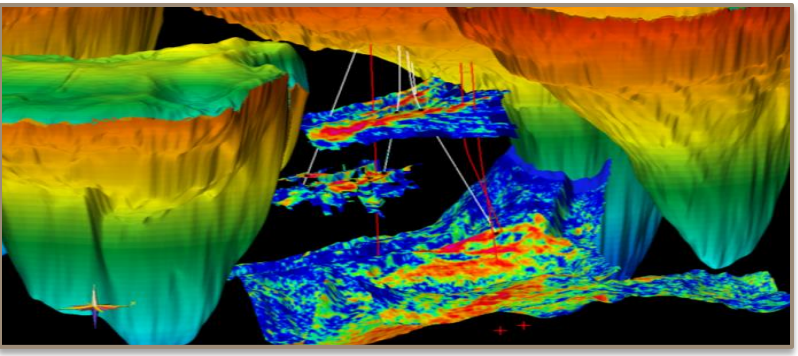
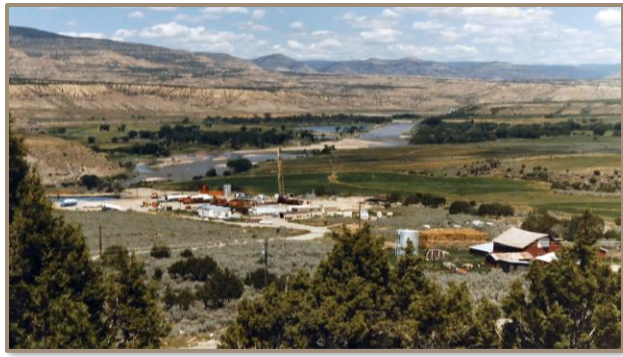
SAND2013-7772P

Exceptional service in the national interest

Sandia National Laboratories





Hydraulic Fracturing: Role of Government Sponsored R&D

Marianne C. Walck, Ph.D., Director
Geoscience, Climate, and Consequence Effects Center
Sandia National Laboratories

September 18, 2013

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. SAND NO. 2011-XXXXP

The Enormous Impact of Hydraulic Fracturing

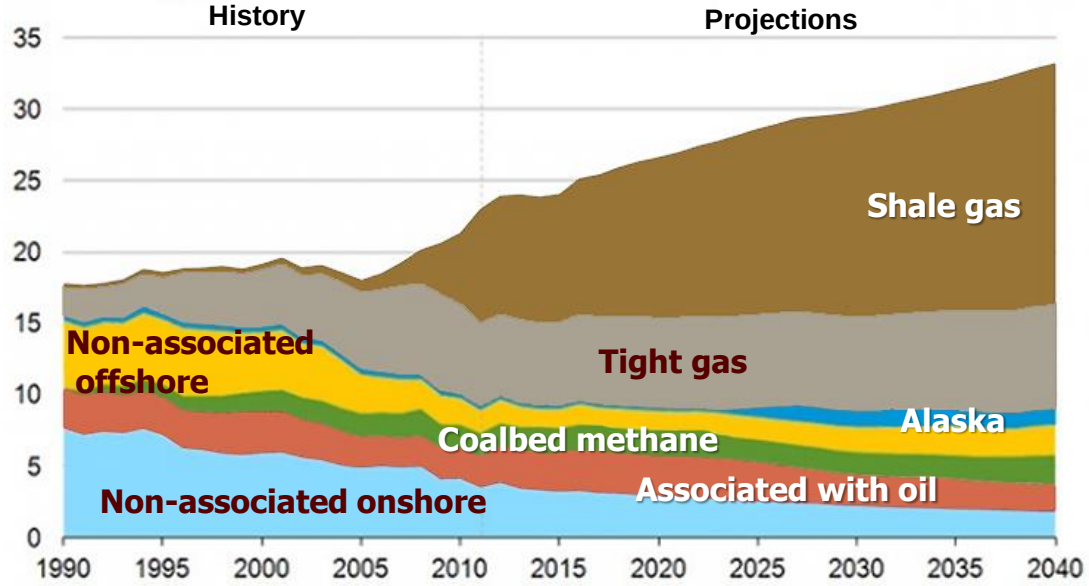
Sandia National Laboratories

US annual dry natural gas production: 26% increase since 2000
Shale gas now provides 40% of US natural gas

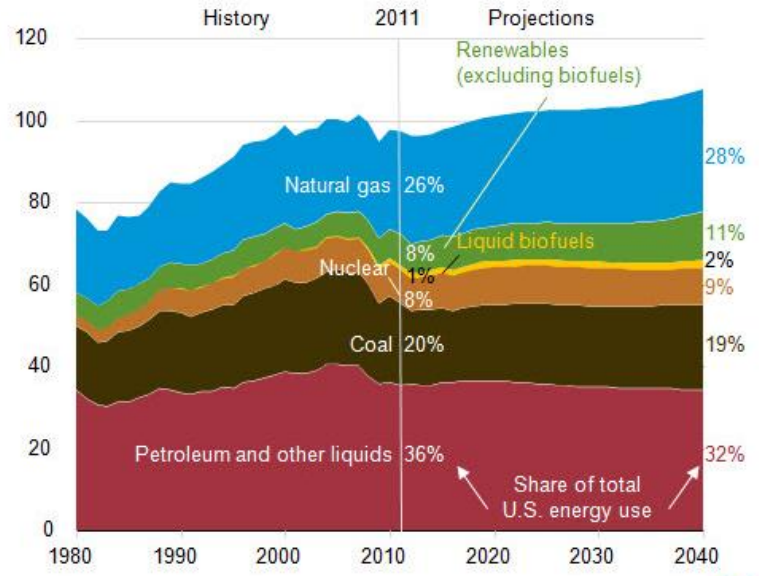
Shale oil production is rapidly increasing

Fossil fuels will continue to be the primary source of US energy for decades

U.S. dry natural gas production (trillion cubic feet)



***Primary energy use by fuel, 1980-2040** (quadrillion Btu)*



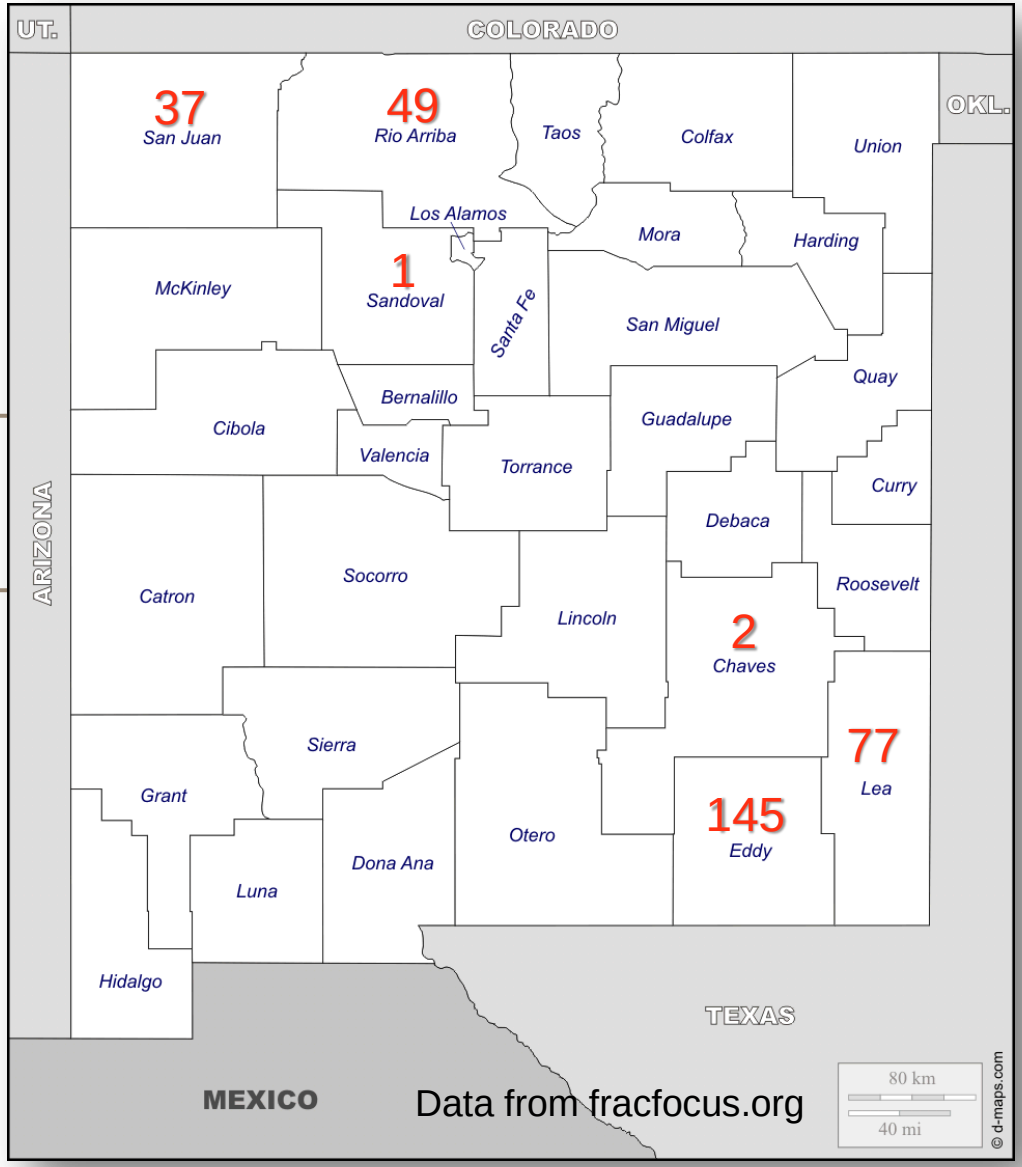
Source: US Energy Information Administration, annual Energy Outlook 2013 Early Release

eia

How much Hydraulic Fracturing occurs in New Mexico?

Sandia National Laboratories

More than 300 wells since 01/01/13

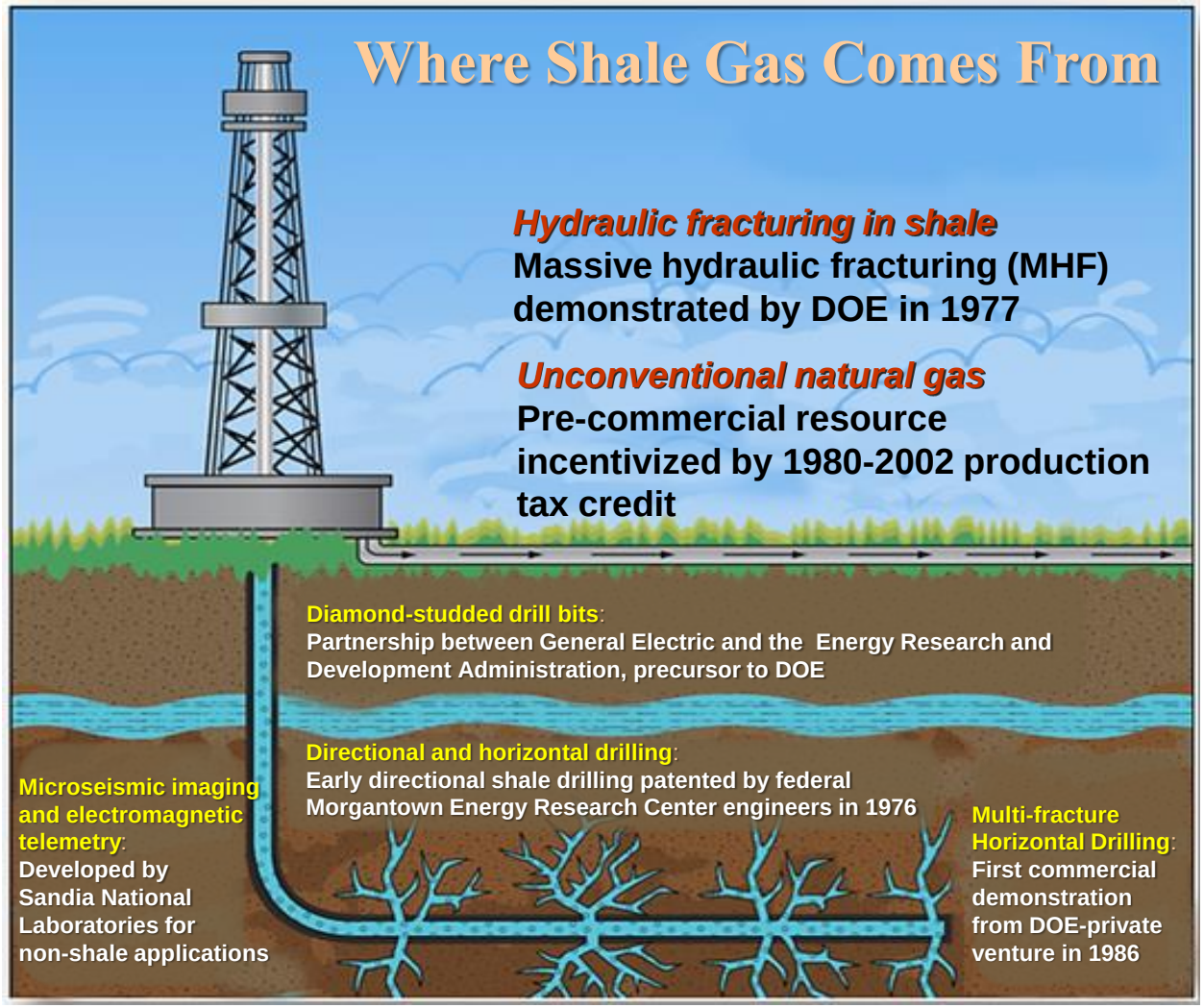


How Did This Happen?

Sandia National Laboratories

Technology advances, deployed by independent producers

Government-funded research enabled drill bit improvements, horizontal drilling, and hydraulic fracture mapping



thebreakthrough.org

DOE Investments that Enable Hydraulic Fracturing

Sandia National Laboratories

PDC drill bits – enable long-reach horizontal drilling

Fundamental work on 'tight' reservoirs –
laid the basis for routine mapping of hydraulic fractures in the subsurface

- Geologic system
- Stress state in the rock
- Microseismic mapping

Both required a unique blend of

- Earth Science
- Engineering – downhole sensors, telemetry, drilling technologies
- High-performance computing
- Large scale field demonstrations

National Laboratories have the interdisciplinary expertise needed to develop these technologies.

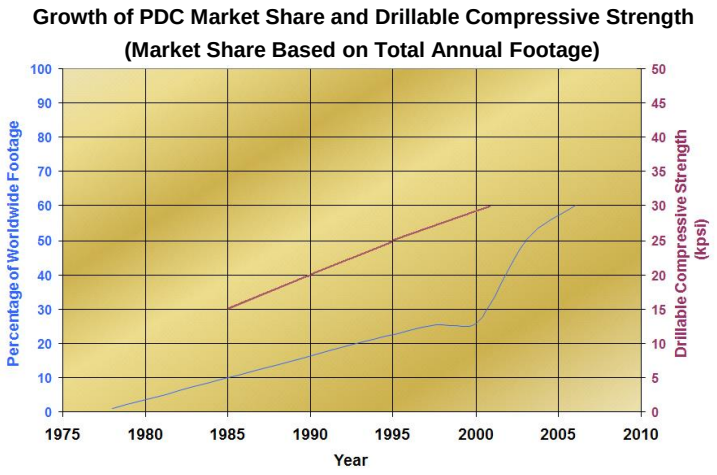
Polycrystalline Diamond Compact (PDC) Bits

Sandia National Laboratories

Early 1980's: DOE program started with Geothermal Program –
Goal: improve PDC performance

- **Fundamental work at Sandia**
  - Finite Element Modeling analyses
  - Bonding
  - Cutter tests
  - CRADAs
  - Bit design / analysis
  - Lab / field testing

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



PDC bits save industry $billions annually

~ 2/3 of world footage today

PDC bits now a ~ $1.5 billion industry

Catalyzed a major industry

Used to drill most of the long horizontal wells used for fracking

Fundamental Studies of Hydraulic Fracturing in the Late 1970's – 1980's

Sandia National Laboratories

Mineback experiments

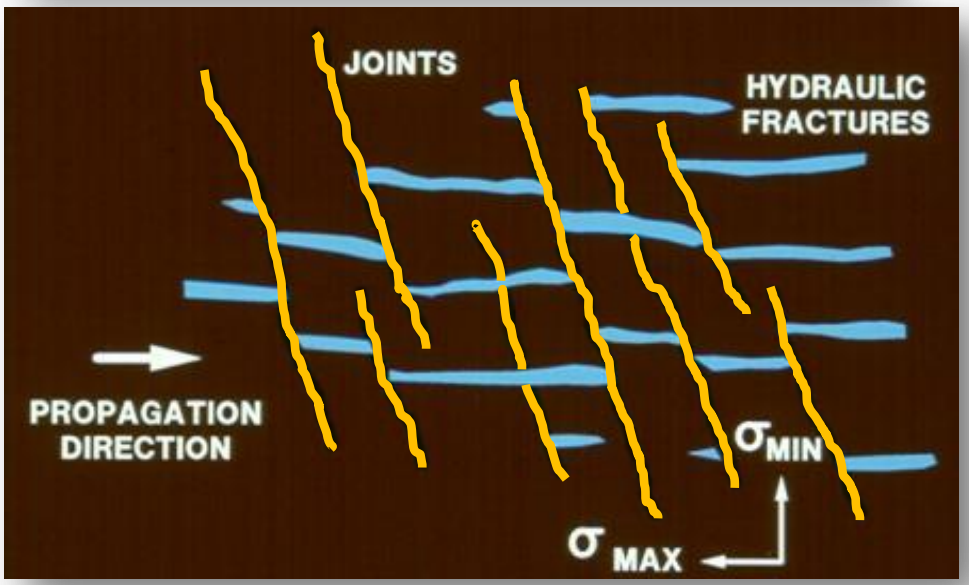
- Nevada Test Site, coal-bed methane

Reservoir characterization

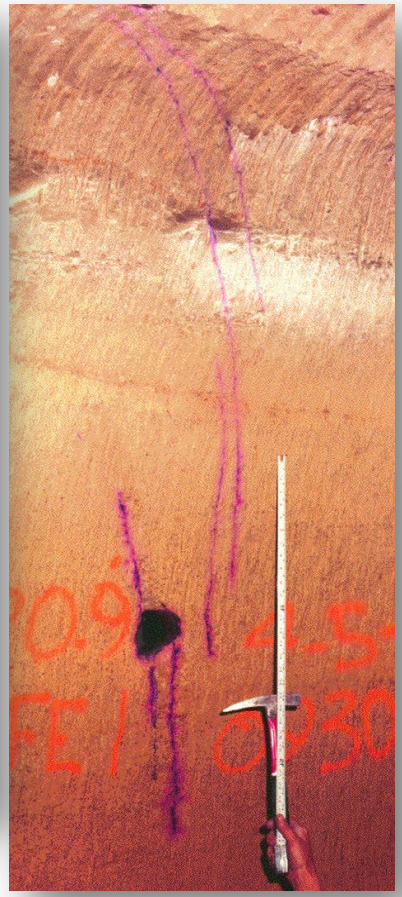
- Natural fractures
- Subsurface stress state
- Core samples
- Geological characterization

Monitoring technologies

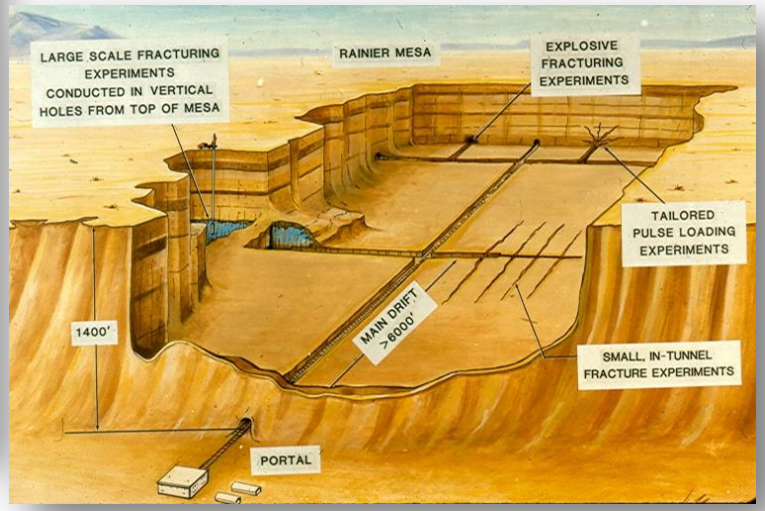
- Seismic
- tiltmeters



Mineback Experiments: 1976-1985



Leveraged Nevada field site and technologies for new applications

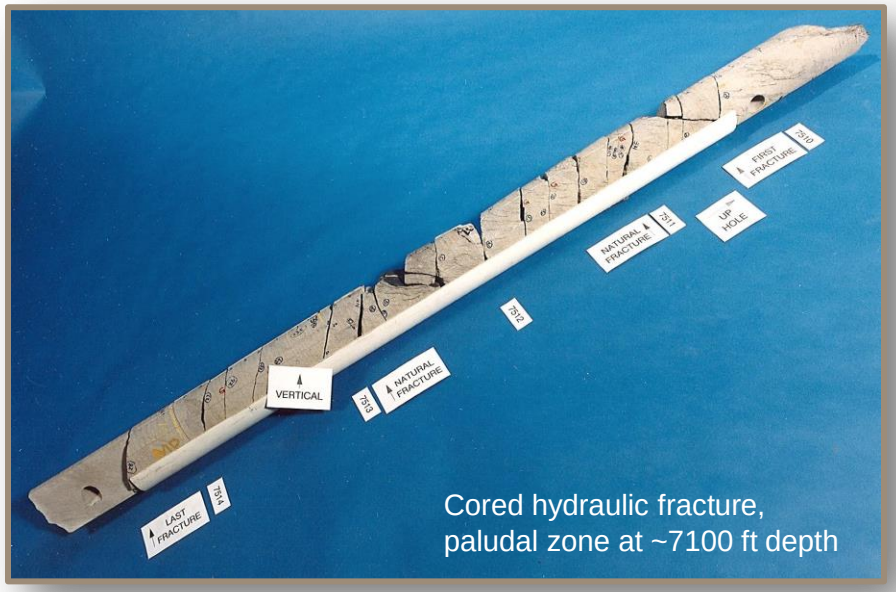


Direct observation of Fractures in the field

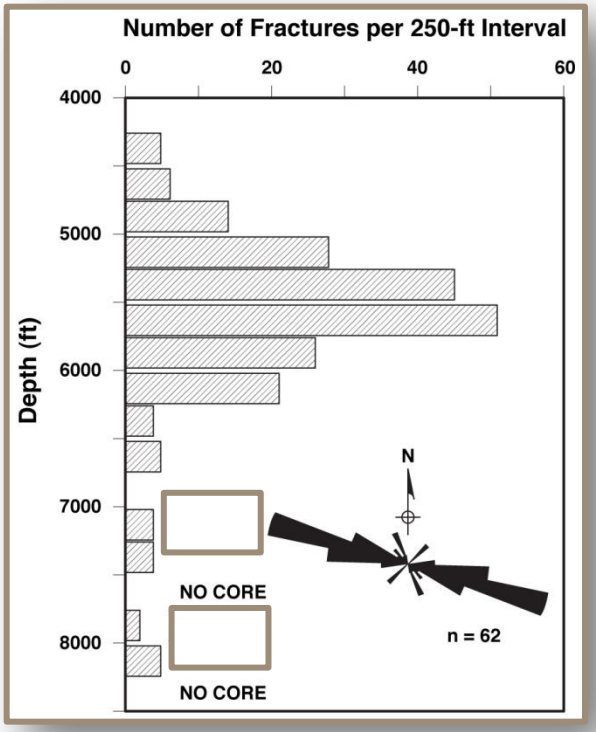
DOE Multi-well Experiment

- 1981-1988
- Field laboratory: improve production from “tight” sands
- 3 closely-spaced vertical wells
- Monitored Stimulation experiments
- Basic data later used to develop technology advances

MWX Learnings



Cored hydraulic fracture, paludal zone at ~7100 ft depth



- Stress measurement techniques developed
- Geology matters – extensive rock core collected
- Fracture-height growth controlled by stress contrasts
- Effectiveness of PDC bits for coring
- Monitoring technologies initiated
- Importance of interdisciplinary teams in a field setting

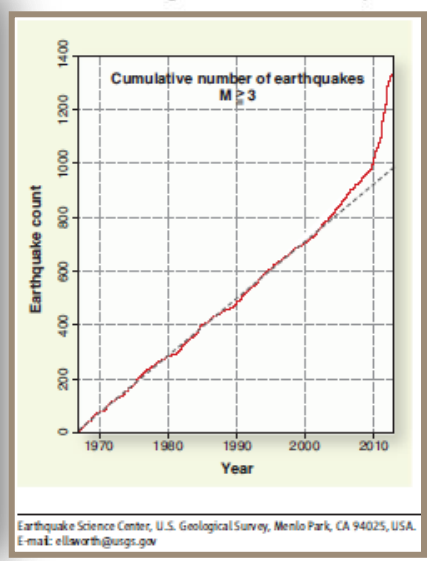
Environmental Questions

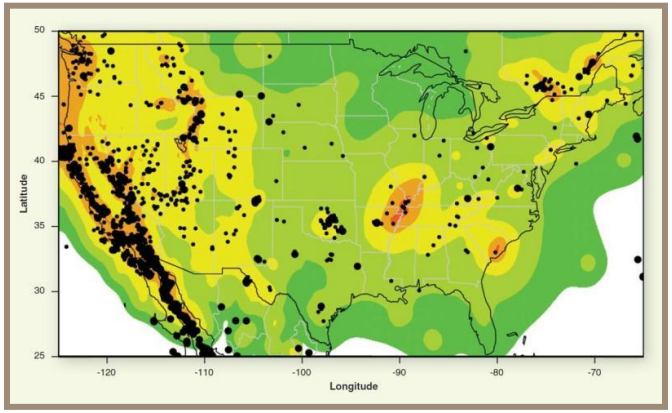
Sandia National Laboratories

Burning natural gas produces about ½ of the CO_2 compared with burning coal – but do **fugitive emissions** offset CO_2 savings?

Examples of Induced Earthquakes

- Rangely, CO, injection experiments (M4.9, 1995), 1945-1995
- Rocky Mountain Arsenal (M5.3, 1967), fluid injection, 1962-1966
- Gazli, Uzbekistan, gas recovery (M7.2), 1976-1984
- Water Reservoirs: Lake Mead (M5), Koyna (M6.3), Oroville (6.1) Tadjikistan, Italy and many others
- Geysers Geothermal Field (M4.6), injection-enhanced production
- Dallas Airport (M3.3), fluid injection, 2008-2009
- Arkansas (M4.7), fluid injection, 2010-2011
- Youngstown, Ohio (M4.0), fluid injection, 2011

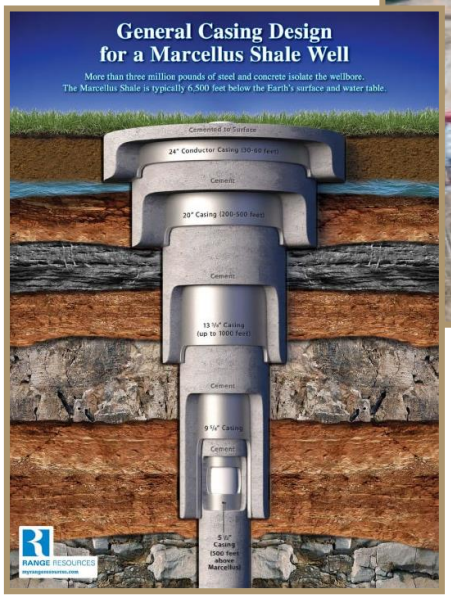




Induced Seismicity

More Environmental Questions

- Well completion
- Industrial footprint
- Chemicals in fracking fluids
- Air pollution
- Spills
- What about water?
  - Quality
  - Usage



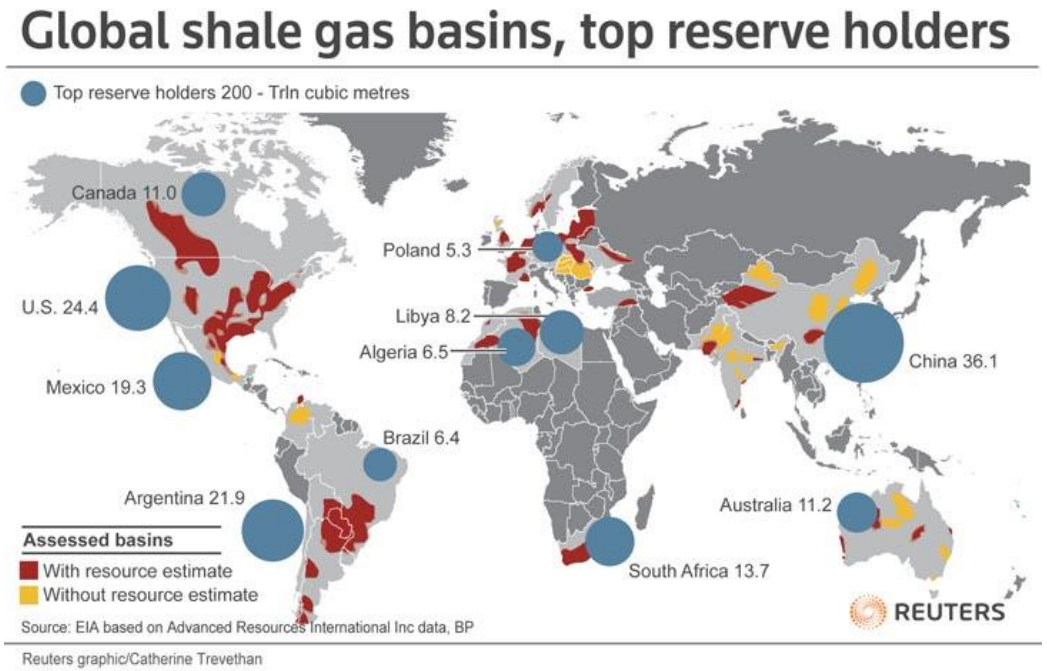
Potential System Impacts

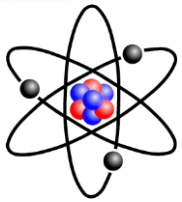
Sandia National Laboratories

Environmental impact of coal due to increasing exports

Renewables insertion for electricity production

International implications





Impacts on the future of nuclear energy in the US

Government-Sponsored R&D can Inform Environmental Issues

Sandia National Laboratories

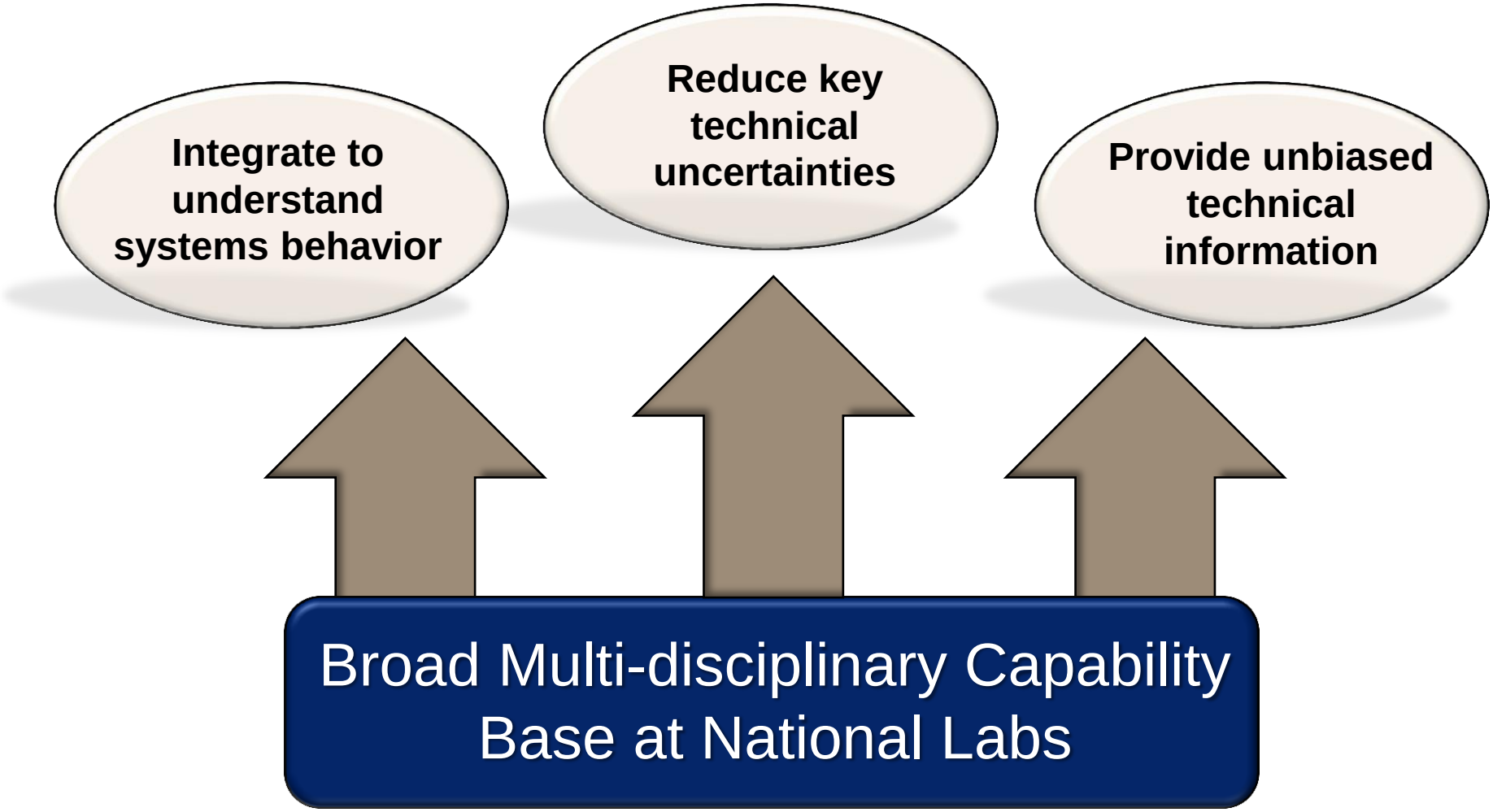
DOE/USGS/EPA research plan in progress

Unbiased technical information for regulatory decisions

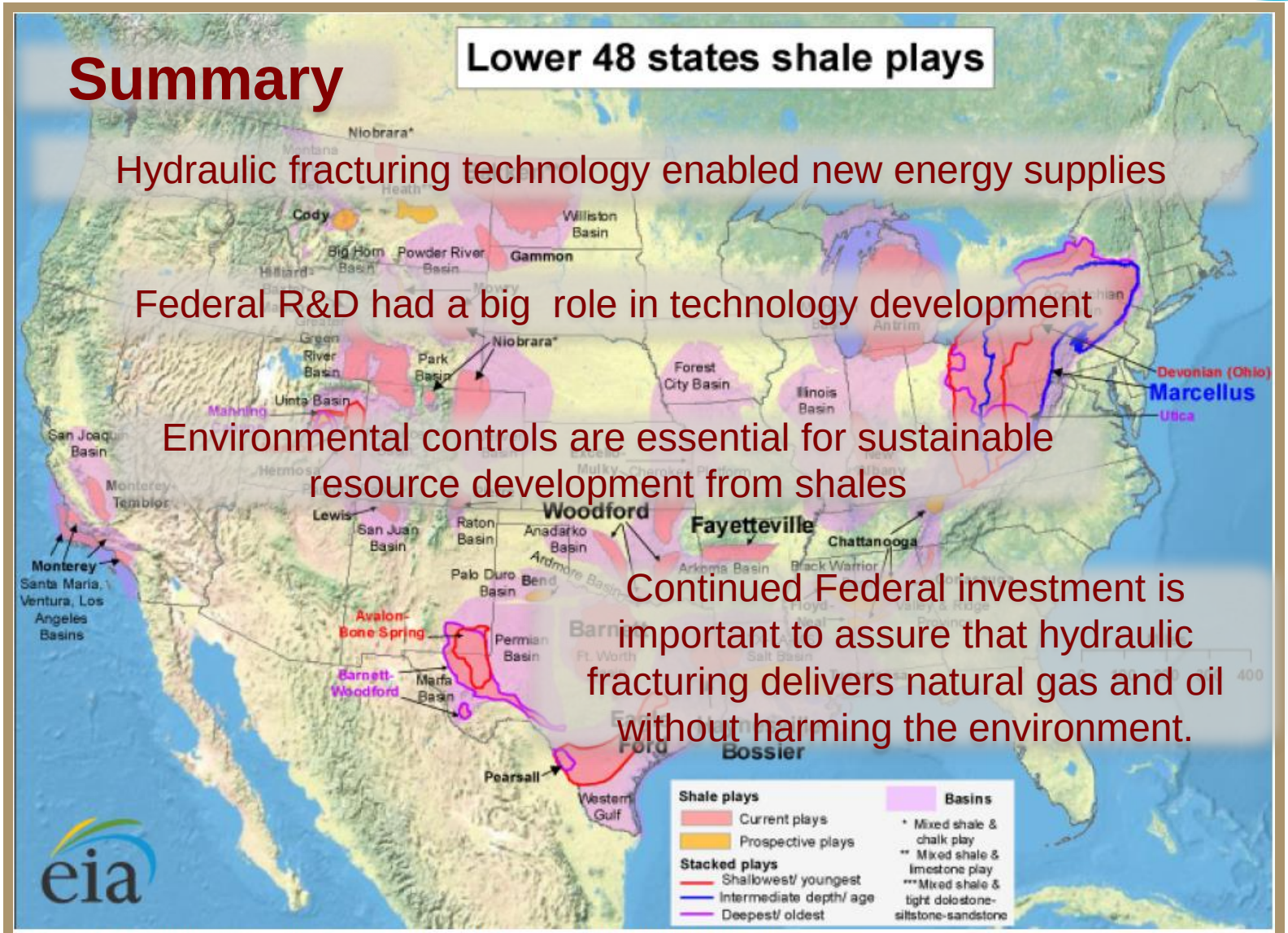
Particular issues of interest for federal R&D investments:

- Fugitive emissions
- Water issues
- Well integrity

What is the Potential Role of National Laboratories?



Summary



Source U.S. Energy Information Administration based on data from various published studies.
Upeate: May 9, 2011

Hydraulic fracturing technology enabled new energy supplies

Federal R&D had a big role in technology development

Environmental controls are essential for sustainable resource development from shales

Continued Federal investment is important to assure that hydraulic fracturing delivers natural gas and oil without harming the environment.