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Dr. Weiland is a Senior Fellow and the Hydrogen R&D Portfolio Lead at NETL's Research & Innovation Center. Prior experience includes:

- Techno-economic of sCO2 and MHD power cycles in NETL's Systems Engineering & Analysis group (2014-2020).
- Experiments and analyses on low-NOx hydrogen combustion, coal/biomass co-gasification, oxy-combustion plasmas, and chemical looping combustion as a WVU research faculty working at NETL (2008-2014)

Sensors, Controls, and Other Novel Concepts Program Overview

Nathan Weiland
Senior Fellow, Energy Conversion Engineering
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U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Sensors, Controls, & Other Novel Concepts

NATIONAL ENERGY TECHNOLOGY LABORATORY

Technology development that enables complex, integrated FECM-relevant applications for optimal process performance, reliability, and environmental integrity

ADVANCED SENSORS

- High temperature and Harsh Environments
- Real-time measurements, Diagnostics, & Inspection
- Optical fiber, Wireless, Imaging, Robotics
- Materials development, Packaging, Prototyping
- Testing in relevant environments

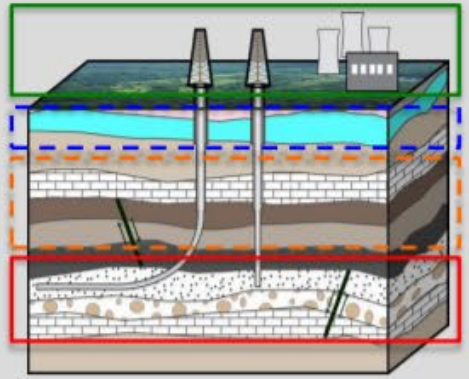
DISTRIBUTED INTELLIGENT CONTROLS

- Controls strategies for advanced energy systems & hybrids
- PID, MPC, Agent-based controls
- Online System Identification
- Cyber-Physical Systems (CPS)
- Condition-Based Maintenance

NOVEL CONCEPTS

- Emerging Technologies
- Cybersecurity R&D (ex: situational awareness, blockchain, visible light communications, etc)
- Quantum Sensing for FECM applications

S&C Applications for FECM

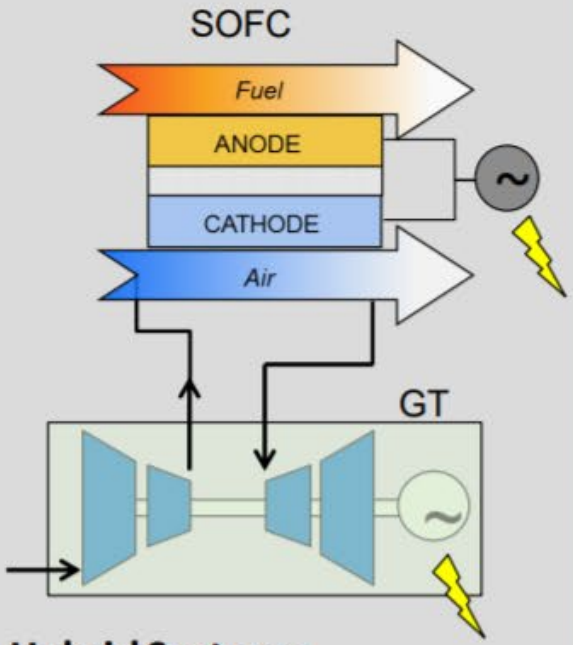


Carbon Storage and Subterranean chemistry

- Assure CO_2 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

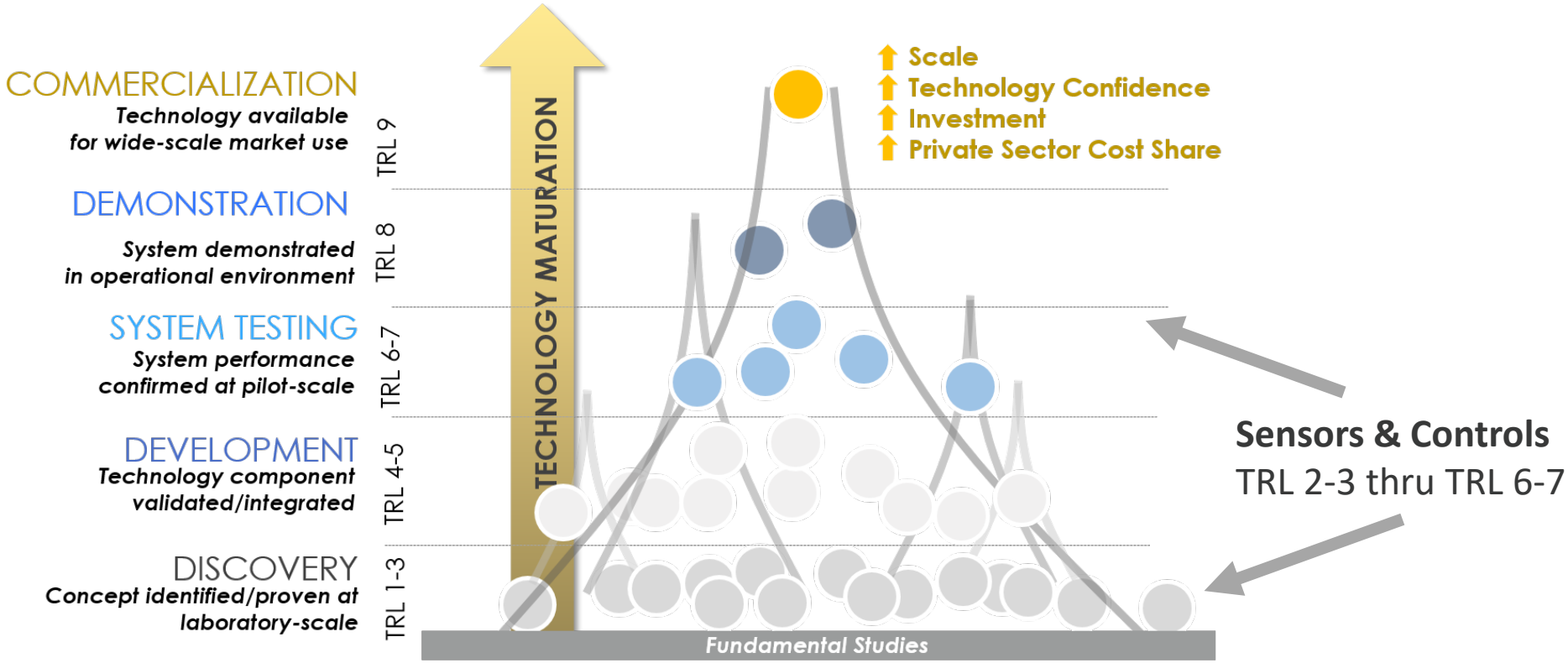
- 800°C in fuel cell
- 1500°C in GT
- Transient controls
- + Storage or polygen

Novel Systems

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

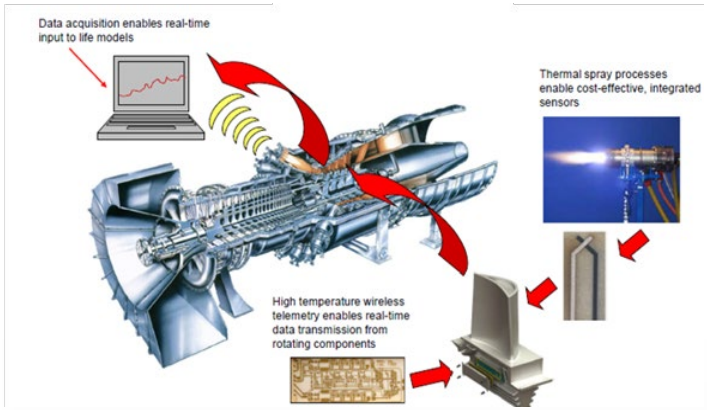
Accelerating Technology Development

Nurture technologies from initial idea/concept through the various stages of development, including proof of feasibility, prototyping, field testing, etc.



Leveraging a History of Success…

HOT GAS PATH SENSORS FOR INDUSTRIAL GAS



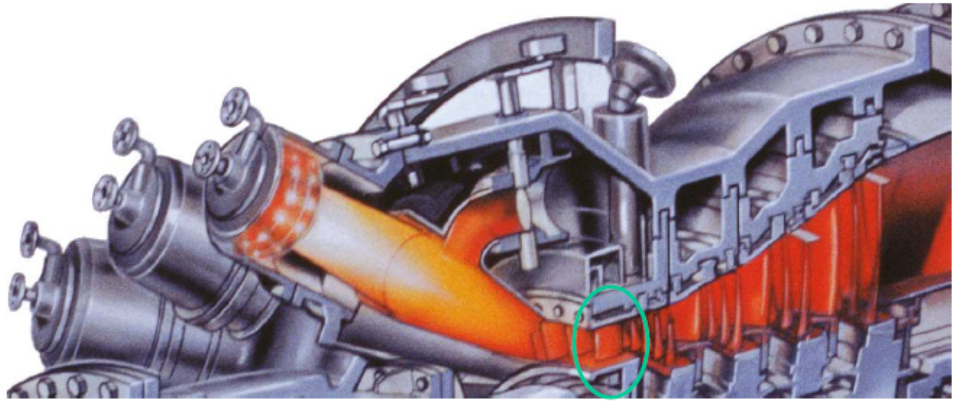
- One (1) project; Siemens Corporation ($4.7M)
- Spray-on TCs rated up to 1400 °C; High-T electronics up to 500°C; Wireless telemetry and power
- Full online test with Duke Energy during 2021

Proposal for Instrumentation of Test engine Instrumentation Scope

SIEMENS

Spray Coated TCs and High Temperature Telemetry Module

- Spray Coated TCs and Reference TCs routed to Row 1 Vane
- Device module bolted to Bulkhead seal with M10 Bolts, reinforced by Wire-Tie
- Temperature range for Electronics is up to 600C
- Pressure Range for Electronics is up to 300 PSI
- Spray Coated TCs operate up to 1400C for up to 200hours and 1100C indefinitely
- Target duration of testing is 100 hours under load
- Row 1 Vane will be seated in position #9 and routed through port #4



Team cleared the design review process for technology demonstration on row 1 vane

- **Row 1 vane with stationary wireless telemetry – made from chips from Raytheon, UK**
- **Multiple iterations to address wireless board functionality for successful transmission of data**
- **Instrumented R1 vane installed along with bolting of wireless telemetry to demonstrate wireless transmission at > 500C during Outage from April 19th to April 27th .**

Kulkarni/ Siemens

****FIRST DEMONSTRATION OF ON-BLADE THERMOCOUPLES IN HOT GAS PATH OF A GAS TURBINE IN OPERATION AT A POWER PLANT****

… To Enable Accelerated Decarbonization

FECM Sensors & Controls Program will play a critical role in Achieving Net-Zero Greenhouse Gas Emissions

- We will continue to **create, mature, and deploy** enabling technologies that allow us to realize carbon management systems of the future
- Continued emphasis on **testing and demonstration**
- Conduct R&D that represents **big ideas** and disruptive innovations

… To Enable Accelerated Decarbonization

Recent S&C Program Activities

- Pivoted the S&C program in FY22 to directly align with FECM goals

- Successful S&C program collaboration with FY22 Gasification program on FOA 2400/Hydrogen
  - 2 awards at $500k/ea., over FY23-FY24
  - Lehigh University: Integration of LIBS with Machine Learning for Real-Time Monitoring of Feedstock in H2 Gasification Applications
  - University of Pittsburgh: Distributed Sensors for Waste Plastics Gasification and Clean Hydrogen Production

Learn more here: https://www.energy.gov/fecm/strategic-vision-role-fecm-achieving-net-zero-greenhouse-gas-emissions

Advanced Sensors and Controls

High Level Goals of FWP

- Develop advanced sensors and controls to support development of technologies within FECM's portfolio
- Enable optimized monitoring and management using novel sensors and controls
  - Increase operational flexibility
  - Maintain or improve efficiency/availability
  - Sharply reducing carbon emissions

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
- Carbon dioxide removal and direct air capture

Advanced Sensors and Controls

Fundamental challenges

- Provide **sufficiently resolved process data** to make operational optimization possible
  - Spatial and time resolution, extreme environments, sensor system cost
- Develop controls to **operate under static or dynamic operating conditions**, especially under load changes while optimizing for:
  - Efficiency
  - Operating cost
  - Safety margin

Examples:
- Boilers/gasifiers (slag, reducing gases, ash, acidic species)
- Solid oxide fuel cells (oxidizing and reducing flows) and reversible SOFCs (load cycling)
- Chemical looping (high temperatures and erosion)

Advanced Sensors and Controls FWP

Portfolio Overview

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
- Online System Identification for power plants

Novel Concepts

- AI for screening and design of functional materials (ended)
- Quantum sensors for FECM applications
- VLC – Alternative to RF (ended)
- Direct Power Extraction (a.k.a. Magnetohydrodynamic power production)

Thank You!

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