# National Energy Technology Laboratory


## Office of Research and Development

**Anthony V. Cugini**

**National Energy Technology Laboratory**

**Office of Fossil Energy**

# NETL Research and Development

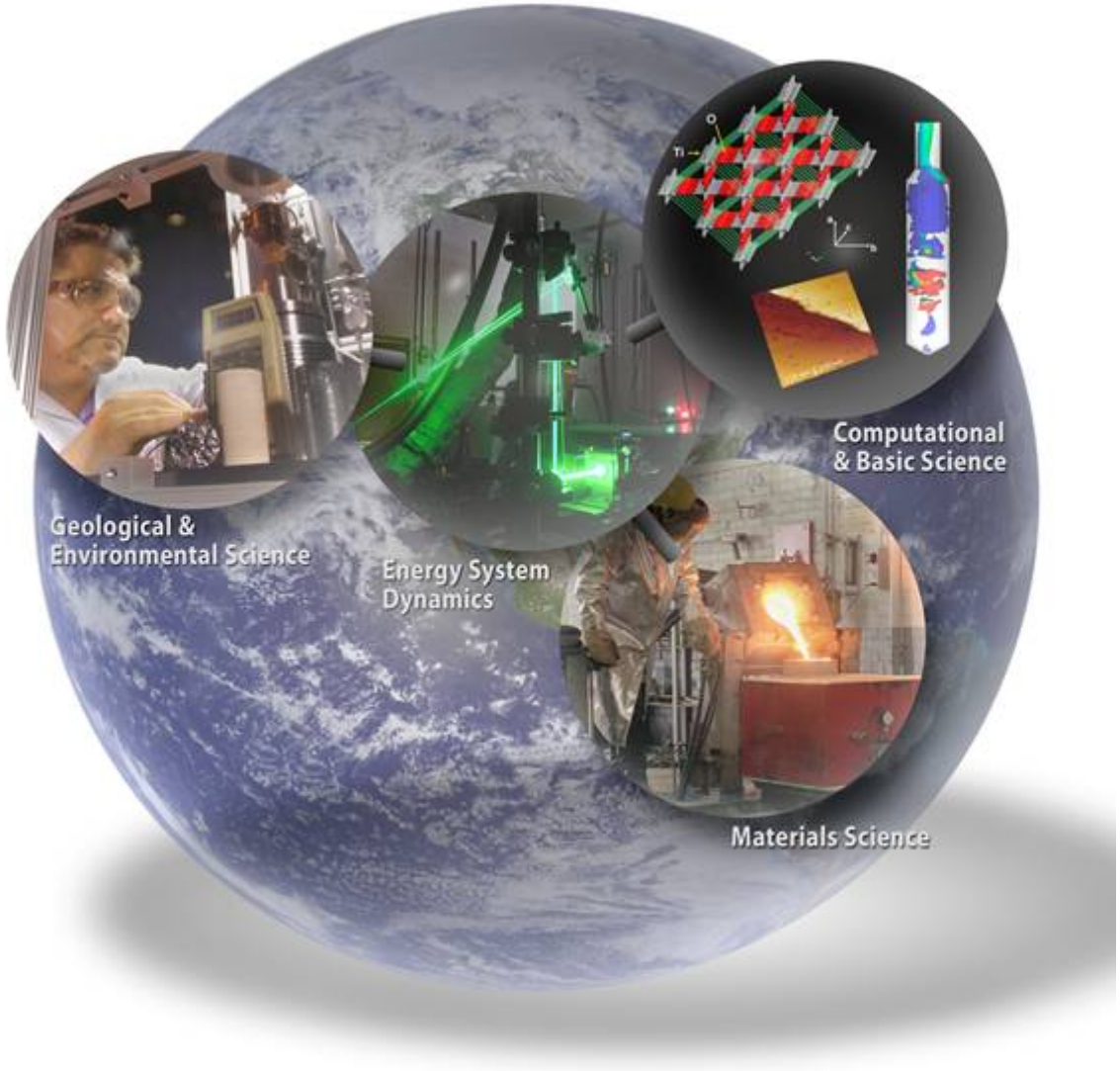
- **DOE's only national lab dedicated to fossil energy R&D**
- **One lab, three R&D locations, one management structure**
  - Government owned and operated
- **Conducting research from fundamental science through technology demonstrations**

***Oregon***

***Pennsylvania***

***West Virginia***

# Research and Development Focus Areas

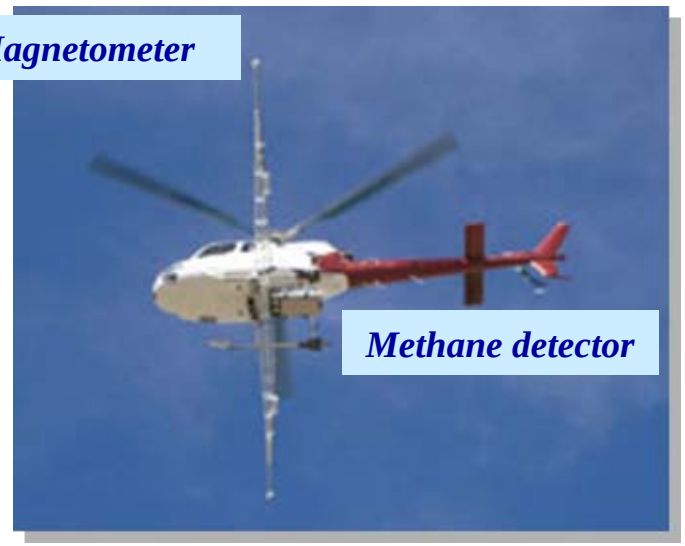


# SEQURE™ Well-Finding Technology

- First R&D 100 Award recognizing sequestration-related technology
- Locates abandoned and leaking wells on large land tracts

*2007*

- Abandoned wells represent the most direct route for sequestered carbon dioxide to escape to the surface
- Wells can be re-cemented to block the direct route to surface




*Dual-sensor airborne system*

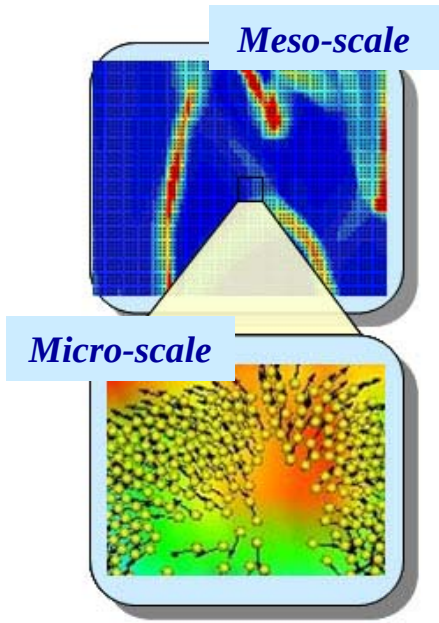
# MFIX Software

2007

2006

- Discrete and continuum gas-solids flow models
- Tech transfer through CRADAs and open-source software distribution

- Since 2001: 1000+ registrations from 500+ institutions
- 50+ publications, 20+ theses
- Application to transport coal gasifier



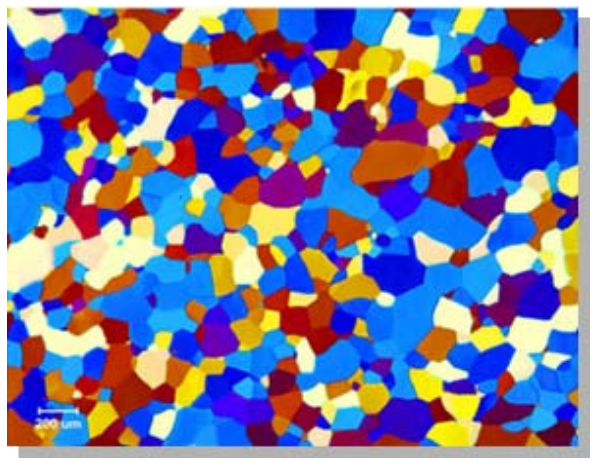

*Particles in fluidized bed*

# Armstrong Process for Low-Cost Titanium

*2007*

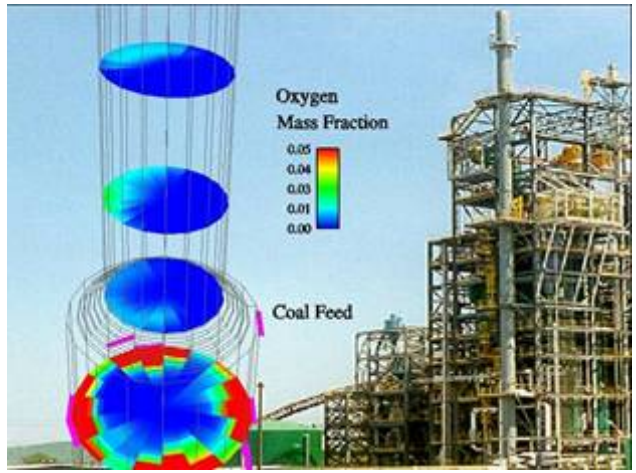
- **Continuously produces titanium and alloyed titanium powder**
- **Powder from research laboratory first sold commercially in 2006**
- **First commercial facility operational in Q1 2009 (4 mm+ lb / year)**

- **Products from commercial plant have been committed under multi-year extended contracts**
- **Will reinforce military armor plate**

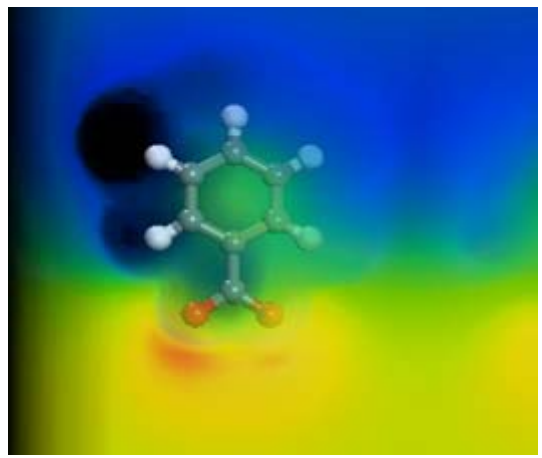


*Titanium plate microstructure*

# Computational and Basic Sciences Focus Area

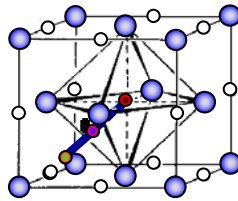



- Fuels Chemistry
- Computational Chemistry
- Device Simulation
- Advanced Fuel Systems
- Gas Hydrates
- Hydrogen and Separation
- Energy Security

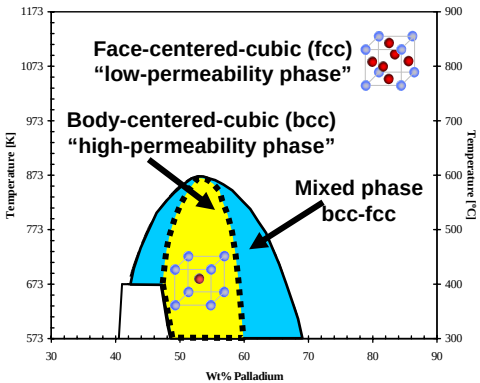



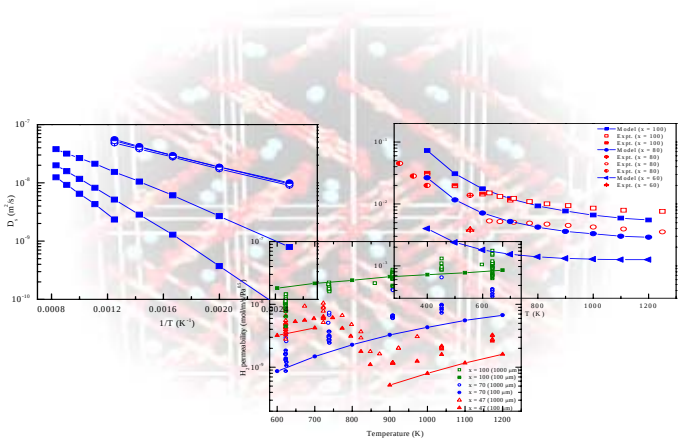
# Computational Modeling and Materials Research

**Develop, using nanoscale technologies, advanced materials for extreme environments, hydrogen separation and hydrogen storage**

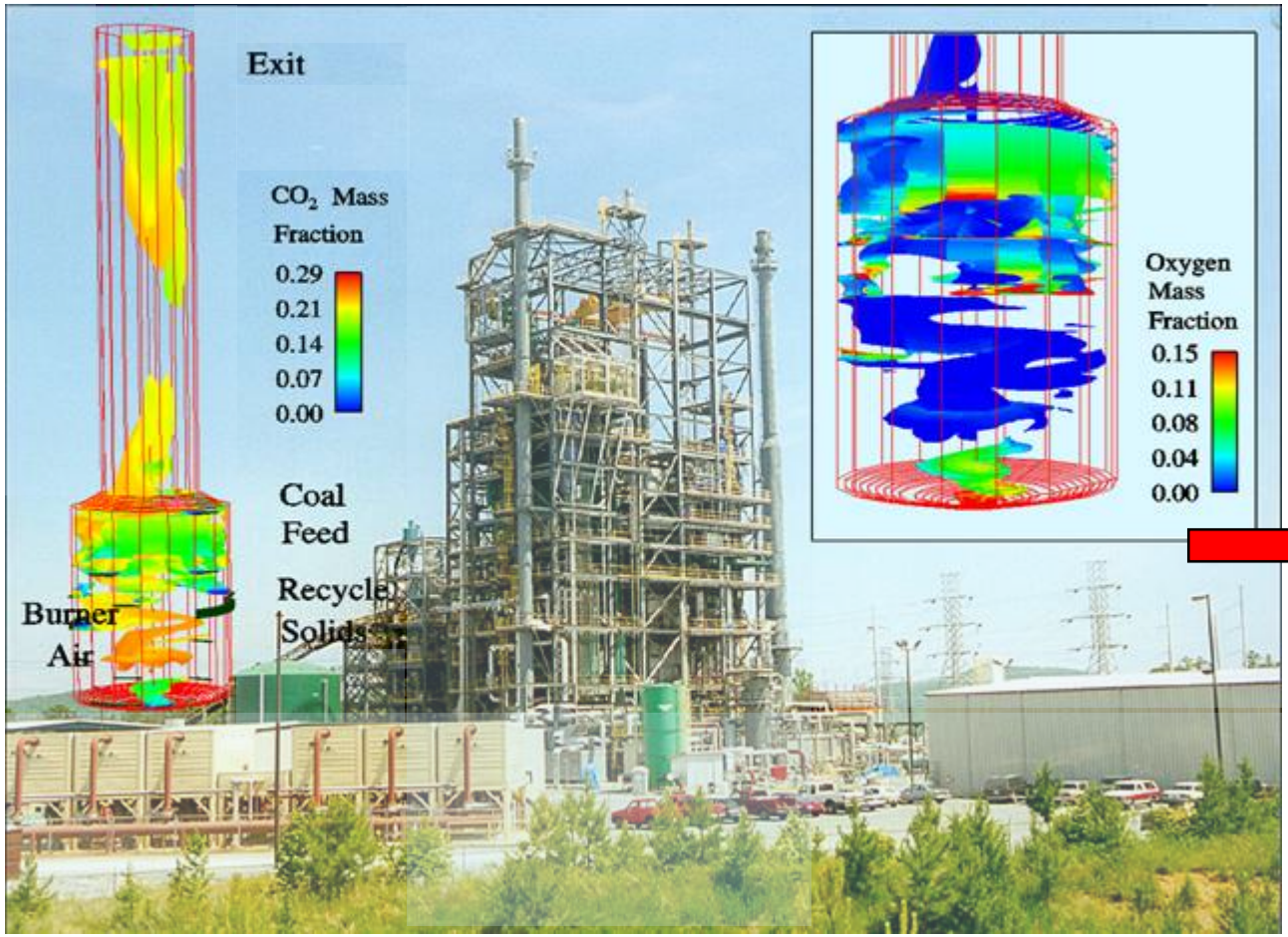


**Significance: New materials are needed that enable the high performance expected of a FutureGen plant.**



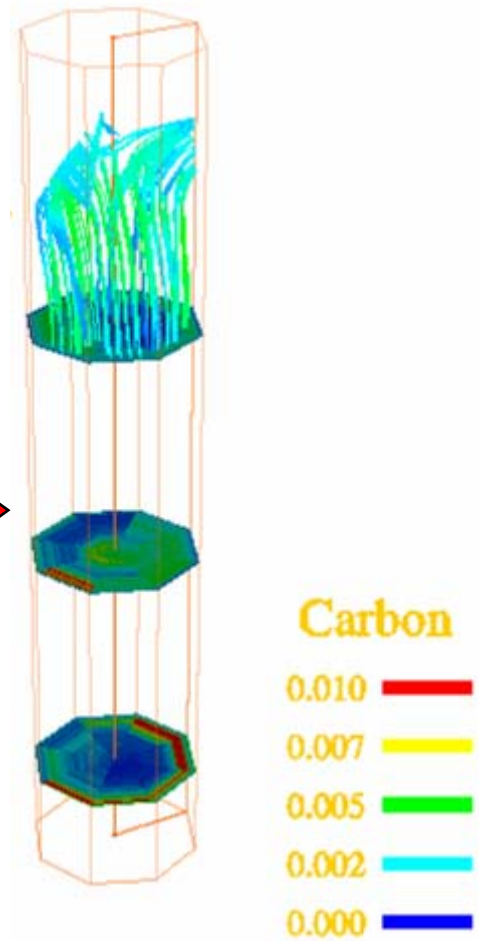




# Gasifier Model Support for IGCC Program




Power Systems Development Facility (PSDF), Wilsonville, Al

$O_2$ and $CO_2$ mass fractions superimposed on isosurfaces of at void fraction values of 0.9. Guenther et al. 2002




KBR/Southern commercial scale transport gasifier (Guenther 2005)

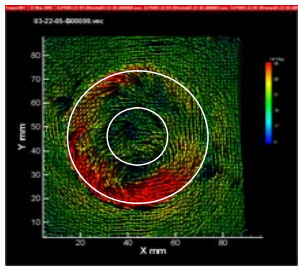
# Energy System Dynamics Focus Area

- High-pressure Turbine Combustion
- Fuel Cells and Fuel Processing for SOFC Power
- Hybrid Turbine Fuel Cells
- Reciprocating Engines for Stationary Power
- Carbon Dioxide Capture for Sequestration
- Sensors and Controls for Energy Systems
- Humid Gas Cleanup for IGCC

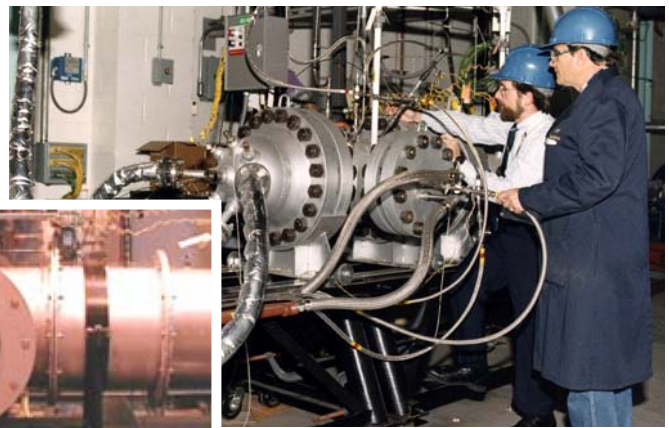
Artist's rendering of the
Department of Energy's Future Gen Power Plant

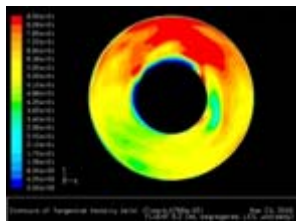
# Fuel utilization in turbine combustion

- **NETL on-site research on low-emission combustion with fuel variability**
  - Emission/operability study for FERC assessing LNG versus domestic NG.
  - Flame dynamics/emissions of $H_2$, methane + $H_2$, and syngas .
  - With Multi-Agency Combustion Coordination Committee:*
    - Develop *predictive* simulation of fuel blends in engines.
    - Use national cyberinfrastructure to accelerate simulation development (via NSF).
  - Sensors systems for fuel blend variability effects on combustion:
    - Patented flame dynamics sensor (licensed to Woodward Industrial control).

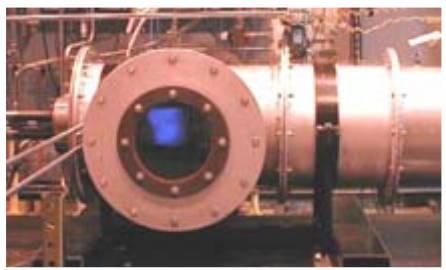



Lab-scale flame dynamics



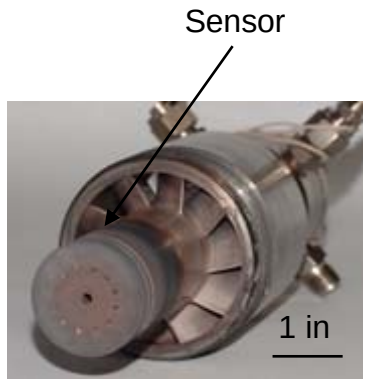


Measured and modeled combustion flow dynamics



Low-pressure development combustor

Dynamic Gas Turbine Combustor

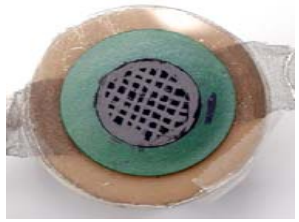



CCADS sensor on prototype fuel injector

***** *AFOSR, Edwards AFB, Wright Patt AFB, NASA-Glenn, NIST, NSF, Army, ESTCP/SERDP, DOE-NETL*

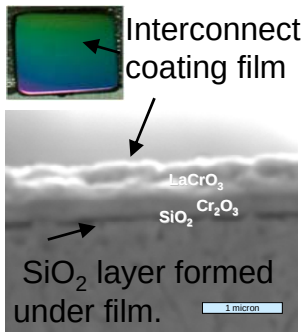
# Fuel Utilization in Fuel Cells

- **Test and evaluation of fuel cell prototypes.**
  - Provides unique SECA (Solid-state Energy Conversion Alliance) program support.
  - Commercial units[1] for evaluation; also open to non-SECA.
- **On-site research for fuel cells and fuel processing**
  - Hydrocarbon reforming for conventional or FT liquid fuels.
  - Low cost interconnect coating & substrate compatibility with coal syngas.
  - Fuel contaminant effects on SOFC cells (Sulfur, Hg, Cl, ….).



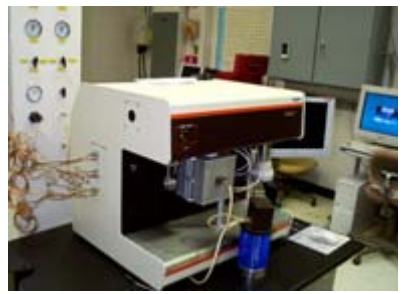

Orientation image microscopy shows grain structure in cell after current flow test

Fuel Cell Test Facility




Interconnect coating and substrate.

Testing with coal-gas slip-stream (planned).



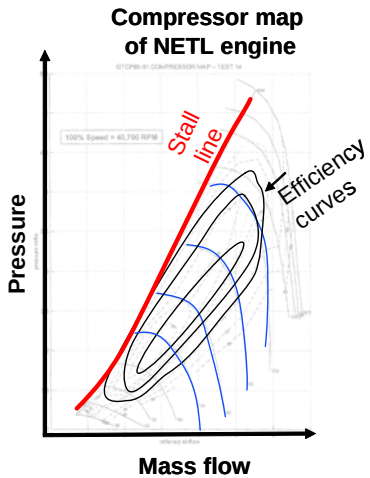
NETL catalyst testing for SOFC reformer

***1.*** *GE, Accumentrics, Delphi, SoFCo-Cummins , Siemens-Westinghouse, Fuel Cell Energy*

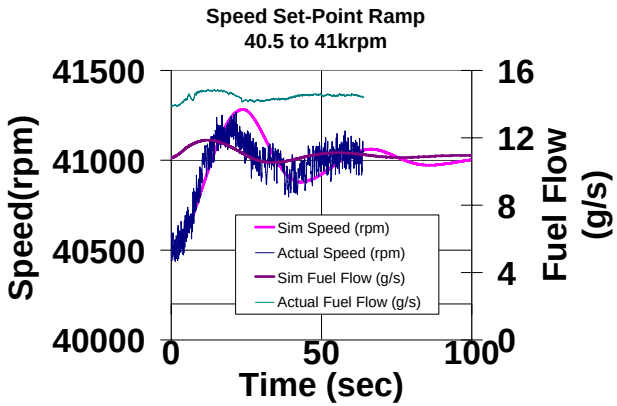
# Fuel Conservation from High Efficiency: Hybrid Turbine Fuel Cell Research

- **Hybrid efficiency exceeds turbine & fuel cell efficiencies.**
- **Technical issues:**
  - How to manage energy split (FC vs. GT), load shed, compressor surge?
  - Can fuel cell tolerate plant dynamics?
- **NETL HYbrid PERformance (Hyper) facility:**
  - Evaluate control architecture to maximize efficiency.
  - Validated models to predict large hybrid performance.
  - Measure real loads expected in fuel cell operation.

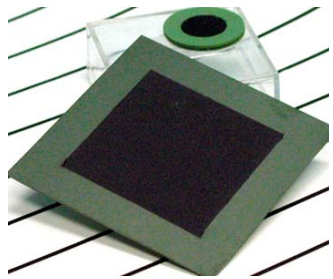
NETL Hyper Facility *simulates* fuel cell dynamics in real turbine environment.




High efficiency occurs near the stall line (red)

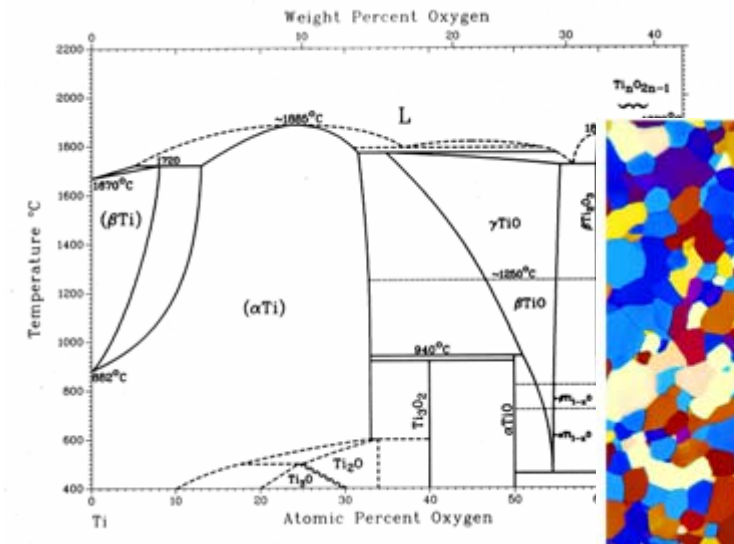


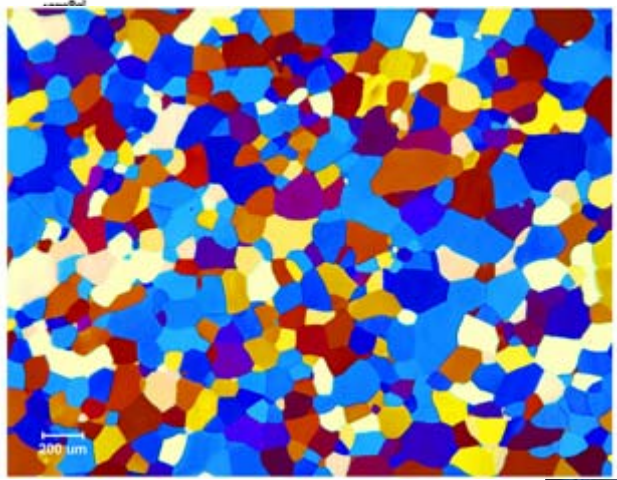

Set-point transients may reverse expected fuel cell flows

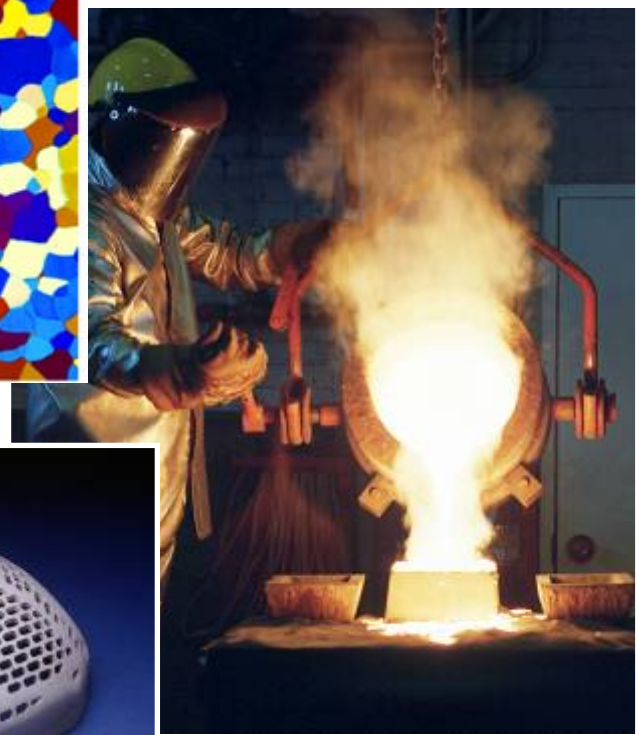


Solid oxide fuel cell can be tested In situ after controlling dynamics

# Materials Science Focus Area

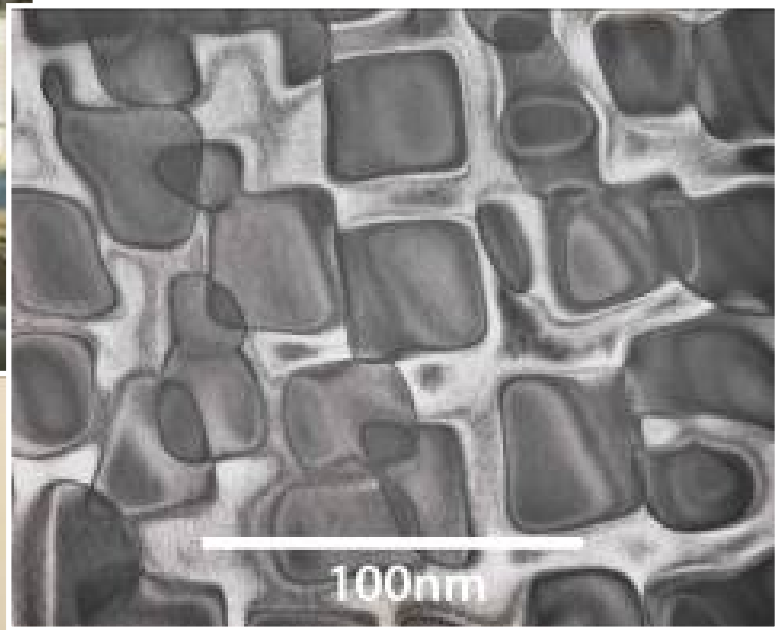


- Fuel Cells
- Advanced Combustion
- Gasification
- FutureGen
- External Partnerships

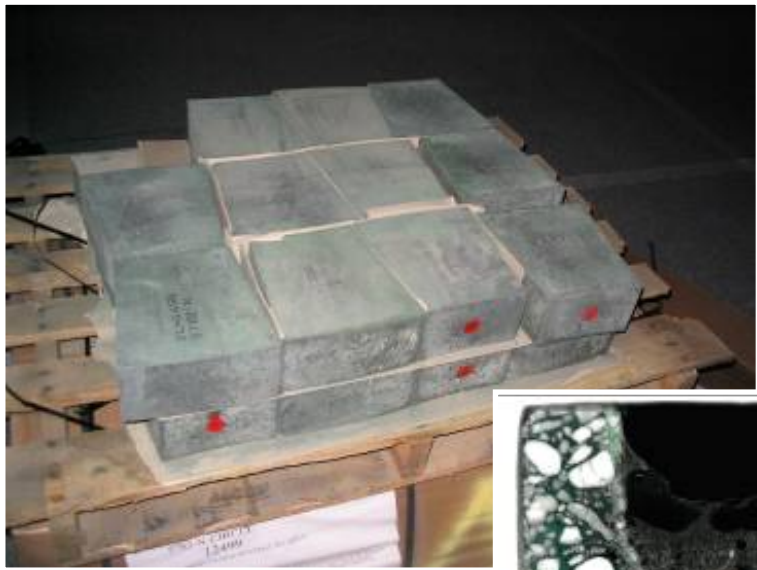
# Materials Performance Assessment

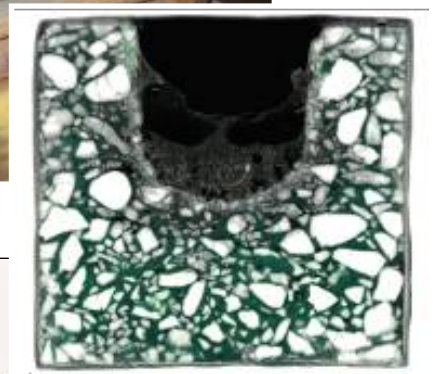



**Corrosion, Wear, Microstructural & Mechanical Stability**

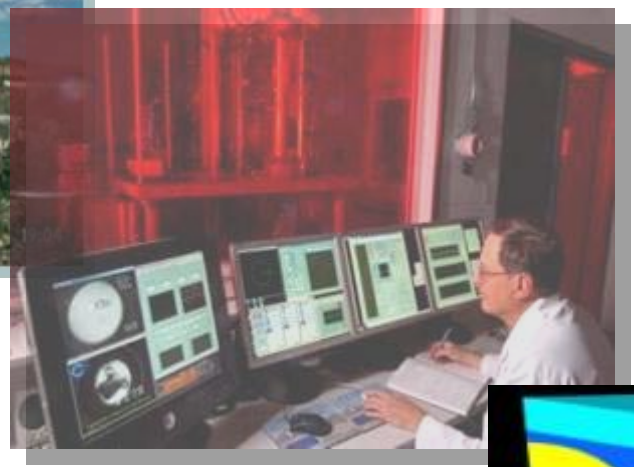
# Materials Performance Improvement

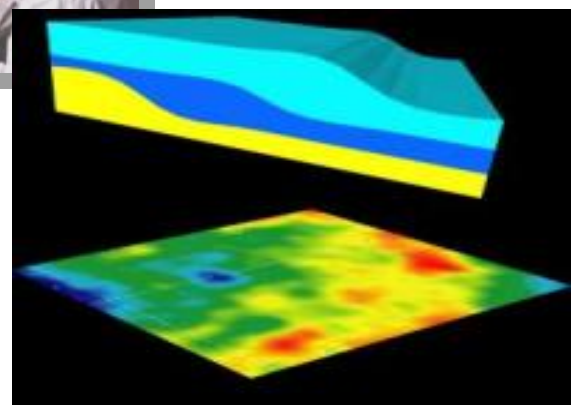
- **Refractories for Gasification**
  - Patent issued
  - Licensing Agreement pending
- **Coating Protection Strategies**
  - Patent pending
- **Surface Treatments for Oxidation Resistance**
  - Patent pending
- **New Iron-Base Alloys for Combustion Systems**
  - Patent pending





# Geological and Environmental Sciences (GES) Focus Area

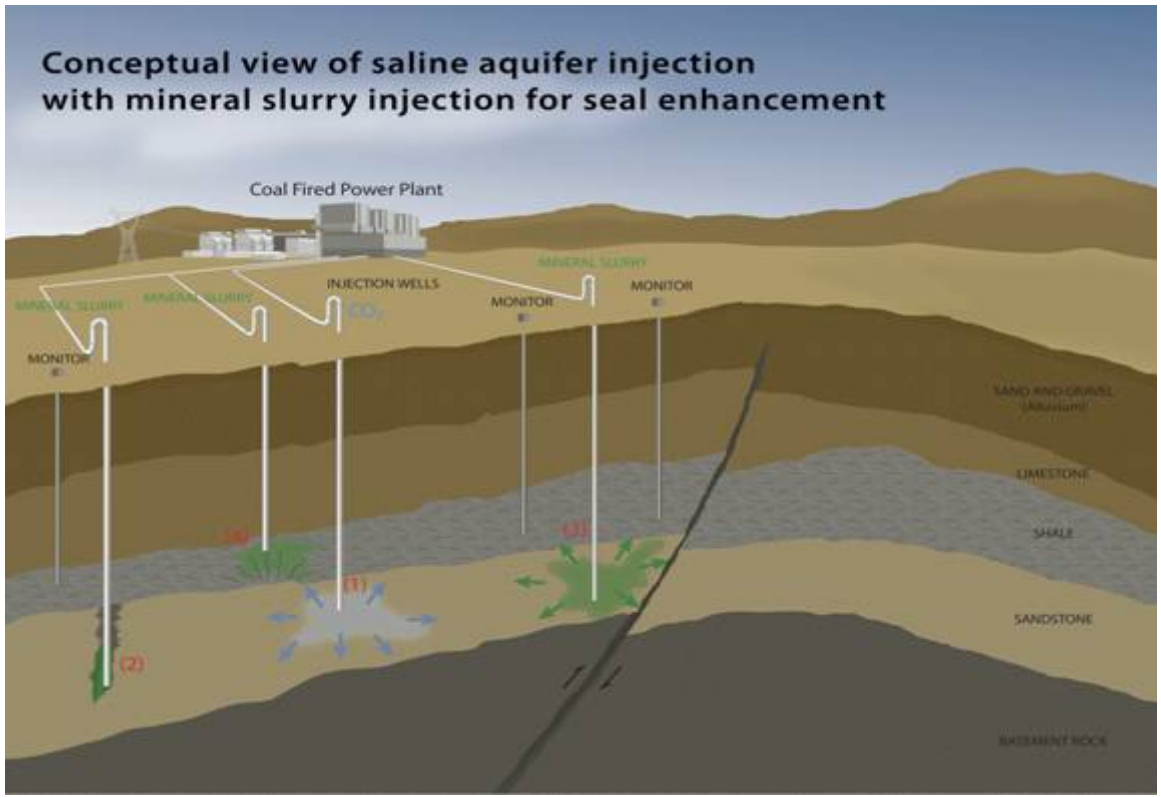




- Carbon Sequestration
- Water & Coal Utilization
- Coal Byproducts
- Risk Assessment
- Monitoring, Measuring, & Verification

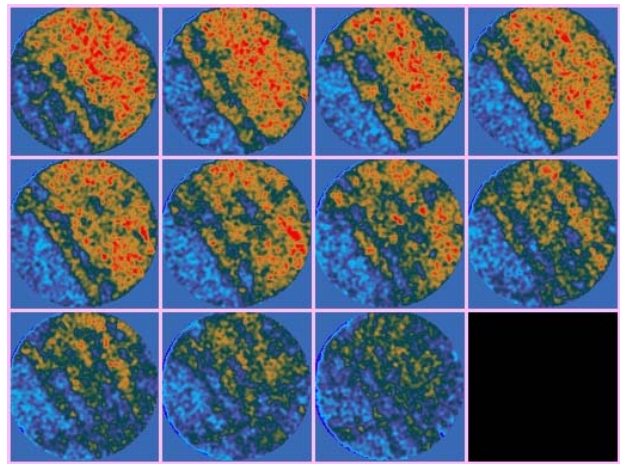
# Storing $CO_2$ in Geological Formations

In collaboration with partners from industry, government, and academia, develop processes to capture and sequester green house gas emissions and other industrial pollutants.

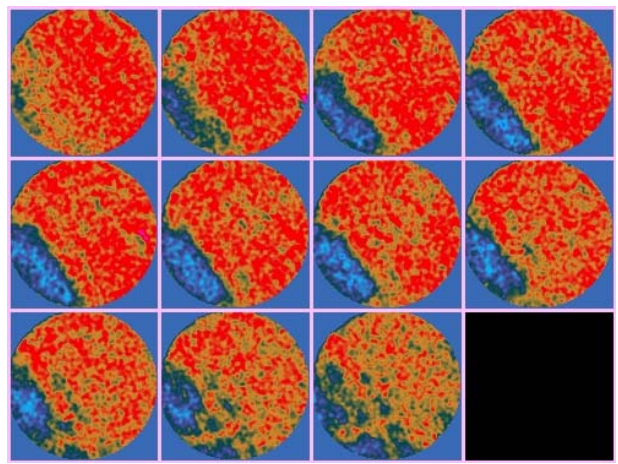


# CT Scanner Measures Sorption of $CO_2$ on Coal Cores

- CT scanner shows amount sorbed in different locations
- Identification of macerals that sorb more or less $CO_2$ can be done with petrographic examination
- Combined CT scanned images and sorption measurements may allow for extrapolation of results to equilibrium



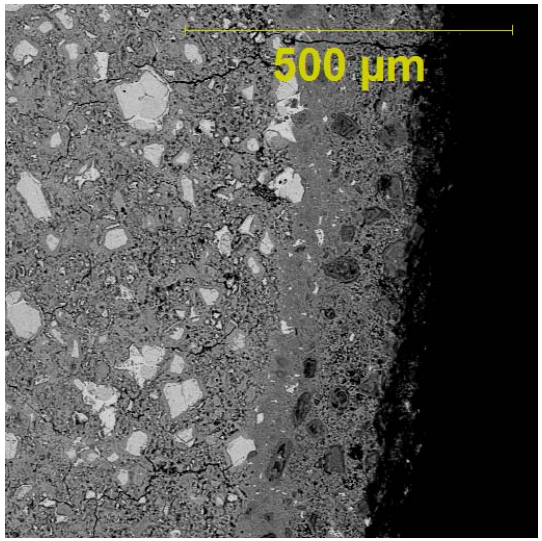
Short time

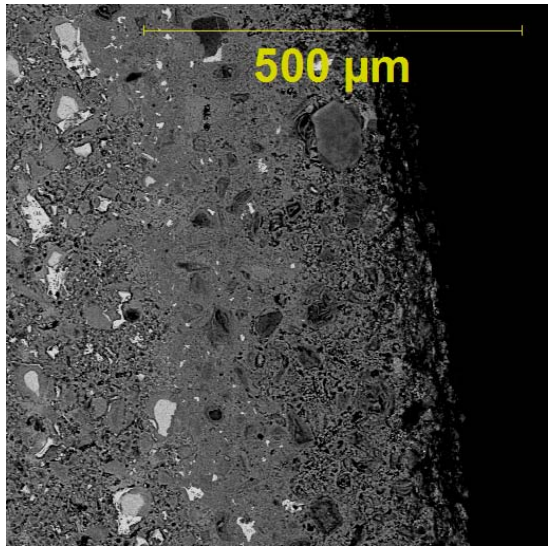


Long time

# Impact of $CO_2$ on Cement Degradation

9 days

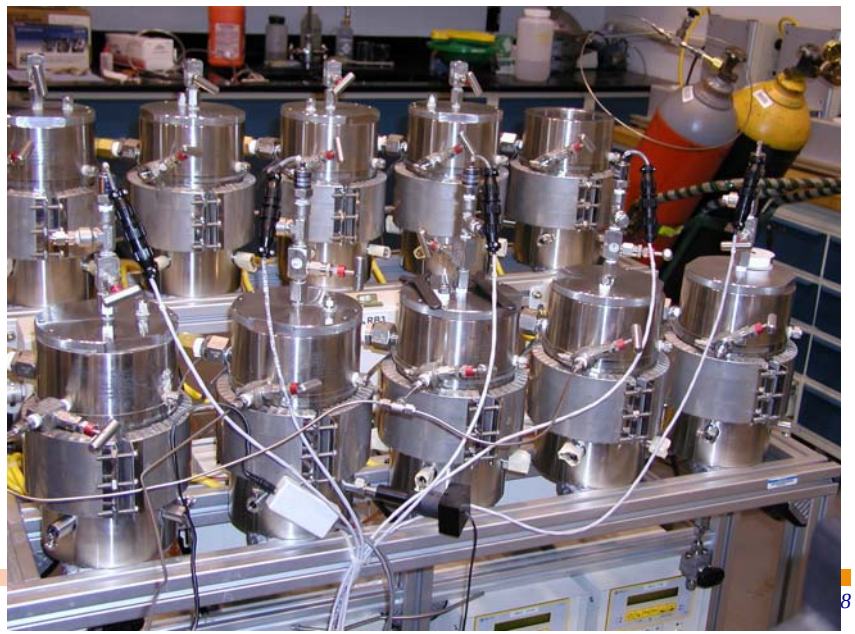



365 days

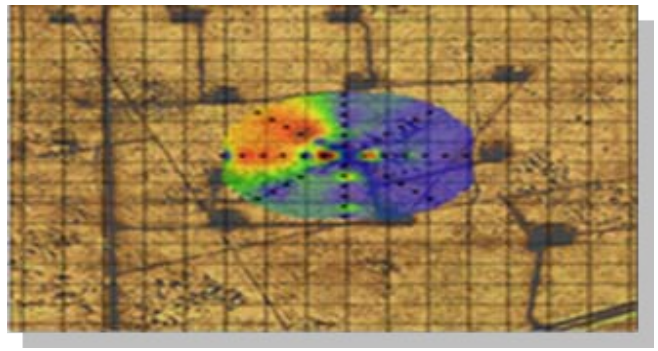
➢T = 50°C, P = 4400 psi

- **Completed a one year test to determine the kinetics of cement degradation under sequestration conditions**
  - Results consistent with field data



# CO2 Measurement, Monitoring, and Verification

**Test $CO_2$storage monitoring at Frio geological sequestration site in Texas using tracers and soil gas monitors for $CO_2$, methane, and radon flux.**



**West Pearl Queen Tracer Tests**

**Significance: Supports Climate Change Initiative. Evaluates methods to monitor $CO_2$ storage. Goal is refined and improved technologies.**

# CCS Modeling at NETL

## Capture Modeling

**Plant**
- IECM
- Aspen Plus
- APECS

**Device**
MFIX
FLUENT

**Atomic Scale**
VASP
accelrys suite
GAUSSIAN

## Sequestration Modeling

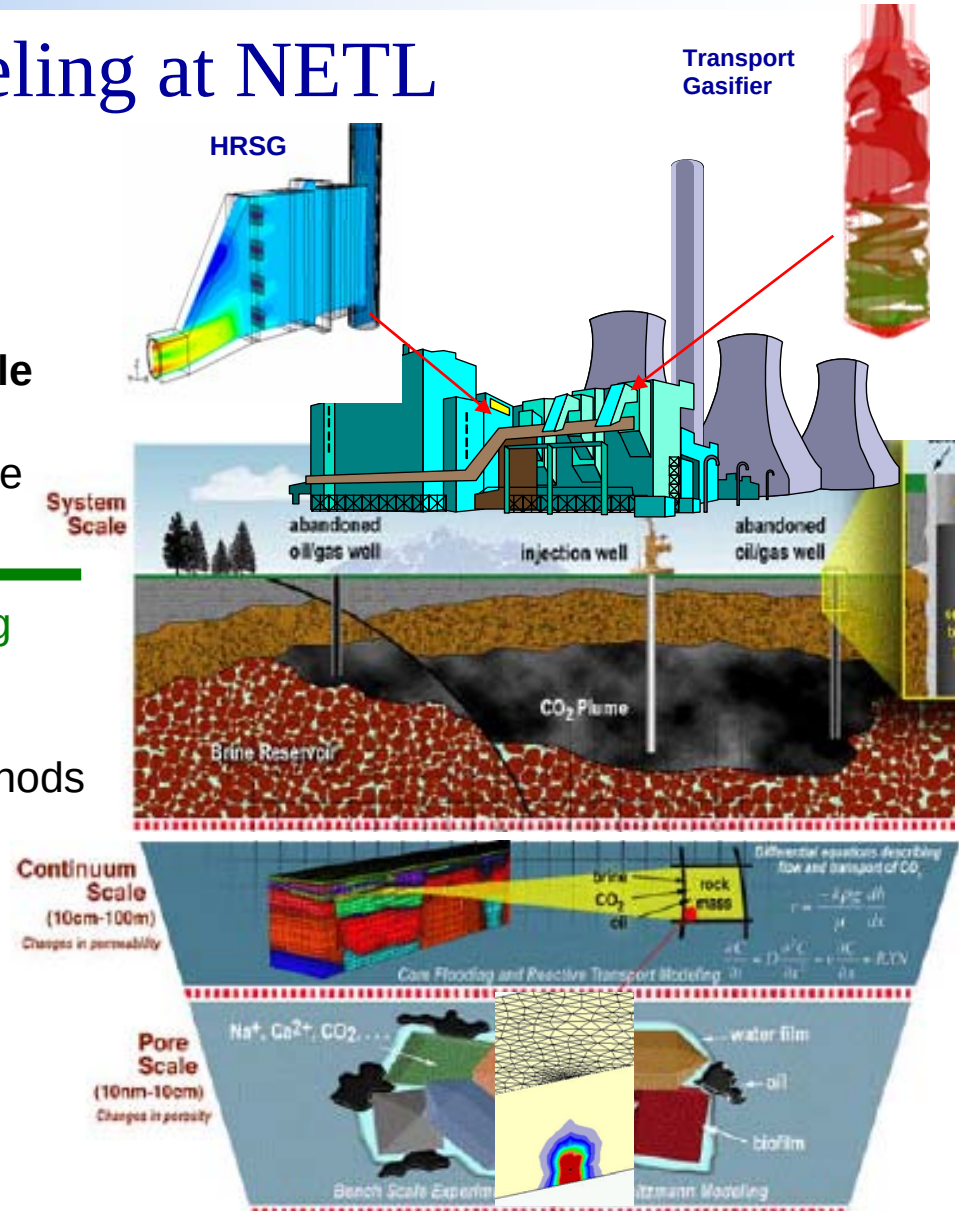
**Reservoir/coal bed**
PSU-COALCOMP
NFFLOW

**Continuum/Pore scale**
FLUENT
NETFlow

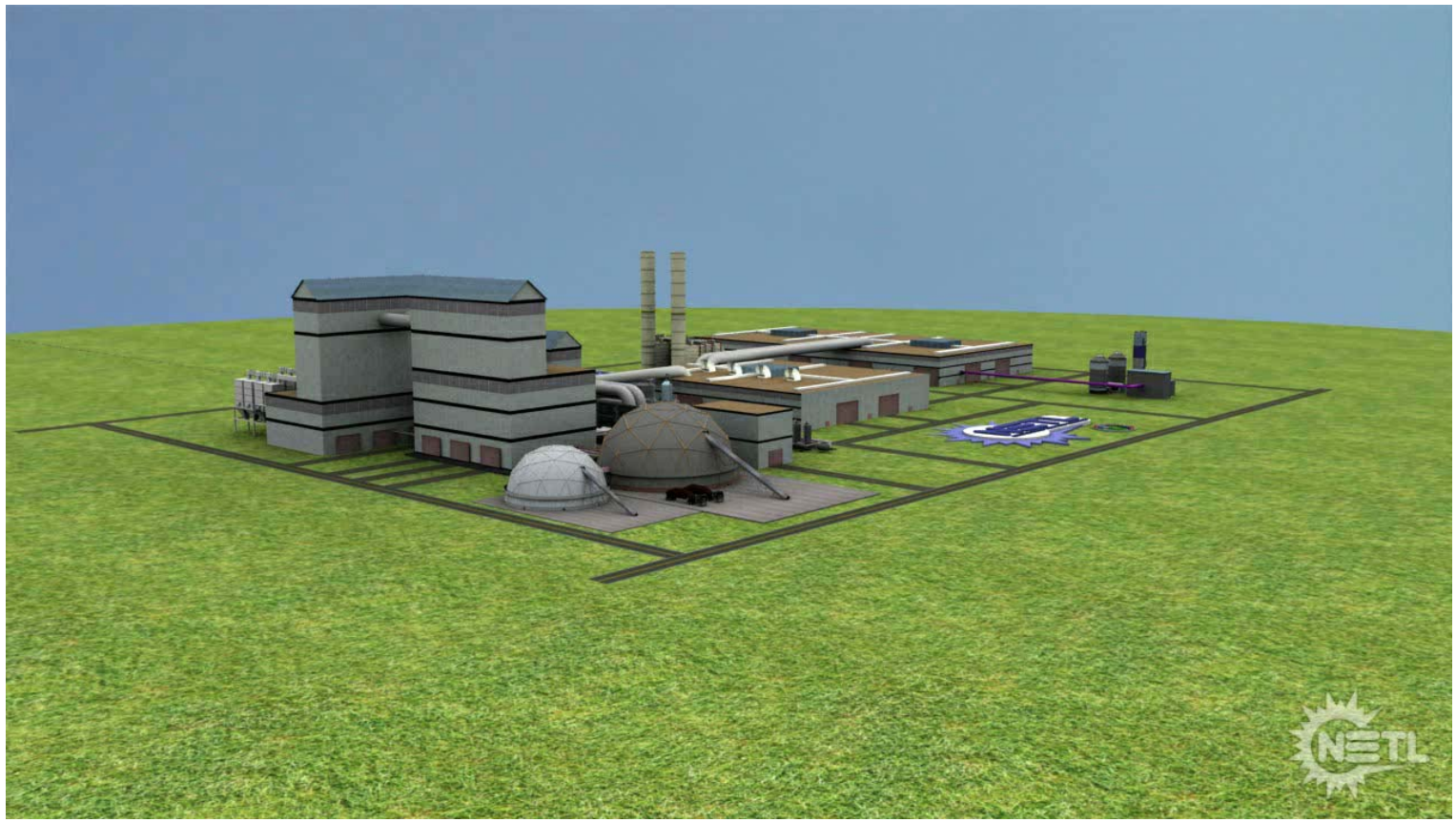
**Geomechanics**
SEQURE
ABAQUS

## MMV Modeling

NFFLOW
TOUGH2
Statistical methods



# Virtual Power Plant with Carbon Management



Click on image above to view WMV video

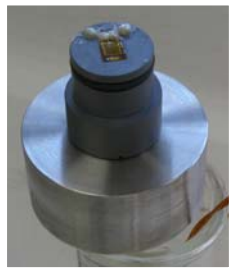
# DOE ORD Program in Gas Hydrates

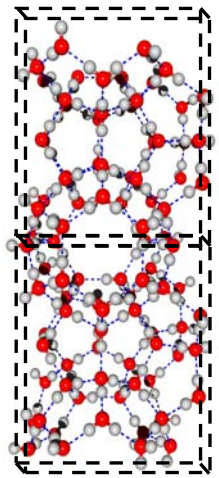
- Provide scientific excellence in support of DOE-Funded and field activities
- Advance GH science through continued collaboration with international R&D partners
- Provide new insights into GH behavior in nature through numerical simulation at molecular, pore and reservoir scales
- Develop new tools for field applications
- Fully integrate modeling into all experimental activities
- Ensure relevance to stated national R&D goals through collaboration and regular peer review

# ORD Gas Hydrates R&D

## *Areas of Expertise*

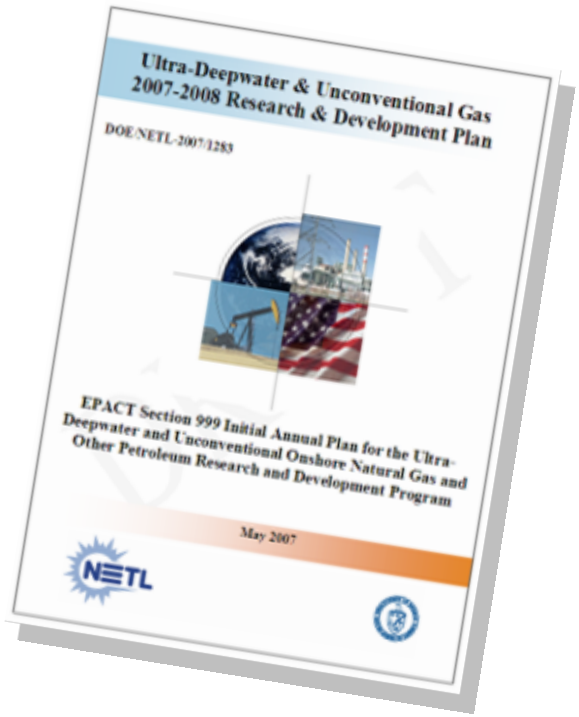
- **Geologic/Geophysical Evaluations**
  - controls on gas hydrate occurrence
  - development of gas hydrate exploration methodologies
- **Numerical Simulation**
  - at all relevant scales
- **Experimentation – Tool Development**
  - Advanced imaging of gas hydrate dissociation – closely linked with modeling
  - Accurate data from field – reduce reliance on analysis of synthetic samples





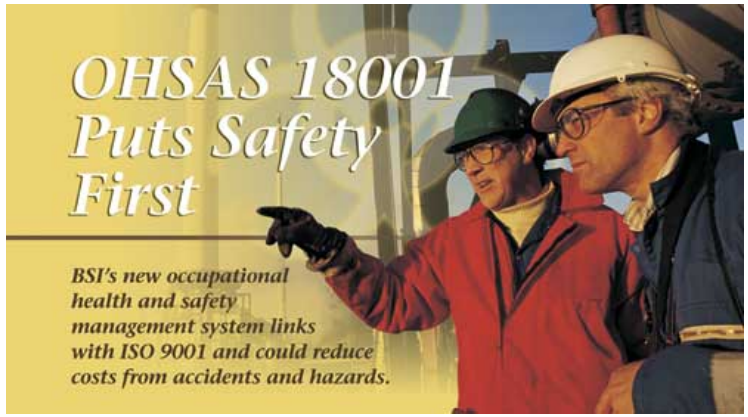
# EPAct 2005 Sec. 999 Ultra-Deepwater & Unconventional Gas
## *Complementary R&D*

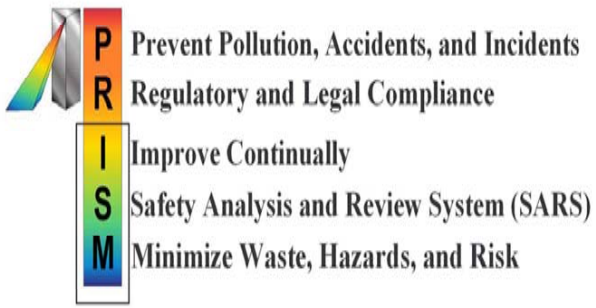
- **$12.5 million per year from royalty trust fund**
- **Unique, high-value O&G work**
- **Focus:**
  - Fundamental science
  - Long-term research providing basis for next-generation technologies
  - Unbiased environmental science
- **Technical areas:**
  - Drilling under extreme conditions
  - Environmental impacts of O&G development
  - Enhanced & unconventional oil recovery
  - O&G resource & technology assessment
- **Annual merit review**



# NETL Environment, Safety and Health Management System

- **Based on:**
  - DOE's Integrated Safety Management System
  - International Organization for Standardization (ISO) 14000 series
  - Occupational Health and Safety Assessment Series (OHSAS) 18000.




- **Albany Site Certifications:**
  - ISO 14001
- **Pittsburgh and Morgantown Certifications:**
  - ISO 14001:2004
  - OHSAS 18001