

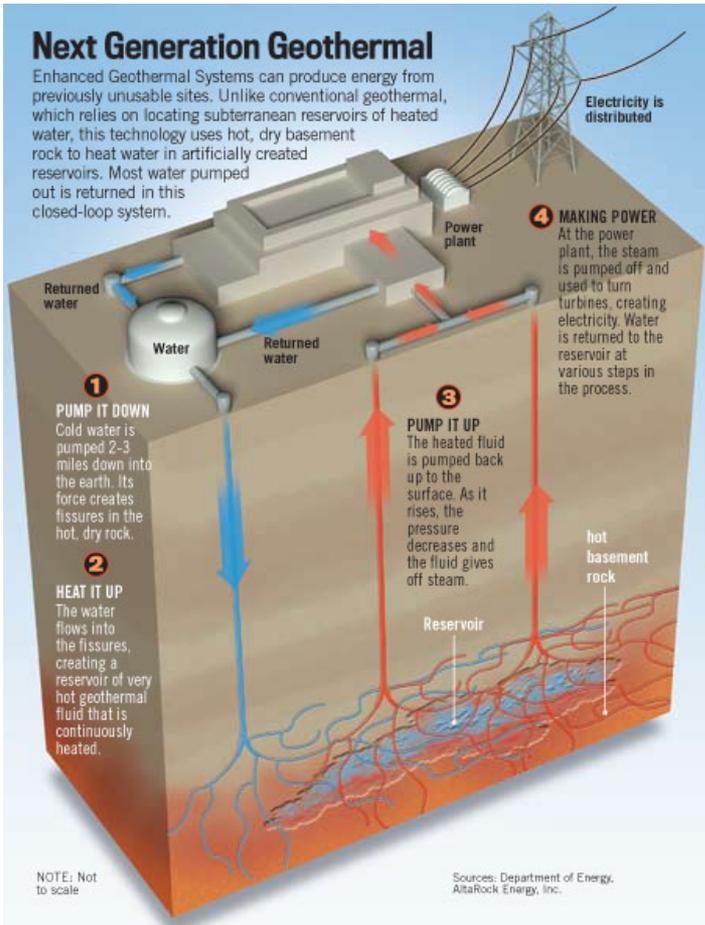
Earth as Battery: Enhanced Geothermal Systems

Dr. Isik C. Kizilyalli, Program Director

Enhanced Geothermal Systems (EGS)

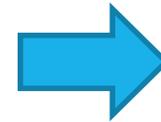
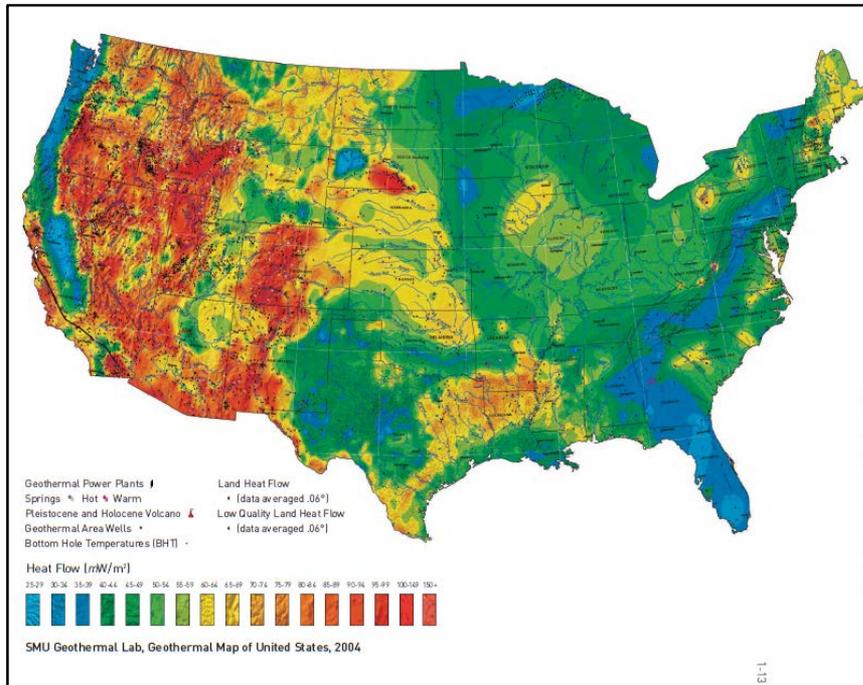
Next Generation Geothermal

Enhanced Geothermal Systems can produce energy from previously unusable sites. Unlike conventional geothermal, which relies on locating subterranean reservoirs of heated water, this technology uses hot, dry basement rock to heat water in artificially created reservoirs. Most water pumped out is returned in this closed-loop system.



- Identify Resource (Hot Rock)
- Create Fracture Network
- Convert Hot Fluid to Electricity

Enhanced Geothermal Systems: Potential



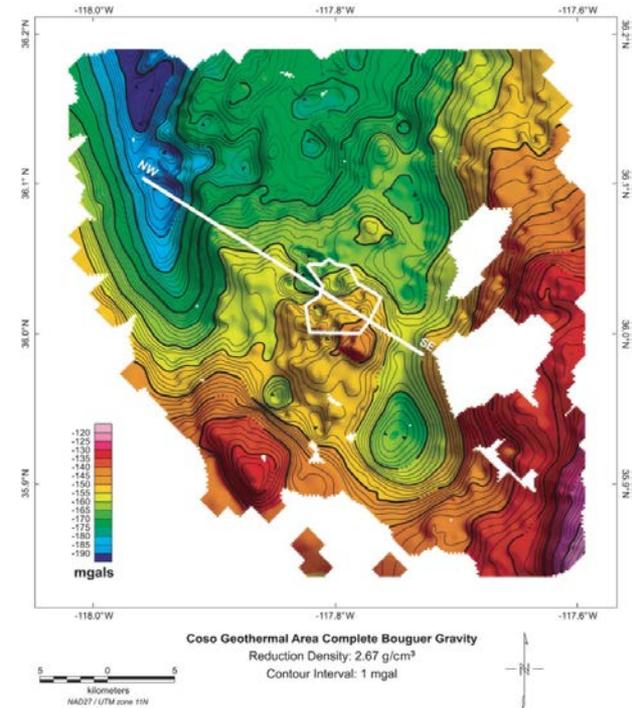
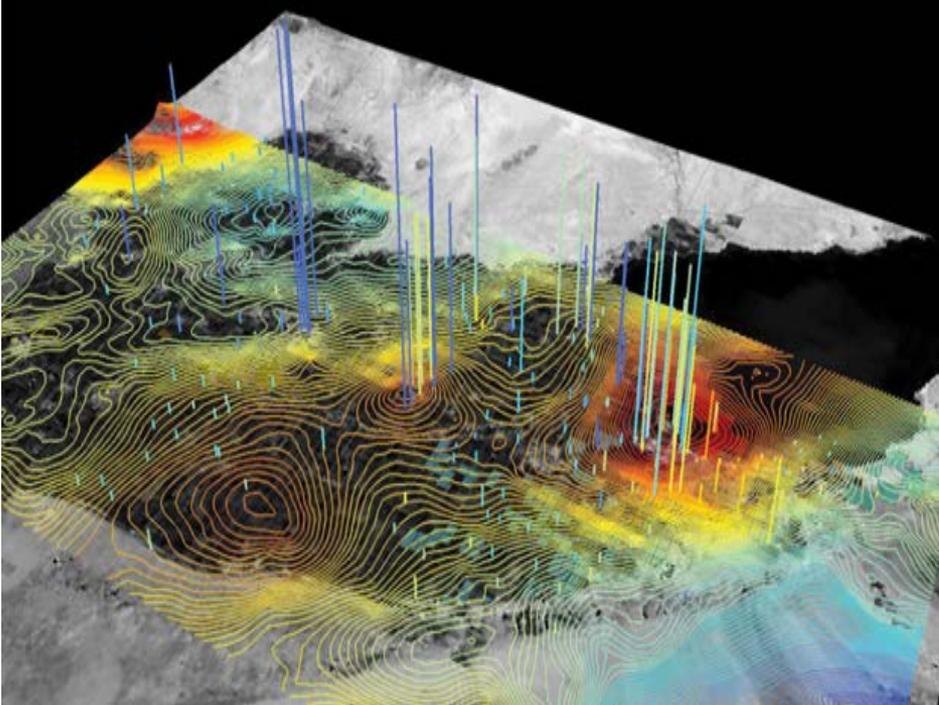
- ▶ 3-10 km
- ▶ > 150°C
- ▶ > 500 GW_e

- ▶ 100GW_e Powers 100M Homes by 2050
- ▶ Renewable and Continuous Source
- ▶ No Carbon Emissions

Reduce Barriers to Entry

Risk	Mitigation
1. Pre-drilling Assessment Expensive (> 4km)	Nano-Satellites / Drones / Robots Inexpensive Identification
2. Subterranean Information 250-350°C Environment	Extreme Electronics
3. Limited H ₂ O Resources EGS Sites	sc-CO ₂ as Working Fluid

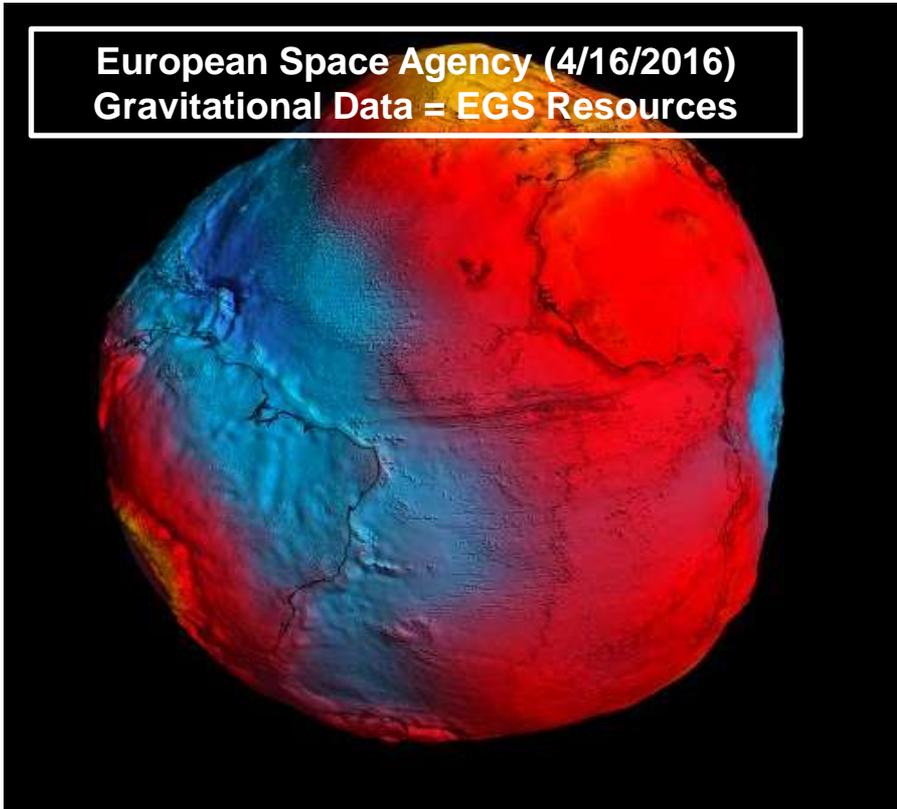
1. Gravitational Anomalies and Geothermal Sites



- Correlation between gravity and geothermal resources
- Geologists map surfaces on foot (1x1 km²): **Time and Labor**

Emerging: Commodity Nano-Satellites, Drones, Robotics

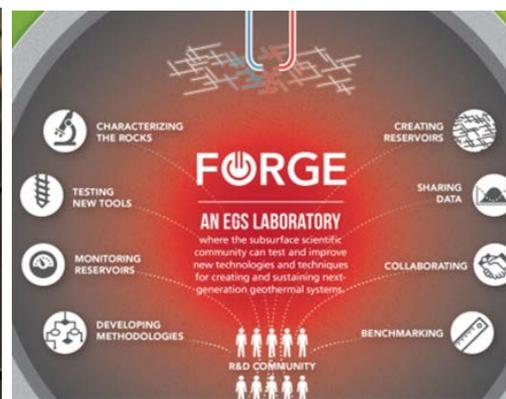
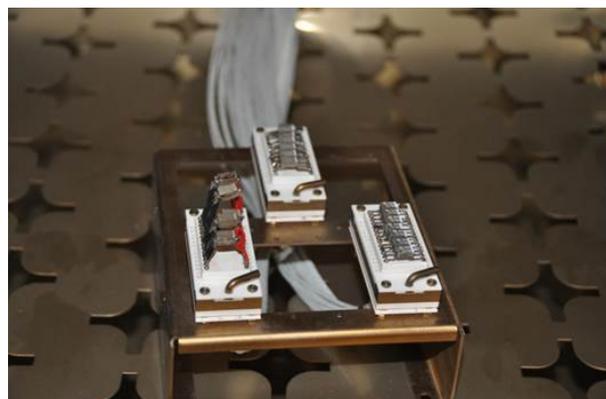
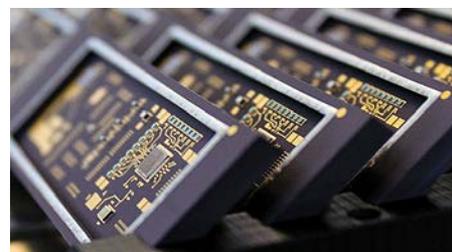
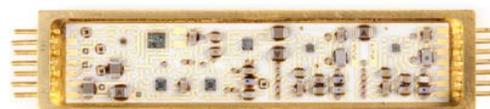
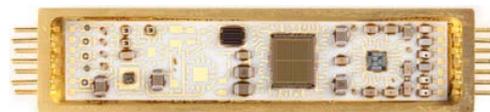
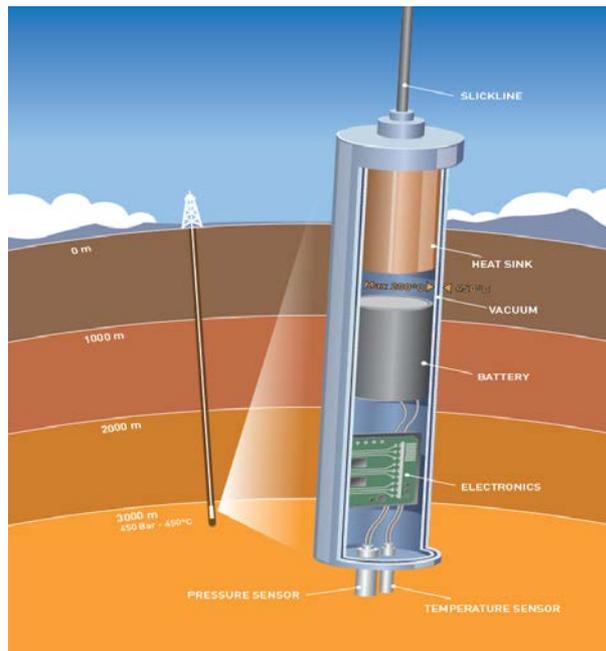
European Space Agency (4/16/2016)
Gravitational Data = EGS Resources



- Low-Cost Light-Weight Hardware
- Measure Gravitation and other Variables
- Use Data Analytics: EGS Resources
- **Need \ll 1 km Resolution**



2. Transformative Subsurface Instrumentation



- ▶ **Survivability at > 300°C**
- ▶ 1 month Reliability in Drilling
- ▶ **10-20 year Lifetime as Monitor**
- ▶ **Self Powered**
- ▶ **Sensors and Detectors**
- ▶ Passive Components
- ▶ Logic and DSP functions
- ▶ Power Electronics (Si or WBG)
- ▶ Die Attach / Wire Bond Materials
- ▶ **Modules / Packaging**
- ▶ Communication protocols
- ▶ Optical Fiber and Wireline
- ▶ **Opportunity to Test in EGS Lab***

***FORGE**
EERE-GTO Office
Manager: Lauren Boyd

We seek your feedback and input

Concepts for:

- 1. Instrumentation for Exploration and site characterization using Nano-satellites, Drones, and Robotics**
 - **Validate** the potential of **EGS resources**
 - **High Resolution Low Cost Data: ARPA-e Nano-Satellite, Drone, Robots**
 - **Big Data Analytics** to identify ideal EGS sites
- 2. Harsh Environment** down-hole instrumentation
- 3. sc-CO₂** as a working fluid

...as well as any other EGS-enabling thrust areas (e.g. drilling methods and technology) you think we should consider