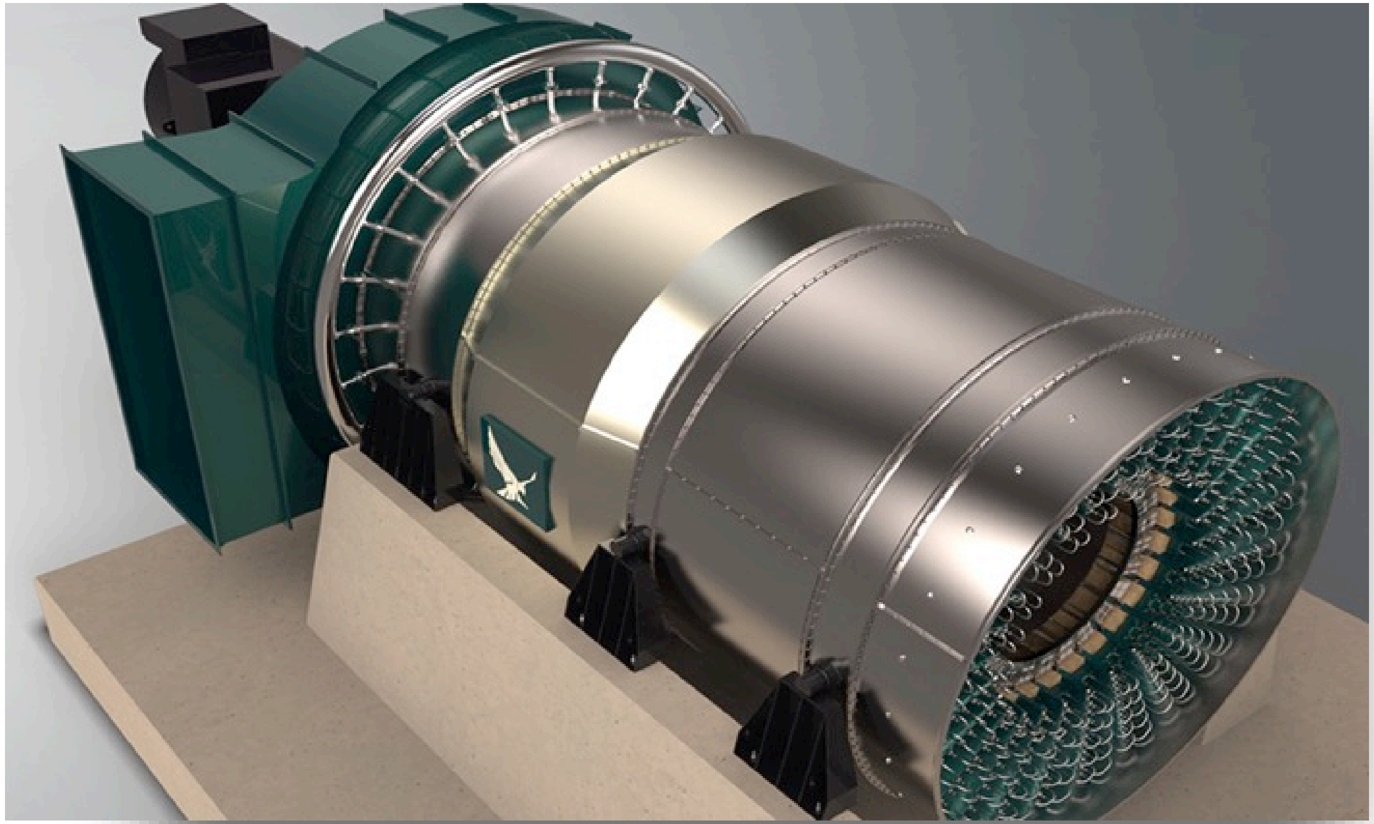
Overview of the Fossil Energy (FE), NETL, & NL Extreme Environment Materials (EEM), *extremEmat*, Program



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FE Extreme Environment Materials - *extremEmat*

Extreme Environment Materials Program — Fossil Energy | National Energy Technology Laboratory

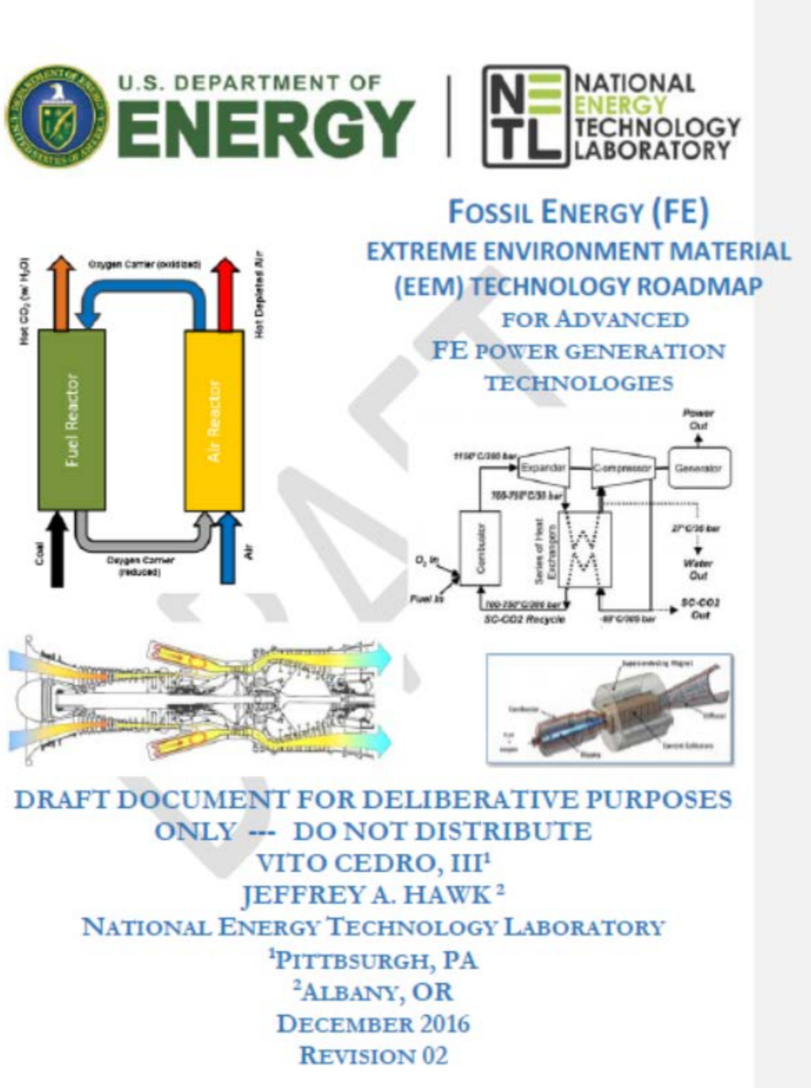
Goal:

Develop modeling methodology tools and manufacturing processes that can provide a scientific understanding of high-performance materials compatible with the hostile environments associated with advanced Fossil Energy (FE) power generation technologies.

Objective:

Materials R&D focused on structural and functional materials that will lower the cost and improve the performance of fossil-based power-generation systems.

Regis Conrad: Advanced Energy Systems Overview (April 28, 2016)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FOSSIL ENERGY (FE)
EXTREME ENVIRONMENT MATERIAL (EEM) TECHNOLOGY ROADMAP FOR ADVANCED FE POWER GENERATION TECHNOLOGIES

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REVISION 02

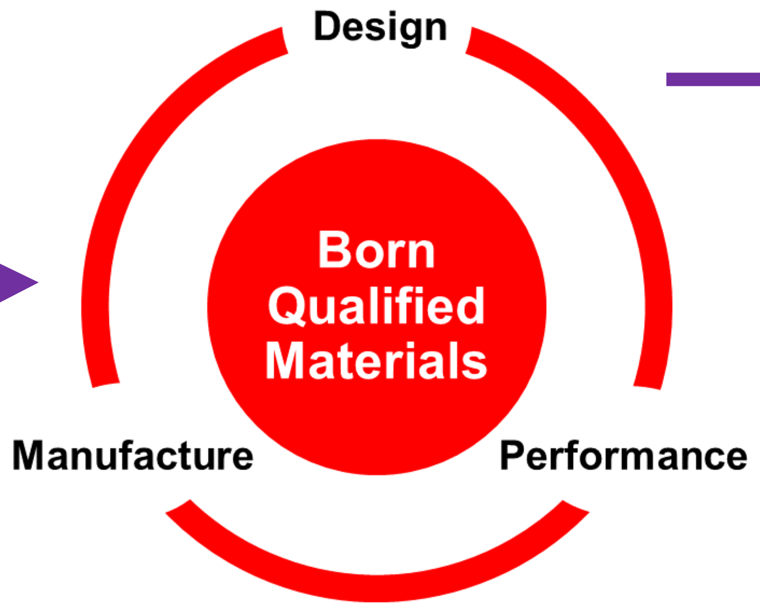
DOE-FE/NETL Vision

"Born Qualified" EEMs

<u>Atoms to Metals</u>
ICME multi-scale computational approaches incorporating best practice manufacturing and focused performance evaluation and characterization

<u>Targeted Validiation Experiments</u>
Conducted in industrial relevant environments and scales

<u>Data Informatics and Analytics</u>
Analyze the large volume of data generated from materials testing incorporate leaning to improve predictive capability of simulations and reduce uncertainty.



Validated simulations linking structure, processing and performance.

Accelerate the identification and deployment of <u>cost effective materials</u> by 2X for extreme environment applications.

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Long-term extremEmat Capability Theme Areas

Manufacturing Science	Modelling and Simulation	*In situ* characterization and test beds	Data Analytics
Pilot Scale Manufacturing Facility Process Modeling and Control Process Science	Integrated Computational Materials Engineering (ICME) Scale Bridging Theories and Codes Code Validation Methods	Capture Kinetic Response Incipient Failure (multi-axial, cyclic/dwell) Showcase multiple condition environments	Flexible Open-Access Databases Materials Properties Data for Extreme Environments Analytical Tools

Developing cross-cutting “tool sets” focused on accelerating discovery & scale-up for reliably manufacturing materials at scale.

Cost Analysis Engine

Applications	**Design for Resilience**	**Modeling & Reliability Validation**	**Manufacturing & Scalability**	**In Situ & Operando Characterization**	**Failure Analysis & Data Analytics**
Advanced Steam/CO_2 Turbines/Thick Wall Components	Increase operating temperature range of current candidate austenitic and martensitic-ferritic steels, e.g., alloy 347, by 50°C.				
Waste Heat Recuperators / Heat Exchangers	Reduce the costs (at least 30% over the life cycle) of a nickel-based alloy, e.g., H282 or IN-740 capable of 760°C, 25 year service in corrosive environment.				

Material Degradation Science and Engineering

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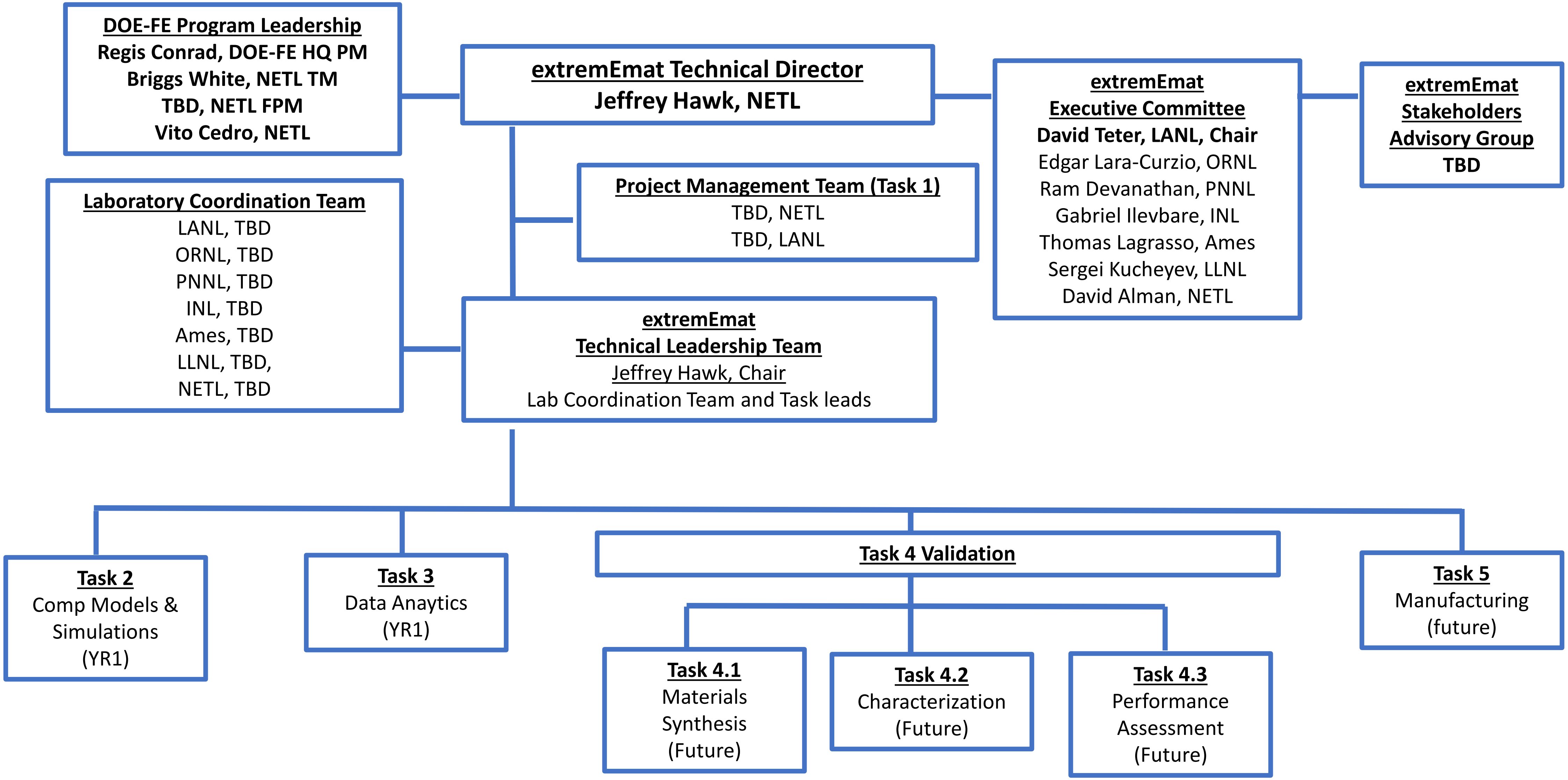
extremEmat - Proposed Organizational Structure



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High Strength, High Temperature Austenitic SS Alloys

- FY17-FY18 Challenge & Technical Effort

Supports EEM Technology Roadmap goal of enabling supercritical CO_2 (sCO_2) technologies through development of High Yield Strength, High-Temperature Austenitic Stainless Steels for extended high temperature service in demanding environments.

Challenge: Increase the yield strength of austenitic SS above current state-of-the-art commercial SS alloys to enable long-term operation at temperatures, at least 50ºC above 650ºC, while maintaining low cost and fabricability, making use of NL complex computational tools integrated with experimental validation.

Benefit: While targeting austenitic SS, the computational methodologies & validation procedure developed in this project will benefit other lower cost alloys such as 9-12% Cr steels. Modeling framework & informatics/analytics development tools should benefit more difficult/complex materials issues in gas turbines, direct energy extraction, etc.

Leverage Opportunity: In addition, there is interest in improving the creep strength of ferritic alloys at 700°C by designing the size, morphology, distribution, and composition of precipitates (i.e., mesoscale microstructure development).

Low Cost, High Performance Ni-based Alloys

- FY17-FY18 Challenge & Technical Effort

Supports EEM Technology Roadmap goal of enabling supercritical CO_2 (sCO_2) and gas turbine (limited) technologies through development of high performance, low(er) cost nickel superalloys for extended high temperature service in demanding environments.

Challenge: Develop nickel superalloys with higher creep strength than H282 and IN740H at no, or minimal additional alloy, cost while maintaining the favorable fabrication and welding properties of both alloys. (1) Lower cost by element substitution approach; (2) Improve high temperature mechanical strength overall, and creep life in particular, by optimally stabilizing microstructure relative to H282/IN740H.

Benefit: Nickel alloys are expensive and to facilitate use they must be affordable on a cost to performance basis. Their use can guarantee optimum efficiency design goals for A-USC, sCO_2 and other FE systems needing performance at this level. (Ditto: Modeling framework …)

Leverage Opportunity: Achieving similar performance through element manipulation, and/or improving microstructure stability leading to improved creep life, can in principle be used on other alloy system classes (e.g., high γ' fraction nickel superalloys).

FY17: Gap Analysis of Computational Techniques

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    - Michael Glazoff, INL
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    - Ram Devanathan, PNNL
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  - **2.4 Mechanical Models**
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    - Richard Wright, INL
  - **2.5 Continuum Models**
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    - Jeffrey Hawk, NETL
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    - Michael Gao, NETL
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