RIC Advanced Sensors & Controls FWP

Overview 2022

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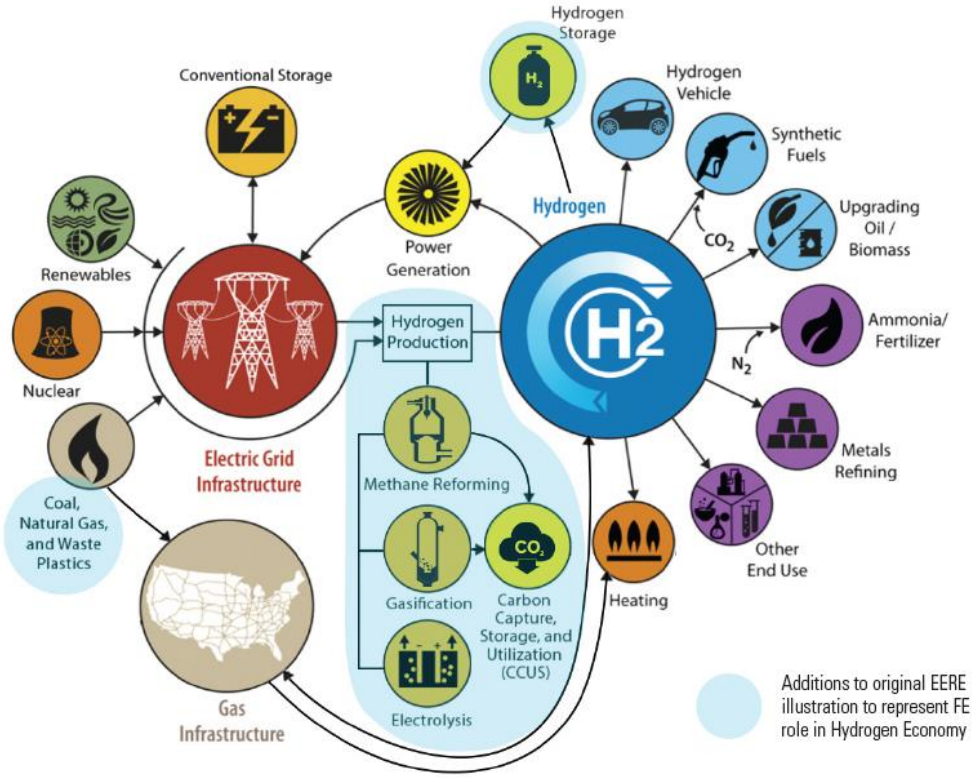

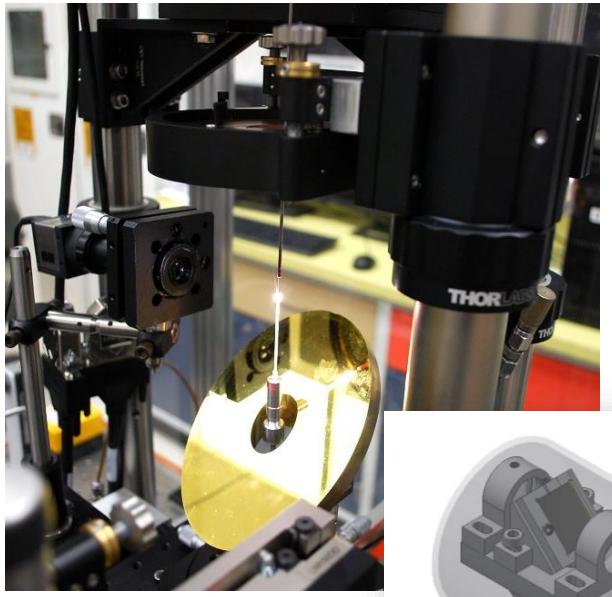

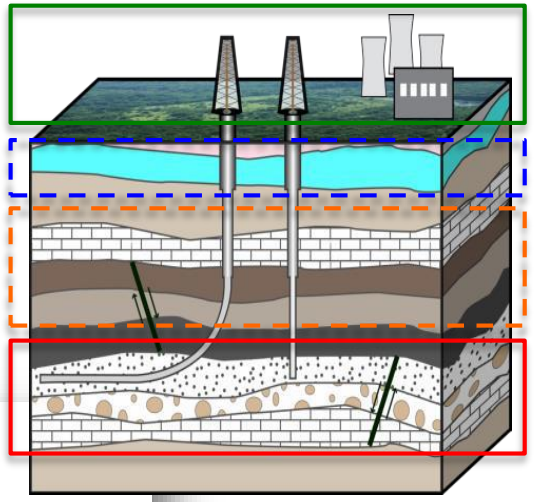

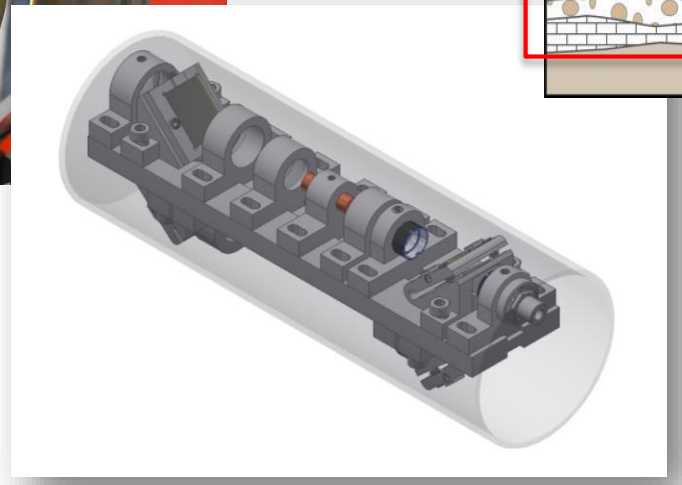

FECM Spring R&D Project Review Meeting, May 4, 2022

Outline

- NETL Research & Innovation Center
- R&D Motivation and Challenges
- FWP Overview

Research Focus by Site

Multiple Sites Operating as One Lab System

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

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

- Energy Conversion Devices
- Simulation-Based Engineering
- *In-Situ* Materials Characterization
- Supercomputer Infrastructure
- Microwave Reactors

Oil and Gas Strategic Office

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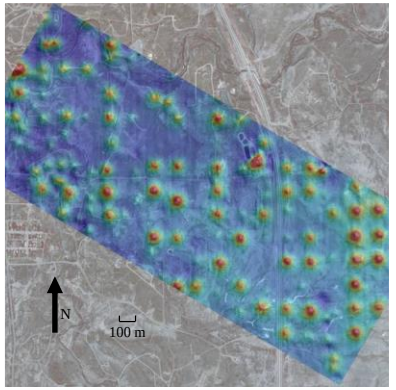
NETL Core Competencies

NATIONAL ENERGY TECHNOLOGY LABORATORY

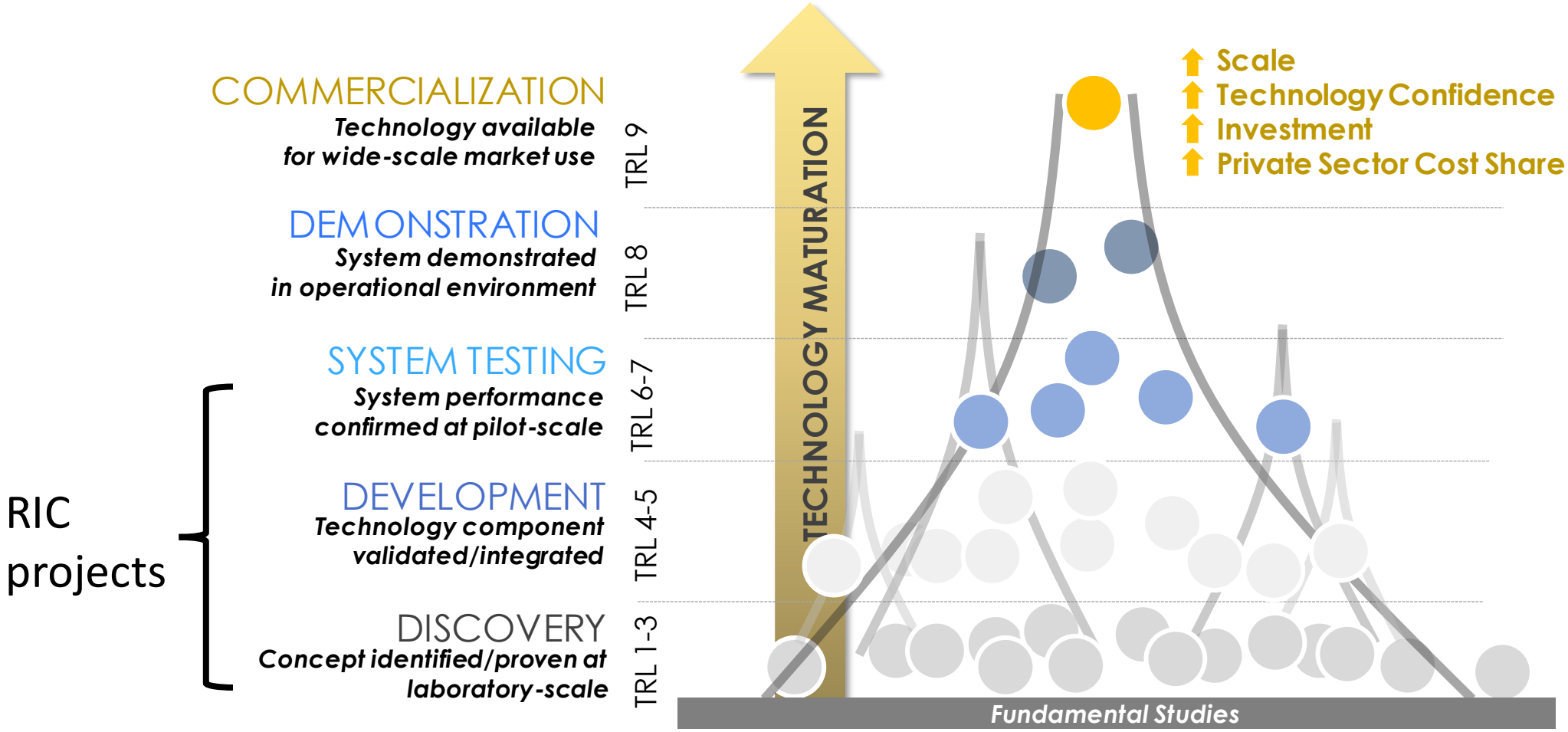
Effective Resource Development • Efficient Energy Conversion • Environmental Sustainability



Computational Science & Engineering	Materials Engineering & Manufacturing	Geological & Environmental Systems	Energy Conversion Engineering	Strategic Systems Analysis & Engineering	Research Planning & Delivery
High Performance Computing	Structural & Functional Materials	Geo-Analysis & Monitoring	Reaction Engineering	Energy Process & System Engineering	Technical Project Management
Multi-Scale Modeling Atomistic to Device	Design, Synthesis, & Performance	Reservoir Engineering	Design & Validation	Multi-scale Modeling, Simulations & Optimization	Business Management & Agreements
Artificial Intelligence & Machine Learning	Characterization	Geochemistry	Thermal Sciences	Energy Markets Analysis	
			Advanced System Engineering		

Technology Development Pathway

An Active Portfolio from Concept to Market Readiness



Getting to a Net-Zero Carbon Future

Increase Flexibility, Reduce CO_2 Emissions

Executive Order 14008 set a goal of a carbon pollution-free power sector by 2035

FECM 2022 Strategic Vision

- Focus on the future (2050)
- Role in ensuring graceful transition from fossil-fuel based system

Net-zero carbon power

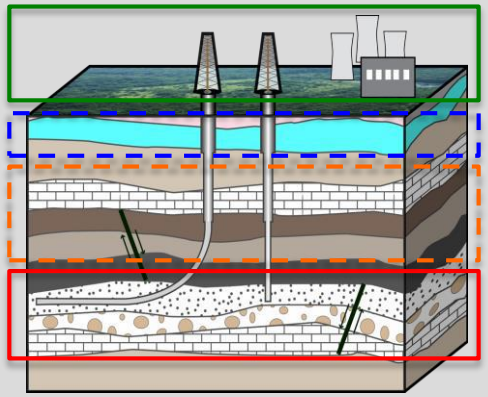
- NG turbines with Point-Source Capture
- Hydrogen as bulk clean **energy storage**
- **Hydrogen production from carbon-based fuels** with **carbon capture** **– support transition**
- Hydrogen utilization
  - Hydrogen/NG blend turbines
  - Hydrogen hybrid systems

Sensors & Controls R&D Activities

- Sensors for hydrogen blend systems
- Dynamic controls for Integrated Energy Systems
- Optimized power plant and grid control strategies
- Sensors to assure environmental safety of carbon storage and hydrogen systems

Zero-net carbon, flexible and integrated energy systems are needed to complement renewables to provide reliable and resilient power and sharply reduce CO_2 emissions.

Technology Challenges for Sensors and Controls for Hydrogen and Carbon Management

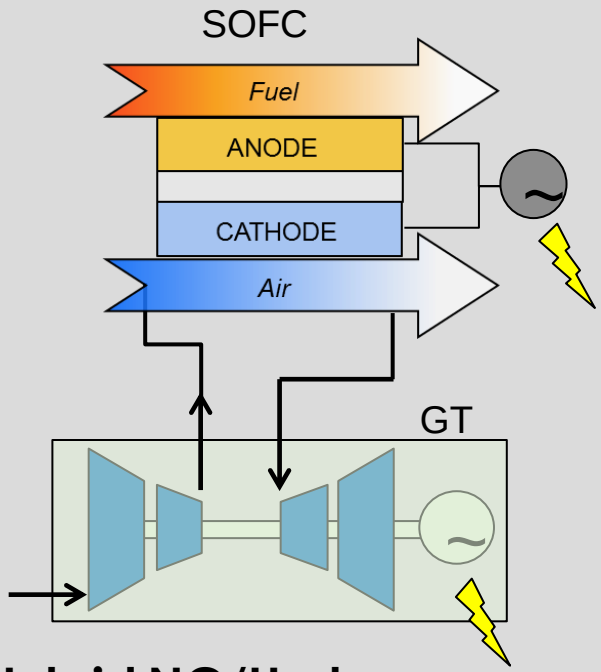


Carbon Storage and Subterranean chemistry

- Assure CO_2 storage stability
- At the Wellhead
- Downhole
- High pressure water or brine

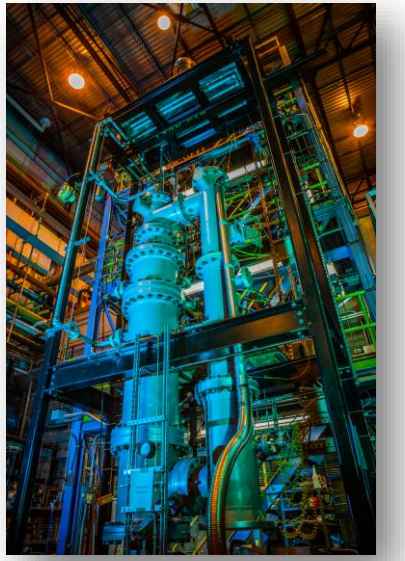
Hydrogen Production and Utilization

- Modular gasification
  - waste plastics / MSW
  - Sustainable biomass
  - Coal waste deposits
- Microwave fuel reforming
- Chemical Looping
- Hydrogen/Blend GT
- SOEC
- Ammonia systems



Hybrid NG/Hydrogen Systems

- 800°C in SOFC
- 1500°C in GT
- Transient controls
- + CO_2 storage



Novel Systems

- Direct Air Capture
- Supercritical CO_2 cycles

Overview of Adv Sensors & Controls FWP (EY22)

Sensors & Instruments

- High temperature optical fiber sensors
  - Crystalline fiber
  - Sensing materials
  - Interrogation
- Real-time gas composition analysis of hydrogen blends
- LIBS for subterranean sensing of fluid migration

Controls

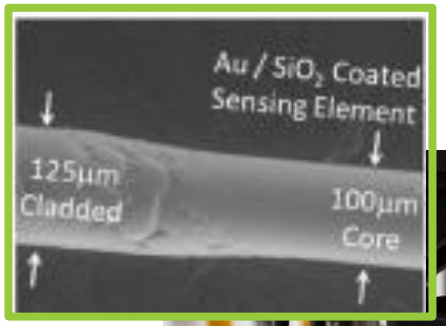
- Cyber-physical systems as a zero-carbon integrated energy system development acceleration tool

Cybersecurity and Novel Concepts

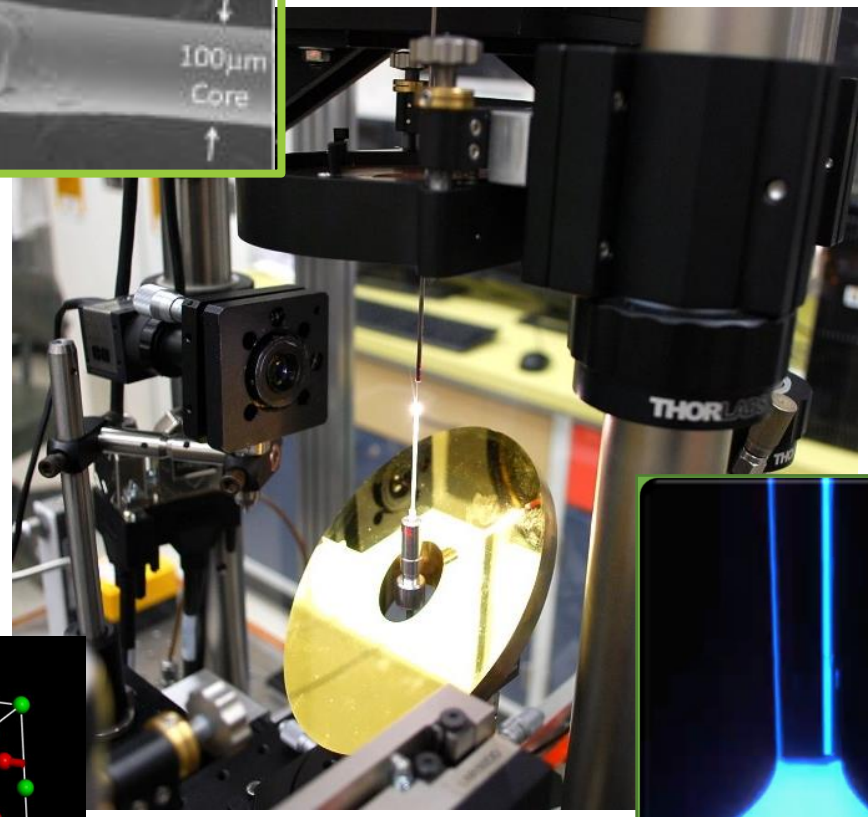
- VLC – Alternative to RF
- AI for screening and design of functional materials
- Quantum sensors for FECM applications

Optical Fiber Sensing for Harsh Environments

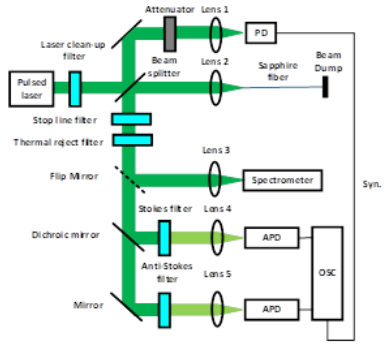
Developing materials and methods for fiber-based sensing concepts to provide spatially resolved chemical species and temperature measurements from an optical fiber at harsh conditions (>800°C)



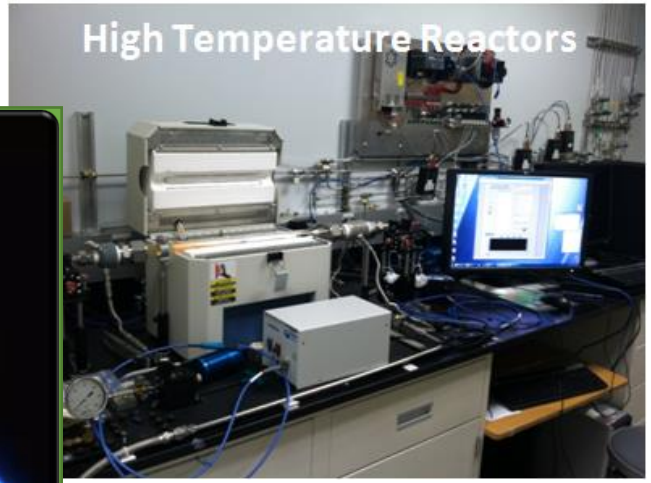
Functional nanomaterials



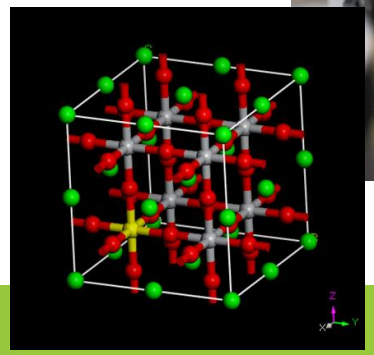
LHPG system



Commercial and novel multipoint interrogation



Fossil energy relevant gases



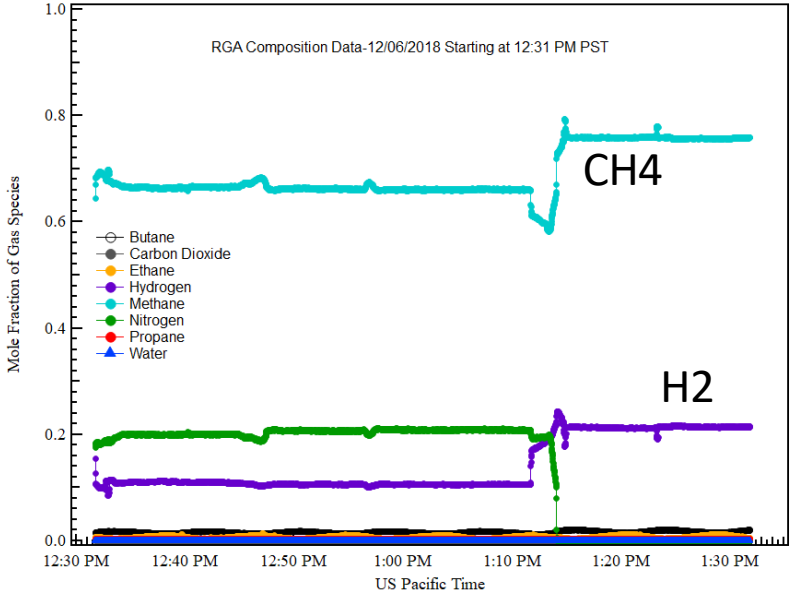
Material modeling

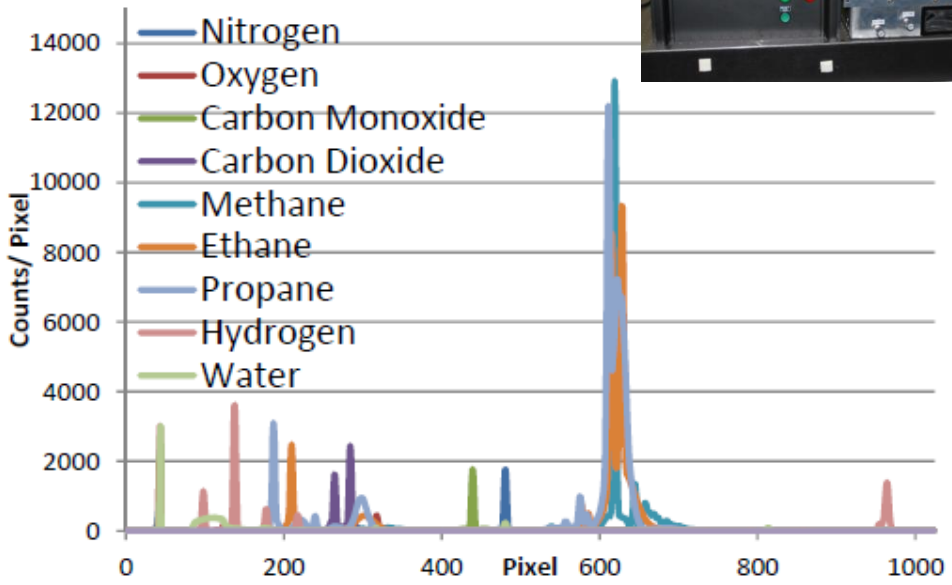
Dr. Michael Buric to present later

Fast Raman Gas Analyzer

- Applications to **low carbon power generation** (e.g. hydrogen blend turbines)
- 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: Rack mount design constructed**

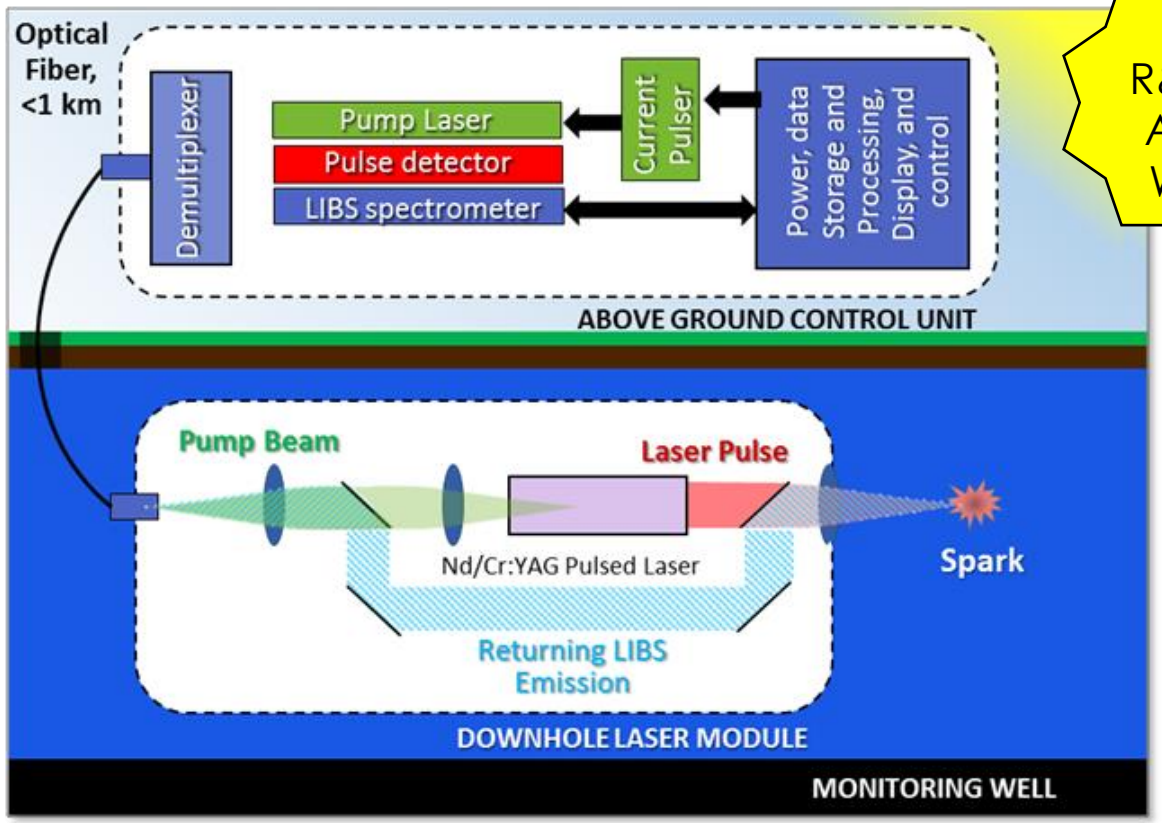
US Patent 8,674,306,
NETL and U. of Pittsburgh



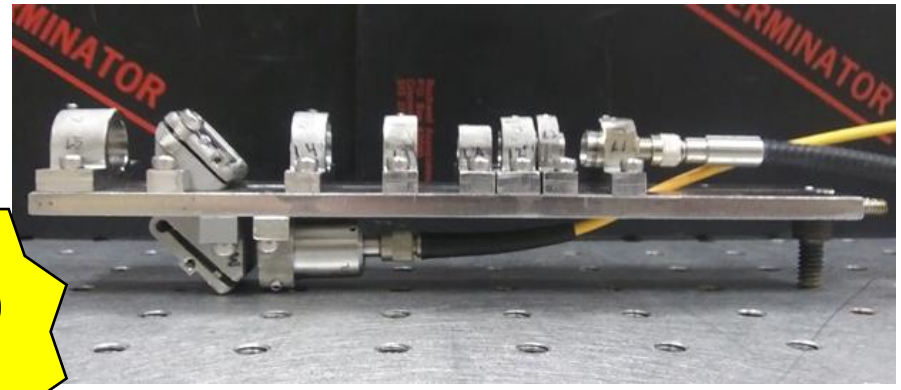


LIBS for Subterranean Sensing

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



2019 R&D 100 Award Winner

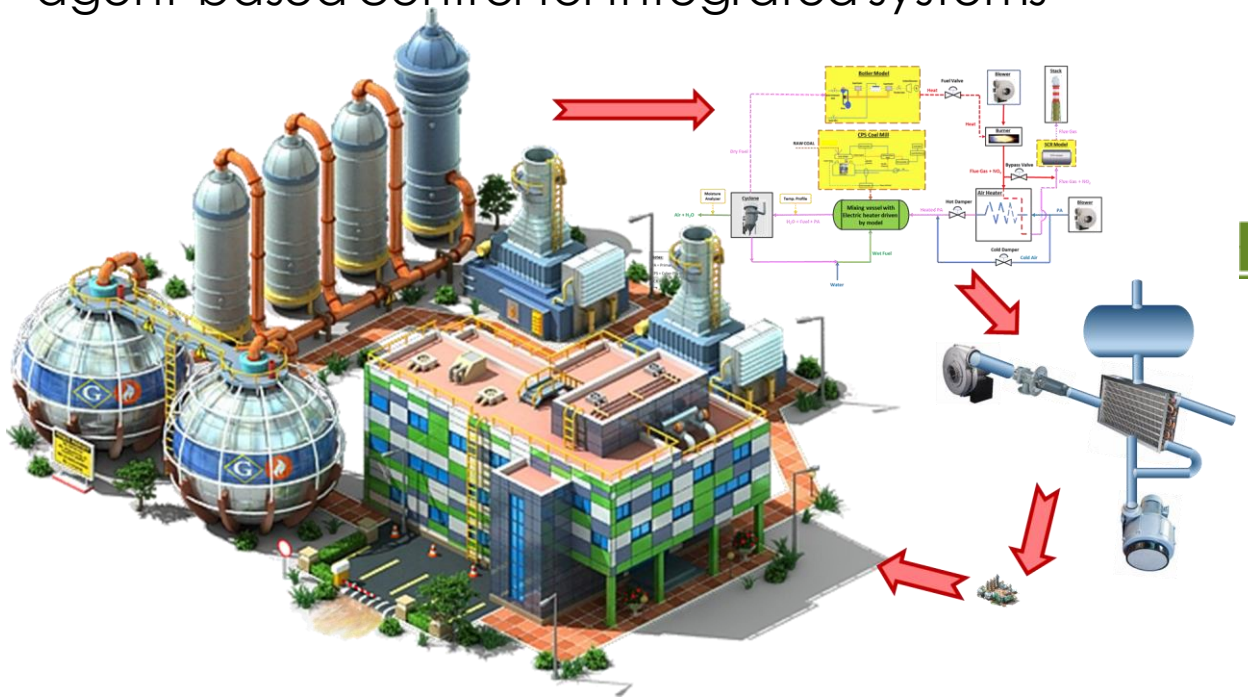


Dr. Dustin McIntyre to present later

Advanced Controls and Cyber-physical Systems

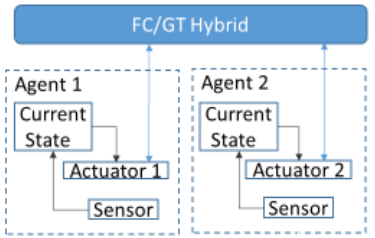
Partner with Ames NL on design method and use of cyber-physical systems for accelerating development of Integrated Energy Systems and Hydrogen Hybrids

Develop and demonstrate advanced control methods such as online system identification, and agent-based control for integrated systems

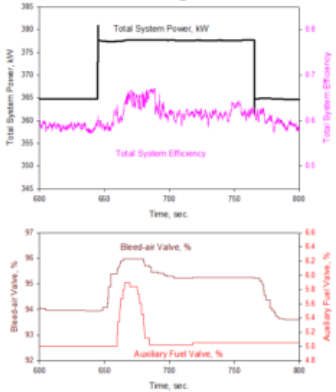


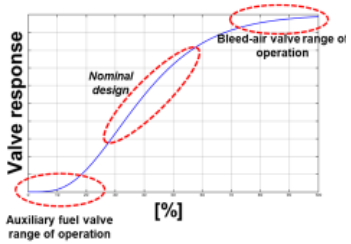
Model-Free Control (Agent-Based)

- 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





Valve are saturated when fully closed making conventional control unstable

U.S. DEPARTMENT OF ENERGY

P. Pezzini, D. Tucker, and K.M. Bryden, Turbine speed control in a direct-fired fuel cell hybrid system, *SUstainable PolyEnergy generation and HaRvesting–LEAP 2019*, Savona, Italy, September 5, 2019, 10 pp. 11

More in presentations by Dr. David Tucker (NETL) and Harry Bonilla-Alvarado (Ames Laboratory)

Visible Light Communication

More secure alternative to RF communication for sensors?

Transmitter and receiver in testing

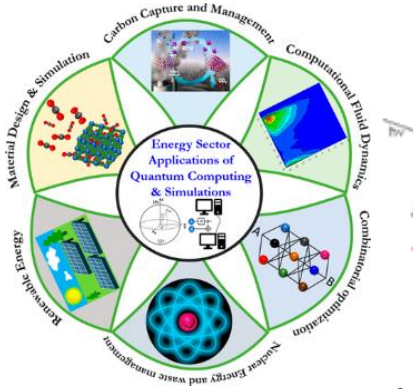
- Eye-safe, power LED based system
- Mounted onto poles separated by 100 yards on NETL site
- Battery powered with solar recharge

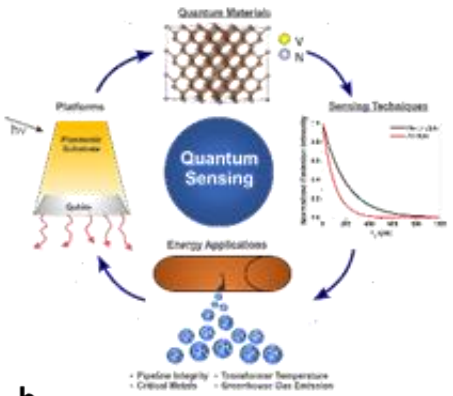
Data collection to evaluate weather impact

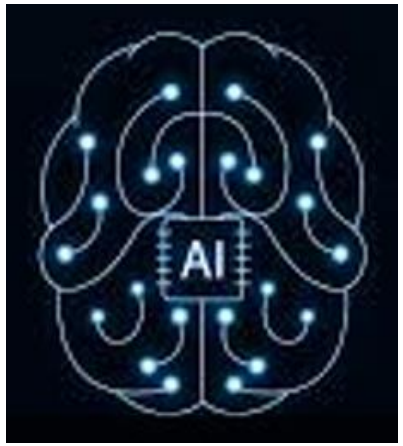
Early 2021 prototype

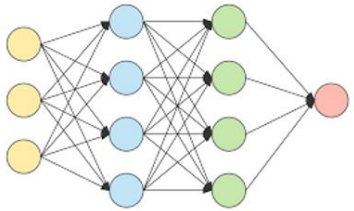
Quantum Sensing and Machine Learning / AI

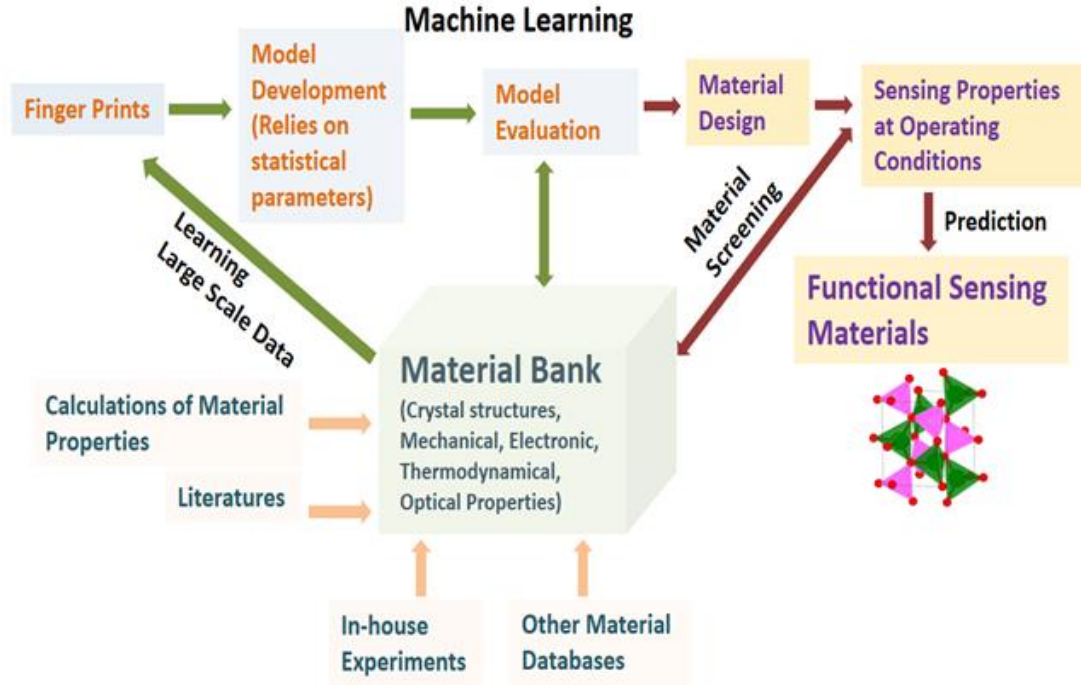
Quantum Sensing: Nanodiamonds with nitrogen-vacancy defects

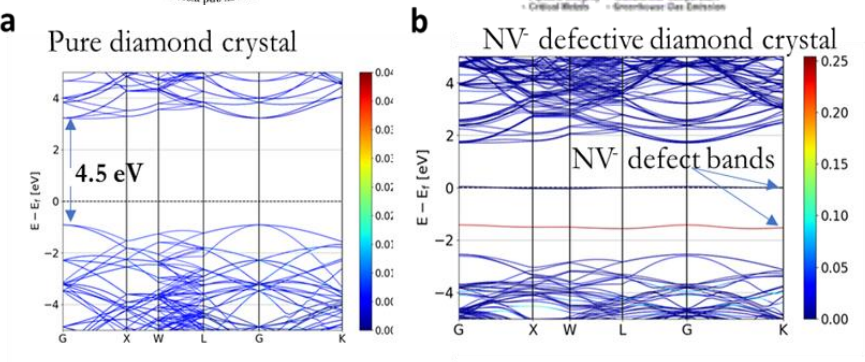


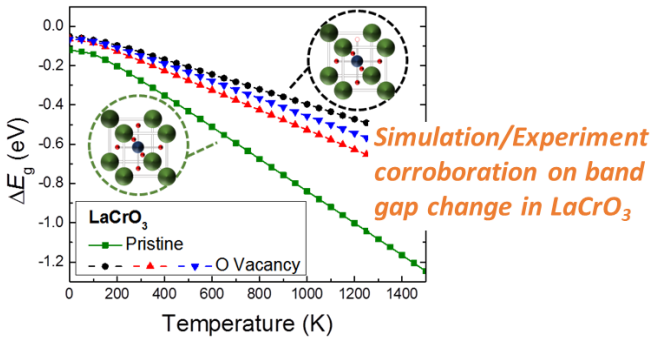




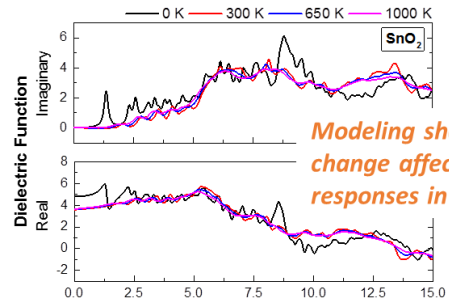








Simulation/Experiment corroboration on band gap change in $LaCrO_3$



Modeling shows band gap change affects optical responses in SnO_2, SnO

Pause