

NETL Coal Center of Excellence Overview

Delivering Affordable, Reliable, and
Secure Energy Solutions

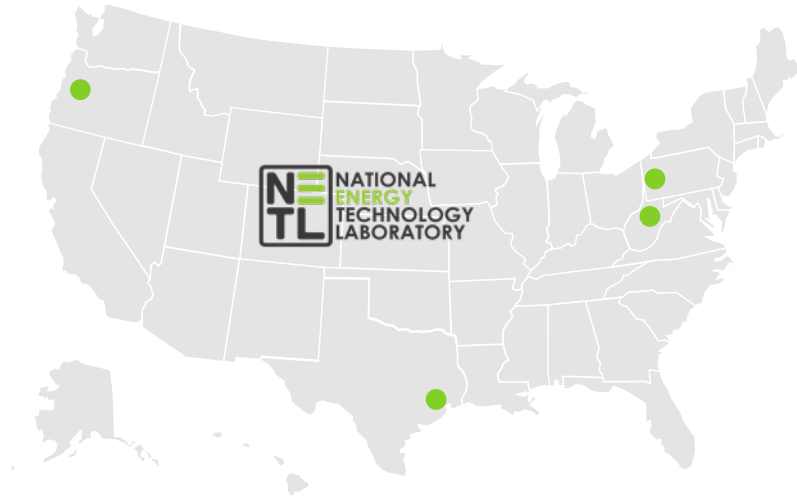
Nathan T. Weiland, Ph.D.



Driving Innovation, Delivering Solutions



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- One lab, multiple campuses
- **THE** National Lab **dedicated to carbon and applied subsurface research**
- Only **GOGO** DOE Lab
- **One of three applied** national labs
- **Over a century** of delivering innovation and solutions
- **>1,400** Staff, **> \$1B** in infrastructure



Morgantown, WV

COAL
CENTER of EXCELLENCE



Pittsburgh, PA

OIL & GAS
CENTER of EXCELLENCE



Albany, OR

**CRITICAL MINERALS
& ADVANCED ALLOYS**
CENTER of EXCELLENCE

NETL Coal Center of Excellence



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Goal: Deliver integrated research and technology solutions that advance and expand the efficient use of coal resources in alignment with DOE priorities and industrial needs.

- ✓ Launched February 2026, but NETL began coal research over 100 years ago on mine safety and coal dust explosions at the NETL Pittsburgh site
- ✓ R&D portfolio formulated to help stabilize, optimize, and grow the American coal industry
- ✓ Industry-focused research to ensure relevance, impact, and tech transfer
- ✓ State-of-the-art laboratory capabilities advancing secure, reliable, and affordable coal use
- ✓ Morgantown Campus: 41 Laboratories, 442,000 ft² of building space, \$364 million replacement value



NETL Coal Center of Excellence Leadership Team



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LEADERSHIP



Nate Weiland
Center Director,
NETL Coal Center of Excellence



Kirk Gerdes
Associate Lab Director,
NETL Coal Center of Excellence



Sarah Forbes
Director, Office of Coal,
HGE0

Mining & Processing

Conversion & Products

Power & Capture

DIVISION DIRECTORS



Benjamin Chorpene
Division Director



Dushyant Shekhawat
Division Director



Mehrdad Shahnam
Division Director



Chris Guenther
Division Director

R&D PROGRAM LEADS



Hema Siriwardane
Program Lead,
Mining &
Processing



Christopher Matranga
Program Lead, Coal
and Gas Waste to
Products



Mehrdad Shahnam
Program Lead,
Gasification



Dave Luebke
Program Lead,
Capture



Anthony Burgard
Program Lead,
Power

NETL Coal Center of Excellence Funding Snapshot



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**Extending Life of Existing
Coal Plants and Mines**



**Enhancing Operational and
Economic Opportunities for Coal**



**Developing New
Coal Technologies**

	Mining & Processing	Conversion & Products	Power & Capture	Total (\$k)
STABILIZE	\$300	\$0	\$2,205	\$2,505
OPTIMIZE	\$750	\$3,000	\$6,295	\$10,045
GROW	\$250	\$5,250	\$4,745	\$10,245
	\$1,300	\$8,250	\$13,245	\$22,795

Industry Engagement



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- Funded by HGEO to perform collaborative coal R&D with industry
 - >\$22M in research for April 2026 to March 2027 Period of Performance (EY26)
 - Planning for next Period of Performance (EY27) begins next week
 - Coal CoE cannot fund industry coal R&D
- Seeking collaborative industry research:
 - 16 projects identified for current research year, aligned to NETL scope of work
 - Deep Dive presentations
 - “Opportunities” sections of posters
 - Seeking ideas for collaborative research next year
 - Poster Discussions

Pillar	FWP Collabs	Other Agreements
Mining & Processing	4	0
Coal & Waste to Products	3	4-6
Gasification	4	2-4
Power	3	0
Capture	2	12-14*
Total	16	18-24*

* Includes existing cooperative agreements

Industry Engagement



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- NDAs/MTAs: Sharing of industry data or samples for NETL research
- In-kind CRADAs: Each partner equitably contributes their own resources to a collaborative scope of work that meets HGEO's priorities
- Funds-in CRADAs: Industry partner directs and funds NETL research, with added data and IP protections
- Contributed Funds Agreement: NETL performs testing services for industry
- Licensing: See [SAM.gov](https://sam.gov) for opportunities
- Other engagements:
 - NETL may perform work on behalf of HGEO as part of an HGEO-funded Cooperative Agreement with and industry awardee
 - The Coal Center of Excellence is a resource for information on coal R&D activities

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The Toolkit

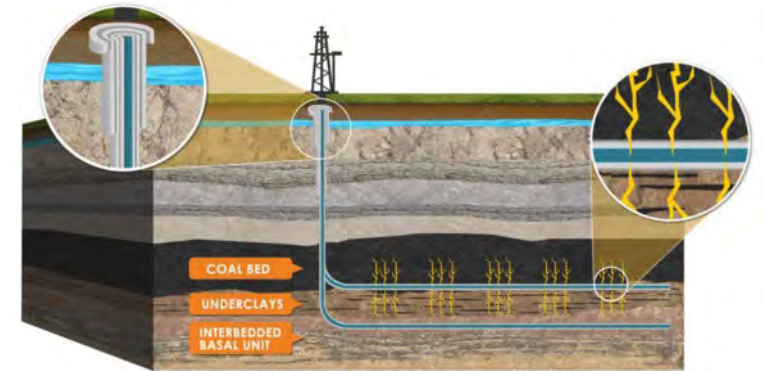
- Cooperative Research and Development Agreement (CRADA)
- Contributed Funds Agreement (CFA)
- Memorandum of Understanding (MOU)/
Memorandum of Agreement (MOA)
- Non-Analysis Agreement (NAA)
- Non-Disclosure Agreement (NDA, NDA+)
- Other Transaction Agreement (OTA)
- Partnership Intermediary Agreement (PIA)
- Informal Discussions
- Licenses

<https://netl.doe.gov/business/tech-transfer/agreements>
Definitions and processes are located at this site.

Available Technologies

Technologies and intellectual property available for licensing on NETL's website:

<https://www.netl.doe.gov/business/tech-transfer/available-technologies>



Notices of Funding Opportunities (NOFOs)

<https://www.netl.doe.gov/business/solicitations>



NETL Coal R&D Portfolio



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Mining & Processing



Coal & Waste Gas to Products



Gasification



Capture



Coal Power



Digital Engineering



Stabilize



Modernize and extend the life of our existing coal mines and coal-based power fleet

Optimize



Optimize efficiencies across extraction, capture, processing, and power generation

Grow



Access and valorize unmineable coal seams, assess technology gaps, and develop R&D plans to overcome gaps

Coal to Carbon Products



- Pitch and Coke for EAF Applications
- Coal to Graphite
- Porous Carbons for Energy Storage Electrodes

Waste Gas to Products



- Electrochemical Processing
- Microwave Processing

Gasification



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Simulation-Driven Design

High-fidelity simulations lower costs and risks while accelerating scale-up

Strategic Data-Driven Analysis

Techno-economic and AI-assisted analyses define design guidelines and optimize gasifier configurations for challenging feedstocks

Next-Generation Gasification Systems

Innovations like cyclic oxidation-reduction mechanism (i.e. modular oxygen production), and microwave-assisted gasification improve efficiency and reduce costs

Commercialization and Industry Impact

Validated models and pilot demonstrations accelerate commercialization and support competitive coal-derived fuel production



Capture



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Carbon Dioxide to Energy

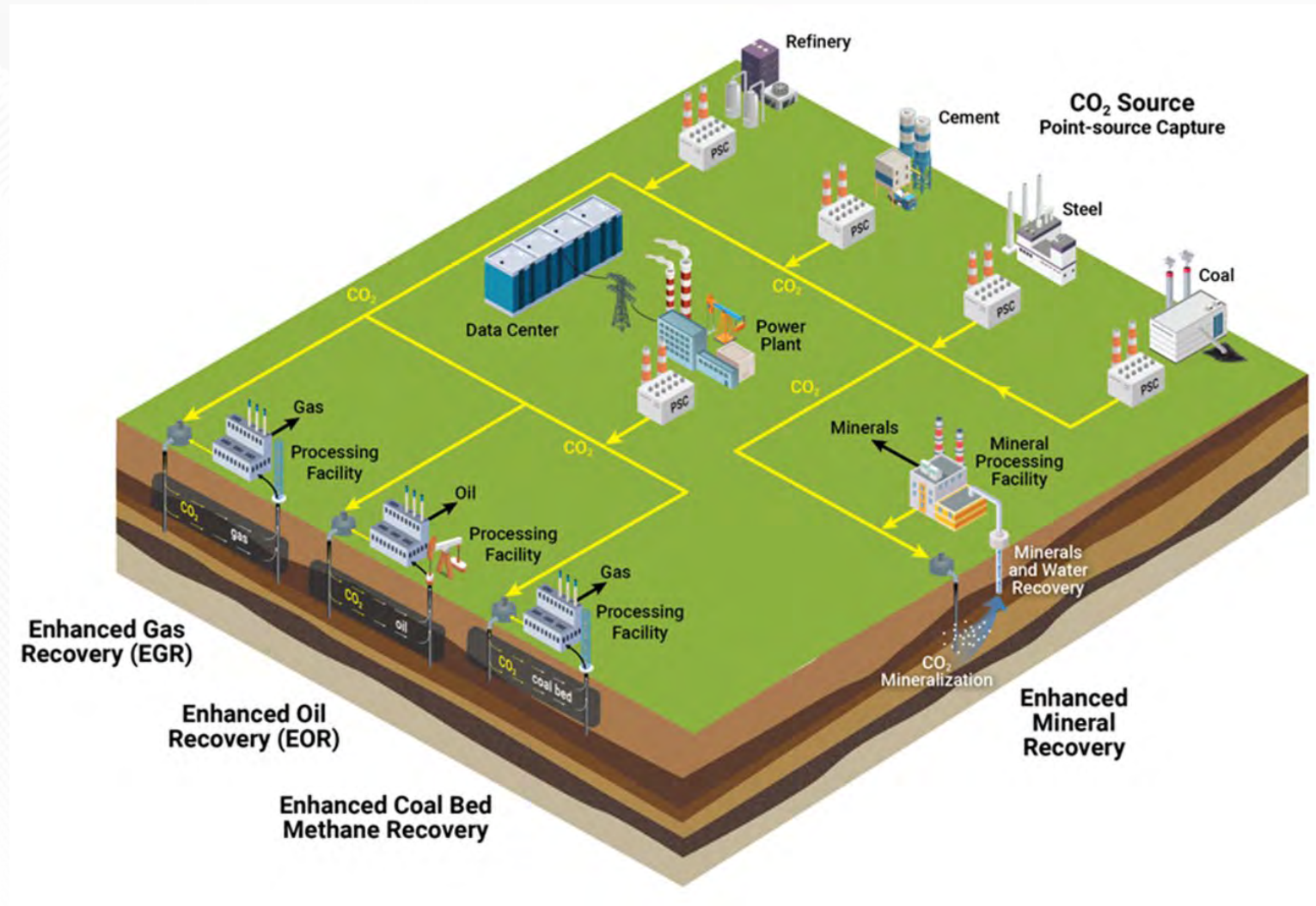
Capture Opens the Door to Enhanced Hydrocarbon Recovery

NETL Supporting Industry

Understanding the business case

De-risking the technology

Scaling improved technology from the laboratory to the field



Coal Power

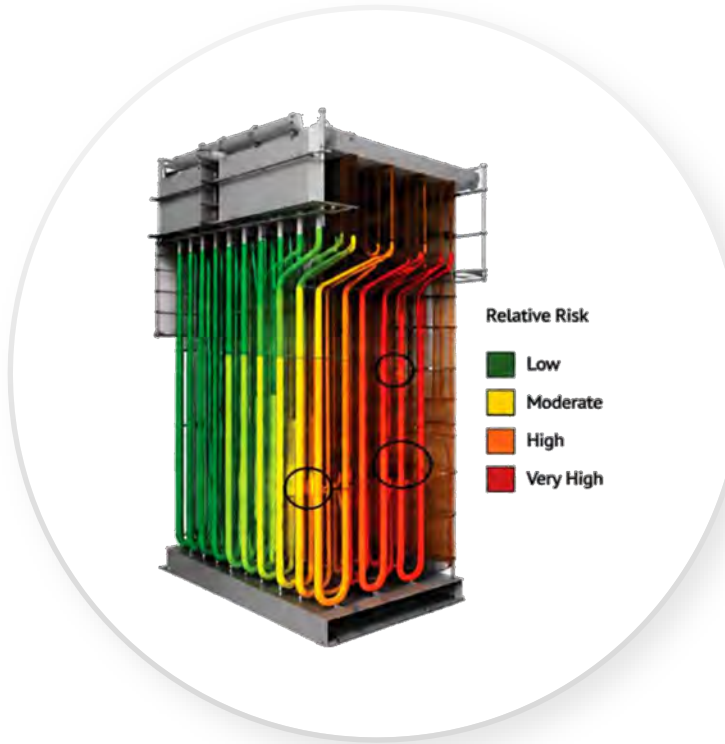
Anthony Burgard, Ph.D.



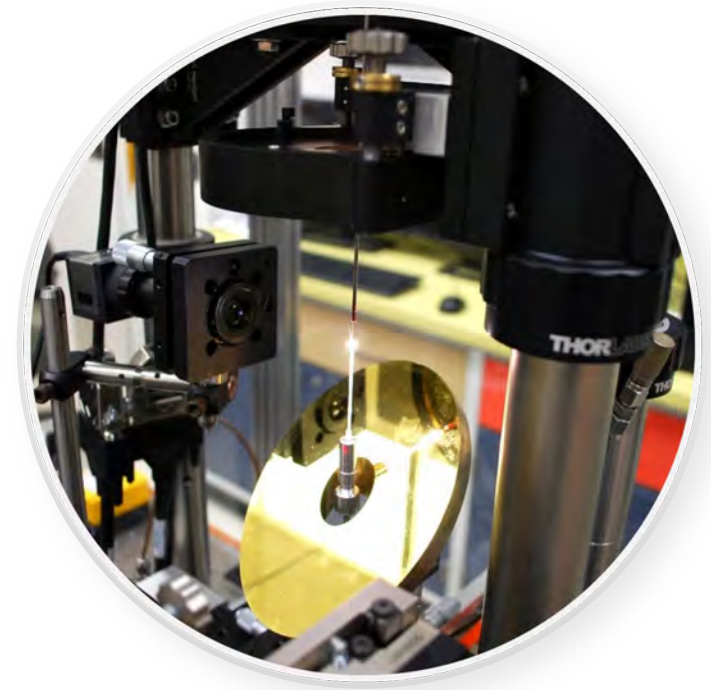
Materials



Systems Analysis



Sensors



Core Materials Capabilities

Multiscale Materials Characterization

- Chemistry, microstructure, defects, physical properties and accumulated damage

High-Temperature and Environmental Testing

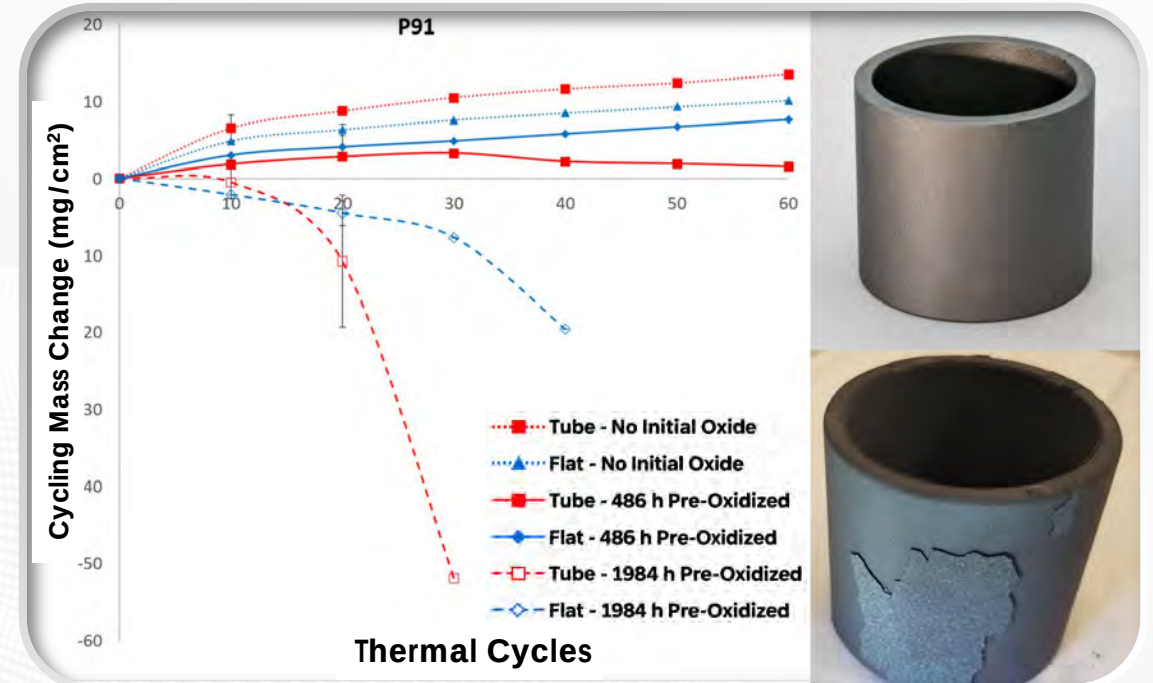
- Creep, creep-fatigue, oxidation, corrosion, supercritical steam/sCO₂ exposure

Degradation and Life-Prediction Modeling

- Link composition, exposure, and damage to remaining life

Alloy Manufacturing and Processing

- Melt, forge, roll, heat-treat and fabricate alloys at pre-production scales (up to 500 lbs)



Existing Fleet and Replacement Components

- Assess service-exposed components & rejuvenation treatments
- Develop improved 9Cr steels for replacement components and targeted upgrades

Future Coal Systems

- Develop affordable 9-12 Cr steels for higher temperatures and pressures
- Improve ductility while retaining creep strength and component life

Accomplishments

ADVANCED 9Cr STEELS

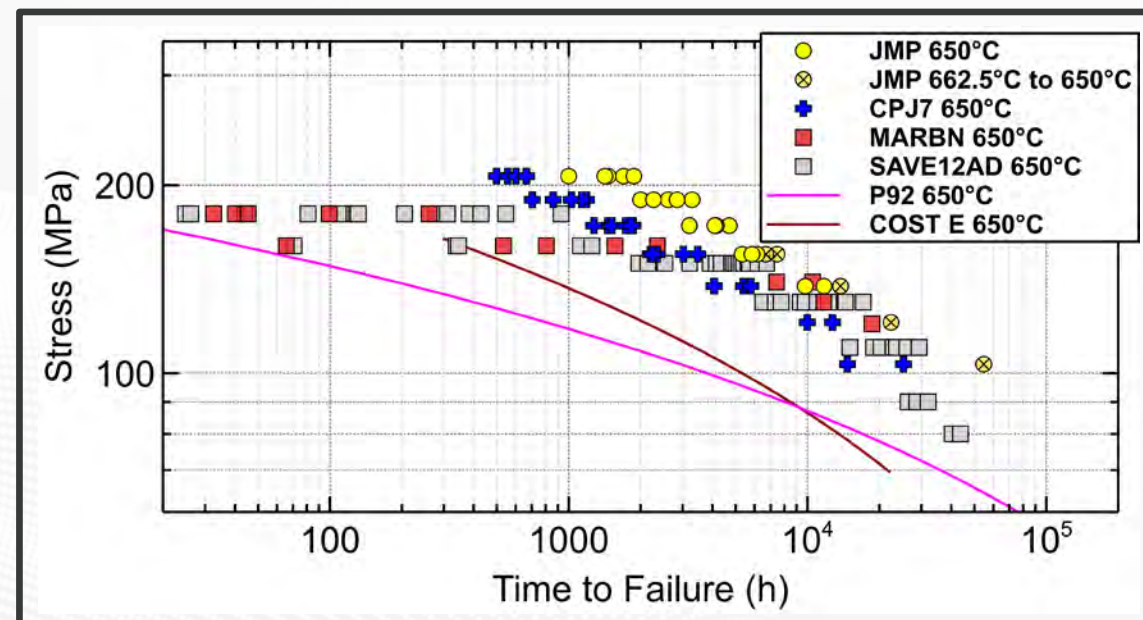
- Developed CPJ-7 and JMP alloy families, ~50 compositions manufactured using industry-relevant methods

420,000 h

- Cumulative in-house creep testing; JMP-4 reached 21,908 h at 662.5°C / 103 MPa

STATE-OF-THE-ART CREEP PERFORMANCE

- JMP as good as or better than MARBN and SAVE12AD across 103–207 MPa



Industry Engagement

EPRI

- Advanced alloy designs
- Helped establish 70% ductility as a commercially relevant target

U.S. Coal Fleet Utility

- Material degradation, condition assessment, and life extension discussions
- Offered to help source service-exposed boiler tubes for characterization and model validation

Core Systems Analysis Capabilities

Performance & Cost Analysis

- Common-bases TEA, LCOE, NPV and sensitivity analysis

Integrated Plant Modeling

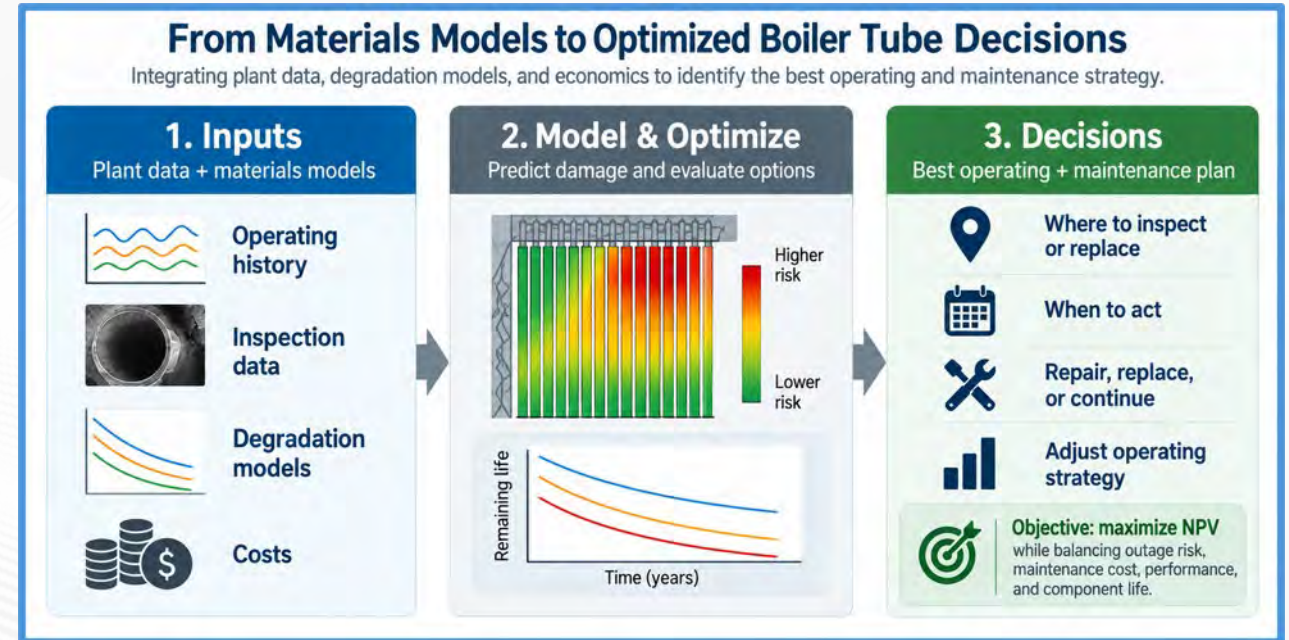
- Steady-state and dynamic models of plant systems and controls

Data Integration & Model Validation

- Reconcile plant data; calibrate and validate models

Degradation-Aware Multi-Period Optimization

- Link operating profiles to component damage, remaining life, and plant performance



Current Efforts

Digital Engineering

- Boiler-tube inspection and replacement planning
- Plant-specific operational and maintenance support

Core Systems Analysis Capabilities

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Integrated Plant Modeling

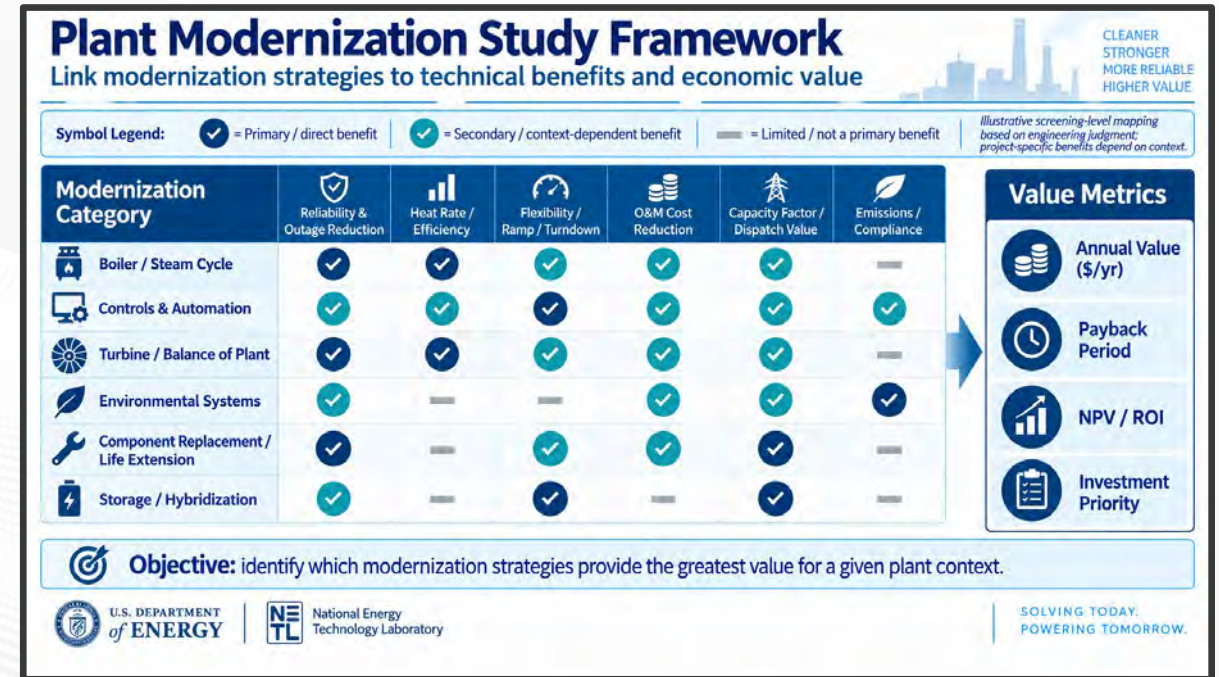
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Current Efforts

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Fleet Modernization

- Modernization and life-extension analysis
- Valuation of coal plant attributes
- Forced-outage driver analysis and mitigation

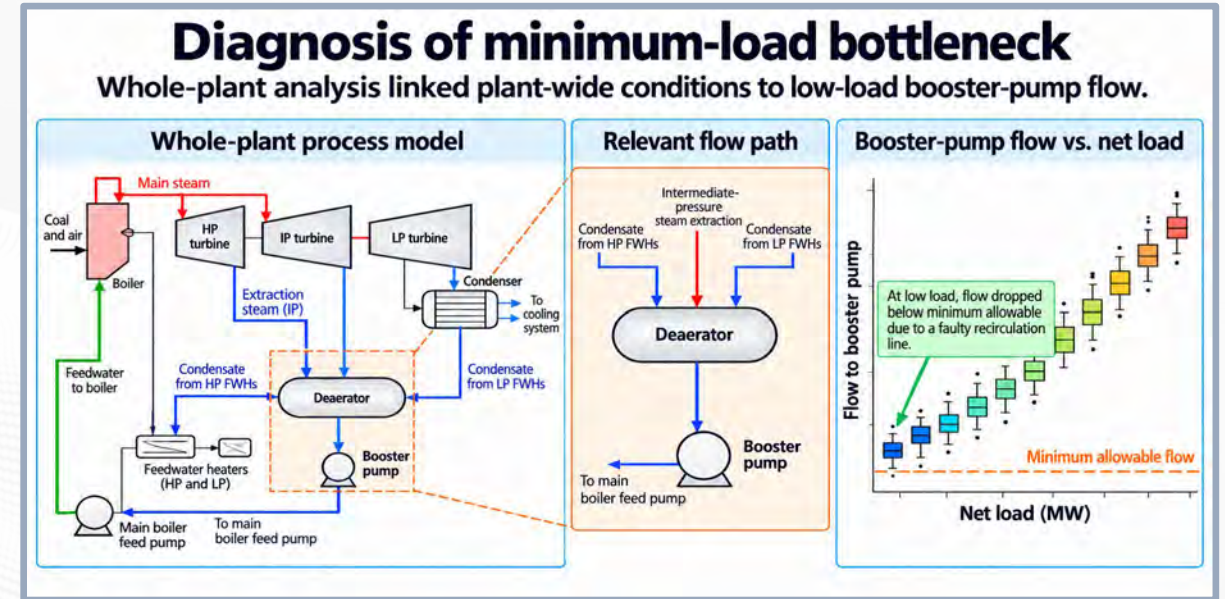
Core Systems Analysis Capabilities

44%

Lower minimum operating load;
Plant-specific modeling helped reduce
minimum load from **90 to 50 MW**

4-5 days

Potential early warning of superheater
plugging; compared with only 1-2 days
of visible warning before prior failure



Industry Engagement

U.S. Coal Fleet Utility Partner

Wet FGD optimization down-selected for detailed scoping

EPRI

Industry input on boiler-tube inspection and replacement modeling

Core Sensing Capabilities

Crystalline Optical Fiber Development

- Sapphire-fiber growth, dopants, splicing & high-temperature packaging for extreme environments approaching $\sim 1,500^{\circ}\text{C}$

Distributed Temperature Sensing (DTS)

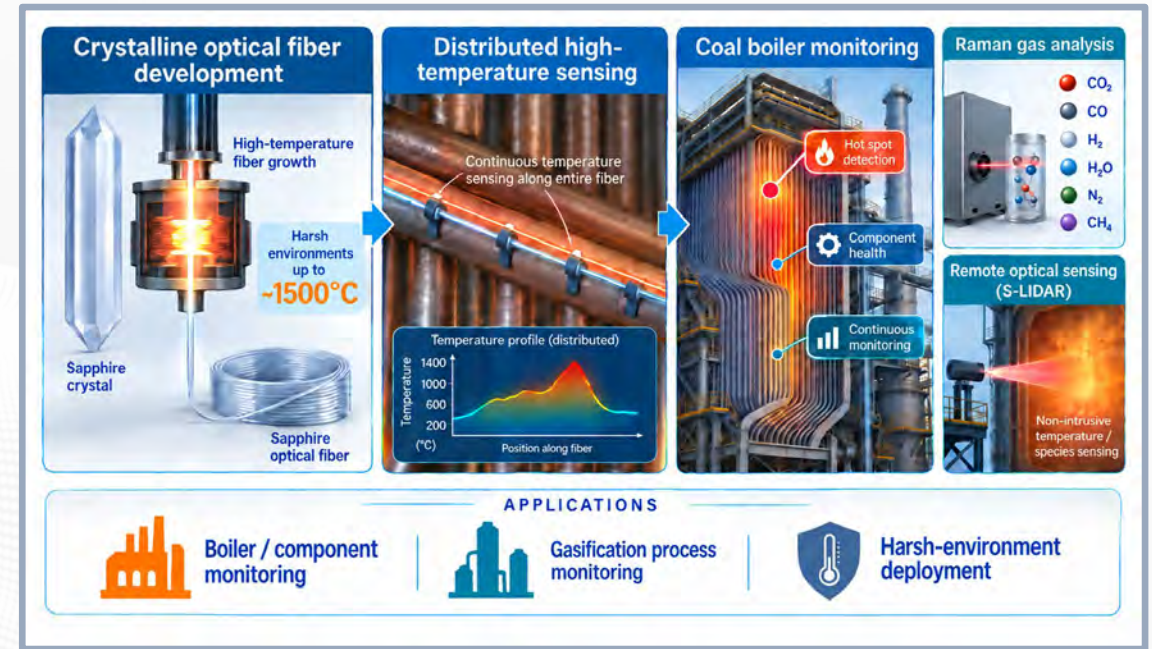
- Raman-DTS along crystalline fiber with several-centimeter spatial resolution

Fast Raman Gas Analysis

- ~ 1 -second, multi-species gas measurements at elevated pressure

Remote Optical Sensing

- Raman Light Detection and Ranging (LIDAR) for spatially resolved temperature/species measurements with single-point optical access



Current Efforts

Coal Boiler Temperature & Component Monitoring

- Identify highest-value sensing applications and performance targets
- Develop and bench-test boiler-relevant fiber packaging
- Establish a 2027 field-test pathway

High-Temperature Distributed Sensing

- Improve fiber length, optical performance, and R-DTS range/resolution
- Translate laboratory fiber performance into deployable sensing systems

Raman Process Sensing

- Test the Raman Gas Analyzer under gasification-relevant conditions
- Advance LIDAR optics toward non-intrusive boiler measurement

Accomplishments

HIGH-TEMPERATURE CRYSTALLINE FIBER

Improved sapphire-fiber dopants and sol-gel recipes to enable longer sensing fibers.

1m

NETL-grown crystalline sapphire fiber demonstrated w/ custom R-DTS

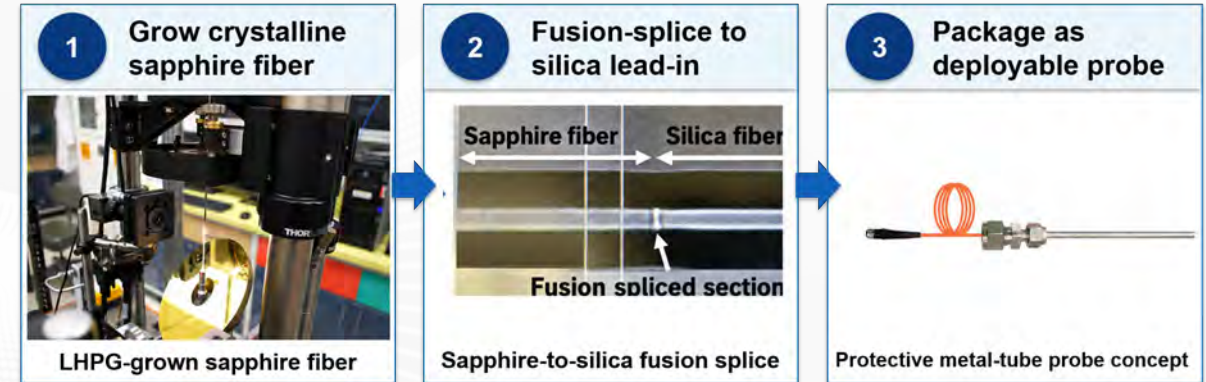
Coal-boiler applications expected to require ~5–10 m

5–10 cm | ~1,500°C

R-DTS spatial resolution and high-temperature capability

Optical design revised to improve range and resolution

Crystalline Fiber Growth & Packaging Progress



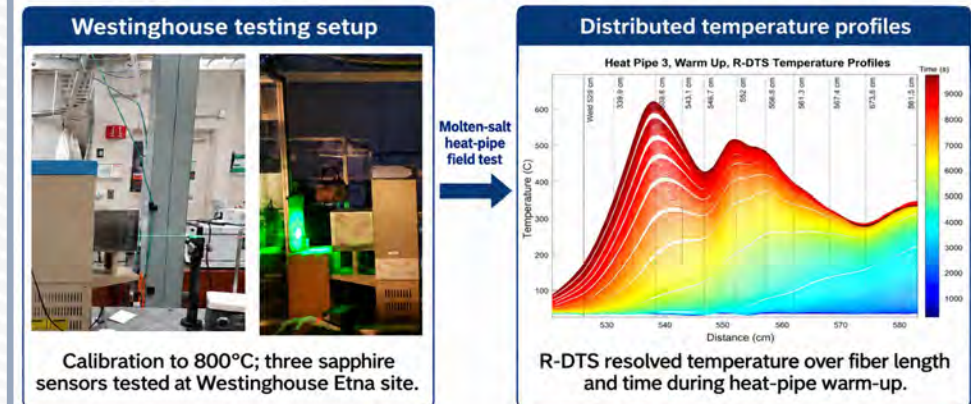
From fiber growth to a deployable harsh-environment sensing probe

Industry Engagement

Westinghouse

- Completed CRADA field testing of NETL sapphire R-DTS on molten-salt heat-pipe hardware
- Captured distributed temperature profiles during warm-up and cool-down

Field Testing of Distributed Temperature Sensing

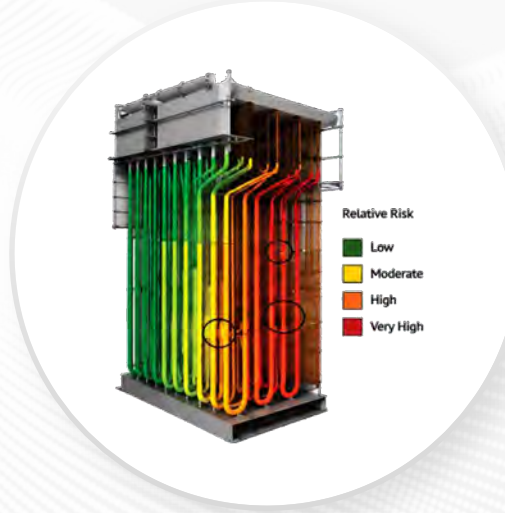


Materials



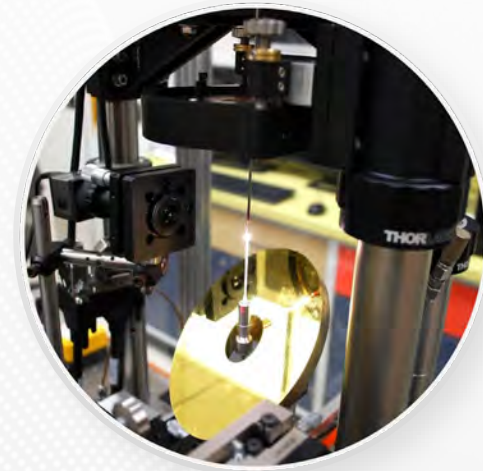
- Service-exposed components and operating histories
- Performance targets for creep, ductility, and component life
- Priority applications for advanced alloys and rejuvenation

Systems



- High-value reliability, flexibility, and efficiency challenges
- Plant operating, inspection, and failure data
- Modernization business cases — costs, benefits, valuation & decision criteria

Sensors



- Highest-value locations & applications
- Pilot/field testing opportunities for packaging, survivability, and long-duration performance
- Performance targets for sensing length, resolution, response time, and accuracy

Digital Engineering

Kirk Gerdes, Ph.D.



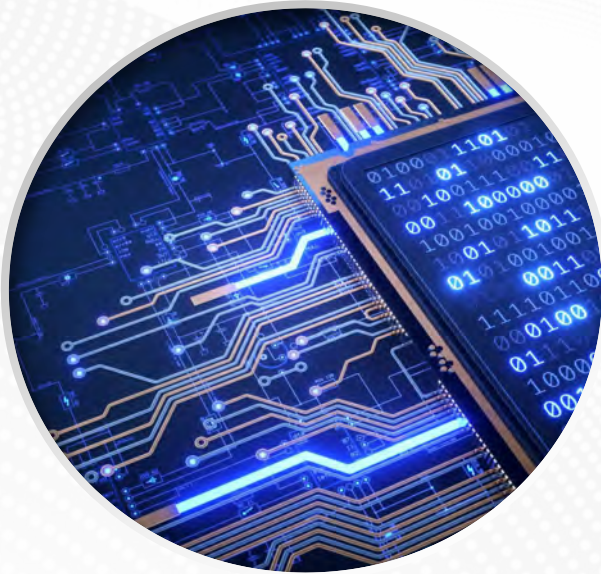
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Our Focus: Leveraging Data for Reliable Power



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With digital engineering and digital twins, we can:

- Increase the life of existing coal-fired generation resources
- Improve data center design and function
- Facilitate/optimize integration of both into the existing grid



Benefits for the Nation include:

- Coal-fired power plants: extend life, more profitability
- Power grid: manage massive challenges, balance customer interests with needs of data center industry/country
- Data centers: better designs, more rapid commissioning, increased ability to meet market need



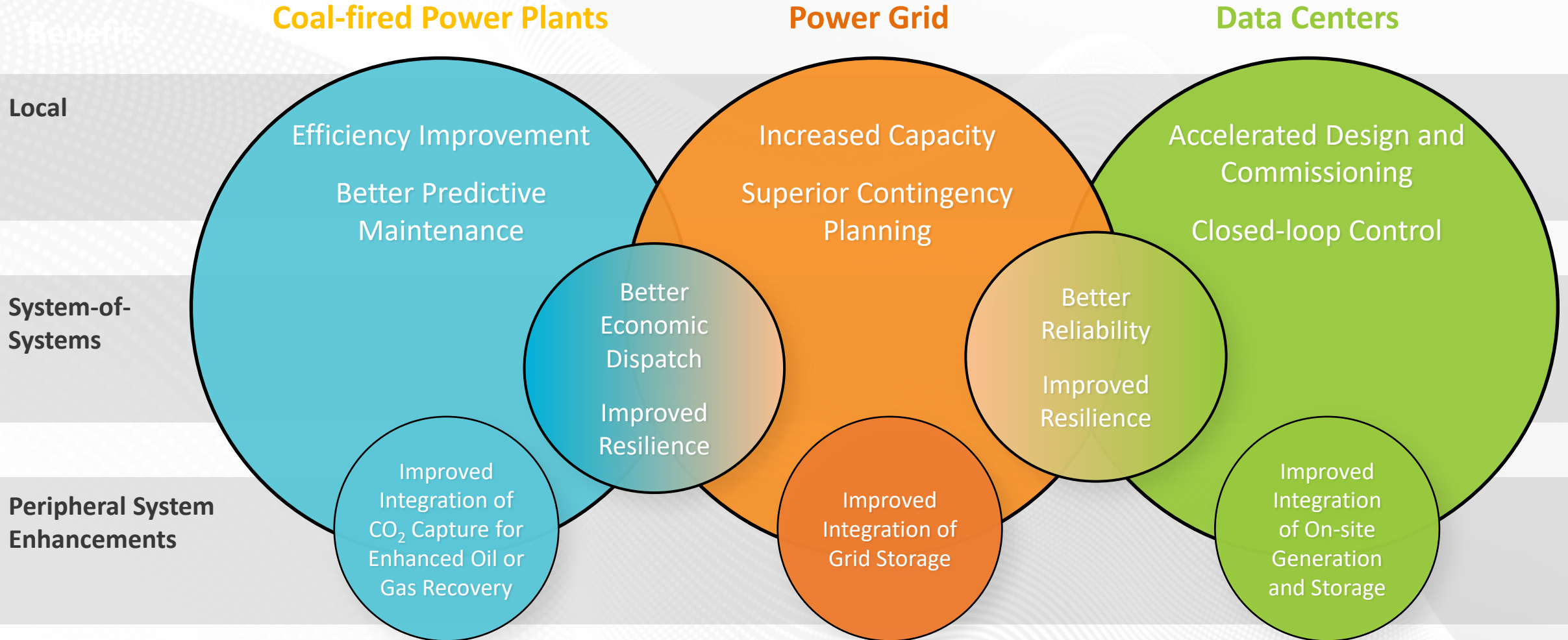
With NETL's expertise, we can have:

- Reliable, affordable, secure baseload power
- A resilient, modern power grid
- Lower electricity bills for communities
- A robust AI/data center industry that ensures America's role as a leader on the world stage

Digital Engineering Lowers Costs, Improves Reliability



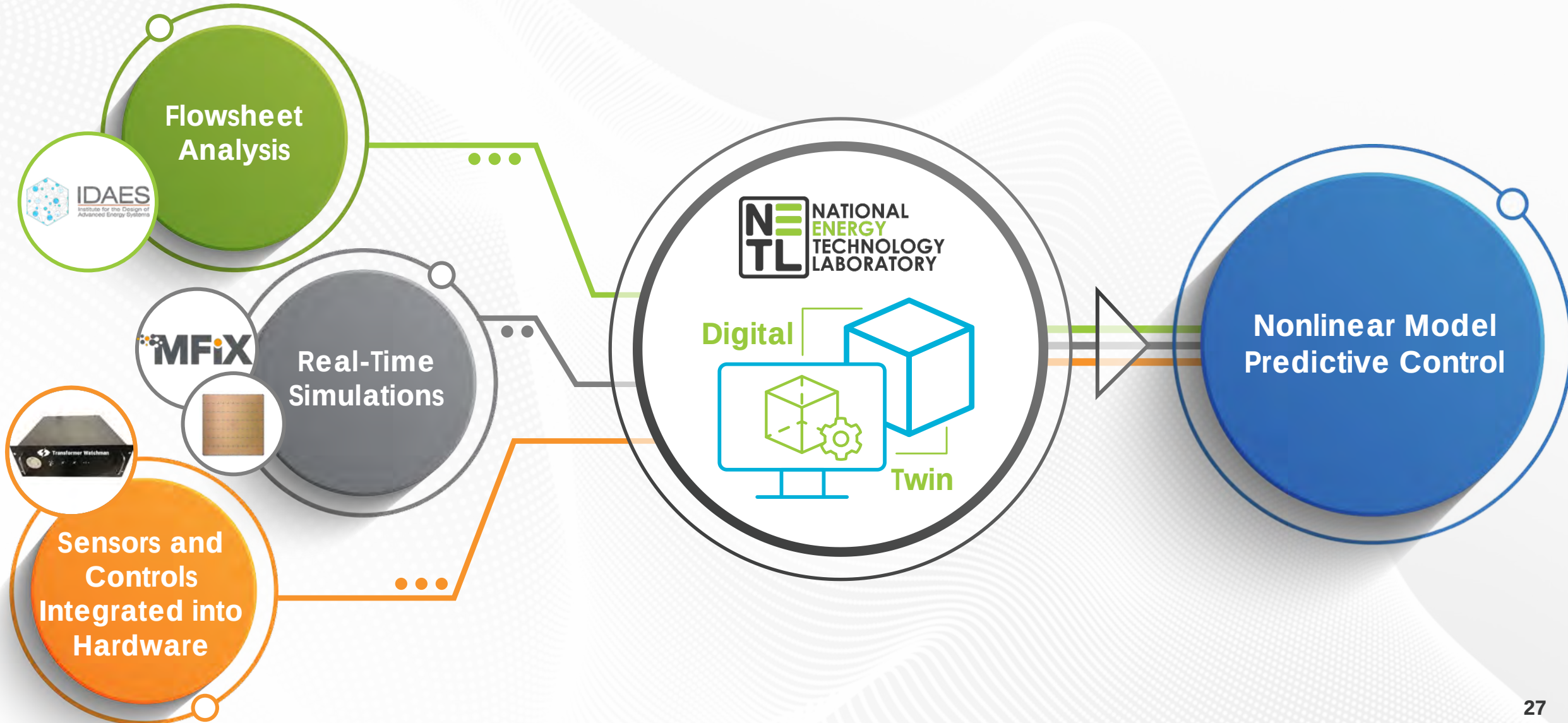
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Digital Engineering in Action



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Flowsheet Analysis



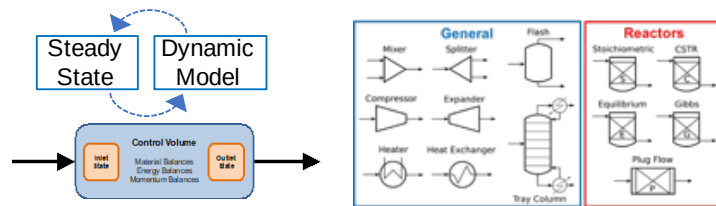
IDAES Integrated Platform



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Modeling Framework



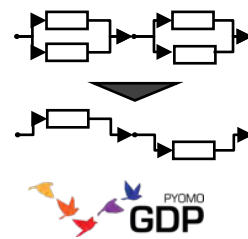
Hierarchical - Steady-State & Dynamic - Model Libraries

Open Source: github.com/IDAES/idaes-pse

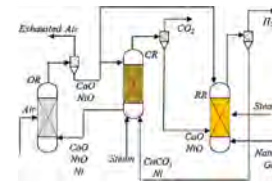
Documentation: idaes-pse.readthedocs.io/en/stable/

Lee, et al., *J. of Adv. Manufacturing and Processing* (2021)

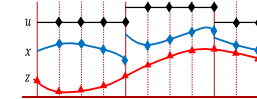
Conceptual Design



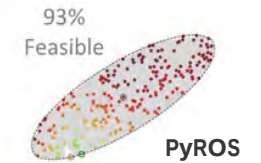
Plant Design Process Optimization



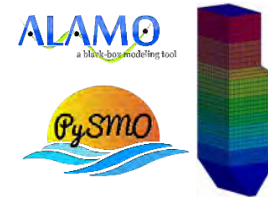
Process Operations Dynamics & Control



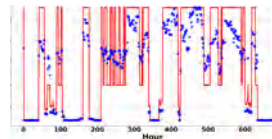
Uncertainty Quantification Robust Optimization



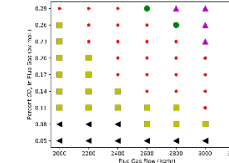
AI/ML Surrogate Modeling



Process/Market Co-Optimization



Process Family Design



Infrastructure Planning of Reliable Power Systems





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Real-Time Simulations



Models & Simulations at Unprecedented Speeds

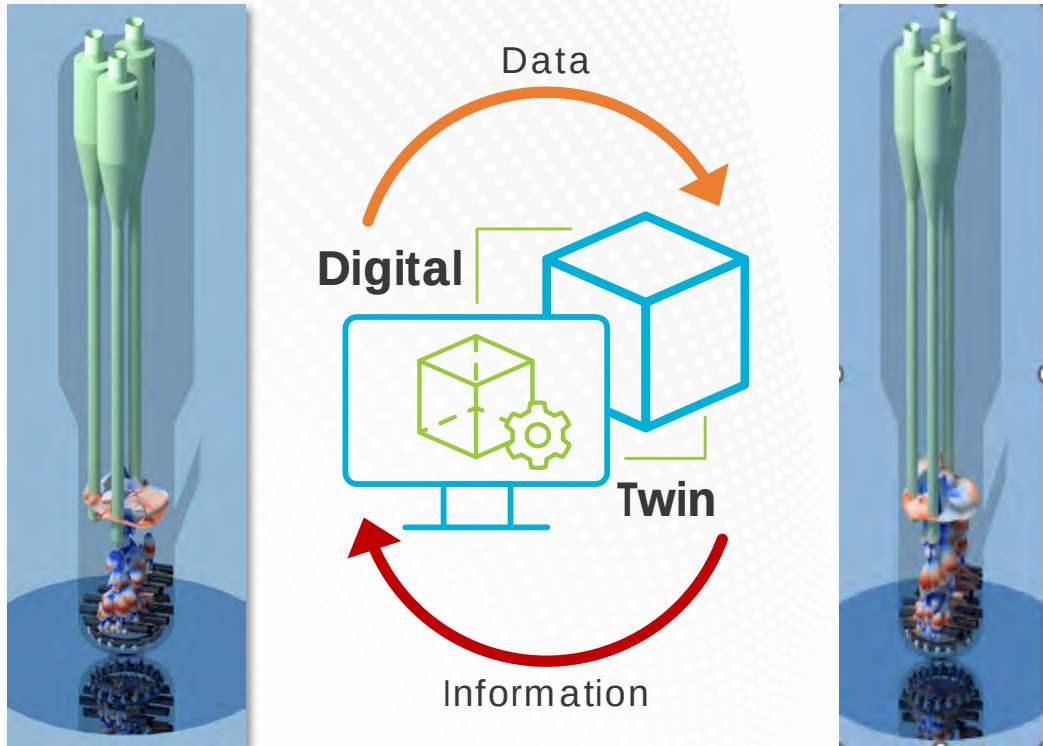


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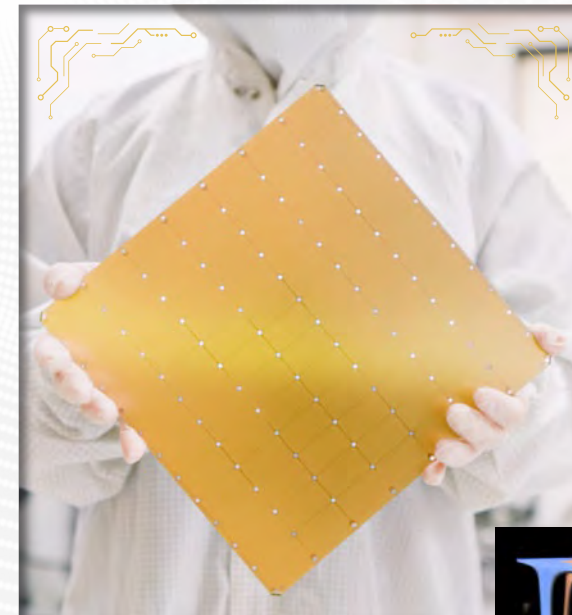
Run MFiX simulations on Joule 3.0 Supercomputer:

- Exascale-capable multiphase computational fluid dynamics code
- 107K cores, 6.11 PFLOPS

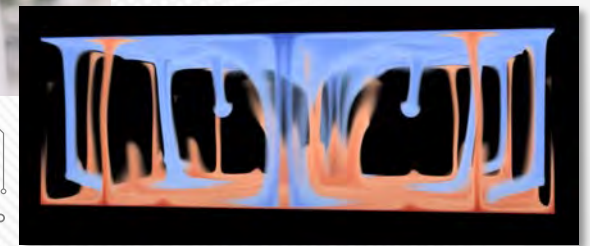


Level up with the Cerebras Wafer Scale Engine:

- Fastest AI chip on Earth
- 900K cores, 125 PFLOPS



1,000x
More power efficient
than HPC

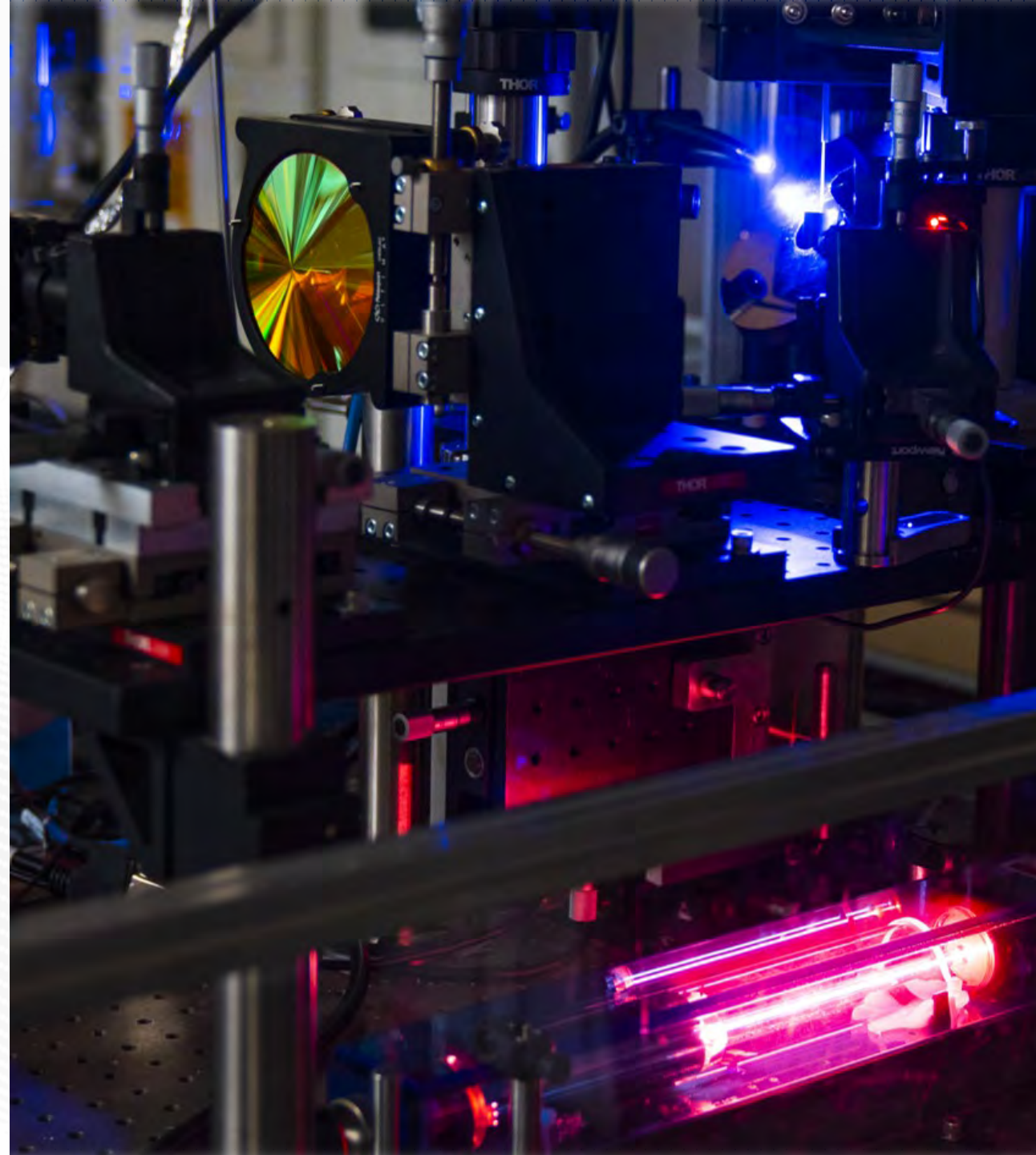




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Integrated Sensors & Controls



Nonlinear Model Predictive Control



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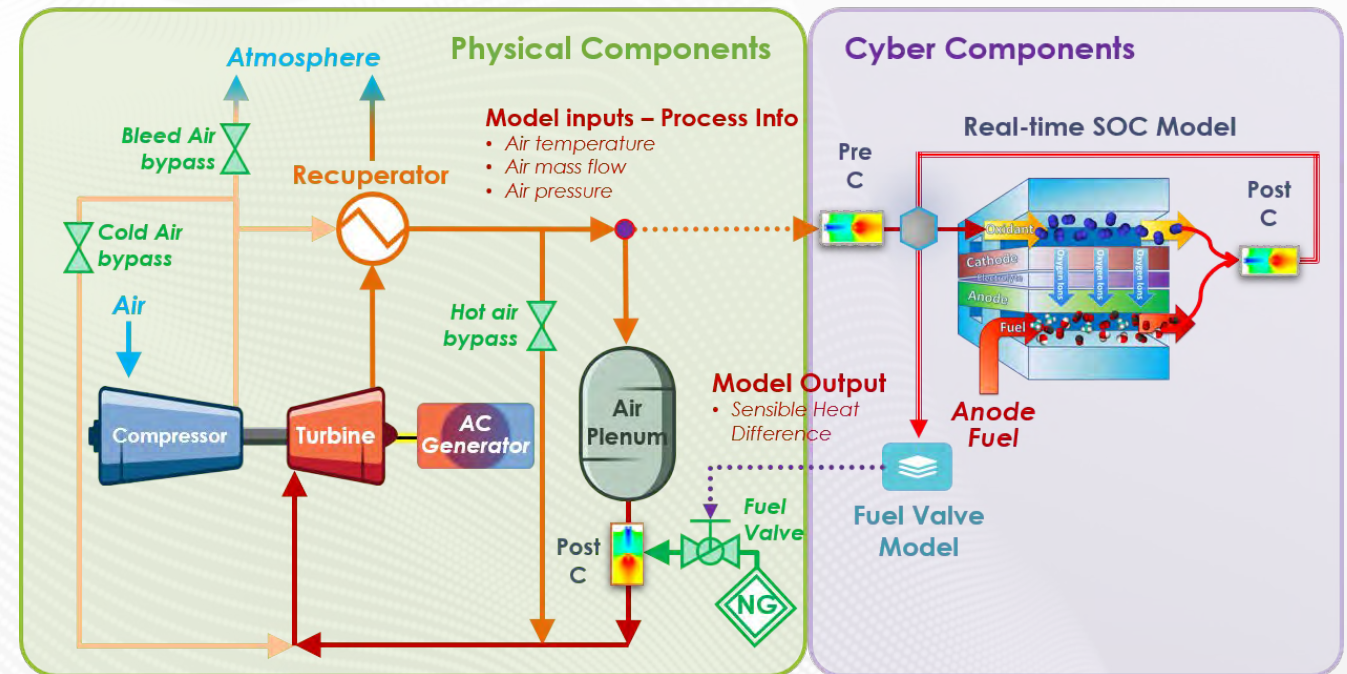
Real-time device models enable systems integration and optimization

NETL established a framework for linking WSE models to cyber-physical systems, enhancing system/device co-optimization

- Developed submodules for each set of physics
- Validated against conventional models
- Prepared input/output requirements for interfacing WSE model with cyber physical systems in real time

The result: A readily-adaptable framework to optimize performance and lower costs

HYPER Cyber-physical System



Solutions to address a rapidly-evolving challenge



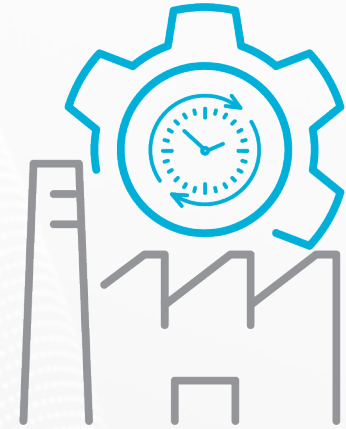
Efficiency Improvements

- Combustion Optimization and Excess Air
- Improved Steam Temperature Control
- Auxiliary Parasitic Load Reduction



Better Predictive Maintenance

- Intelligent, Dynamic Soot Blowing Improves Boiler Tube Life
- Improved Condenser Performance and Backpressure Optimization
- Extended Auxiliary Equipment Life



Extended Operational Life

- Increased Flexibility in Operations and Startup
- Improved Cost Competitiveness



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Thank You!

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