Adaptive Control of Subsurface Fractures and Fluid Flow: A New U.S. Department of Energy Subsurface Technology and Engineering Research, Development and Demonstration Crosscut Initiative*

Douglas W. Hollett[1] and Julio Friedmann[2]

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[1]Deputy Asst. Sec., Renewable Power, U.S. Dept. of Energy, Office of Energy Efficiency and Renewable Energy, Washington, DC (Douglas.Hollett@ee.doe.gov)
[2]Principal Deputy Asst. Sec., U.S. Dept. of Energy, Office of Fossil Energy, Washington, DC (Julio.Friedmann@hq.doe.gov)

*Adapted from Town Hall Meeting oral presentation given at AAPG Annual Convention and Exhibition, Denver, Colorado, May31-June 3, 2015

Abstract

The US Department of Energy has commenced an initiative designed to address common subsurface energy challenges across a number of sectors, with a central theme of Adaptive Control of Subsurface Fractures and Fluid Flow. The targeted outcomes, which encompass the geothermal, oil and gas, storage and waste disposal sectors, will lead to improved recovery factors, reduced operational and environmental risks, improved safety and reliability; they have major policy implications. The primary R&D pillars are wellbore integrity, subsurface stress and induced seismicity, permeability manipulation, and new subsurface signals, and are predicated upon testing new technologies and concepts in a series of fit-for-purpose field observatories. In addition, new foundational science into imaging geophysical and geochemical signals in the subsurface will be addressed. Initial project funding commenced in FY14 through the national laboratories, with competitive funding solicitations scheduled to start in FY16. Implementation of a new collaborative model to tackle an energy "grand challenge" faced by multiple sectors, provides the opportunity to achieve enduring economic and environmental benefit to the United States. Further information is available at www.energy.gov/subsurface-tech-team.

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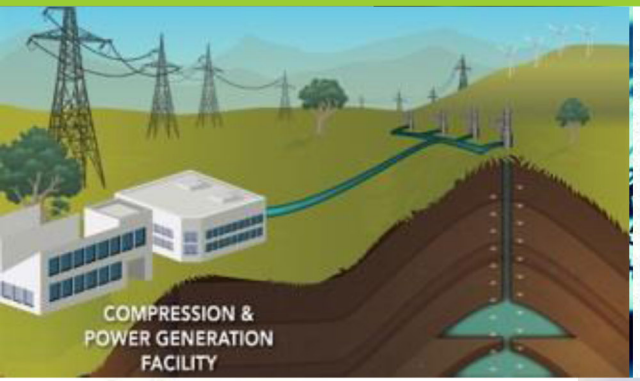
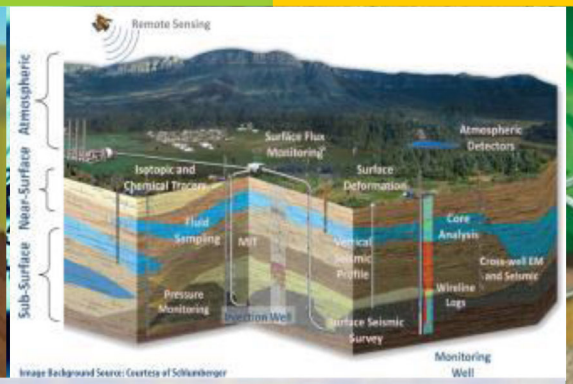
AAPG Town Hall Meeting
DOE Subsurface Crosscut

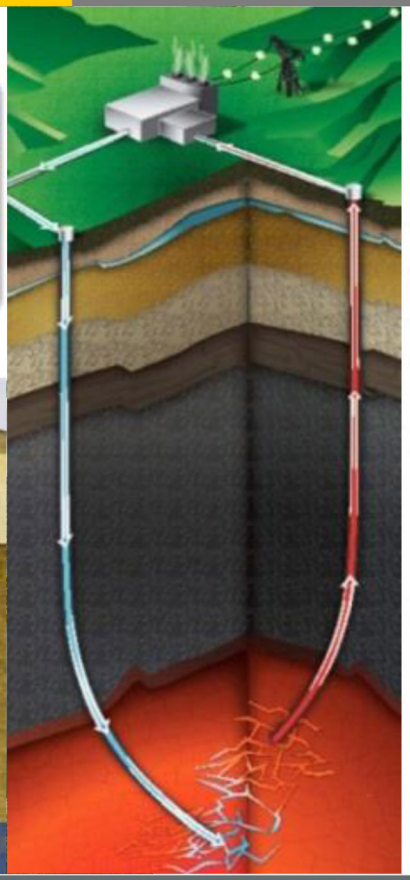
ADAPTIVE CONTROL OF SUBSURFACE FRACTURES AND FLUID FLOW: A NEW U.S. DEPARTMENT OF ENERGY SUBSURFACE TECHNOLOGY AND ENGINEERING RESEARCH, DEVELOPMENT AND DEMONSTRATION CROSSCUT INITIATIVE

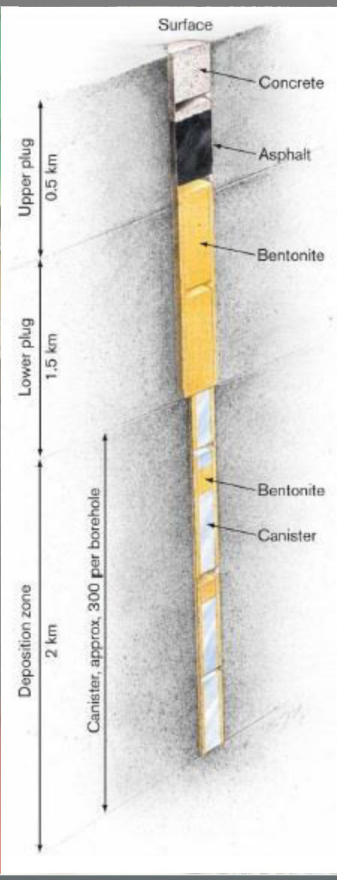
DOUGLAS W. HOLLETT AND JULIO FRIEDMANN

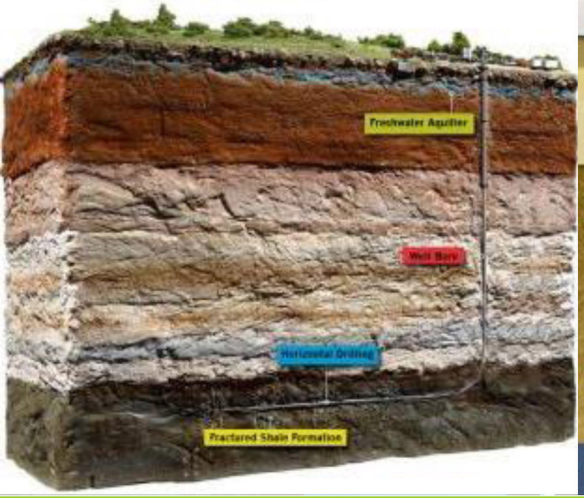
U.S. DEPARTMENT OF ENERGY | SubTER

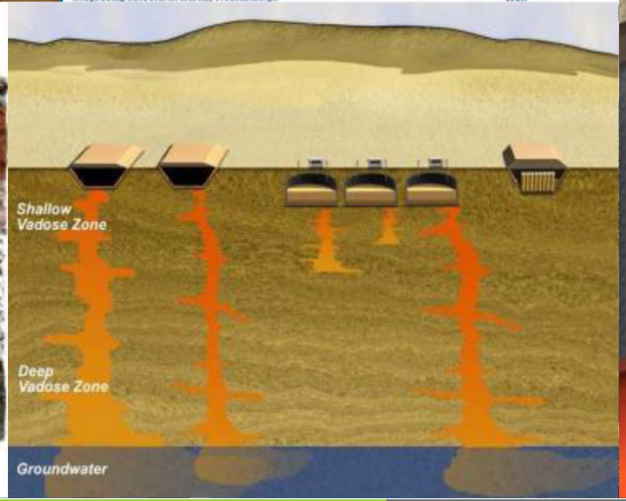












Subsurface Technology and Engineering Research, Development and Demonstration Crosscut

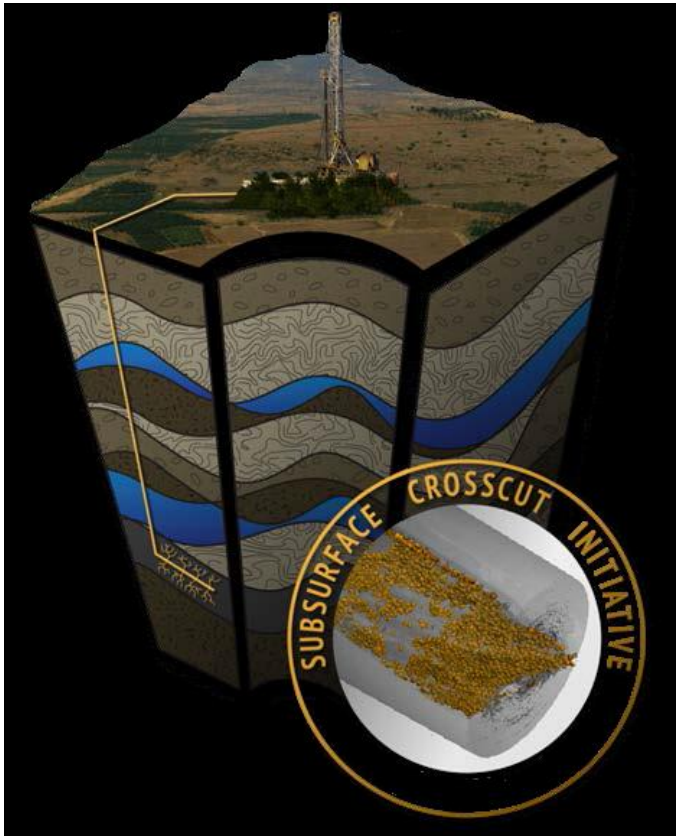
Doug Hollett
Deputy Assistant Secretary, Renewable Power
OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY
June 2, 2015

Welcome!

AAPG Town Hall Meeting

June 2, 2015 5:10-6:40

DOE Crosscutting Subsurface Initiative: Adaptive Control of Subsurface Fractures and Fluid Flow



Common Subsurface Energy Challenges

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

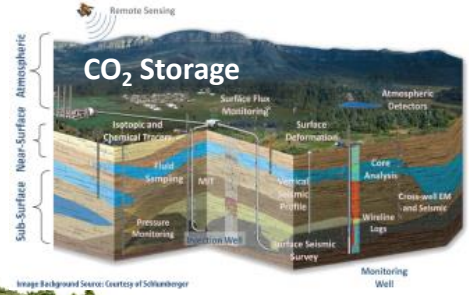
Create/construct desired subsurface conditions in challenging high-pressure/high-temperature environments

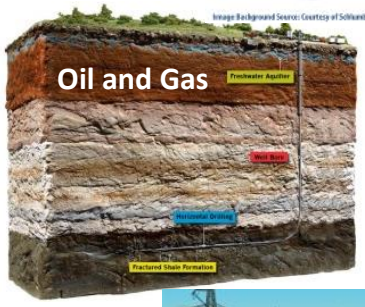
Sustaining

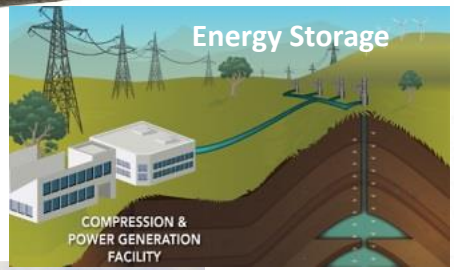
Maintain optimal subsurface conditions over multi-decadal or longer time frames through complex system evolution

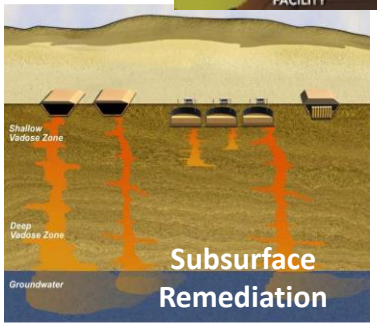
Monitoring

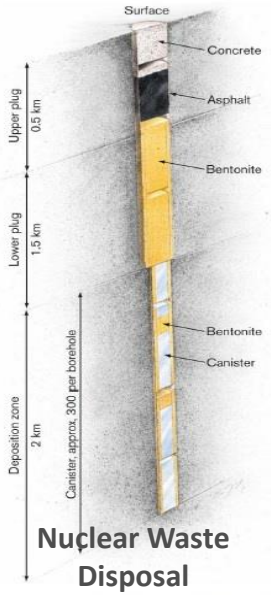
Improve observational methods and advance understanding of multi-scale complexities through system lifetimes











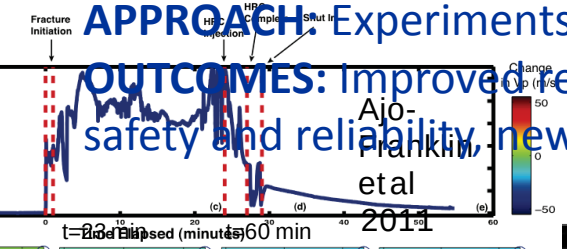
National Lab Big Idea Summits 2014/2015

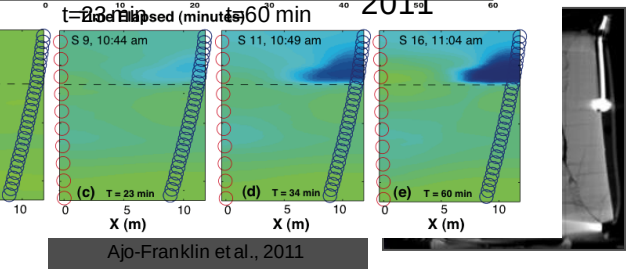
Adaptive Control of Subsurface Fractures and Fluid Flow

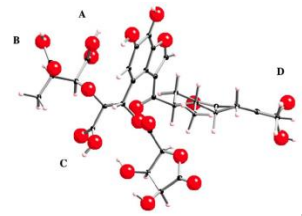
GOAL: Real-time measurement and control of fracture networks & associated flow

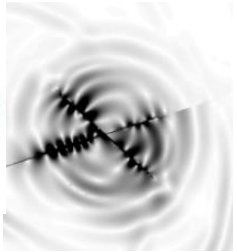
APPROACH: Experiments, simulations, theoretical frameworks, & field tests

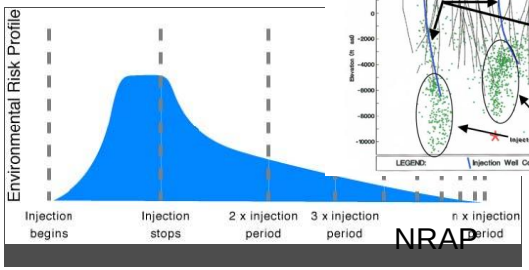
OUTCOMES: Improved recovery factors, reduced operational and environmental risks, safety and reliability, new energy sectors – *major policy implications*

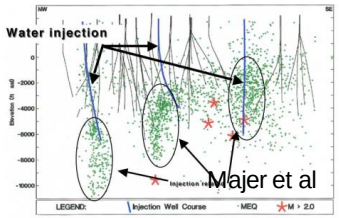












Fracture geomechanics, geochemistry and fluids basics

Characterization, Monitoring and Prediction

Strategies for Large-Scale Control

Adaptive Control of Subsurface Fractures and Fluid Flow

Environmental Risk

Drilling technologies and materials

Energy Field Observatories

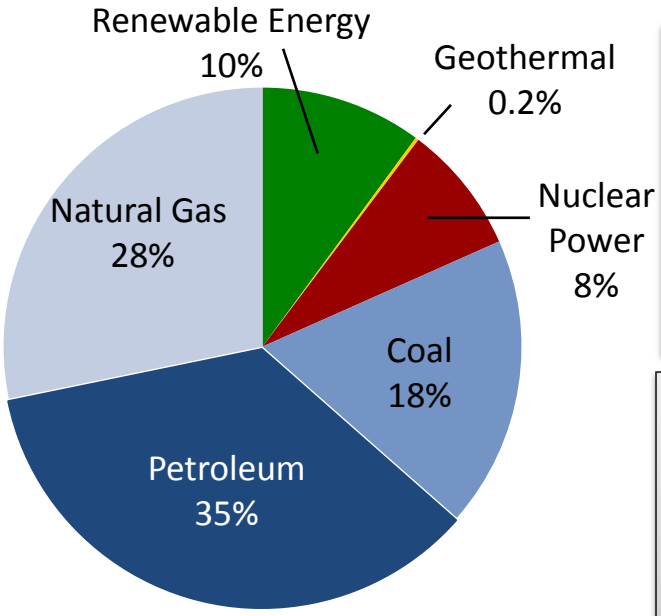
Today we cannot accurately or sufficiently image, predict, or control fractures with confidence or in real-time.

What is needed?

Subsurface Control for a Safe and Effective Energy Future

Wellbore Integrity	Subsurface Stress & Induced Seismicity	Permeability Manipulation	New Subsurface Signals

Energy Field Observatories



Primary Energy Use by Source, 2014

Quadrillion Btu [Total U.S. = 98.3 Quadrillion Btu]

ENERGY PRODUCTION AND ENERGY SECURITY

- Increase U.S. unconventional oil and natural gas for multiple uses
- Increase U. S. electricity production from geothermal reservoirs

ECONOMIC & SOCIAL BENEFITS

- U. S. leadership
- Public confidence
- Increase revenues (taxes and royalty) to Federal, State, and local governments
- Impact on overall economy

PROTECT THE ENVIRONMENT

- President's Climate Action Plan: Safely store CO_2 to meet GHG emissions reduction targets
- Safe storage/disposal of nuclear waste
- Reduced risk of induced seismicity
- Protect drinking water resources

Subsurface Control for a Safe and Effective Energy Future

Adaptive Control of Subsurface Fractures and Fluid Flow

Wellbore Integrity	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		Novel stimulation methods	
Advanced drilling and completion tools (e.g., anticipative drilling & centralizers)			
Well abandonment analysis/ R&D			

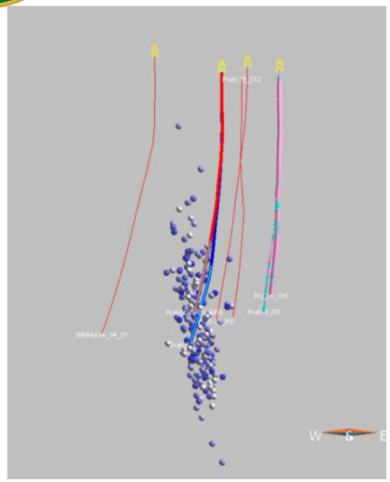
Energy Field Observatories

Fit For Purpose Modeling and Simulation

Risk Assessment Tools and Methodologies ***NEW!!***

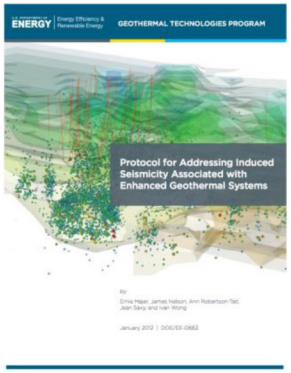
Criticality of Core Themes

Subsurface Stress and Induced Seismicity



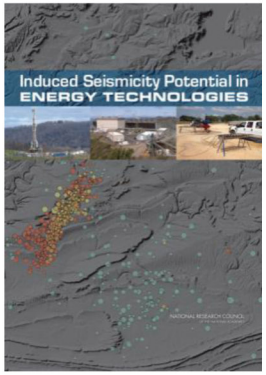
Induced Seismicity at The Geysers Geothermal Field (Calpine)

Increasing societal relevance of induced seismicity as EGS deployment and CO_2 storage grow, akin to oil and gas today



Approaches to Date:

- Geothermal sector has proactively developed its own induced seismicity management protocol.
- CO_2 storage developing new risk assessment tools through NRAP.



Subsurface Stress and Induced Seismicity

- Improved stress measurements
- Advanced risk assessment tools

Permeability Manipulation and **New Subsurface Signals**

- Critical for effective reservoir management
- Essential for scaling up EGS and CO_2 storage safely and effectively

Outcomes:

- Improved understanding of the subsurface
- Mitigated and reduced risk
- Improved resource identification and development

Criticality of Core Themes

Wellbore Integrity

Deep borehole disposal concept provides an alternative approach

New Study Published in the Proceedings of the National Academy of Science Highlights Wellbore Integrity as a critical issue

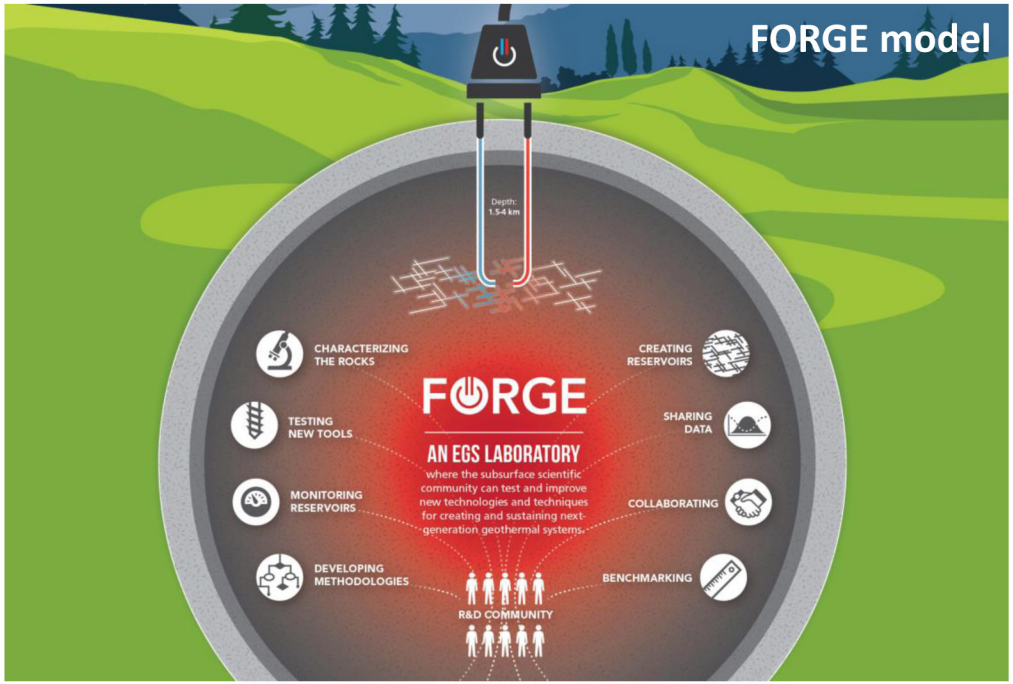
-Darrah et al. PNAS- September 15, 2014

Quarrels Continue Over Repository for Nuclear Waste –New York Times, June 27, 2013

Field Observatories are Critically Important

Required for fundamental subsurface progress

- Validation through monitoring/production
- Strong industry engagement
- Multiple business models:
  - Fit-for-purpose, dedicated site (FORGE, RMOTC)
  - Isolated, targeted effort (Frio CCS pilot)
  - Opportunistic (Weyburn)



Phase 1
$2 M
Site Selection

Phase 2
$29 M
Site preparation & characterization

Phase 3
Funding Subject to Appropriations
R&D testing, monitoring, innovative drilling, advanced stimulation, sustainability testing

Decommission/ Transfer site

PHASE 1 | PHASE 2 | PHASE 3 | Closeout

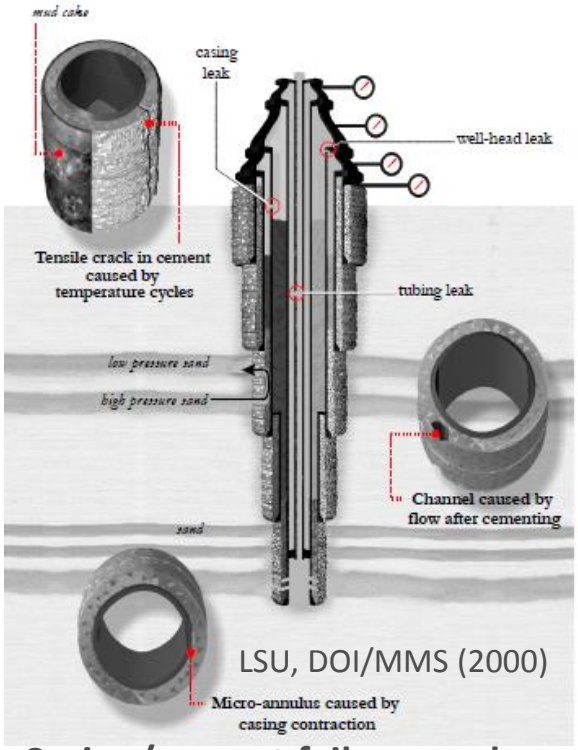
Validation of new results and approaches at commercial scale;
Road-test monitoring, stimulation, and permeability- and flow-control tools

Approach: Wellbore Integrity R&D

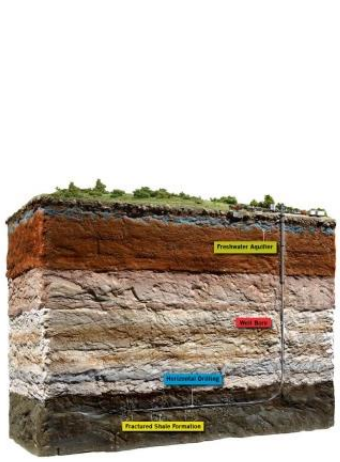
Wellbore Integrity: Self-healing cements and integrated-casing monitoring systems for enhanced wellbore performance assurance

wide band gap semiconductors + advanced manufacturing + HT electronics and sensors + materials science

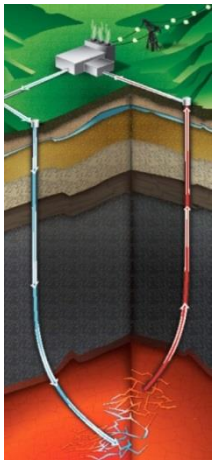
industry + national labs + academia



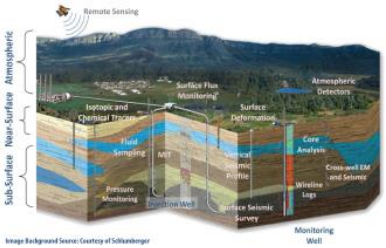
Casing/cement failure modes



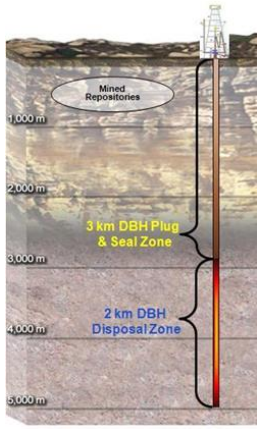
Oil and Gas



Geothermal



CO_2 Storage



Nuclear Waste Deep-Borehole Disposal Concept

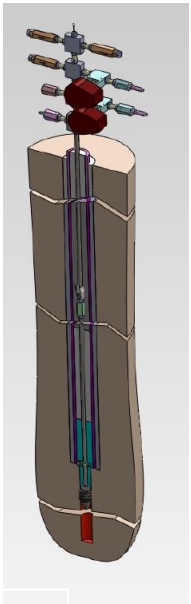
multi-decadal **REQUIRED LIFETIME** **millennial**

Approach: New Ways to Control Permeability and Flow

Precise control over fracturing and fluid flow is critical for efficient extraction of energy resources, as well as for containment of CO_2 and waste streams.

Approach to Date:
- Geometry/volume-based approaches
- Chemical manipulation

***SubTER Permeability Manipulation objectives*:**
- Novel stimulation techniques (e.g., water-free energetics, shape-memory alloys)
- Advances in reservoir and seal performance mechanisms for contaminant flow and trapping
- In-situ, real time imaging, modeling, and analysis of flow



Gas phase bi-propellant energetic stimulation design (Sandia National Laboratories)

Outcomes:
- Improved control over fluid migration and reservoir integrity
- Improved recovery factors
- Safe scale up of EGS, carbon storage, and high-level waste disposal

BES Roundtable on Foundation Research in Support of SubTER

May 22, 2015 Germantown, MD
Laura Pyrak-Nolte (Purdue) and Don DePaolo (LBNL), Chairs

Priority Research Directions:

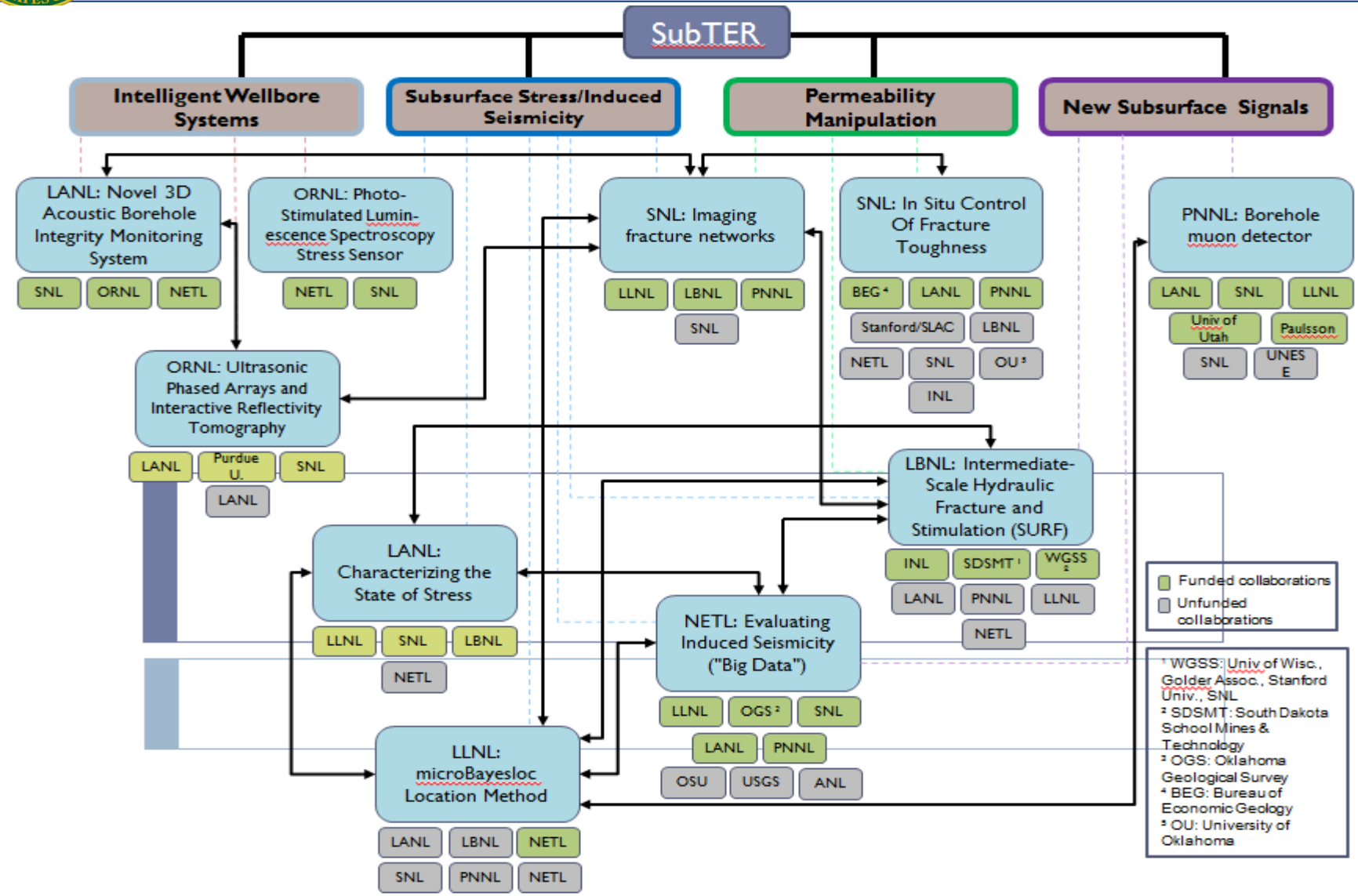
1. Advanced computational methods for heterogeneous, time-dependent geologic systems
2. Architected geomaterials as model systems for heterogeneity and scaling
3. Nanoporous geomaterials – reactivity, flow and mechanics in ultra-small voids
4. Reactive flow in fractured systems with multiphase fluids
5. Interactions between engineered and natural geomaterials
6. Chemical-mechanical coupling in stressed geomaterials

Grand Challenge:

Imaging geophysical (esp. stress) and geochemical signals in the subsurface

These groupings are still under development – final report is pending.

FY14 SubTER Seedling Lab Projects Breakdown by Pillar



FY14 SubTER Seedling Lab Projects

Selections for continued funding in FY15

Projects selected under the FY15 SubTER Lab Call (~$9 M TOTAL)
LANL: Evaluating the State of Stress Beyond the Borehole
LANL: Development of Novel 3D Acoustic Borehole Integrity Monitoring System
LBNL: Intermediate-Scale Hydraulic Fracture and Stimulation Field Laboratory in a Deep Mine for the Investigation of Induced Seismicity and Fracture Flow
LLNL: Development of microBayesloc Location Method
NETL: Evaluating Induced Seismicity with Geoscience Computing & Big Data – A Multi-Variate Examination of the Cause(s) of Increasing Induced Seismicity Events
ORNL: Photo-Stimulated Luminescence Spectroscopy Stress Sensor For In-Situ Stress and Behind Casing Cement Integrity Measurements
ORNL: Ultrasonic Phase Arrays and Interactive Reflectivity Tomography for Nondestructive Inspection of Injection and Projection Wells
PNNL: Borehole Muon Detector for 4D Density Tomography of Subsurface Reservoirs
SNL: Imaging Fracture Networks Using Joint Seismic and Electrical Change Detection Techniques

FY2014-2015 SubTER Progress

National Labs

White Papers May 2014

Big Ideas Summit March, 2014

FY14 Seed projects initiated

Lab Scoping Meeting Nov 2014

FY15 project proposals

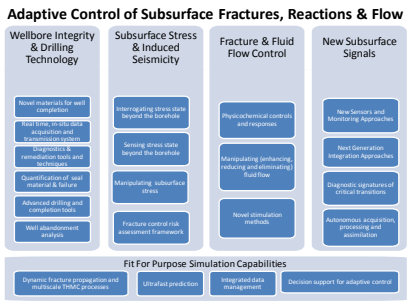
Town Halls

2014

2015

DOE

SubTER Workshop
Subsurface Technology and Engineering R&D Crosscut
March 14, 2014
SRA, International, 1801 K Street, Suite 460



Crosscut framework identified

RFI: Grand challenges in subsurface engineering

Subsurface Hill Briefings

USEA United States Energy Association

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JASON Reports

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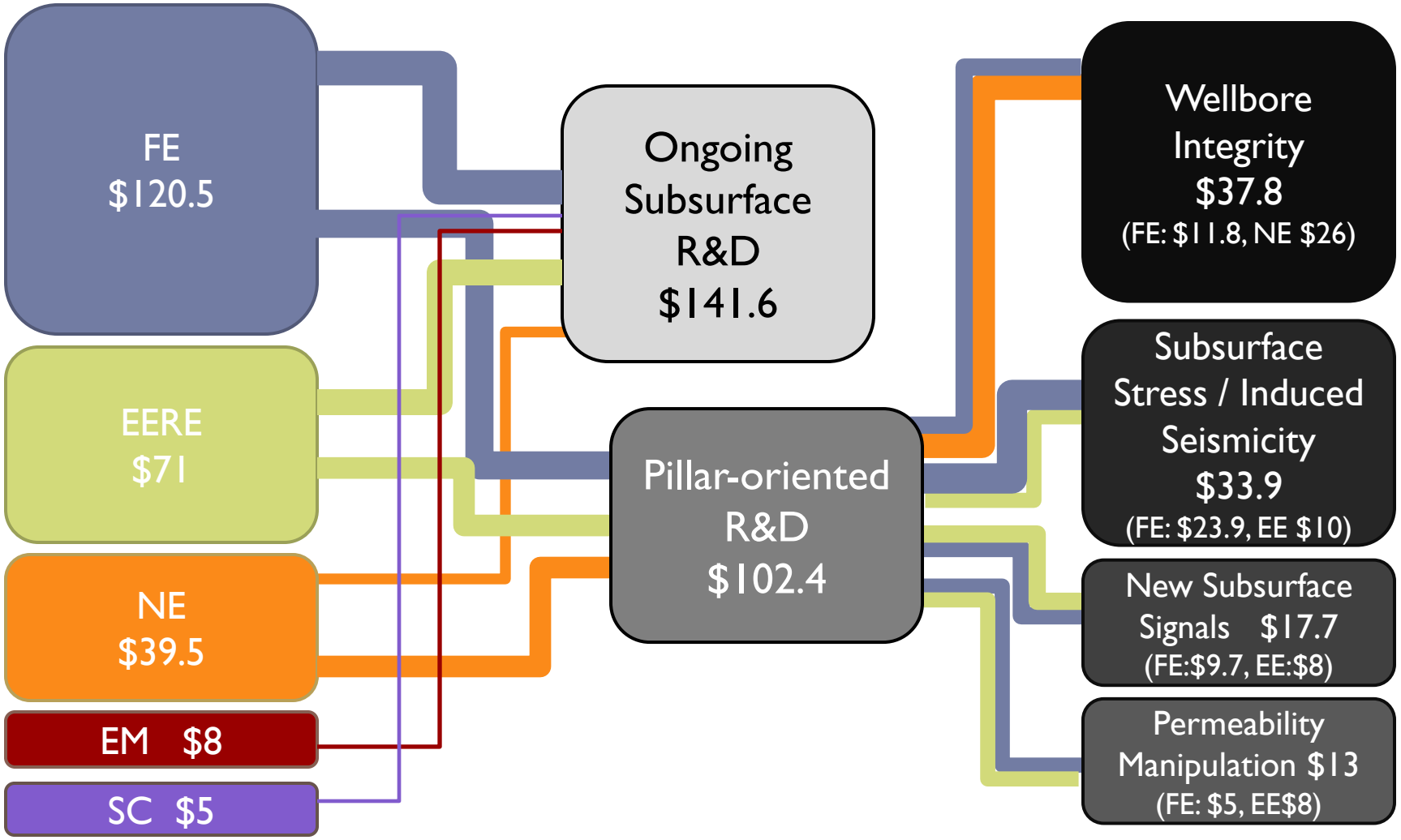
FORGE FOA released

SubTER in FY16 President's Budget Request ($M)



What Is Unique About the SubTER Initiative?

- Increases recovery factors from tight formations that can vastly increase the longevity of US **energy security**
- Facilitates innovation to address **climate change** and reduce greenhouse gas emissions
  - Safe storage of CO_2
  - Reduction of fugitive methane emissions through improved wellbore technologies, etc.
- Addresses challenges and opportunities with **water** management
- Drives innovation to improve **safety** associated with subsurface energy operations
- Advances new concepts for safe and responsible disposal of **nuclear waste**

Implementation of a new collaborative model

to tackle an energy "grand challenge" faced by multiple sectors

How can you be involved?

- **Your input now can contribute to shaping the scope of SubTER.**
- **Please visit the SubTER website for updates on funding opportunities (pending availability of appropriations)**

Please Provide Feedback

- **Do these challenges and related R&D directions, accurately represent the technology landscape related to fracture propagation and fluid flow in the subsurface?**
- **Are there additional areas or themes within this topic, which should be considered?**
- **Is this a high-impact problem or challenge?**
- **Is the topic sufficiently open, i.e., does it address the broad problem, and is it appropriately open to new ideas, approaches, directions?**
- **Does solution of this problem, result in enduring benefit to the United States – economic, environment, etc.? What could be the impact?**

subsurface@hq.doe.gov

Additional Questions

- What are the gaps between what is being pursued in the private sector, vs. publicly funded R&D?
- Are there opportunities for new JIP's on these topics?
- Ideas for new field-based projects and R&D?
- Are there new or unique ways to leverage industry-collected data?
- How does this fit into the overall funding landscape for the subsurface?
- Does it fit the proper federal role in R&D?

subsurface@hq.doe.gov

For More Information

Website:
http://energy.gov/subsurface-tech-team

Email:
subsurface@hq.doe.gov

Subsurface Crosscut Fact Sheet

U.S. DEPARTMENT OF ENERGY | Office of the Under Secretary for Science and Energy

Energy Department Subsurface Crosscut

Addressing Common Subsurface Challenges

The ability to master the subsurface continues to elude researchers and practitioners working on a variety of energy production and storage applications. The DOE is implementing a new collaborative model to tackle this "energy grand challenge" through a coordinated RD&D strategy. Common challenges faced by the participating offices include:

1. **Discover, Characterize, and Predict**
   - accurately characterizing the subsurface using integrated geophysical and geochemical technologies
   - Quantitatively inferring subsurface evolution under current and future engineered conditions
   - Finding viable, low-risk resources
2. **Access**
   - safe, cost-effective reservoir integrity
3. **Engineer**
   - Creating/constructing desired subsurface conditions in challenging high-pressure/high-temperature environments
4. **Sustain**
   - maintaining optimal subsurface conditions over multi-decadal or longer time frames through complex system evolution
5. **Monitor**
   - improving observational methods to advance understanding of multi-scale complexities through system lifetimes

The SubTER technical team identifies and facilitates crosscutting RD&D and policy activities for DOE, to enable programs with common technical challenges to work together toward solutions. The SubTER crosscut reports to the Under Secretary for Science and Energy and leverages program budget priorities to better plan for investment and assistance. While each of the offices brings new activities to the table, the sector benefits as a whole from crosscutting solutions. Partnerships include Departmental programs and offices, labs, academia, and industry, as well as synergies across federal agencies.

Subsurface Technology and Engineering Research, Development, and Demonstration (SubTER) Crosscut

Subsurface energy sources satisfy over 80% of total U.S. energy needs. Finding and effectively exploiting these resources while mitigating impacts of their use constitute major technical and socio-political challenges. Still, the opportunities are vast. Next generation advances in subsurface technologies will enable increases in domestic natural gas supplies, as well as 100+ GWe of clean, renewable geothermal energy. The subsurface provides hundreds of years of safe storage capacity for carbon dioxide (CO_2), and opportunities for environmentally responsible management and disposal of hazardous materials and other energy waste streams. The subsurface can also serve as a reservoir for energy storage for power produced from intermittent generation sources. These opportunities have immediate connection to societal needs and administration priorities. Clean energy deployment and CO_2 storage are critical components of the President's Climate Action Plan, necessary to meet the 2050 greenhouse gas (GHG) emissions reduction target. Increasing domestic energy supply from greater hydrocarbon resource recovery, in a sustainable and environmentally sound manner, are also Administration goals that enhance national security and fuel economic growth.

Who's Involved?

Representing the geosciences, research, modeling, technology development, policy, and stakeholders, the participating program offices include:

- 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 & Intergovernmental Affairs
- Energy Information Administration

http://energy.gov/sites/prod/files/2015/05/f22/SubTER-fact-sheet-2015.pdf