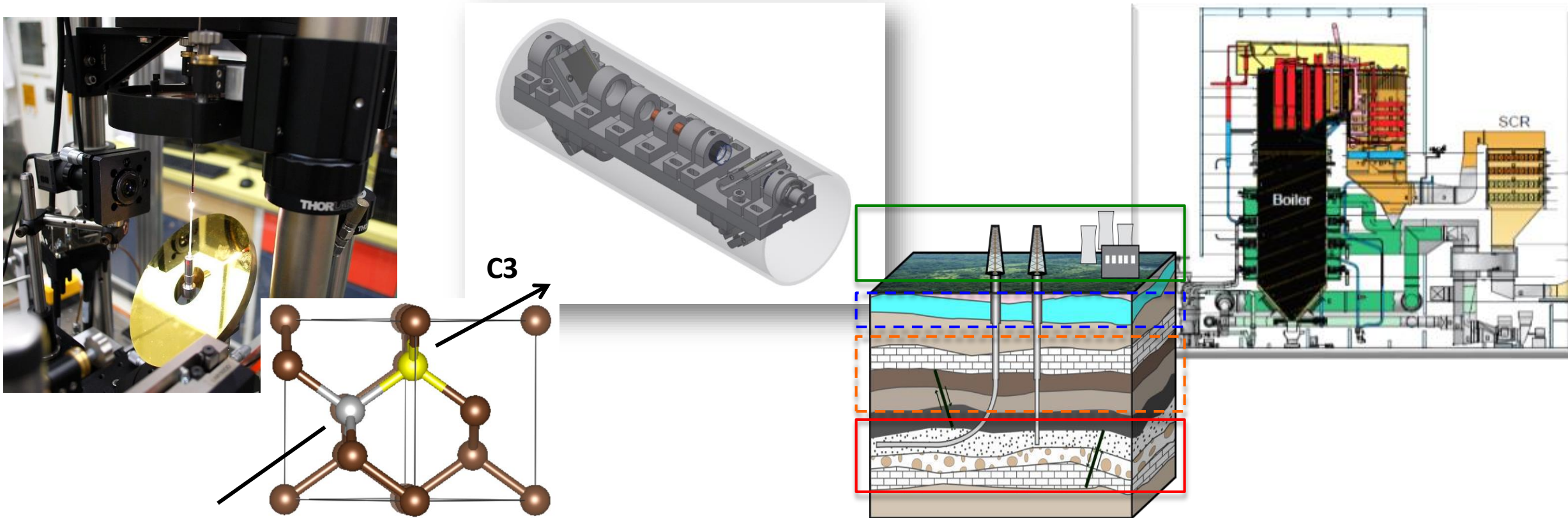


RIC Advanced Sensors & Controls FWP

Overview

Dustin McIntyre, Michael Buric, Yuhua Duan, Dan Haynes, David Tucker, Larry Shadle, Erik Shuster, Joe Yip, Steve Richardson, Jeff Wuenschell, Dan Hartzler, Chet Bhatt, Juddha Thapa, Nari Soundarrajan, Subha Bera, Yan Zhou, Nick Park, Swarom Kanitkar, Hari Paudel, Farida Harun, Jennie Stoffa

Presenter: Benjamin Chorpeneing, Ph.D.
Technology Portfolio Lead
Benjamin.Chorpeneing@netl.doe.gov



Introduction



First a little about the Research & Innovation Center...

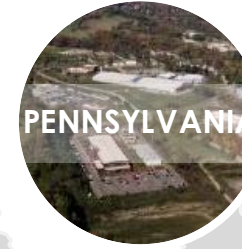
Research Focus by Site

Multiple Sites Operating as One Lab System



OREGON

- Materials Performance
- Multi-environment Materials Characterization
- Alloy Development/Manufacture
- Geospatial Data Analysis



PENNSYLVANIA

- Process Systems Engineering
- Decision Science
- Functional Materials
- Environmental Sciences
- Energy Systems Optimization



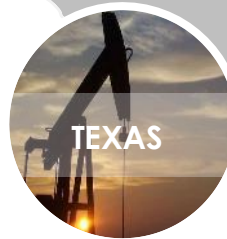
WEST VIRGINIA

- Energy Conversion Devices
- Simulation-Based Engineering
- *In-Situ* Materials Characterization
- Supercomputer Infrastructure
- Diagnostics, Sensors, and Controls



ALASKA

Oil and Gas
Strategic Office

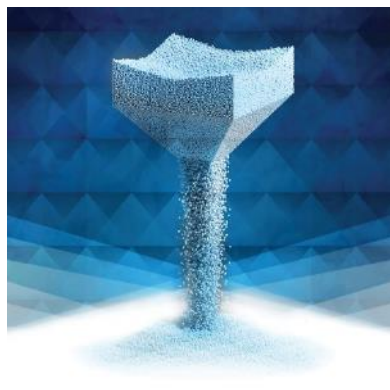


TEXAS

Oil and Gas
Strategic Office

NETL Core Competencies

EFFECTIVE RESOURCE DEVELOPMENT • EFFICIENT ENERGY CONVERSION • ENVIRONMENTAL SUSTAINABILITY



COMPUTATIONAL SCIENCE & ENGINEERING

High Performance
Computing

Multi-Scale Modeling
Atomistic to Device

Artificial Intelligence
& Machine Learning

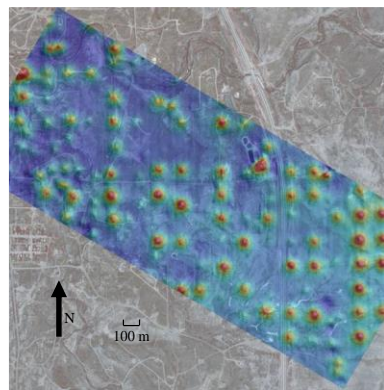


MATERIALS ENGINEERING & MANUFACTURING

Structural & Functional
Materials

Design, Synthesis, &
Performance

Characterization



GEOLOGICAL & ENVIRONMENTAL SYSTEMS

Geo-Analysis &
Monitoring

Reservoir
Engineering

Geochemistry



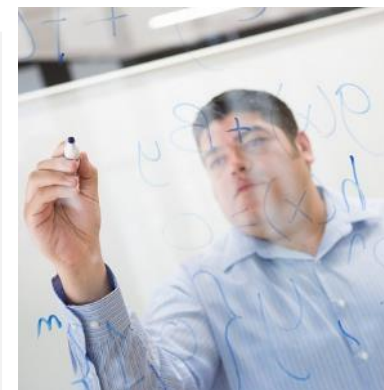
ENERGY CONVERSION ENGINEERING

Reaction Engineering

Design & Validation

Thermal Sciences

Advanced System
Engineering



STRATEGIC SYSTEMS ANALYSIS & ENGINEERING

Energy Process & System
Engineering

Multi-scale Modeling,
Simulations &
Optimization

Energy Markets Analysis



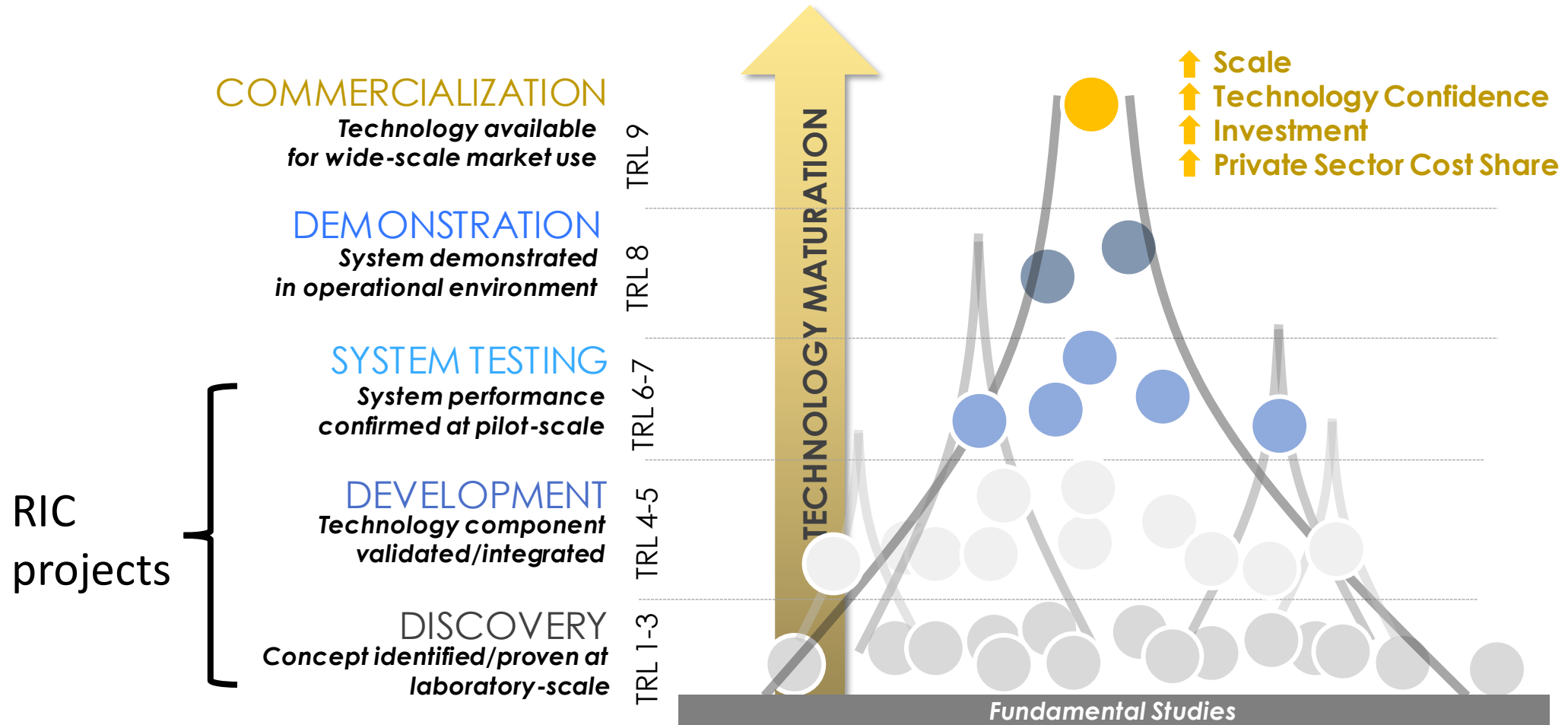
RESEARCH PLANNING & DELIVERY

Technical Project
Management

Business Management
& Agreements

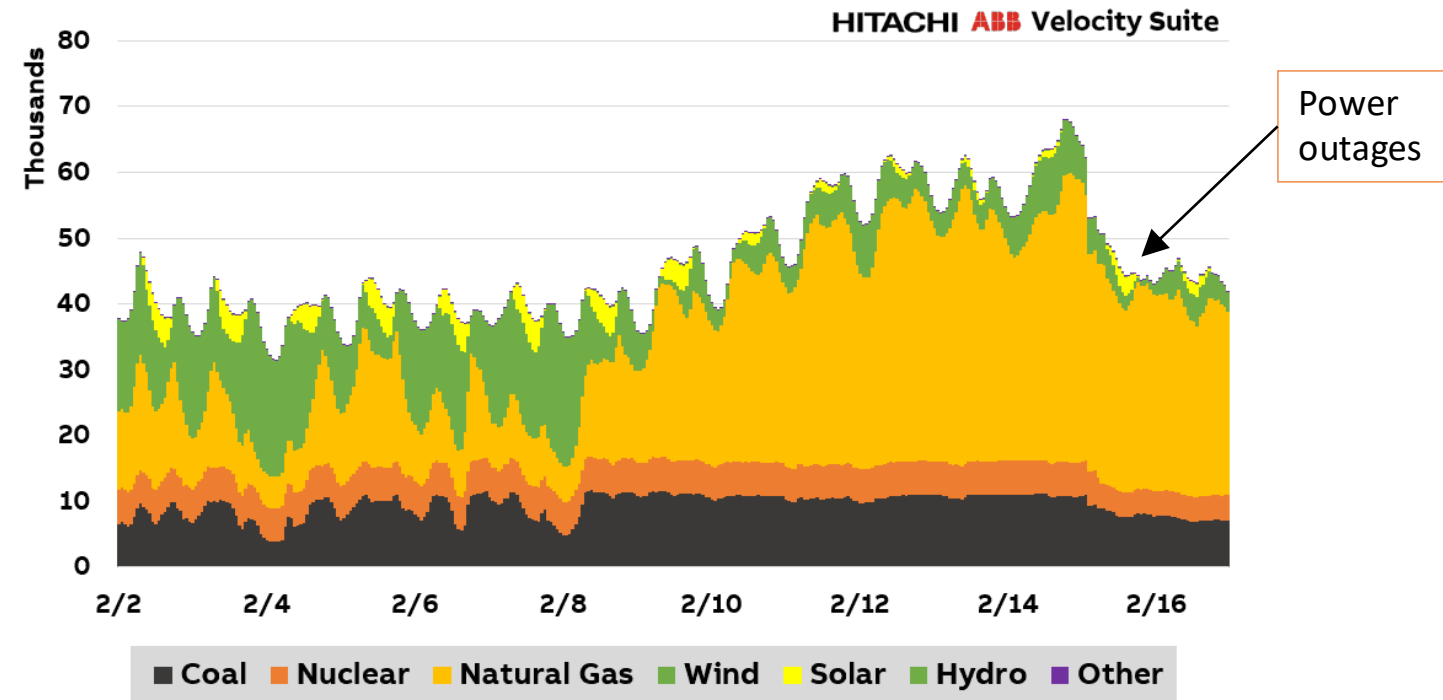
Technology Development Pathway

An Active Portfolio from Concept to Market Readiness



Power Generation Case Study: Texas freeze

- Storm Feb 11-19, 2021
- At coldest point, Feb 15-16, Houston had snow and temperatures as low as 15°F, and widespread subfreezing temperatures across Texas.
- Major generation failures after 11 PM Feb 15 due to cold
- Wind and solar decrease at onset of storm



ERCOT hourly electricity by fuel, Feb. 3-16, 2021, MWh. Source: Hitachi ABB Power Grids (Power Magazine, 2/19/2021)

Changing Requirements for Fossil Energy Power

Increase Flexibility, Reduce CO₂ Emissions

Executive Order 14008 includes a goal of a carbon pollution-free electricity sector by 2035

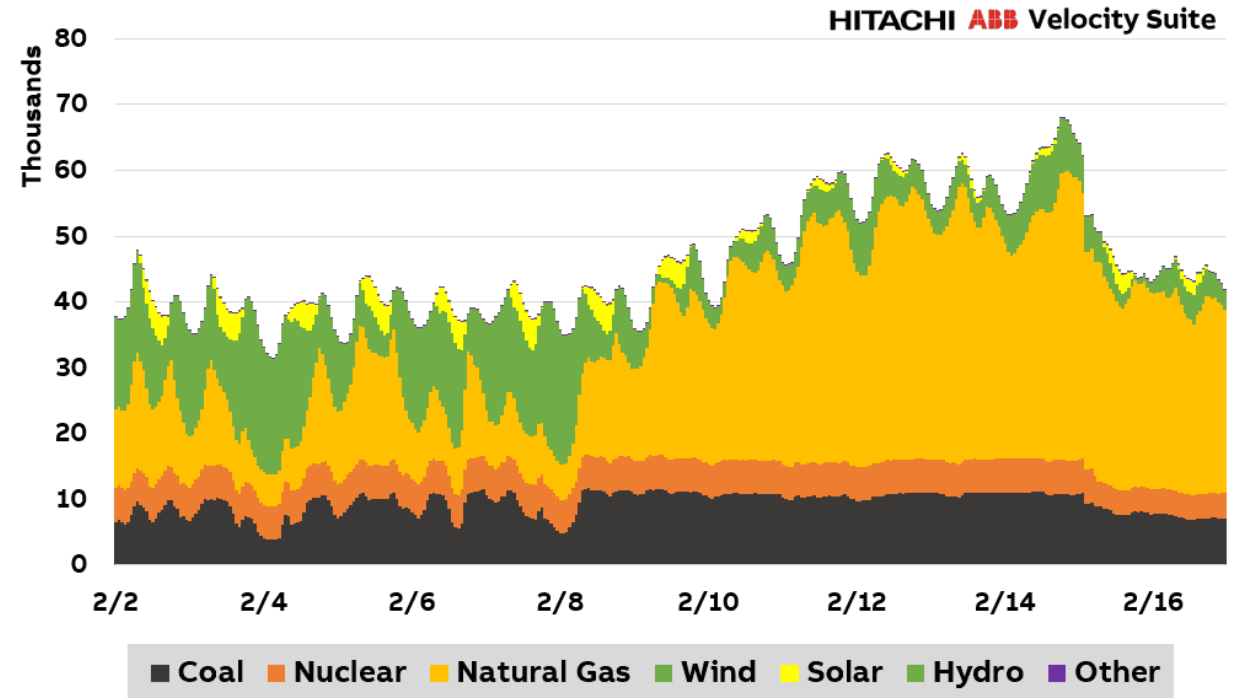
How do we get there?

Fossil power plants

- Improve dispatchable power flexibility
- Integrate operation with **energy storage**
- Integrate with **carbon capture**

This will require development of

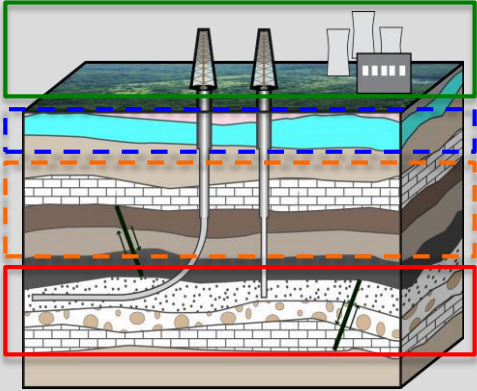
- Sensors to increase actionable plant information
- Optimized plant and grid control strategies
- Integrated system dynamic controls
- Sensors to assure environmental safety of carbon storage



ERCOT hourly electricity by fuel, Feb. 3-16, 2021, MWh. Source: Hitachi ABB Power Grids (Power Magazine, 2/19/2021)

Dispatchable power generation must flex better to coordinate with renewables to meet power demand while reducing CO₂ emissions.

Technology Challenges for Sensors and Controls for Flexible Fossil Energy and Carbon Management



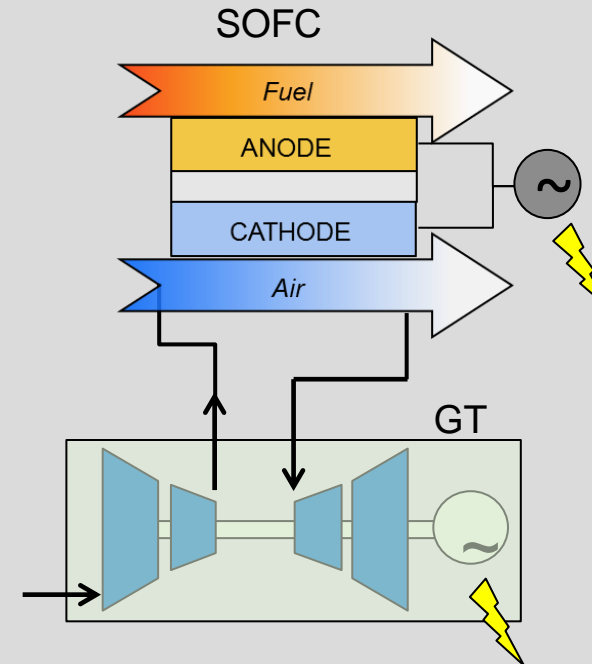
Carbon Storage and Subterranean chemistry

- Assure CO₂ storage stability
- At the Wellhead
- Downhole
- High pressure water or brine



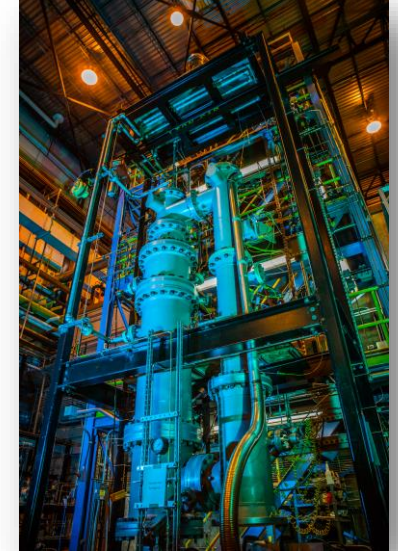
Hydrogen Production and Utilization

- Thermal gasification 1100 - 1500°C
- Microwave fuel reforming
- Chemical Looping
- Hydrogen GT
- SOFC/SOEC
- Ammonia systems



Hybrid Systems

- 800°C in fuel cell
- 1500°C in GT
- Transient controls
- + Storage or polygen



Novel Systems

- Direct Air Capture
- Supercritical CO₂ cycles
- FE + storage
- FE + biomass
- FE + plastics

Sensors & Instruments

- High temperature optical fiber sensors
 - Crystalline fiber
 - Sensing materials
 - Interrogation
- Real-time gas composition analysis
- LIBS for subterranean chemical sensing
- In-boiler temperature field measurements

Controls

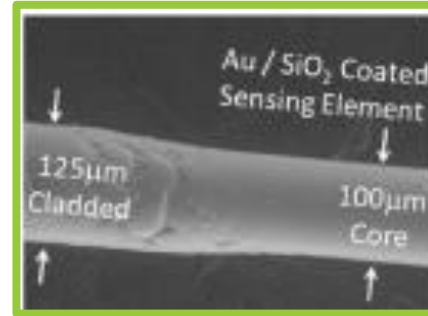
- Testing online system identification for detecting equipment problems
- Cyber-physical systems as a hybrid power plant development acceleration tool

Cybersecurity and Novel Concepts

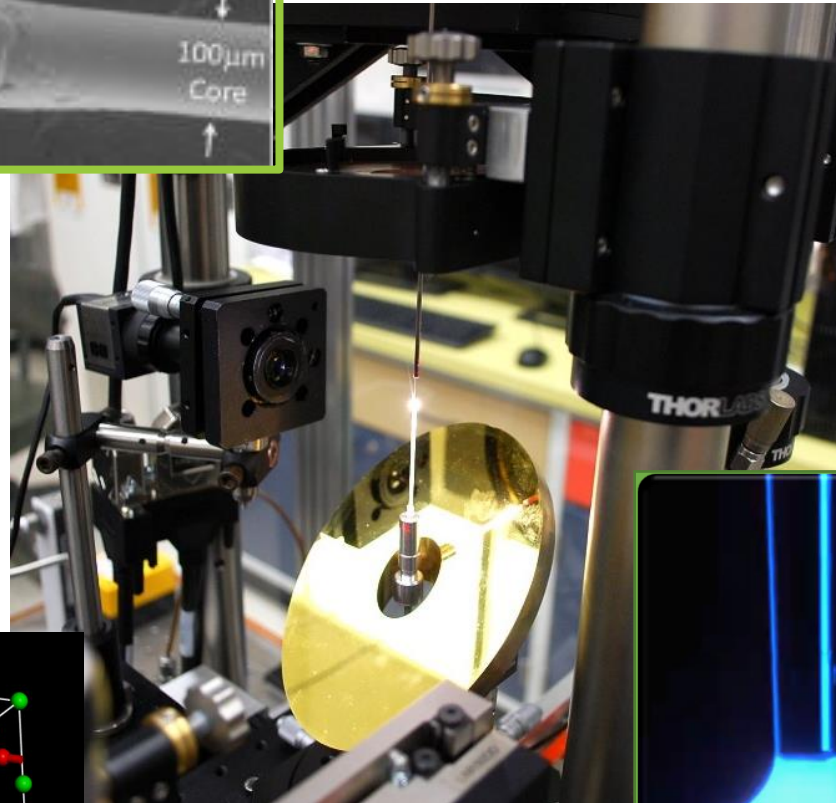
- VLC – Alternative to WiFi
- Strengthening Cybersecurity with Fast Proxy Models in High Fidelity Digital Twins
- AI for screening and design of functional materials
- Quantum sensors for fossil energy applications

Optical Fiber Sensing for Harsh Fossil Energy Applications

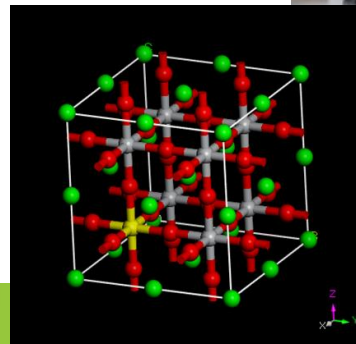
Developing materials and methods for fiber-based sensing concepts to provide spatially resolved chemical species and temperature measurements from an optical fiber at harsh conditions ($>800^{\circ}\text{C}$)



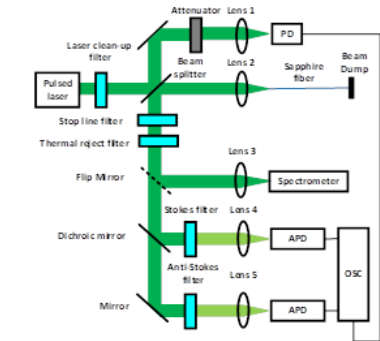
Functional nanomaterials



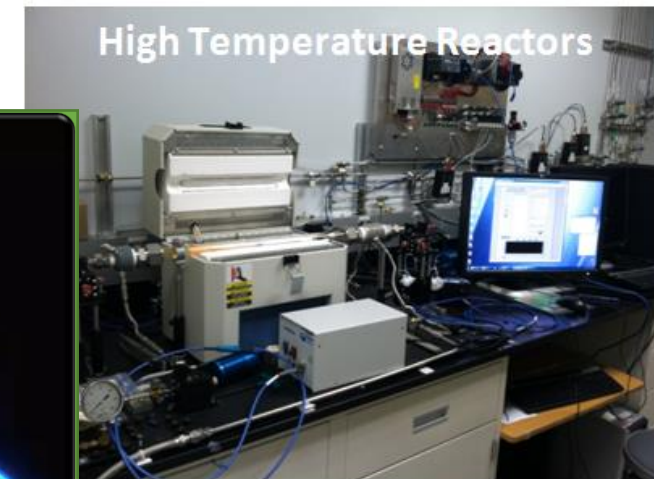
LHPG system



Material modeling



Commercial and novel multipoint interrogation



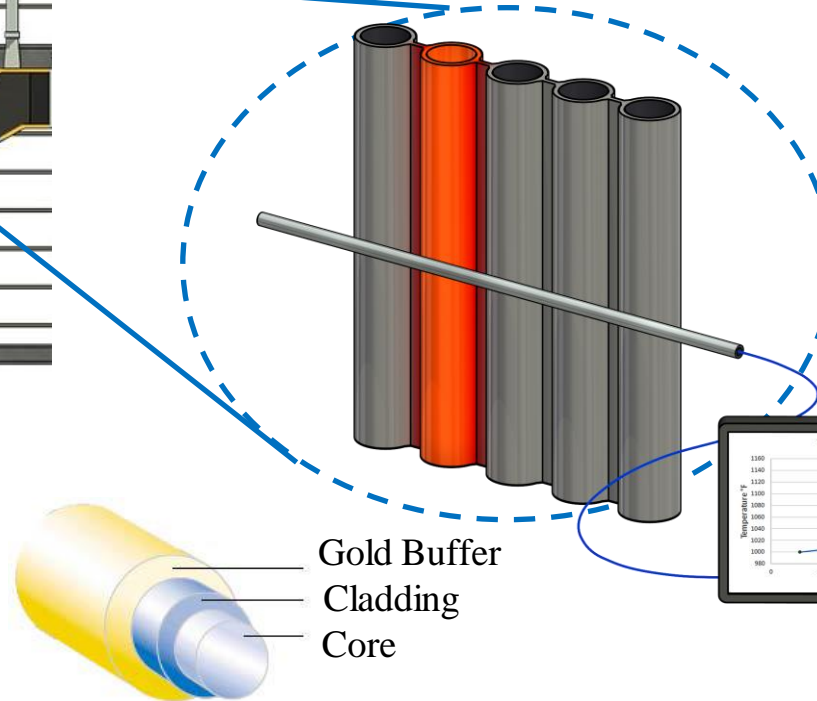
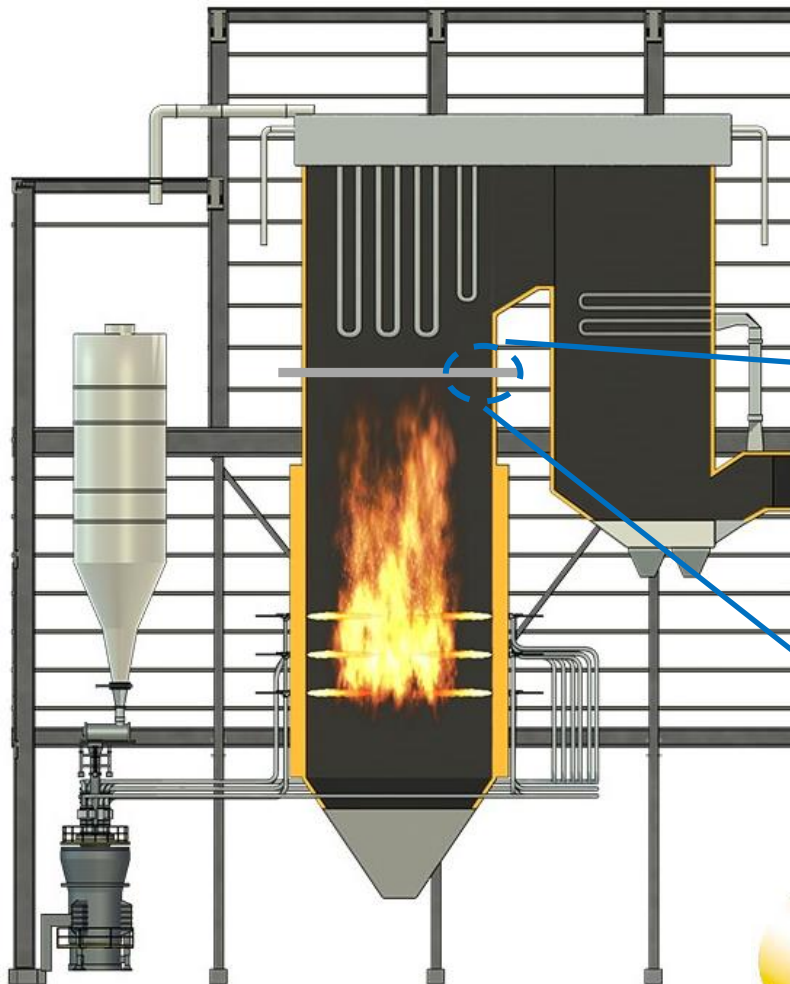
High Temperature Reactors

Fossil energy relevant gases

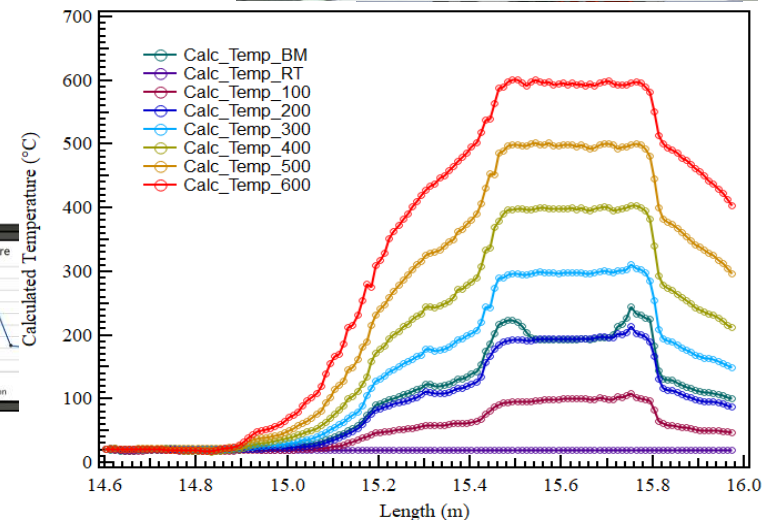
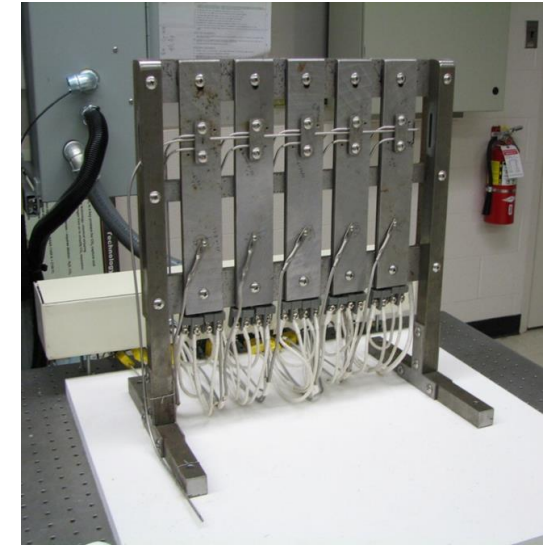
Multipoint Boiler Tube Temperature Monitoring

Measure temperatures from every tube

- Expected spatial resolution 1 inch (200 ft long)
- Identify local hot spots on tube wall
- Spot maldistribution of steam flow at low power
- Gold-coated silica fiber possible: $<1200^{\circ}\text{F}$ (650°C), air
- Other application locations possible



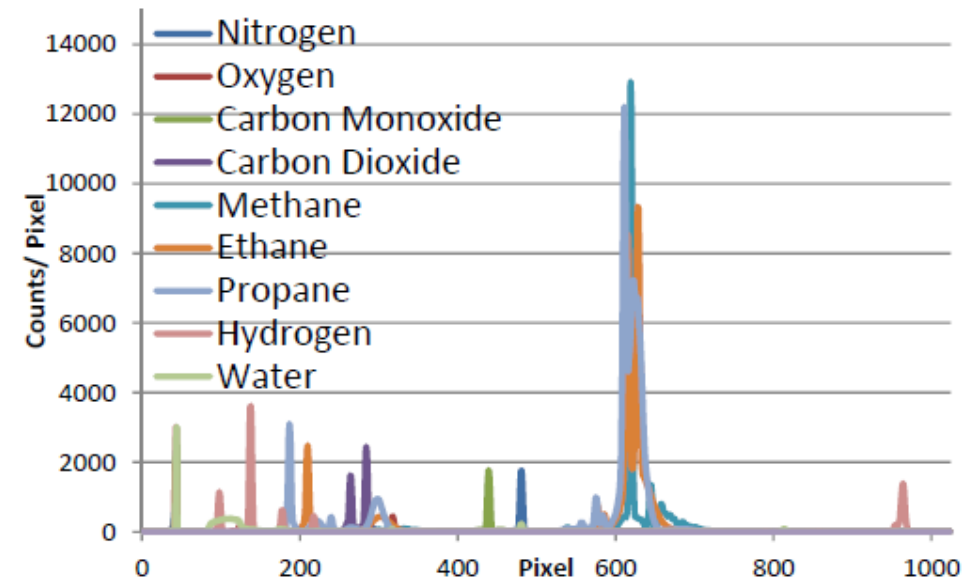
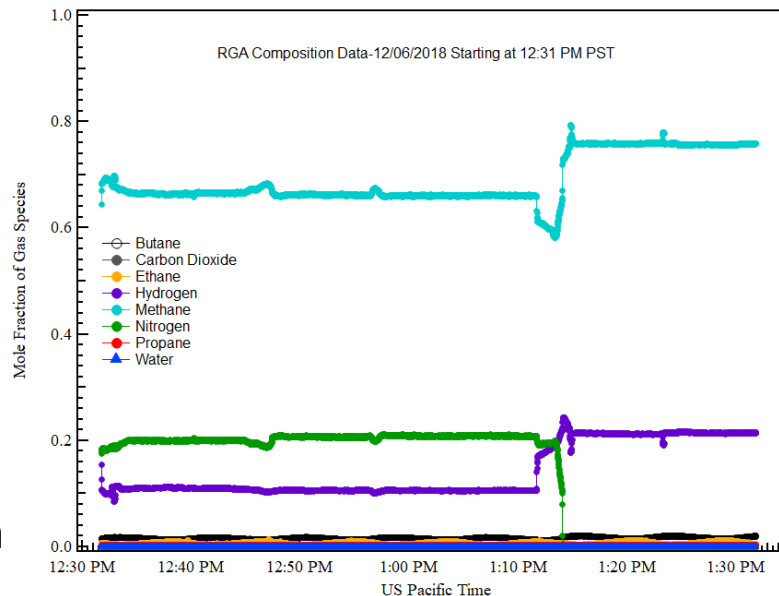
Gold Buffer
Cladding
Core



Fast Raman Gas Analyzer



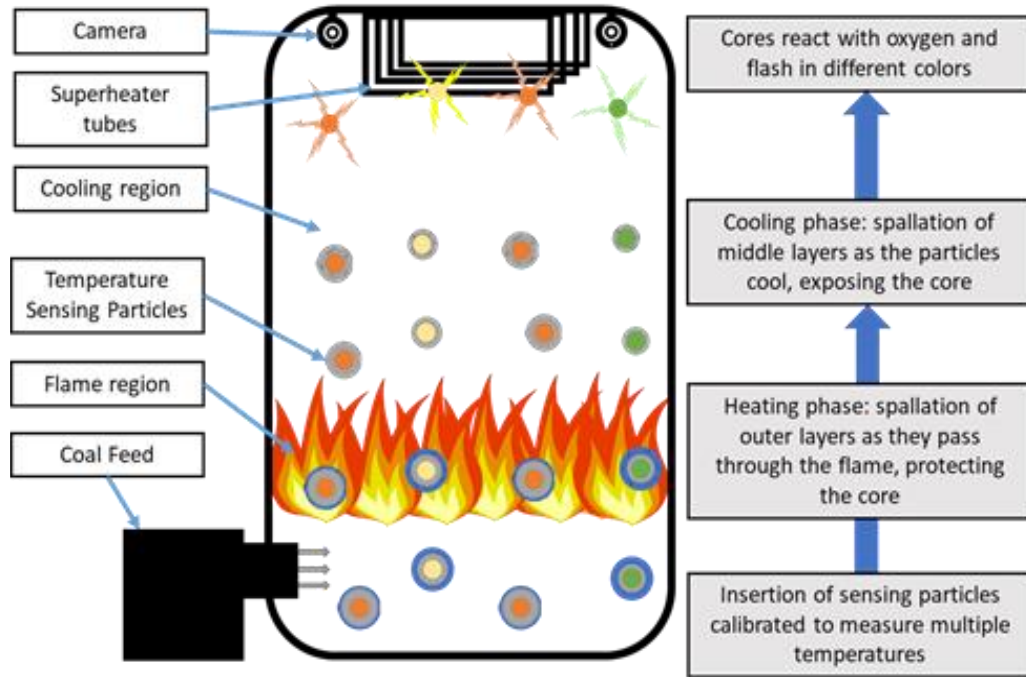
- Applications to **power generation** and **chemical process control**
- Prototype tested in pilot scale laboratory applications
- Fast - 1 second measurement time
- Species concentrations measured to 0.1%
- Optical waveguide technology boosts Raman signal more than 1000X
- No recalibration needed in normal operation
- **EY21: Construction of new rack-mount size design**



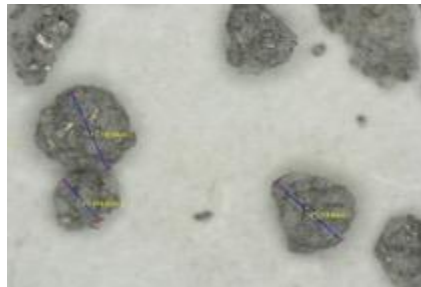
US Patent 8,674,306,
NETL and U. of Pittsburgh

Novel Methods for Boiler Temperature Mapping

Engineered Reactive Particles

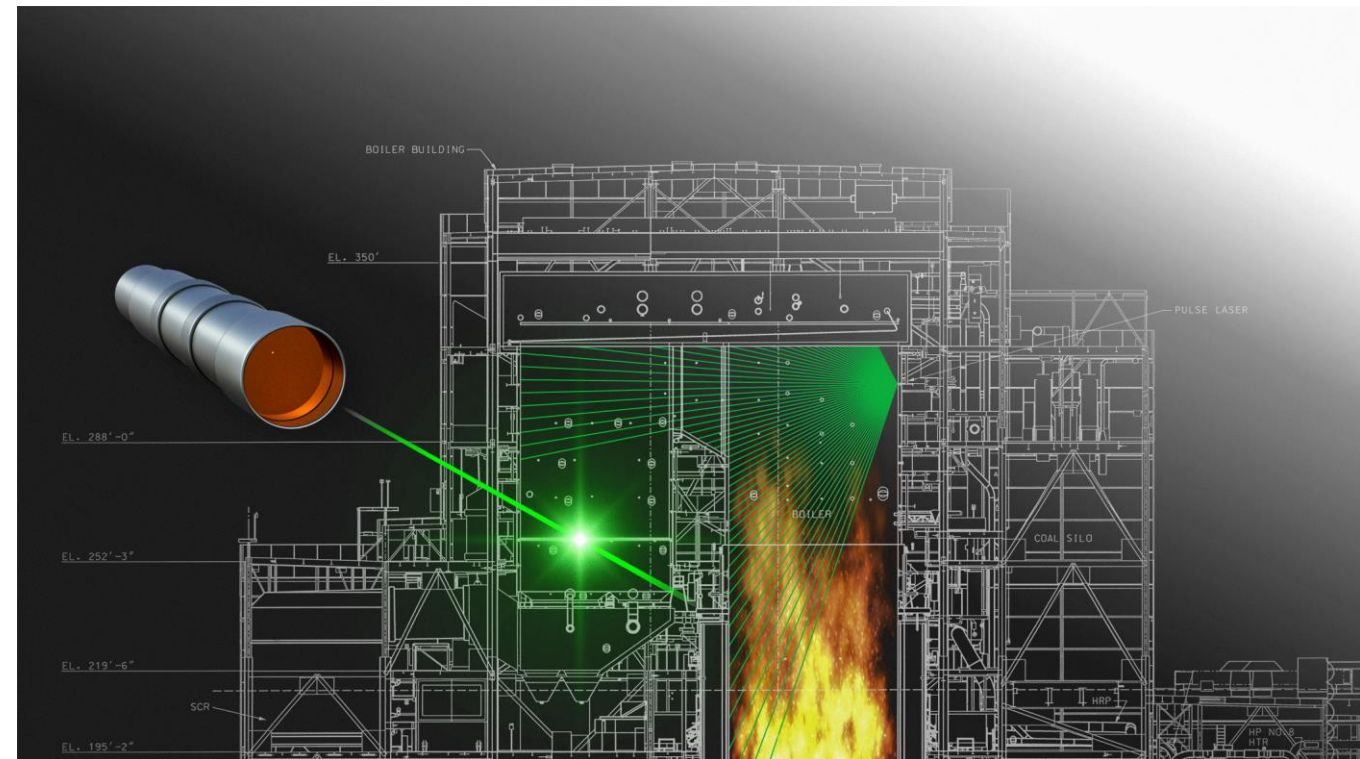


Implementation of temperature sensing particle into a boiler.



More about these on
Thursday 9:30 AM EDT

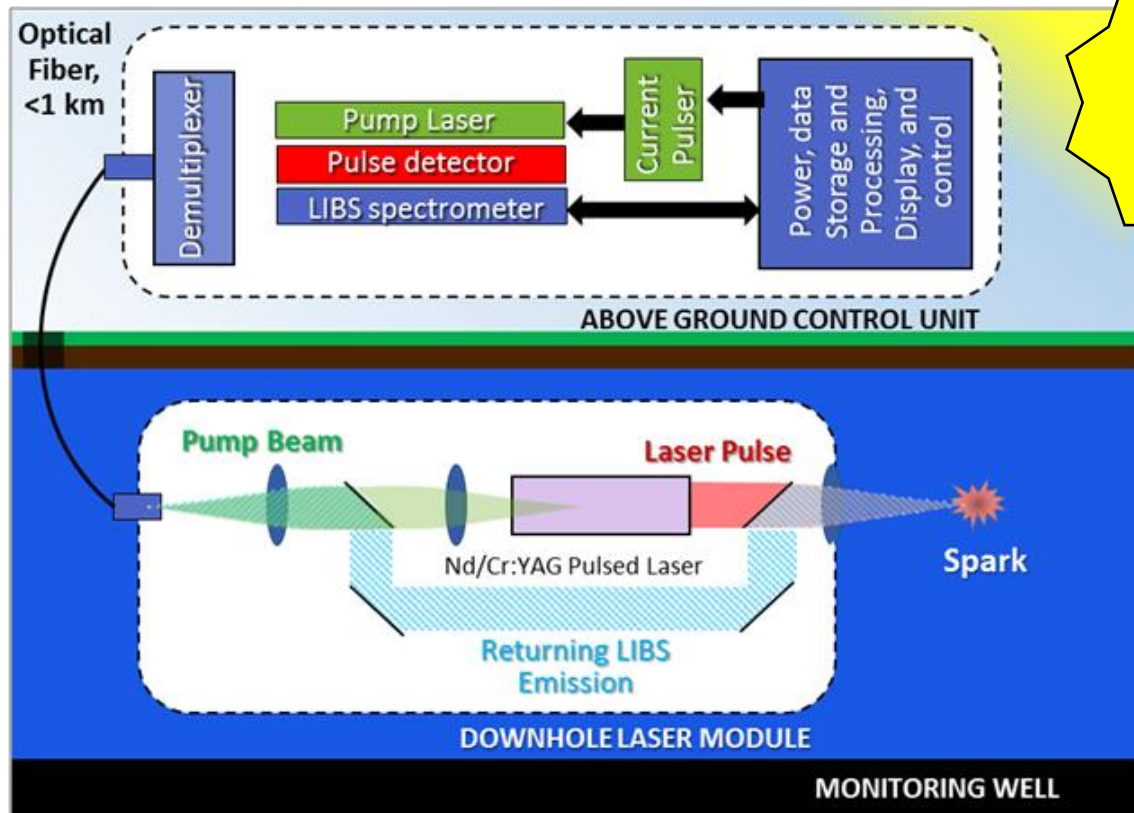
Ultrafast Pulsed Laser Measurements



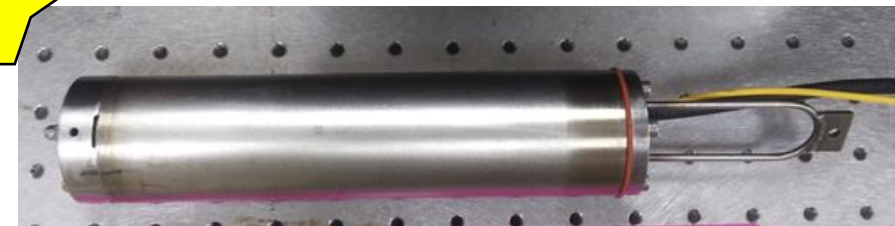
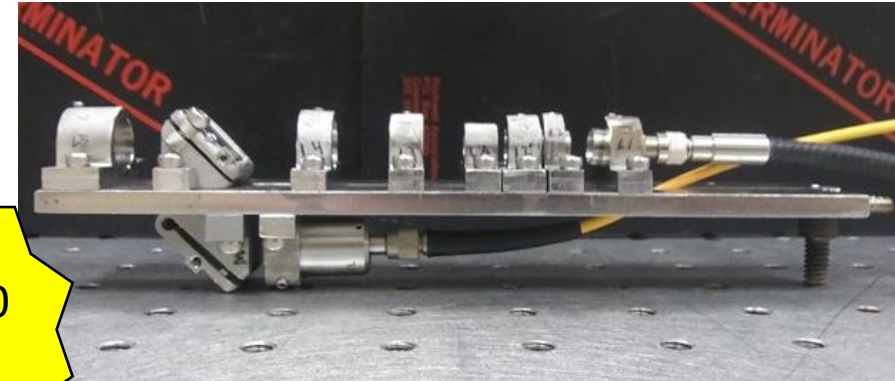
Apply to boiler, HRSG, or large industrial process

LIBS for Subterranean Sensing

- Objective: Development, optimization and testing of a deployable miniaturized LIBS system for subterranean chemical sensing

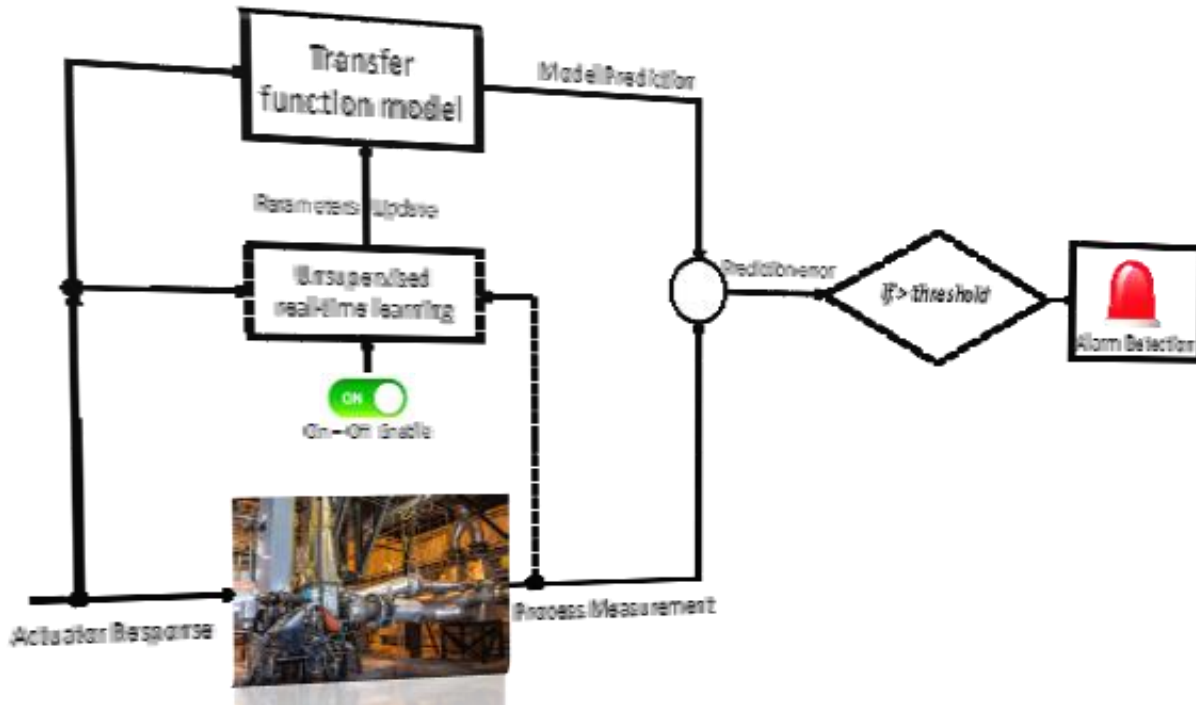


2019
R&D 100
Award
Winner



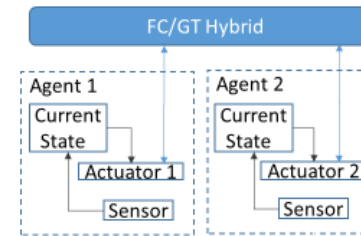
Advanced Controls and Cyber-physical Systems

- Partner with Ames NL on design method and use of cyber-physical systems for accelerating research and technology maturation
- Demonstrate utility of online system identification for detection of tube leaks, and support technology transfer to industry

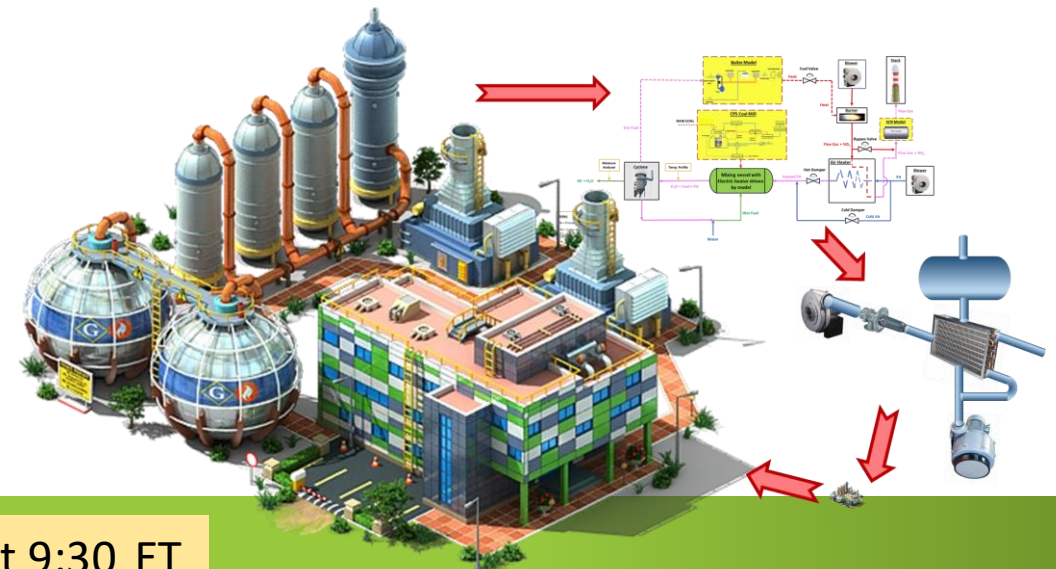
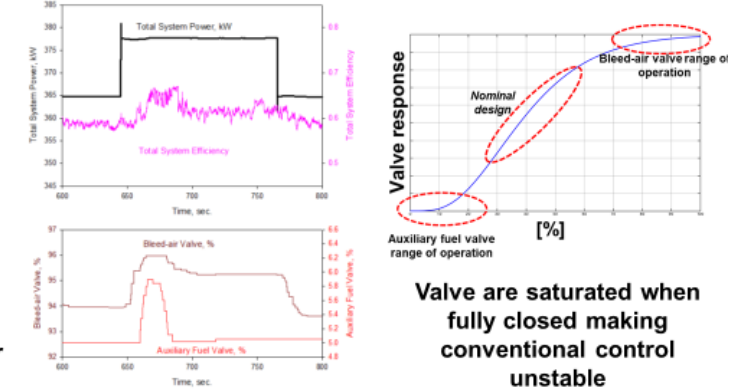


Model-Free Control (Agent-Based)

- Reconfigurable on different power plants
- Multi-agents emulate intelligent control
- Agents can coordinate their behavior to achieve multiple objectives
- Load following was achieved while minimizing the transient impact on efficiency

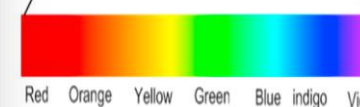
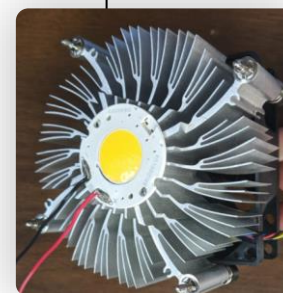
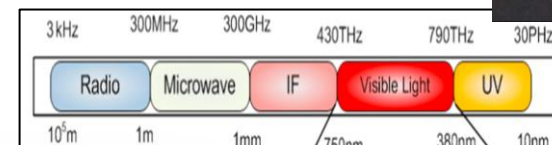
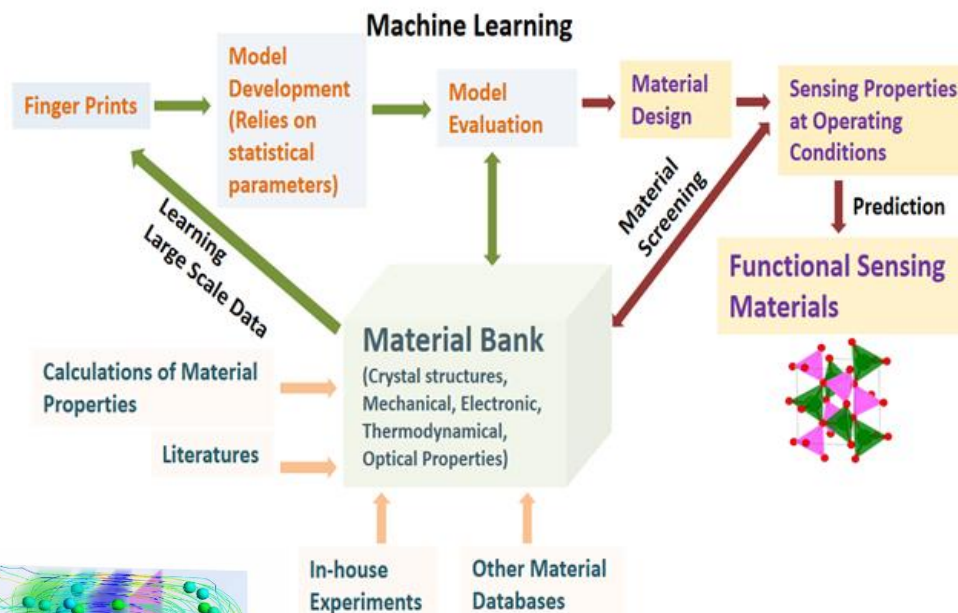
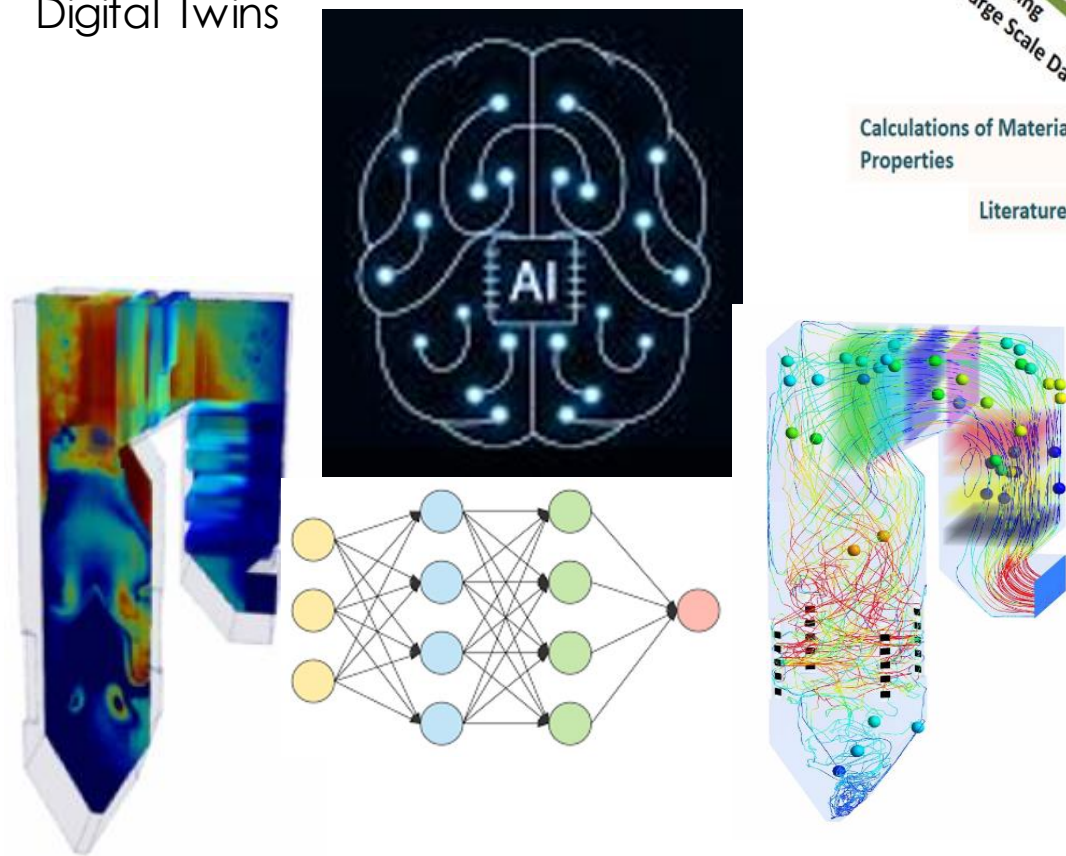


Two (2) agent controller demonstrated on laboratory power equipment in the Hyper facility

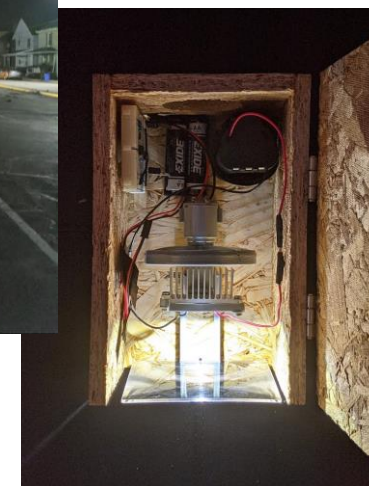
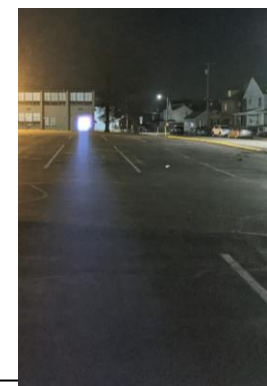


Cybersecurity and Machine Learning

High Fidelity Proxy Models for
Digital Twins



Univ. of Pittsburgh



Pause – Thank you for your attention

Benjamin.Chorpening@netl.doe.gov

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