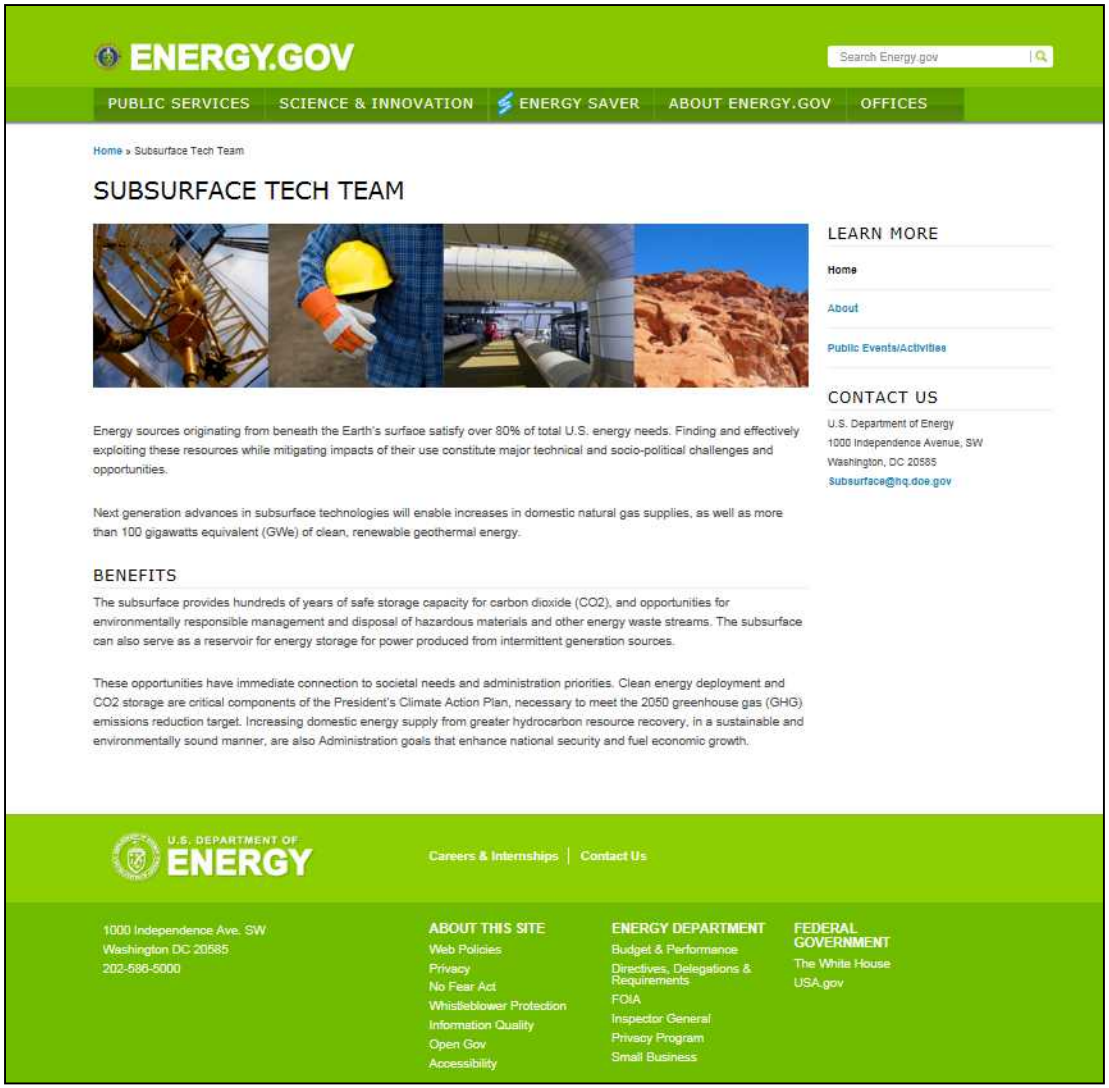
NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

DOE Secretary Moniz has made a difference!

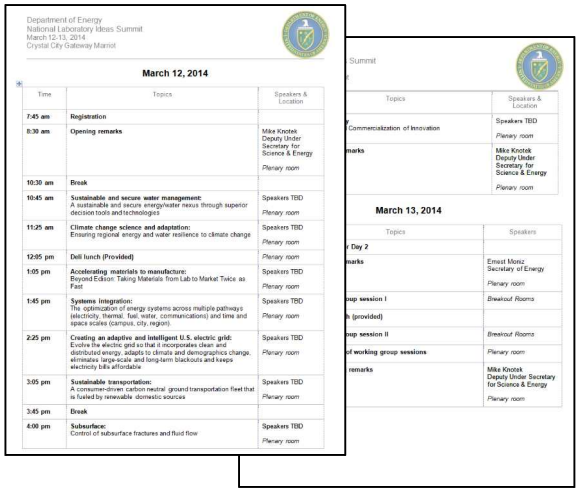
- **Secretary Moniz created:**
  - Undersecretary for Science and Energy to better integrate Energy Technology Programs with basic research
  - 6 crosscutting "Tech Teams" : Goal – Large FY16 programs
    - Grid
    - Water-Energy (WETT)
    - Supercritical CO_2 Brayton Cycle
    - Advanced Computing
    - Manufacturing
    - Subsurface Technology and Engineering RD&D (SubTER)

Subsurface Tech Team is in a leading position with DOE



National Laboratory "Big Idea" Summit: March, 2014

- **DOE asked the NL Chief Research Officers to develop a set of "Big Ideas" for DOE to consider for large FY16 investments**
- **Laboratories developed multi-lab teams for 8 ideas:**
  - Advanced Manufacturing
  - Nuclear Energy
  - Climate
  - Energy/Water
  - Subsurface
  - Grid
  - Energy Systems Integration
  - Transportation


Department of Energy
National Laboratory Ideas Summit
March 12-13, 2014
Crystal City Gateway Marriot

March 12, 2014

Time	Topics	Speakers & Location
7:45 am	Registration	
8:30 am	Opening remarks	Mike Knotek Deputy Under Secretary for Science & Energy Plenary room
10:30 am	Break	
10:45 am	Sustainable and secure water management: A sustainable and secure energy/water nexus through superior decision tools and technologies	Speakers TBD Plenary room
11:25 am	Climate change science and adaptation: Ensuring regional energy and water resilience to climate change	Speakers TBD Plenary room
12:05 pm	Deli lunch (Provided)	Plenary room
1:05 pm	Accelerating materials to manufacture: Beyond Edison: Taking Materials from Lab to Market Twice as Fast	Speakers TBD Plenary room
1:45 pm	Systems integration: The optimization of energy systems across multiple pathways (electricity, thermal, fuel, water, communications) and time and space scales (campus, city, region).	Speakers TBD Plenary room
2:25 pm	Creating an adaptive and intelligent U.S. electric grid: Evolve the electric grid so that it incorporates clean and distributed energy, adapts to climate and demographics change, eliminates large-scale and long-term blackouts and keeps electricity bills affordable	Speakers TBD Plenary room
3:05 pm	Sustainable transportation: A consumer-driven carbon neutral ground transportation fleet that is fueled by renewable domestic sources	Speakers TBD Plenary room
3:45 pm	Break	
4:00 pm	Subsurface: Control of subsurface fractures and fluid flow	Speakers TBD Plenary room

Summit

Topics	Speakers & Location
Commercialization of Innovation	Speakers TBD Plenary room
marks	Mike Knotek Deputy Under Secretary for Science & Energy Plenary room

March 13, 2014

Topics	Speakers
Day 2	
marks	Ernest Moniz Secretary of Energy Plenary room
up session I	Breakout Rooms
h (provided)	
up session II	Breakout Rooms
of working group sessions	Plenary room
remarks	Mike Knotek Deputy Under Secretary for Science & Energy Plenary room

- **SNL Leadership in Subsurface, Energy/Water, Transportation**
- **Summit meeting: March 12-13, 2014**

The National Labs Subsurface Big Idea: Adaptive Control of Subsurface Fractures and Flow

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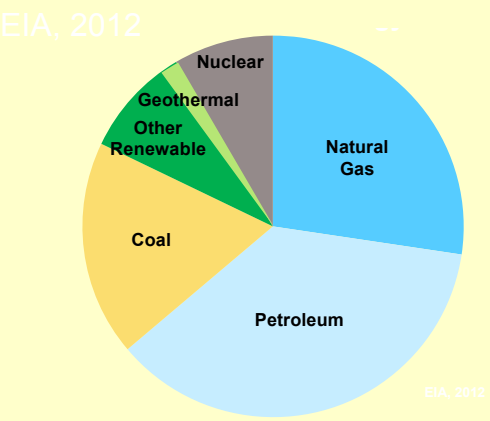
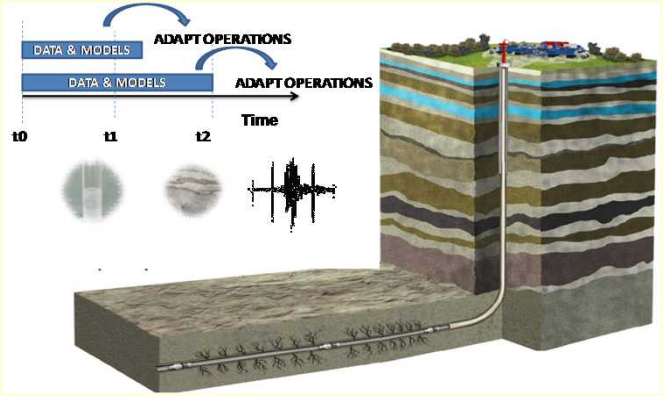
FRACTURE CONTROL IS CRITICAL FOR MANY SUBSURFACE ENERGY STRATEGIES
shale hydrocarbon, geologic carbon sequestration, enhanced geothermal energy, nuclear waste disposal, compressed air energy storage



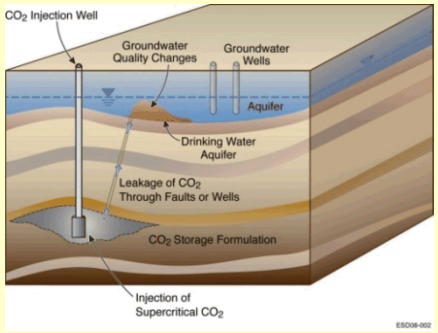
The subsurface supplies >80% of US Energy

Shale Hydrocarbon Production



Control fracture length & branching patterns, and flow

Safe Subsurface Storage of CO_2



Enhance injectivity, optimize storage, plug leakage pathways

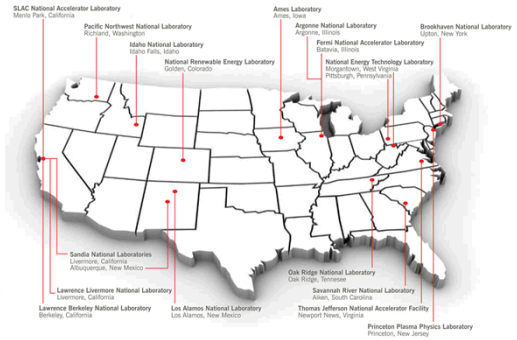
Anticipated Outcomes:

- Doubling of recovery efficiency from tight hydrocarbon reservoirs
- Order-of-magnitude increase in geothermal production
- Technical basis for safe and secure carbon sequestration and geologic nuclear waste disposal
- Increased public confidence
- Sustained US leadership in subsurface technologies

Subsurface Working Team: 13 Laboratories

Sandia National Laboratories

ANL:	Mark Nutt
BNL:	Martin Schoonen
INL:	Earl Mattson, Hai Huang
LANL:	Rajesh Pawar, Melissa Fox, Andy Wolfsberg
LBNL:	**Susan Hubbard (co-lead)**, Curt Oldenburg (deputy), Jens Birkholzer
LLNL:	Roger Aines, Jeff Roberts, Rob Mellors
NREL:	Charles Visser
NETL:	George Guthrie, Grant Bromhal
ORNL:	Eric Pierce, Yarom Polsky
PNNL:	Alain Bonneville, Dawn Wellman
SLAC:	Gordon Brown
SNL:	**Marianne Walck (co-lead),** Doug Blankenship (deputy), Susan Altman
SRNL:	Lisa Oliver, Ralph Nichols

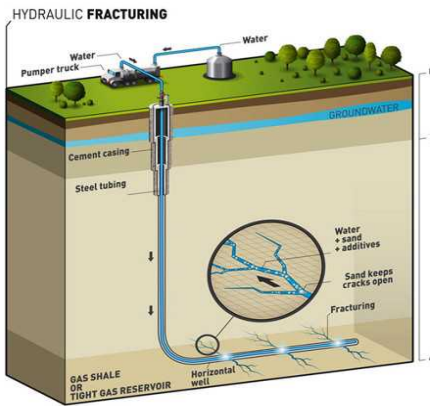


Argonne NATIONAL LABORATORY · BROOKHAVEN NATIONAL LABORATORY · INL Idaho National Laboratory · Los Alamos NATIONAL LABORATORY EST. 1943 · BERKELEY LAB LAWRENCE BERKELEY NATIONAL LABORATORY

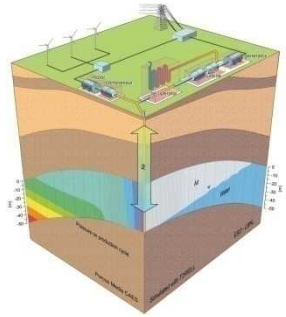
NETL · NREL NATIONAL RENEWABLE ENERGY LABORATORY · OAK RIDGE National Laboratory · Pacific Northwest NATIONAL LABORATORY · SLAC NATIONAL ACCELERATOR LABORATORY · Sandia National Laboratories · SRNL SAVANNAH RIVER NATIONAL LABORATORY

"Adaptive Control" of subsurface fractures and flow

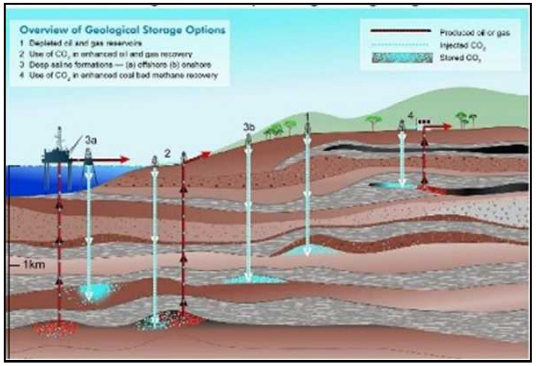
Ability to adaptively manipulate – rapidly and with confidence - subsurface fracture length, aperture, branching, connectivity and associated reactions and fluid flow.



Fractures by Design: Control fracture length & branching patterns in real-time

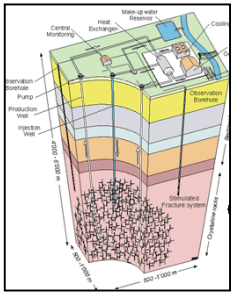


Compressed Air Energy Storage

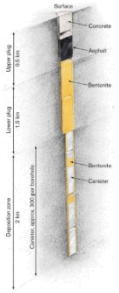


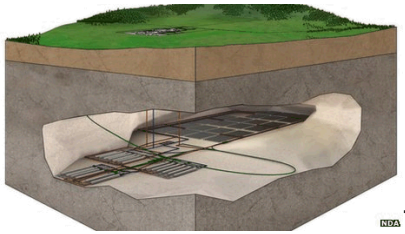
Enhance injectivity, optimize storage, plug leakage pathways

Safe subsurface storage of nuclear waste



Enhanced geothermal energy





Advances in Subsurface R&D led the way

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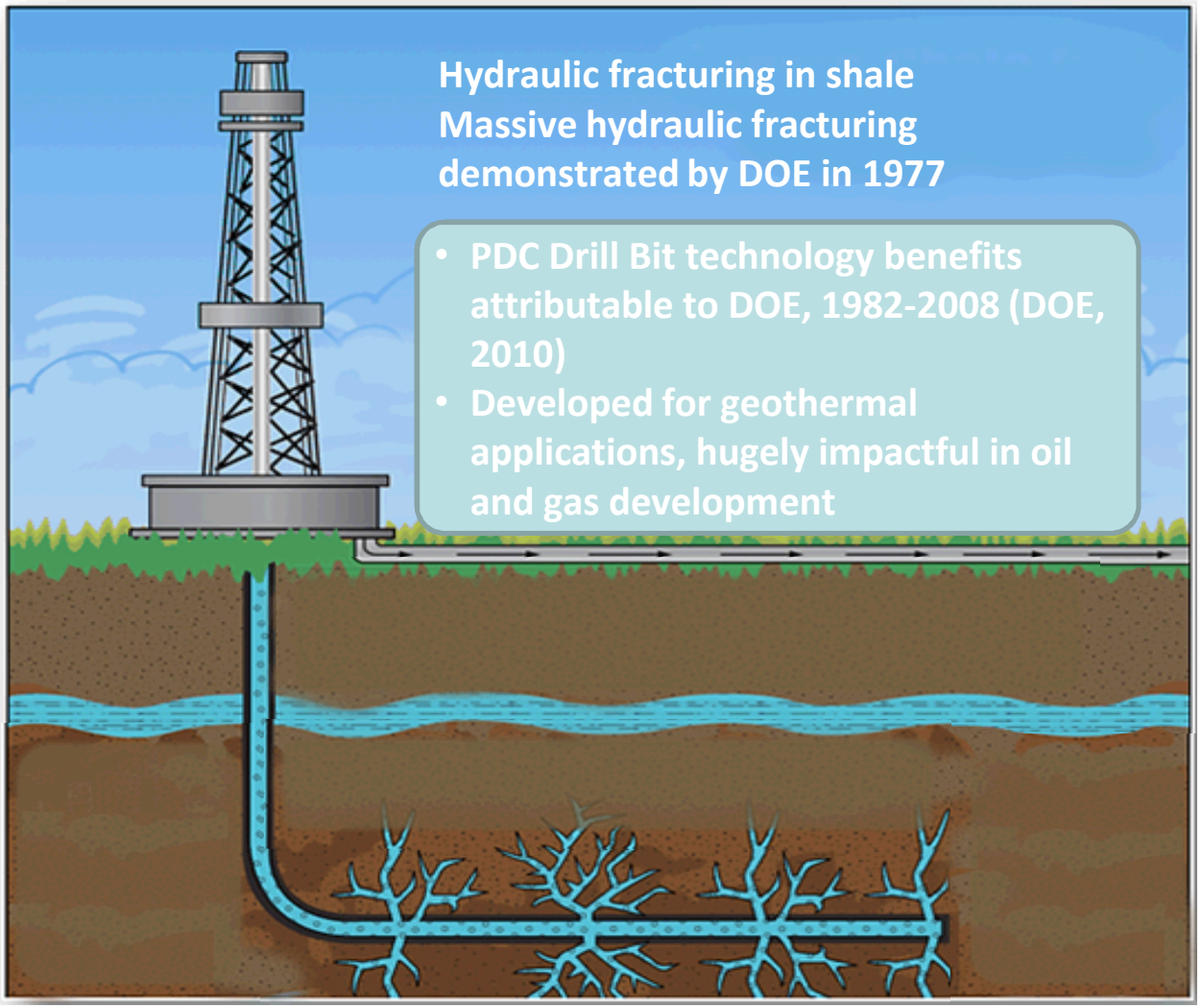
Government funded R&D

- Drill bit improvement
- Horizontal drilling
- Multiple massive fractures
- Hydraulic fracture mapping

Technology advances deployed by independent producers



thebreakthrough.org

DOE Energy 100 Award for Synthetic Diamond Drill Bits (2000)

Real-Time ('ADAPTIVE') Control
Numerous Challenging Scientific and Technical Issues

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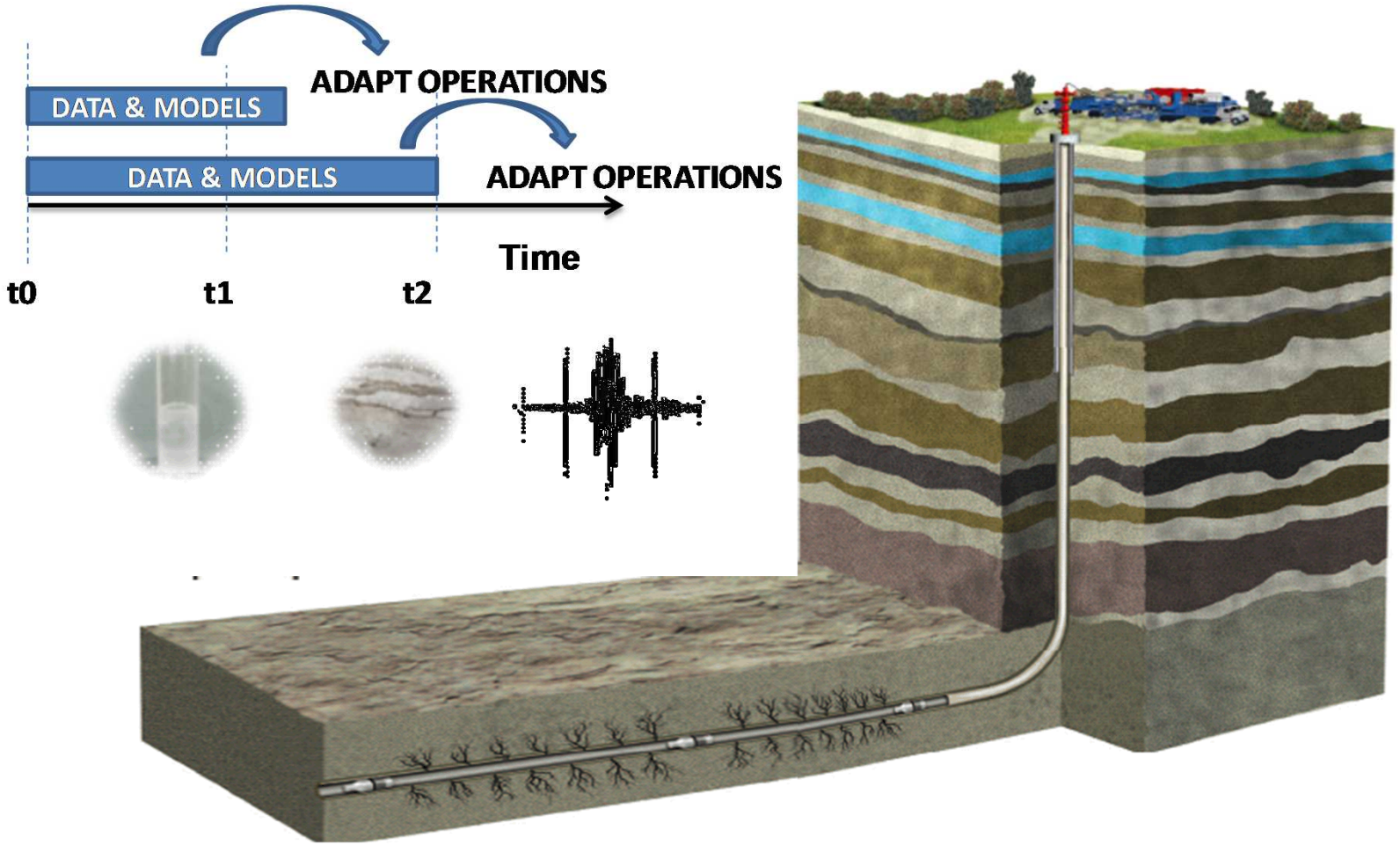
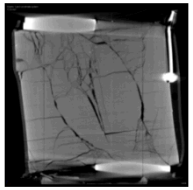
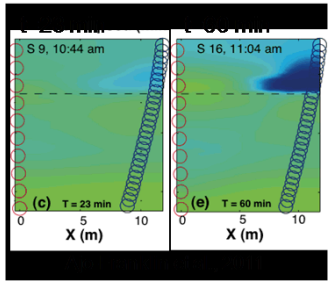
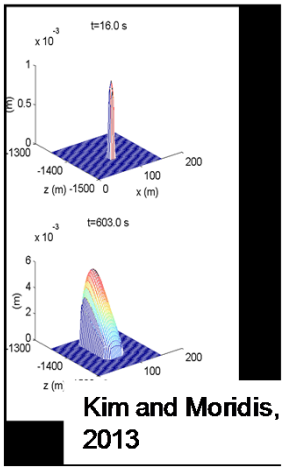


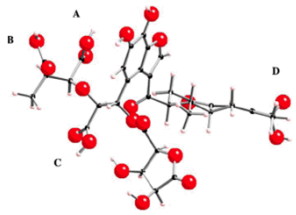
DOE National Laboratories have the multi-disciplinary expertise and unique facilities to meet this challenge, and will partner with industry, academia and regulators to develop transformational solutions

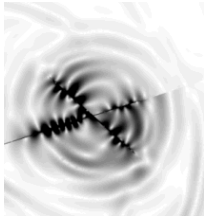
Technical Elements

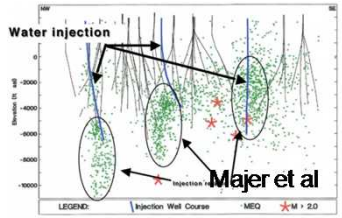


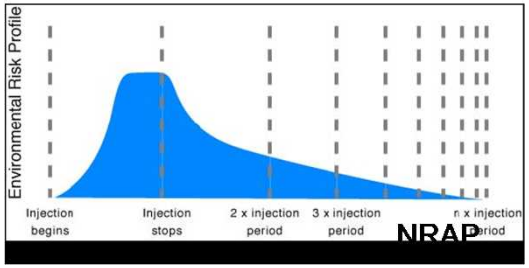












Fundamentals of fracture geomechanics, geochemistry and fluids

Characterization, Monitoring and Prediction

Environmental Risk

Control Subsurface Fractures and Fluids

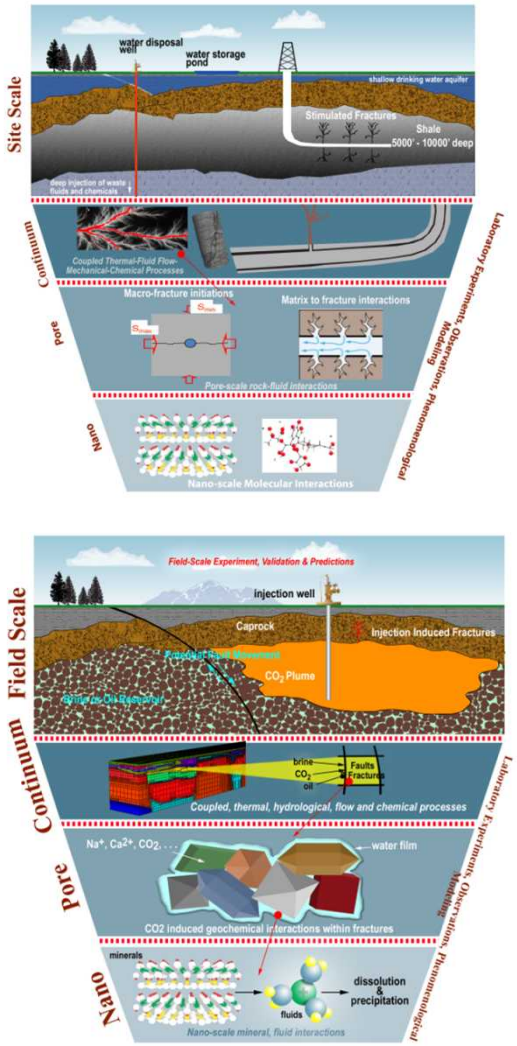
Adaptive Large-Scale Control Strategies

Drilling technologies and materials

Energy Field Observatories

Technical baseline:
State of knowledge & practice

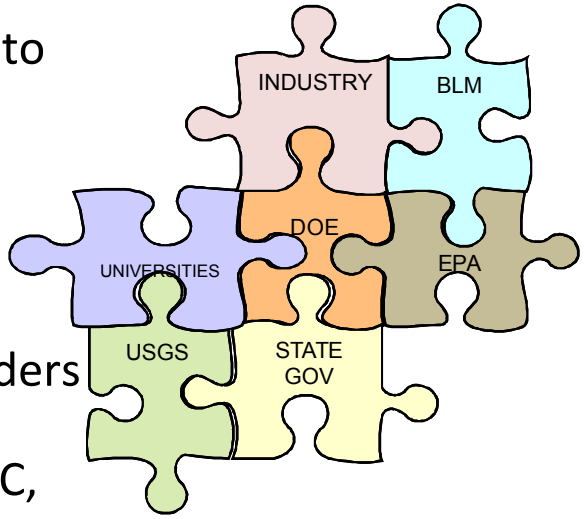
- Reservoir stress distribution and material properties are highly heterogeneous and largely unknown
- Mechanistic understanding of multi-scale processes that influence fracture formation and flow is lacking - limits both production and subsurface storage
- Industry is developing approaches to improve fracture creation, commonly guided by empirical field evidence. Industry not attempting 'real time' control
- Petroleum industry has been approaching National Laboratories for assistance: DOE is a leading sponsor of subsurface R&D
- Significant public concern and uncertainty associated with environmental risks



Today we cannot accurately image, predict, or control fractures with confidence or in real-time.

Federal Role & key stakeholders

- DOE: address energy and environment challenges through transformative science and technology – nuclear waste is a federal responsibility
- Develop next-generation technologies that industry will not: regulatory drivers lacking or cost-prohibitive
- Benefit for all: many sectors, super-majors to independents
- Provide independent technical basis of environmental risk to inform policy/regulatory decisions
- Employ unique measurement and computational facilities

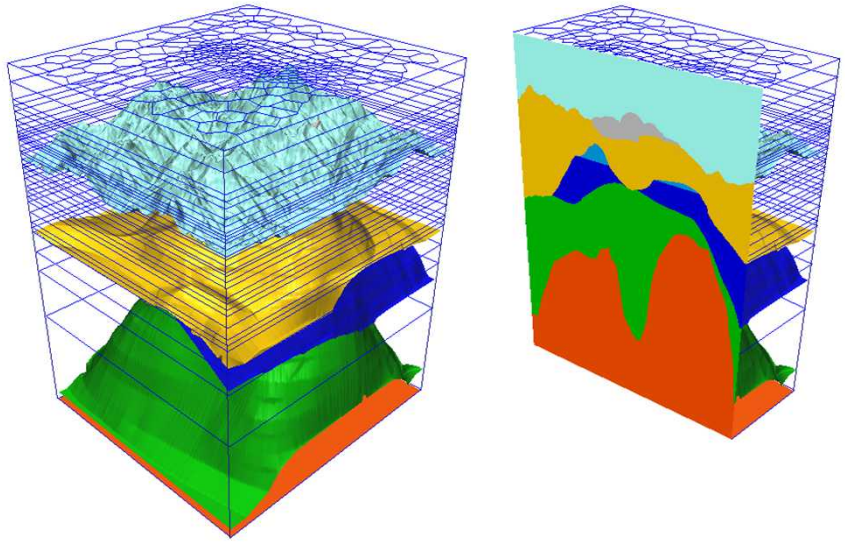


- Integrate National Laboratory resources with key stakeholders & partners to meet National challenge
- Well-aligned with DOE SubTER Tech Team: FE, NE, EERE, SC, EM, OE, EPSA, ARPA-E, EIA

Integration of Big Idea and CrossCut Team

- Integration began before Idea Summit – March 4 conference call
- March 14 workshop (post-summit)
- Further development of themes (pillars)

- **Fossil Energy-Oil and Gas**
- **Fossil Energy-CO_2 Storage**
- **EERE-Geothermal Technologies Office**
- **Nuclear Energy**
- **Environmental Management**
- **Office of Science**
- **ARPA-E**
- **Office of Electricity**
- **Energy Policy & Systems Analysis**
- **Congressional & Inter-governmental Affairs**
- **Energy Information Administration**



Common Challenges: Solvable or "Chasms"?

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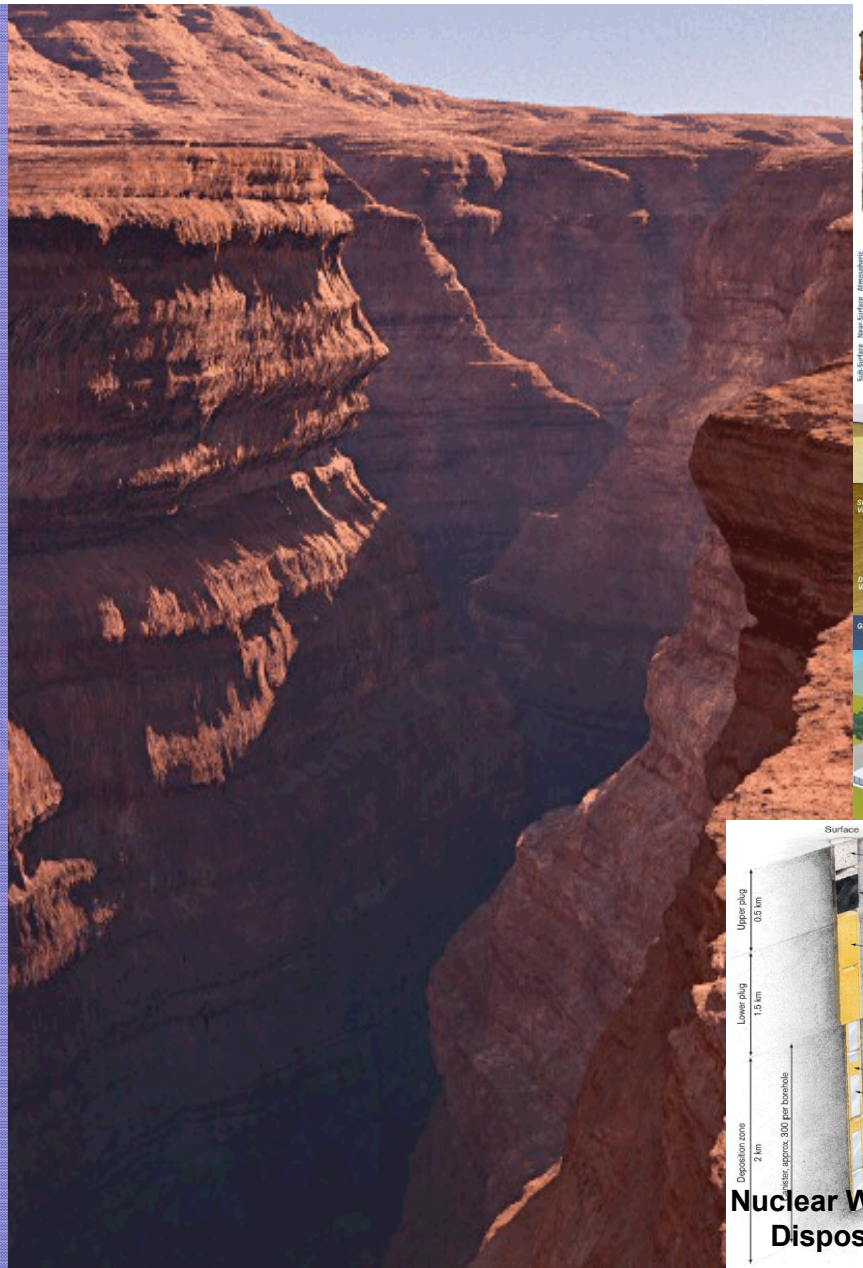
Discovering, Characterizing, and Predicting
Efficiently and accurately locate target geophysical and geochemical responses, finding more viable and low-risk resource, and quantitatively infer their evolution under future engineered conditions

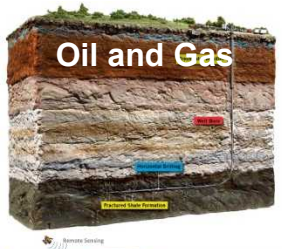
Accessing
Safe and cost-effective drilling, with reservoir integrity

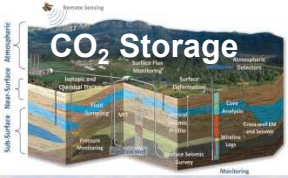
Engineering
Create/construct desired subsurface conditions in challenging high-pressure/high-temperature environments

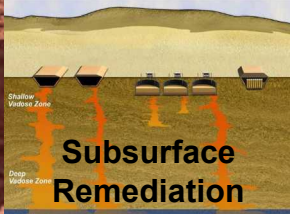
Sustaining
Maintain optimal subsurface conditions over multi-decadal or longer time frames through complex system evolution

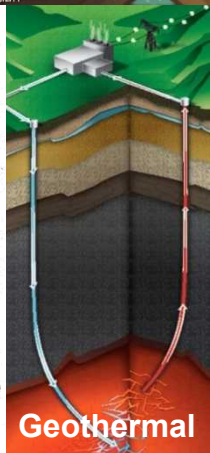
Monitoring
Improve observational methods and advance understanding of multi-scale complexities through system lifetimes











Subsurface Control for a Safe and Effective Energy Future

Sandia National Laboratories

Adaptive Control of Subsurface Fractures and Fluid Flow

Intelligent Wellbore Systems	Subsurface Stress & Induced Seismicity	Permeability Manipulation	New Subsurface Signals
Materials: adaptive cements, muds, casing	Stress state beyond the borehole	Physicochemical rock physics, including fluid-rock interactions	Diagnostic signatures of system behavior and critical thresholds
Real time, in-situ data acquisition and transmission system	Signal acquisition and processing and inversion	New approaches to remotely characterize in-situ fractures and to monitor fracture initiation/branching and fluid flow	Autonomous acquisition, processing and assimilation approaches
Diagnostics tools, remediation tools and techniques	Localized manipulation of subsurface stress	Manipulating (enhancing, reducing and eliminating) flow paths	Integration of different measurements collected over different scales to quantify critical parameters and improve spatial and temporal resolutions
Quantification of material/seal fatigue and failure	Risk assessment	Novel stimulation methods	
Advanced drilling and completion tools (e.g., anticipative drilling & centralizers)			
Well abandonment analysis/ R&D			

Energy Field Observatories (Wells, Ops and Logistics)

Fit For Purpose Simulation Capabilities

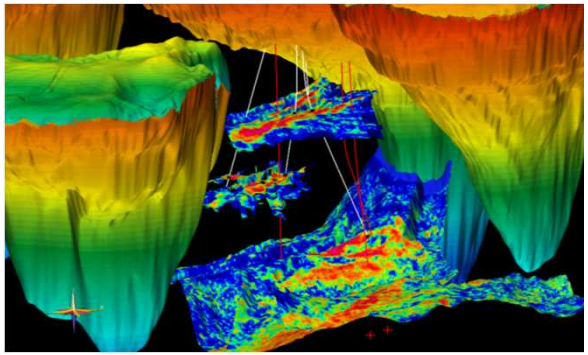
Sandia Capabilities – SubTER themes

Sandia National Laboratories

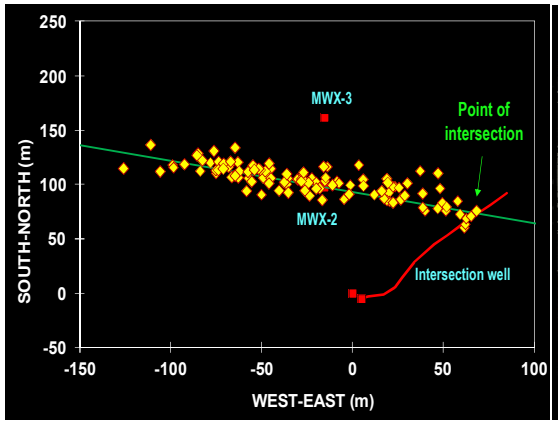
- **Wellbore Integrity and Drilling Technology**
  - Rock reduction and HT/HP Drilling Technologies
  - Drilling vibration mitigation using active cancellation of drill-string dysfunctions
  - Lost circulation control in harsh environments
  - Casing centralization
  - Field studies
- **Subsurface Stress and Induced Seismicity**
  - Hydraulic fracturing research for *in situ* stress Determination
  - Microseismic Monitoring of Reservoir Stimulation
  - Computational Modeling of Hydraulic Fracturing
  - Development of Core Based Stress Measurements (Anelastic Strain Recovery)
  - Computational Geomechanics

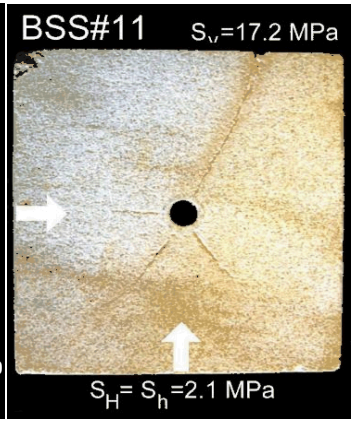
Modern PDC Bit (Courtesy of NOV)

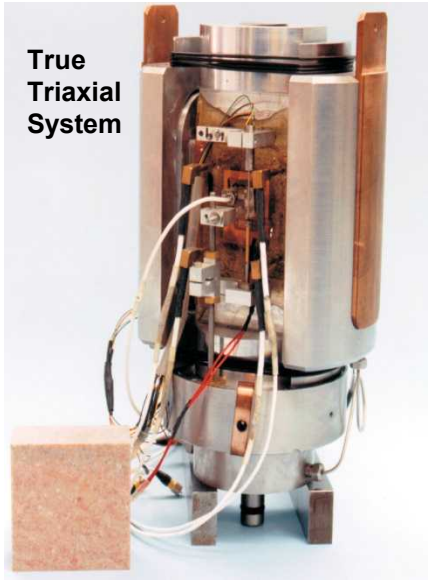
Drilling Dynamics Simulation



Multiwell Experiment (MWX)



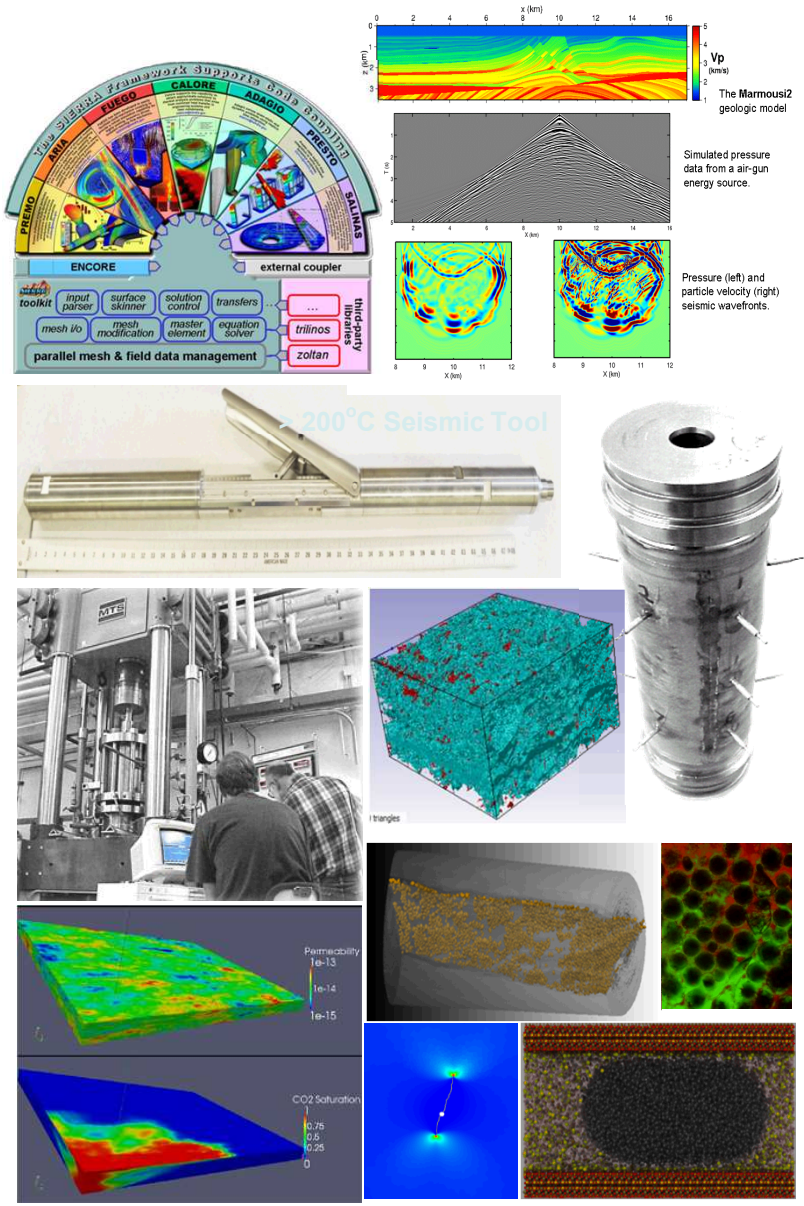




True Triaxial System

Sandia Capabilities – SubTER Themes

- **New Subsurface Signals**
  - High temperature, high pressure monitoring tools
  - Design, implementation, and interpretation of geophysical experiments: seismic, acoustic, EM
  - Finite difference geophysical modeling: data processing, analysis and interpretation
  - Natural tracer experiments
  - Proppant studies
  - Wide band gap devices for instrumentation (CINT/MESA
- **Permeability Manipulation**
  - High pressure and multiphase fluid delivery system for pore-scale flow experiments
  - Advanced “Waterless” Stimulation Technologies with Controlled Energetic Materials
  - Geomechanical testing: uniaxial, triaxial, creep, hydrostatic
  - Porescale and nanoscale experiment and modeling; reactive transport
  - Flow, Imaging and Coupled Constitutive Behavior of Porous Media
  - Risk Analysis methodologies: WIPP, YMP
- **Fit for Purpose Simulation Capabilities**
  - Large-scale Atomic/Molecular Massively Parallel Simulator (LAMMPS)
  - Sierra Mechanics engineering analysis codes
  - Constitutive models, e.g., Kayenta
  - Simulating fluid-induced discrete-fracture propagation using random finite-element meshes
  - Peridynamics fracture modeling



The Big Idea is now incorporated into SubTER

Sandia National Laboratories

- **Labs (SNL, LBNL) weekly conference call with DOE SubTER**
- **Labs: $1.4M of FY14 funds deployed (6 projects)**
- **Stakeholder engagements (DOE/Labs)**
  - NAS/NRC COGGE Capability Presentation: April 29, 2014
  - JASON kickoff: June 20, 2014
  - USEA: July 22, 2014
- **Laboratory Interactions – SNL**
  - Exchange visits with both LANL and LLNL, summer 2014
  - Continual interactions with LBNL
  - Numerous new contacts made with other 11 labs
- **Upcoming events**
  - Shell Rock and Fluid Physics Conference (Amsterdam)
  - AGU: special sessions (2), Town Hall (proposed)
  - Lab Workshop
    - Example Projects
    - Governance
  - Industry engagement
- **SNL response: $500K of Mission Integration Program Management funds provided to support SNL leadership of Subsurface Initiative**
- **DOE: FY15 projects; FY16 roll-out**

DOE Interest/Intent – SNL Leadership – The Future is Promising

Sandia National Laboratories

Thank You!