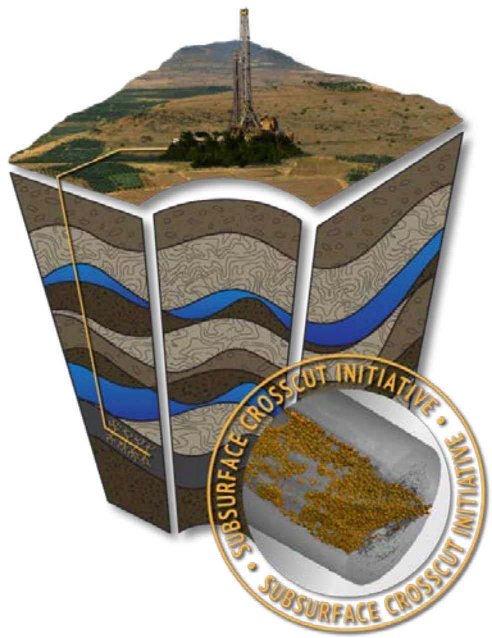
SubTER AGU Townhall
TH25I
December 15th, 2015



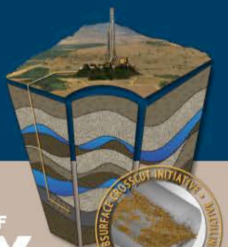
Agenda

- Welcome – Dr. Susan Hamm (Geothermal Technologies Office, DOE)
- SubTER update – Dr. Susan Hubbard (Berkeley Lab)
- Basic Research Agenda Report – Dr. Laura Pyrak-Nolte (Purdue Univ.)
- Discussion

Other SubTER AGU Activities

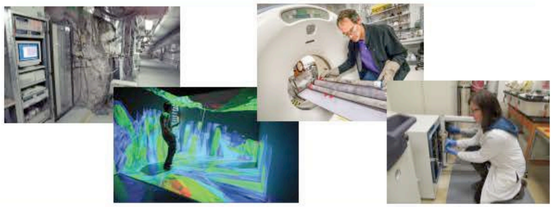
SubTER - **S**ubsurface **T**echnology & **E**ngineering **R**esearch

Adaptive control of the Earth's subsurface for our energy future



Presented by the U.S. DEPARTMENT OF ENERGY and the National Laboratory System

Join the following SubTER events at the AGU American Geophysical Union FALL MEETING 14 - 18 December 2015



Booth #1104

SubTER Booth #1104 – All Week, Exhibit Hall, Moscone North

Interested in participating? Stop by our "DOE Subsurface Crosscut (SubTER)" booth to learn more about future developments, collaboration and funding opportunities, and internships!

SubTER Townhall (TH25I) – Tuesday Dec 15, 6:15-7:15 pm, Moscone West 2004

Revolutionizing Utilization of the Earth's Subsurface for America's Energy Future: the DOE Subsurface Crosscut Initiative

SubTER Initiative (S. Hubbard, Berkeley Lab)

SubTER Science Roundtable Report (L. Pyrak-Nolte, Purdue University)

Poster Session H51M Friday AM

SubTER Poster Session (H51M) – Friday Dec 18, 8 am-12:20 pm, Moscone South

Subsurface Control of Fractures and Flow for Responsible Energy Production and Storage

Co-chairs: T. Daley, D. Blankenship, R. Pawar & A. Bonneville

DOE Crosscutting ‘Big Idea’ Summit: **the Birth of SubTER**

March 2014
- DOE Big Idea Summit I

Dec 2014
- SubTER retreat & AGU Townhall

2014, 2015
- Outreach, many venues

March 2015
- DOE Big Ideas Summit II

Summer 2015
- SubTER Retreat
- Science roundtable

Nov 2015
- SubTER NL Plan briefing to DOE

FE/O&G: Fossil Energy/Carbon Storage

EERE/GTO: Energy Efficiency & Renewable Energy/ Geothermal Technologies Office

FE/O&G: Fossil Energy/Oil & Gas

SC: Science

EM Environmental Management

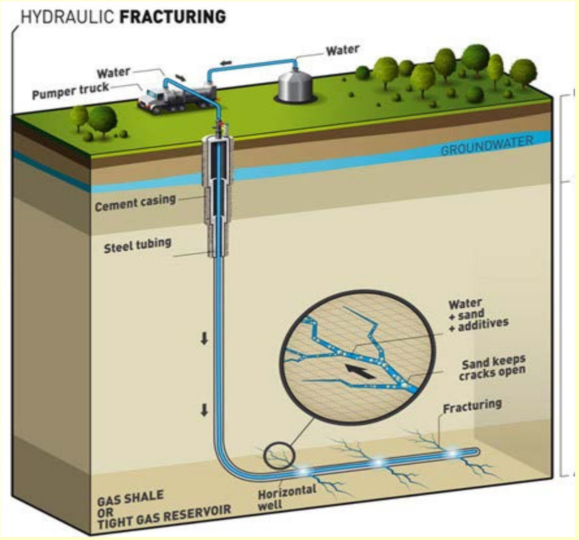
EPSA: Energy Policy & Systems Analysis

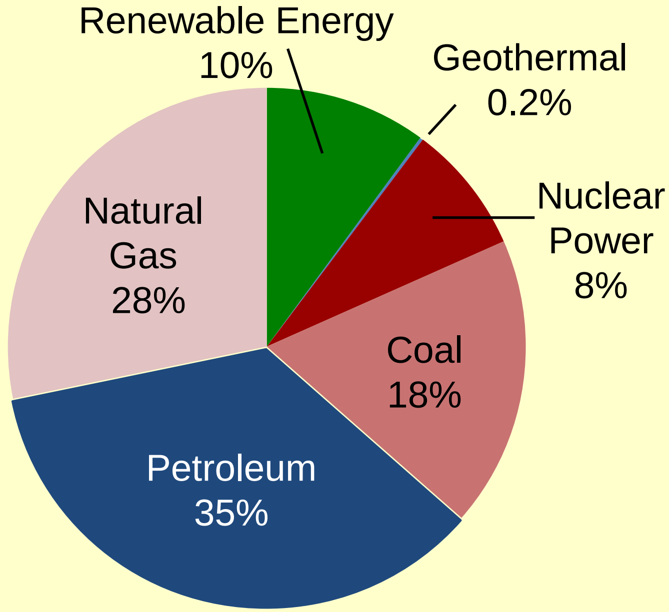
NE Nuclear Energy

Argonne National Laboratory · Brookhaven National Laboratory · INL Idaho National Laboratory · Los Alamos National Laboratory · Berkeley Lab · Lawrence Livermore National Laboratory · NETL · NREL · Oak Ridge National Laboratory · Pacific Northwest National Laboratory · SLAC National Accelerator Laboratory · Sandia National Laboratories · SRNL

Mastery of the Subsurface needed to Greatly Enhance its Utilization

Shale hydrocarbon production

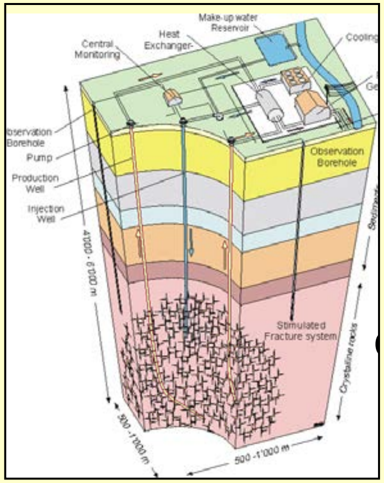




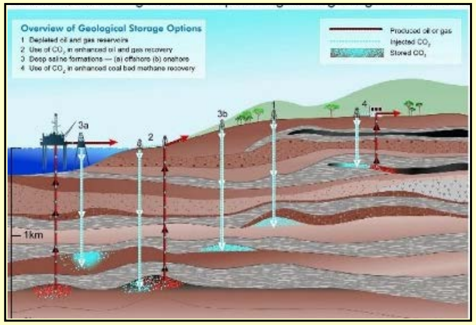
Primary Energy Use by Source, 2014

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

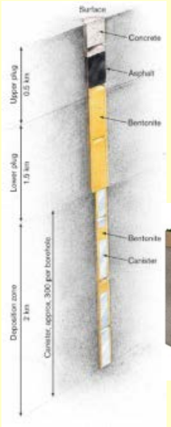
Enhanced geothermal energy

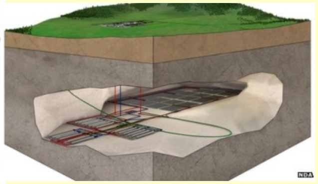


Safe subsurface storage of CO_2

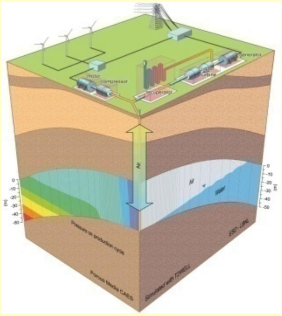


Safe subsurface storage of nuclear waste





Compressed Air Energy Storage



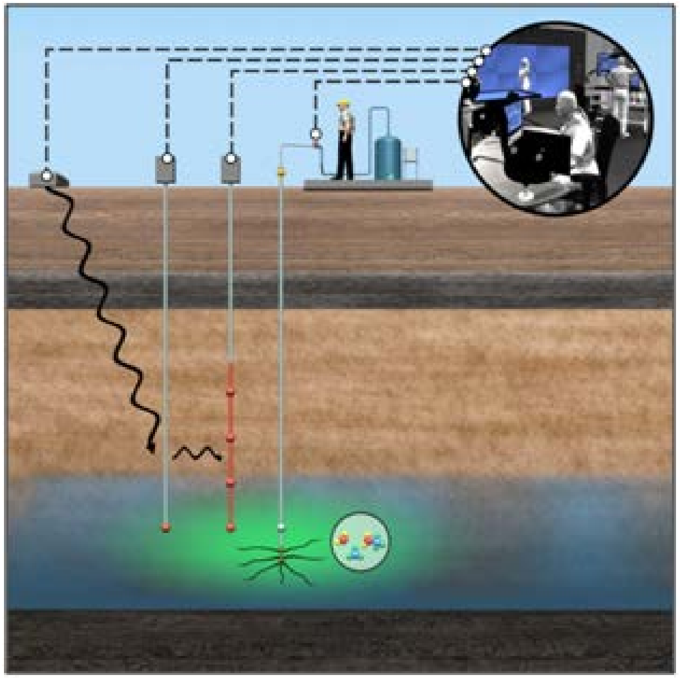
Adaptive Control of Subsurface Fractures and Flow

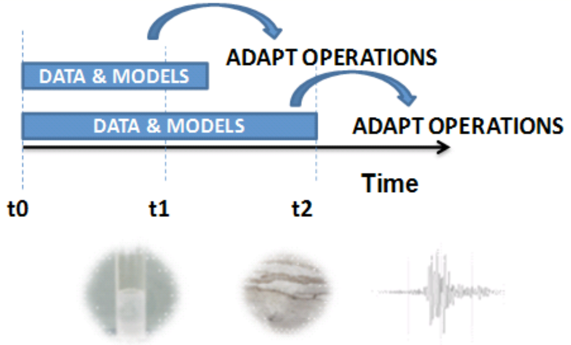
Ability to adaptively manipulate subsurface – with confidence and rapidly.

Within 10 Years:

- A ten-fold increase of U. S. electricity production from **geothermal** reservoirs
- Double **hydrocarbon** production from tight reservoirs
- Establish practical feasibility of deep borehole **disposal**
- Large-scale safe **CO_2 sequestration** to meet targets described in the President's Climate Action Plan

Concurrent protection of the environment (water and air resources, induced seismicity)



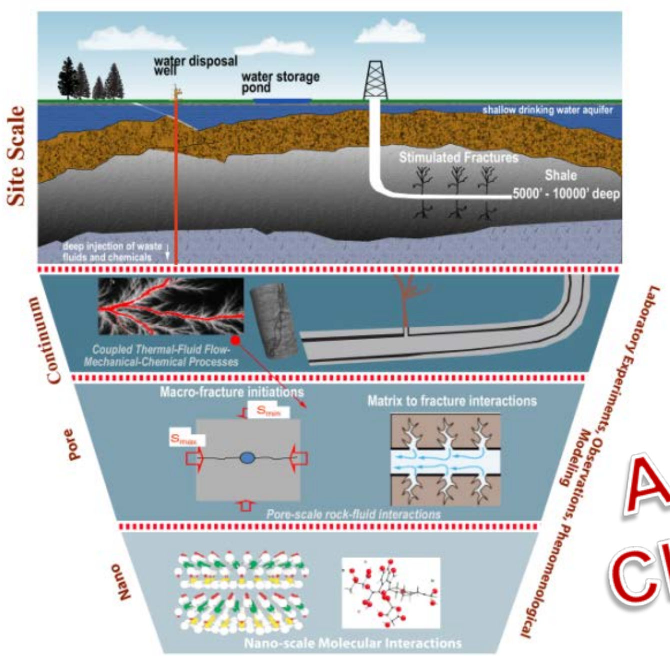


‘Adaptive Control of fractures’ is a Grand Subsurface Challenge

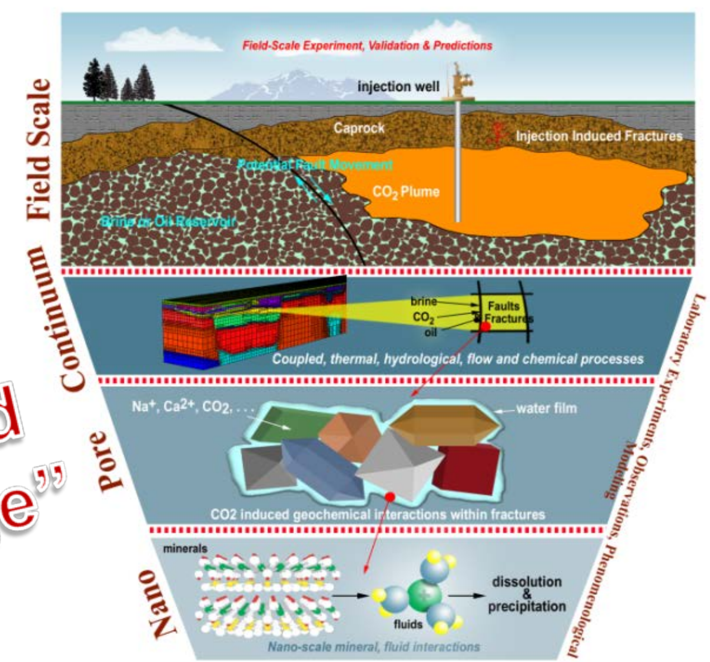
Requires an understanding and ability to manipulate subsurface stress, geochemical reactions, and multi-phase fluid flow

- within heterogeneous geological environments
- across nanometer to kilometer length scales
- remotely within the deep subsurface reservoirs

Requires fundamental through engineering RD&D



A “Grand Challenge”



Activities & Input to SubTER Plan: Select Examples

- National Resource Council, 2014
- National Energy Association, July 2014
- National Academy of Sciences , October 2014
- DOE Subsurface grand challenge RFI May 2014
- AGU town hall 2014
- SubTER –led workshops, 2015:
  - ➢ Shale at all Scales
  - ➢ Grand Challenges in Geological Fluid Mechanics
  - ➢ 3D Printing techniques relevant to rock physics
  - ➢ Novel Cements
- SEG 2015
- National Laboratory Day, June 2015
- GSA SubTER booth 2015
- Centennial Grand Challenges in Rock Physics 2015
- Several discussions w/universities, industr agencies and NGOs

ARMA

National Research Council NRC

NRDC

NATURAL RESOURCES DEFENSE COUNCIL

THE GEOLOGICAL SOCIETY OF AMERICA®

USEA
United States Energy Association

NATIONAL ACADEMY OF SCIENCES

Expert Panels ~ Select Examples

JASON, 2014: 'State of Stress in Engineered Subsurface Systems'

Governmental & Military

JASON

- "DOE should take a leadership role in the science and technology for improved measurement, characterization, and understanding of the state of stress of engineered subsurface systems in order to address major energy and security challenges of the nation."
- "Coordinated research and technology development at dedicated field sites to connect insights from laboratory scales and models to operational environments"

DOE Roundtable, 2015: 'Imaging of stress and geological processes'

Identified Basic Research Priority Research and Crosscutting Directions (Laura Pyrak Nolte)

SubTER Draft Work Plan under review by DOE

Overall Goal:

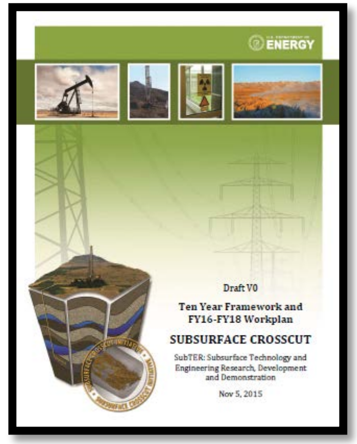
- **Successful demonstration of adaptive control for several energy strategies**

Additional Year 10 goals:

- Manipulate stress away from the borehole
- Inject fluid (eg., carbon sequestration, waste disposal, CAES) with acceptable/predictable seismicity
- Create and plug fractures at will in a variety of subsurface environments
- Create boreholes that do not leak for every subsurface energy application
- Develop and successfully implement technologies that enable access, modeling, and monitoring at scales and resolution for guiding adaptive control
- Provide science to enable a new class of responsible energy production and waste storage options

Year 5 goals...

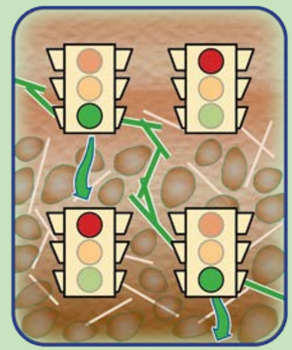
Year 2 goals…



Draft plan will require partnerships between National Labs, academia and industry to meet grand challenge

SubTER Framework

Adaptive Control of Subsurface Fractures and Fluid Flow

Wellbore Integrity and Drilling Technologies	Subsurface Stress & Induced Seismicity	Permeability Manipulation & Fluid Control	New Subsurface Signals
			
Materials and technologies to ensure wellbore integrity over decadal timeframes	Characterization and control subsurface stress and induced seismicity	Approaches to manipulate subsurface fractures, reactions and flow	Sensors and algorithms to monitor subsurface dynamics and facilitate adaptive control

SubTER Framework

Adaptive Control of Subsurface Fractures and Fluid Flow

Wellbore Integrity and Drilling Technologies	Subsurface Stress & Induced Seismicity	Permeability Manipulation & Fluid Control	New Subsurface Signals
Improved well construction materials and techniques	State of Stress (measurement and manipulation)	Manipulating Physicochemical Fluid-Rock Interactions	New Sensing Approaches
Autonomous completions for well integrity modeling	Induced seismicity (measurement and manipulation)	Manipulating Flow Paths to Enhance/Restrict Fluid Flow	Integration of Multi-Scale, Multi-Type Data
New diagnostics for wellbore integrity	Relate Stress and IS to Permeability	Characterizing Fracture Dynamics and Fluid Flow	Adaptive Control Processes
Remediation tools and technologies	Applied Risk Analysis to Assess Impact of Subsurface Manipulation	Novel Stimulation Technologies	Diagnostic Signatures and Critical Thresholds
Fit-for-purpose drilling and completion tools (e.g. anticipative drilling, centralizers, monitoring)			
HT/HP well constr. & completion technologies			

Energy Field Observatories

Fit For Purpose Simulation Capabilities

Subsurface Stress and Induced Seismicity **Element:**

Relate Stress to Induced Seismicity and Permeability

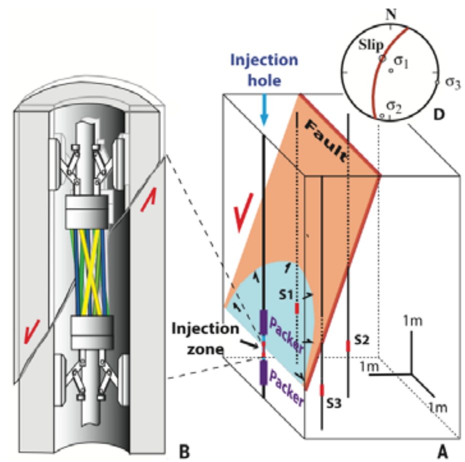
Element	2-year goals	5-year goals	10-year goal
Relate Stress and IS to Permeability	Compile database(s) of publicly available data to test models of permeability/slip relationship(s)	Conduct field demonstration(s) of optimal integrated monitoring, analysis, and characterization techniques	Develop the ability to **utilize stress and induced seismicity to control flow paths along reactivated faults and fractures, predicting permeability behavior** with an order of magnitude improvement over current capabilities
	Design and carry out laboratory and numerical experiments to identify and acquire missing data needed to achieve goals	Demonstrated improved permeability prediction by a factor of 3 over baseline	
	Establish dedicated field observatory site(s). Perform integrated analysis and interpretation of results from initial field experiments, using state-of-the-art techniques	Demonstrate characterization techniques to predict seismic vs. aseismic slip behavior	
	Establish benchmarks for permeability prediction capabilities including both fault leakage and fractured reservoir productivity	Identify and prioritize techniques capable of achieving 10 year goals	

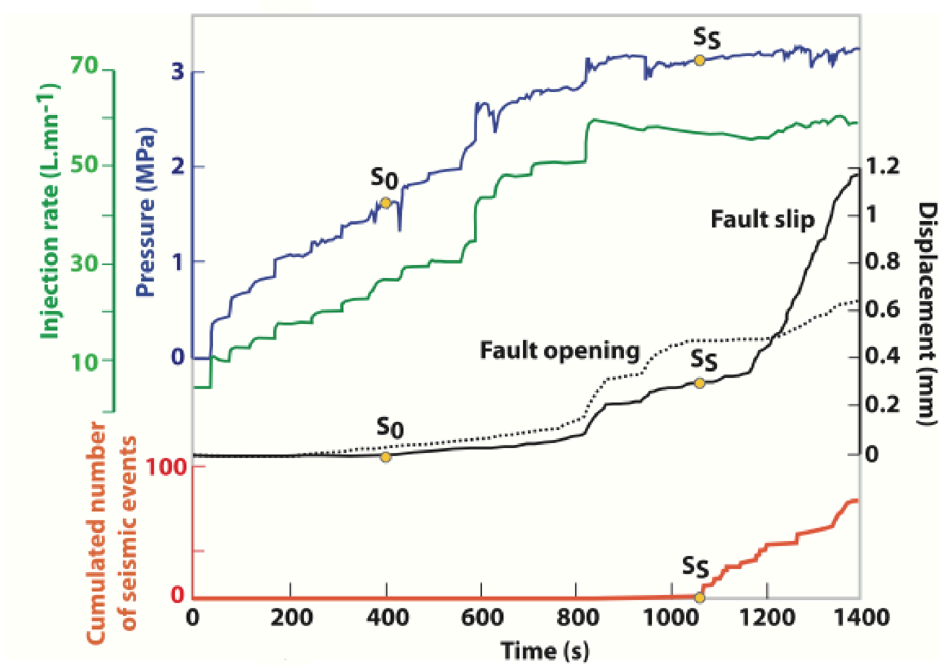
Subsurface Stress and Induced Seismicity **Element:**

Relate Stress to Induced Seismicity and Permeability

Element

Relate Stress and IS to Permeability





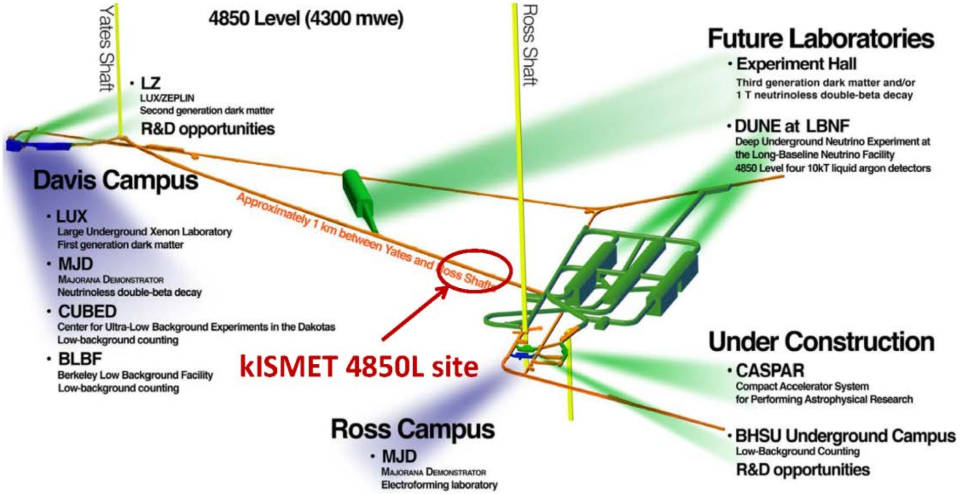
10-year goal

Develop the ability to **utilize stress and induced seismicity to control flow paths along reactivated faults and fractures, predicting permeability behavior** with an order of magnitude improvement over current capabilities

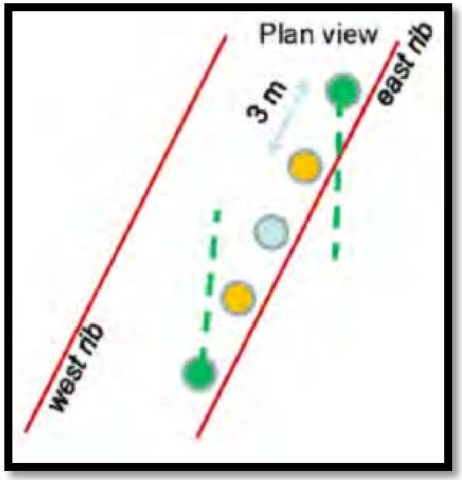
Activity: Underground facility for testing IS as controlled by stress, rock properties & existing fractures

kISMET: Permeability and Induced Seismicity Management for Energy Technologies

- Stress measurements and modeling of natural stress state
  - Univ. Wisconsin, Stanford, Golder Associates
- Joint inversion of displacement (GPS/tilt meter) and velocity (seismic) for the 3D stress field.
- Stimulated fault slip experiments to characterize relationship between rock fabric. stress and the evolution of fractures.



KiSMET @ SURF



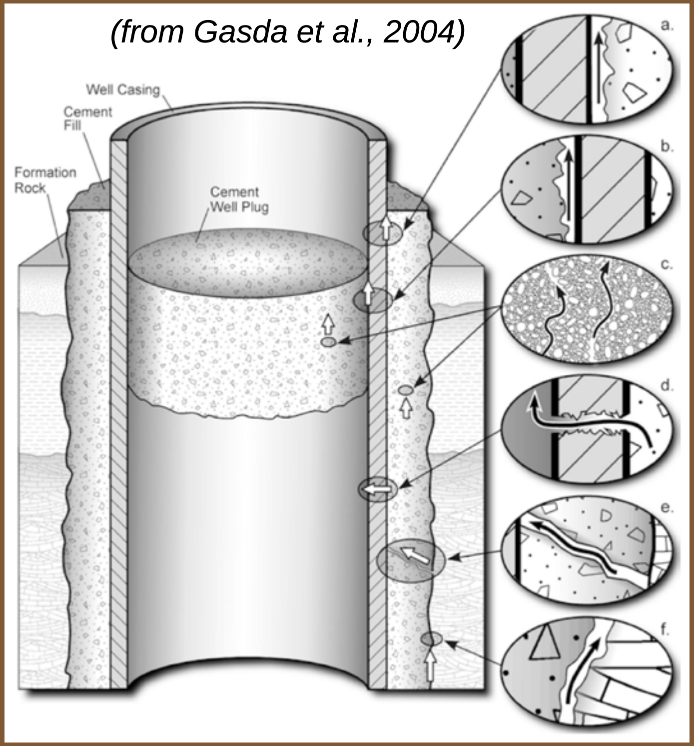
Wellbore Integrity & Drilling Technologies Motivation and Objectives

Motivation

- Current well systems may not meet long term integrity needs and these well systems require further advancement to meet goals of SubTER

Objectives and Goals

- Improve understanding of interaction between well system and natural environment in order to engineer wells that:
  - maintain integrity over decadal time scales
  - facilitate SubTER other pillar goals



Many possible leakage pathways along a well, including:

- between cement and outside of casing
- breached casing
- through fracture in annulus cement
- between cement and rock
- through and around internal wellbore seals

Example Element:
Improved Well Construction Materials

Activity

Quantify stress / chemical evolution needed for material/process improvements

Activity

Develop materials and processes that improve well integrity

Year 2 Goals

- Establish industry partnerships
- Define basis for evaluating performance of candidate materials/technologies
- Perform synthesis and laboratory testing of 5 materials and methods compatible with representative subsurface environments
- Plan for performing field-like deployment

Year 5 Goals

- Perform field demonstration of candidate systems using **advanced materials** and/or processes that provide, for example, at least a **25% increase in bond strength** for anticipated range of well conditions (100-foot demo wells).
- Establish standards and **protocols for evaluating long-term performance** of well construction materials in representative environments and loading conditions.
- Develop methodologies for understanding the **effect of in situ stress evolution** and other forcing functions on the wellbore sealing system

Year 10 Goals

Develop or implement economical fit-for-purpose wellbore construction methods across a wide range of applications (e.g., producing wells, disposal wells, monitoring wells, etc.).

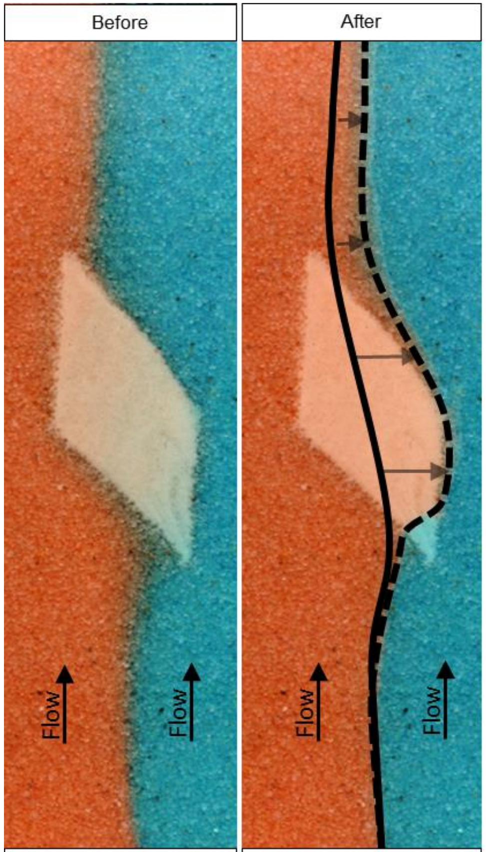
Permeability Manipulation Motivation & Objective

Motivation

- Methodologies to control permeability, fracture development and fluid flow pathways *with finesse* is missing.

Objective

- Develop the scientific basis and technologies to **quantify, characterize and manipulate subsurface flow**
- through an integration of physical alterations, physicochemical fluid/rock interaction processes, and novel stimulation methods implemented at the field scale



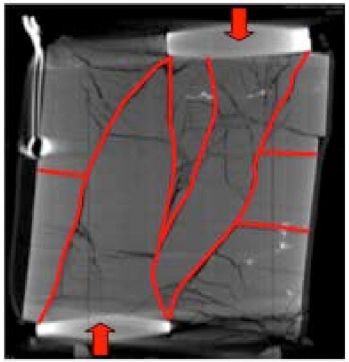
Initial flow pathways. Note: lower permeable parallelogram in higher permeable material

Migration of $BaSO_4$ precipitation front (solid to dash line) and resulting flow pathways

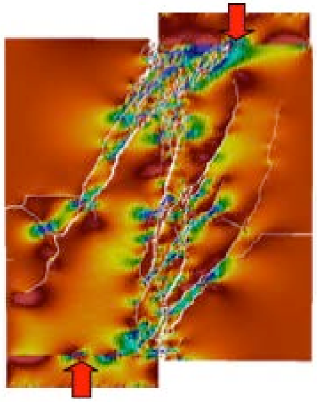
(Fox et al., 2015)

Example activity: Simulation of fracture networks & flow

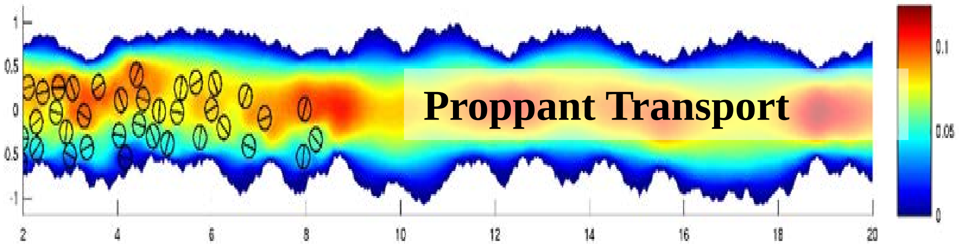
- New numerical methods to simulate fracture initiation, propagation, flow and reactions
- Successful testing at laboratory through field scales

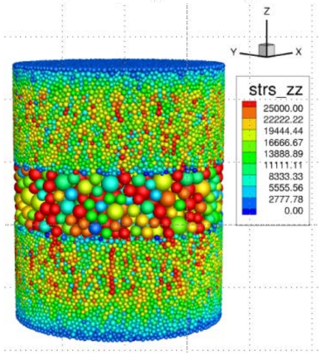


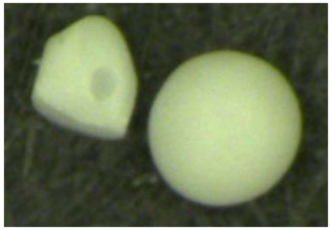
Experimental observations of shale fracturing



Numerical simulation of fracturing



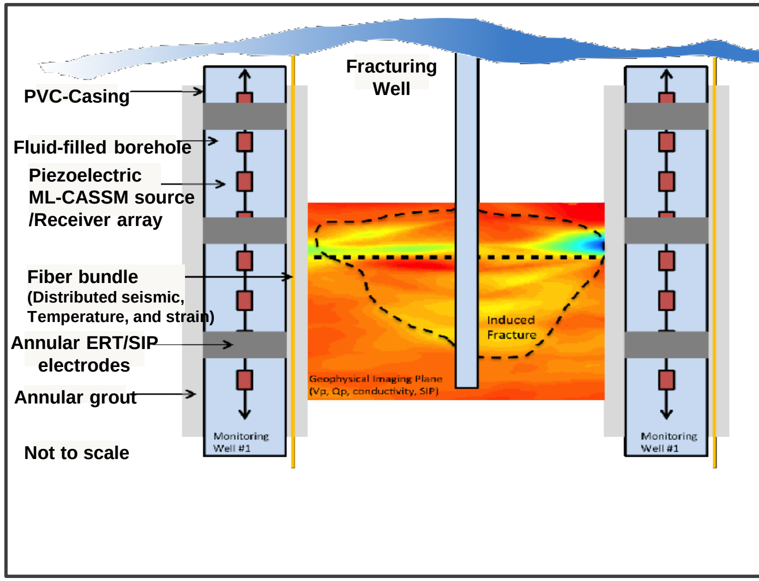


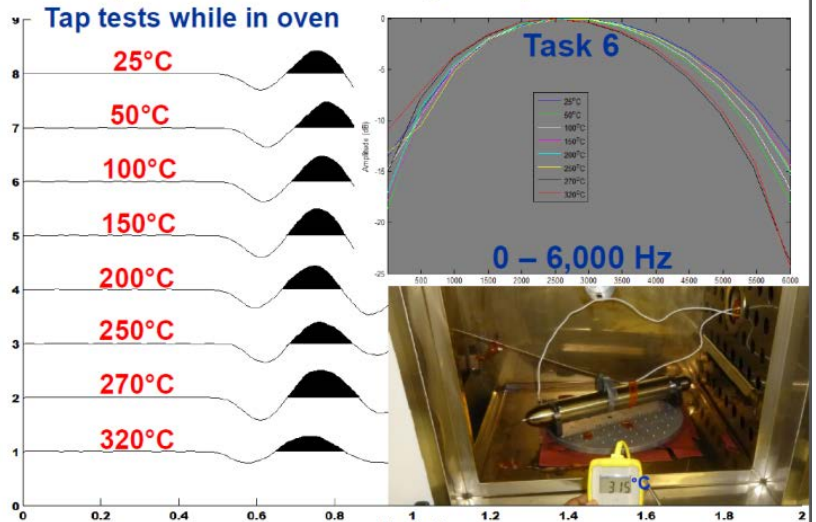


New Subsurface Signals Objective

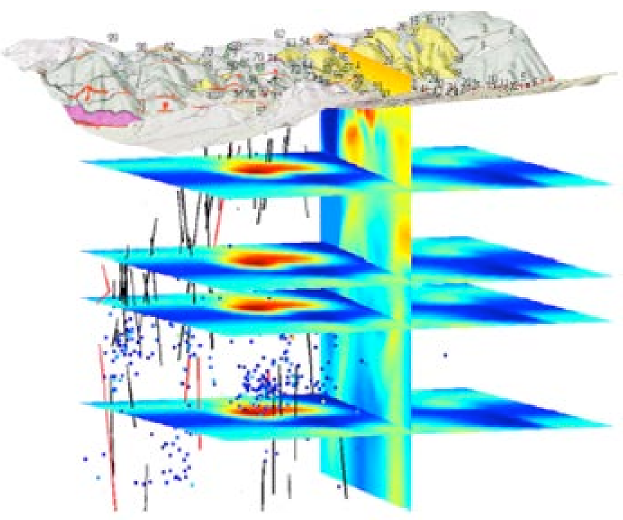
Transform ability to characterize subsurface systems by developing new approaches to:

- ➢ sense the subsurface
- ➢ analyze multiple datasets
- ➢ identify critical system transitions
- ➢ develop process control approaches

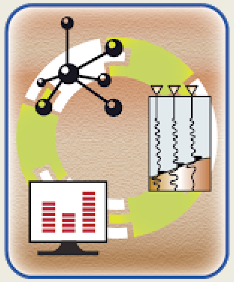




(Paulsson, et al., 2015)



Newman et al., 2008



New sensing approaches | Integration of multi-scale and multi-type datasets | Diagnostic signatures and critical thresholds | Adaptive control processes

Example activities

Novel tracers for fracture system characterization and monitoring

Advanced **Fiber-Optic Monitoring Tools for Seismic & Electrical** Detection

2-year Goals

Identify candidate intrinsic tracers, co-injected tracers, and natural fracture geophysical signatures suitable for pursuit.

Design and construct a fiber-optic point EM vector sensor and distributed EM sensor.

5-year Goals

Demonstrate in field the use of improved tracers and natural signals to characterize a field fracture network.

Demonstrate the utility of the enhanced fiber-optic sensing systems for field scale real-time monitoring of fracture behavior.

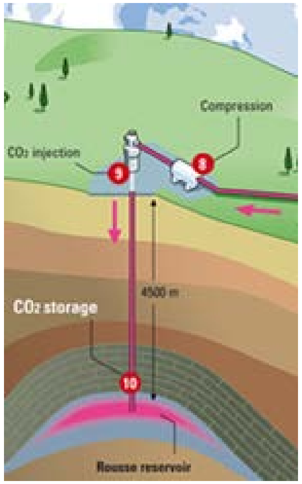
10 –year Goal

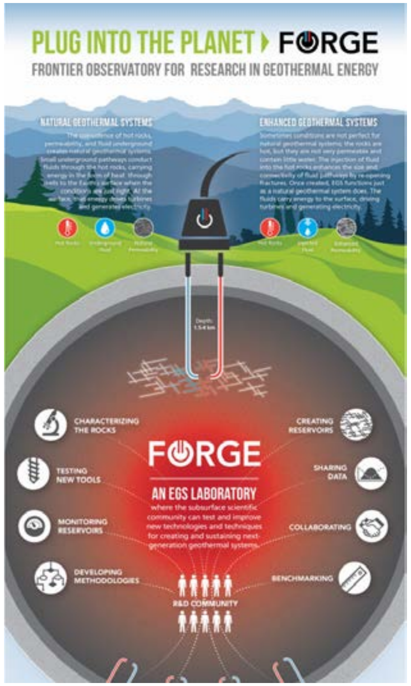
Identification of diagnostic signatures and critical thresholds through transformative collection and analysis of new subsurface signals.

Field Energy Observatories

Field Energy Observatories Enable:

- In situ testing under controlled conditions -a critical aspect of RDD&D
- Coordination of SubTER activities (common site, materials)
- Community engagement
- Partnership with industry and stakeholders
- Partnerships across projects





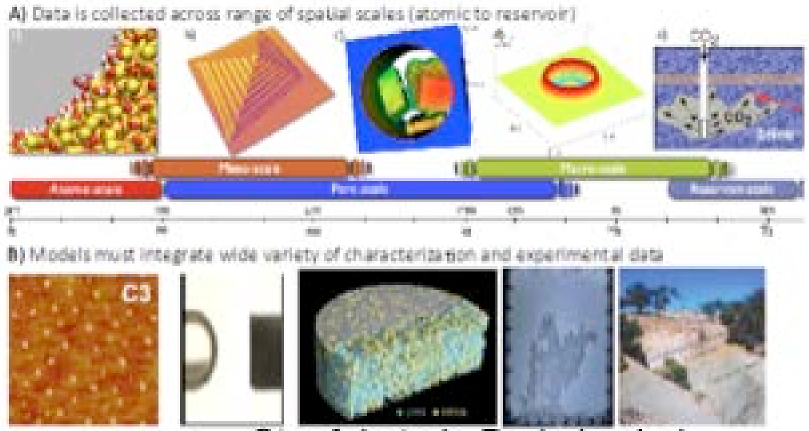
Blue Canyon, NM

KiSMET @ SURF

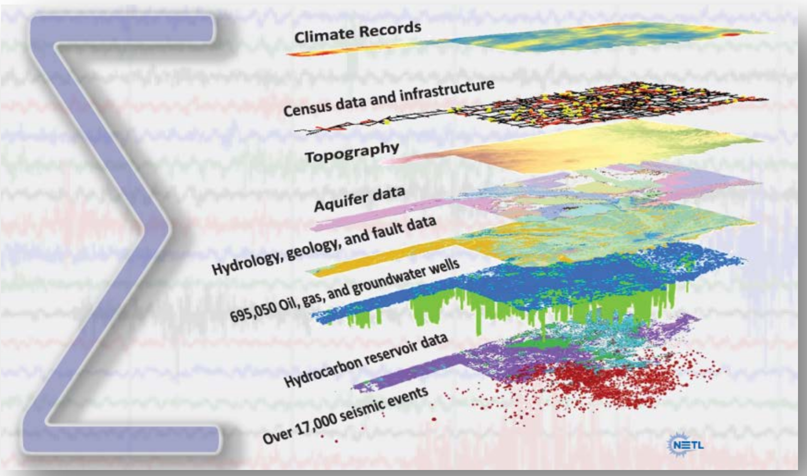
Fit-For-Purpose Modeling
next-generation computational approaches for subsurface control

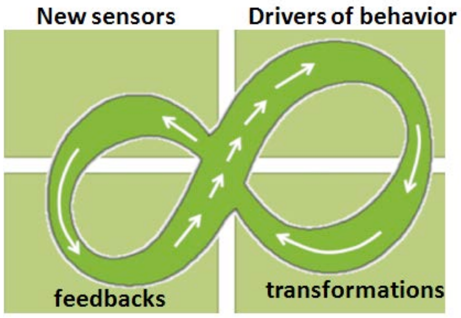
Several advances are required. Examples:

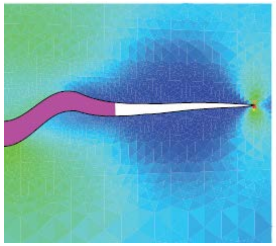
- Modeling **stress evolution** in wellbore environment and in reservoirs
- Accurate simulation of **coupled permeability, fracture propagation, fluid flow** and proppant behavior
- **Anticipate induced seismicity** constrained by diverse datasets
- **Risk assessment** frameworks
- Integrated and **rapid data processing, management, and knowledge** generation from multiple big & diverse datasets
- **Ultra-fast predictions and decision support** – toward decision support using exascale



Steefel et al., Berkeley Lab



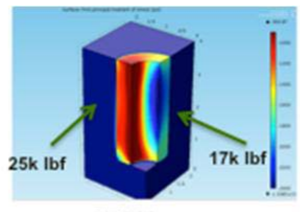


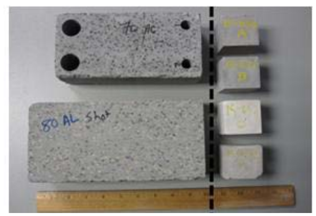


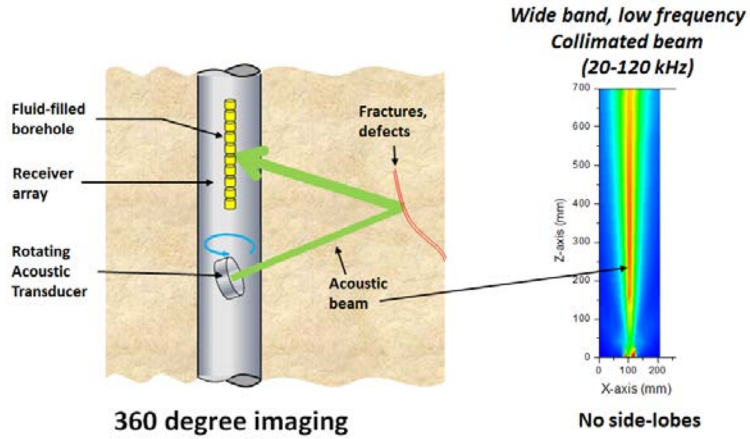
Fracture propagation using an adaptive mesh scheme [Lew et al. 2013]

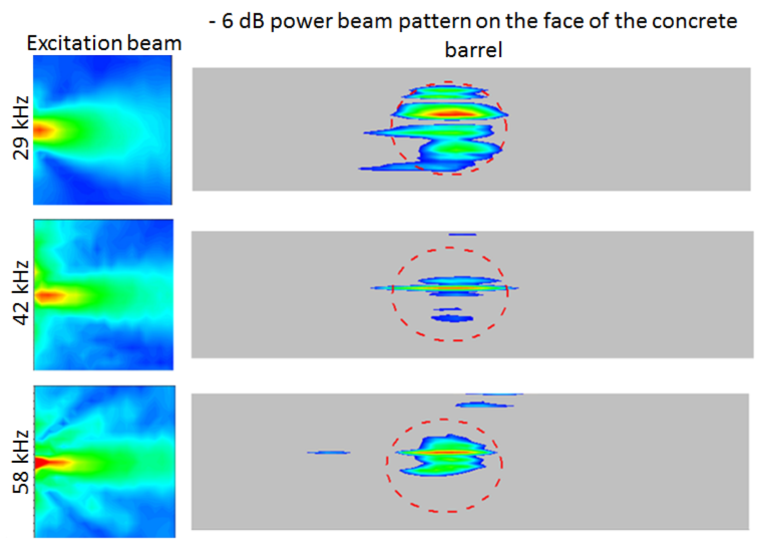
SubTER @ AGU: Poster Session

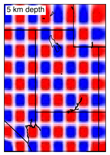
- Friday AM, H51M

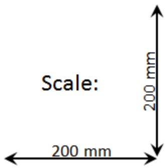


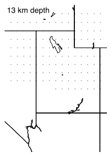












More Information and Next Steps

Next Steps

- SubTER Industry Roundtable, Feb 2016
- Webinar and Engagements with Universities, 2016
- Pending FY16/17 Budget ~ SubTER Funding Opportunities

For More Information:

DOE Webpage: http://energy.gov/subsurface-tech-team

Natl. Lab Team Webpage: http://esd.lbl.gov/subter/home/subsurface-team/

Twitter: https://twitter.com/SubTERCrosscut

LinkedIn Groups: https://www.linkedin.com/groups/7017263

LinkedIn Page: https://www.linkedin.com/pub/subter-crosscut/106/332/85