Advanced Ultra-Supercritical Technology Developments and Update on ComTest Project

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Virtual Meeting

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Goals: The A-USC ComTest Project will lead to…

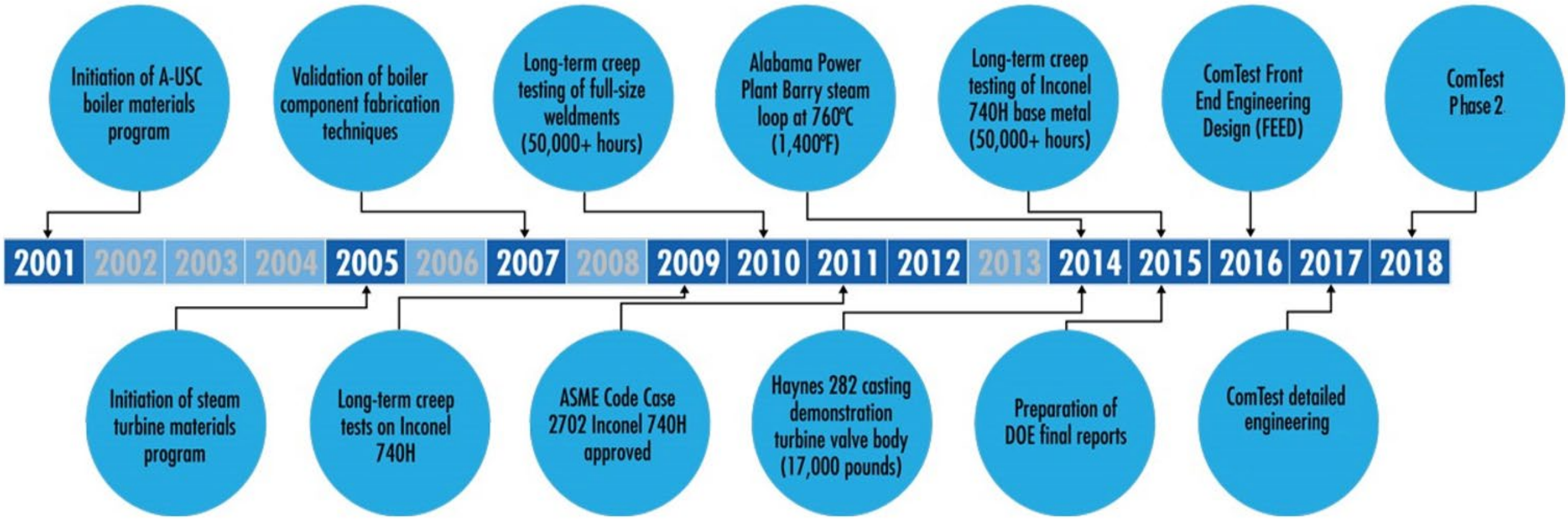
- **Higher efficiency** for new and existing fossil fuel plants
  - 10% above today's new state-of-the-art coal power plants, and
  - 25% above that of the average power plants in the U.S. existing fleet
- **Lower emissions** (NOx, SOx, CO_2)
- **Minimized risk** for utilities desiring to build A-USC plants
- Support for design of **A-USC boiler & steam turbine** at 760°C
- Accelerated development of U.S. domestic **supply chain** for advanced materials and components
- **Validation of technology** applicable to fossil, nuclear, sCO2, and renewable power generation options, all targeted by the U.S. DOE NETL Cross-Cutting Research Technology Program

Pathway to Increased Efficiency of Rankine Cycle

Nomenclature	Steam Conditions	Net Plant Efficiency (HHV)
Subcritical	2400psig 1000 to 1050°F	35%
Supercritical (SC)	>3600psig ~1050°F (550°C) and above	38%
Ultrasupercritical (USC)	>3600 psig ~1100°F (600°C) and above	>42%
Advanced-Ultra Supercritical (A-USC)	4000-5000psig 1300-1400°F (700-760°C)	>45%

Materials are the limiting factor to achieving higher efficiency

History of the United States A-USC Program



Background of US A-USC Materials Programs

Present work builds upon 15-year effort, administratively managed by **Energy Industries of Ohio**, with technical management by **EPRI**, supported by **U.S. Department of Energy**, **Ohio Coal Development Office**, and industry participants

- Boiler Materials for Advanced Ultra-supercritical Coal Power Plant
  - DOE Contract: DE-FG26-01NT41175
  - OCDO Grant: CDO-D-05-02(A)
- Materials for Advanced Ultra-supercritical Steam Turbines
  - DOE Contract: DE-FE0000234
  - OCDO Grant: CDO-D-05-02(B)

Primary Technical Goals of US A-USC Materials Programs

- Evaluate materials technology for A-USC
  - Focus on **nickel-based alloys**
  - Develop fabrication and joining technology for new alloys
- Consider the unique conditions for US program
  - Higher-temperatures than other international programs (760°C versus 700°C) means **additional alloys** evaluated
  - For boiler:
    - Corrosion resistance for **US coals**
    - Data for **ASME BPV Code** acceptance of new materials
    - Impact of combining A-USC with other CO_2 capture technologies such as **Oxy-combustion**
    - Design for cycling operation to maximize flexbility

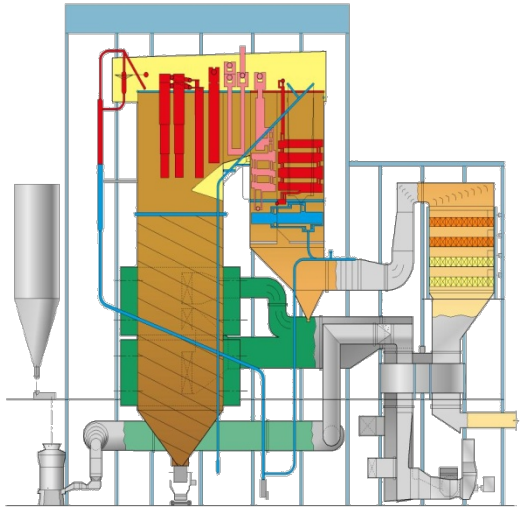
Accomplishments of ComTest Phase I

- Completed Pre-FEED and FEED tasks
- Prepared preliminary capital cost estimates
- Worked with suppliers to develop supply chain
- Developed test plan for Producing Components
- Selected suitable supply chain candidates for making full scale components
- Identified U.S. foundry, forge, extrusion and fabrication capability which is now competing with Defense needs.

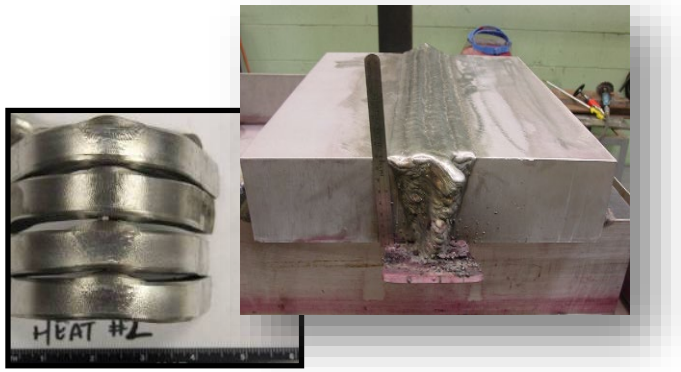
Phase II work plan to build upon Phase I results

Tasks Completed in A-USC Materials Programs

General design studies show favorable economics



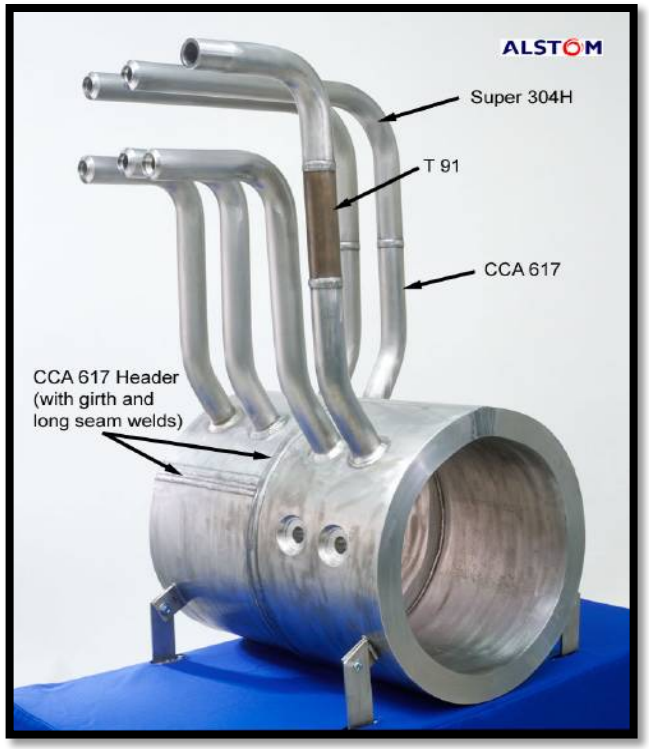
Steam-Side Oxidation



Welding Technology Developments

Fireside Corrosion (High-Sulfur Coal & In-Plant Testing)

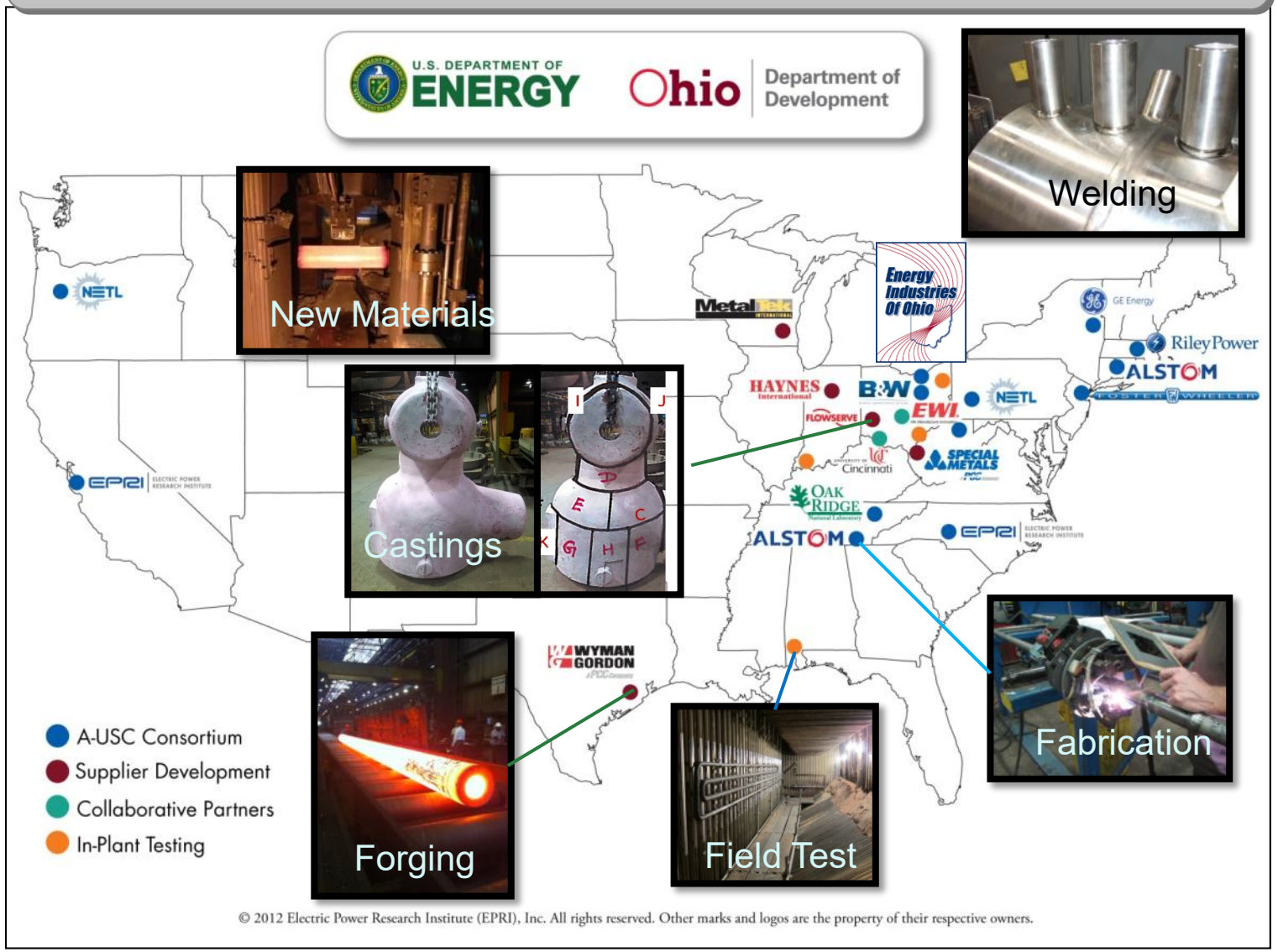
Fabrication Processes



Turbine Component Scale-up

Next Step… Building Upon Prior Work

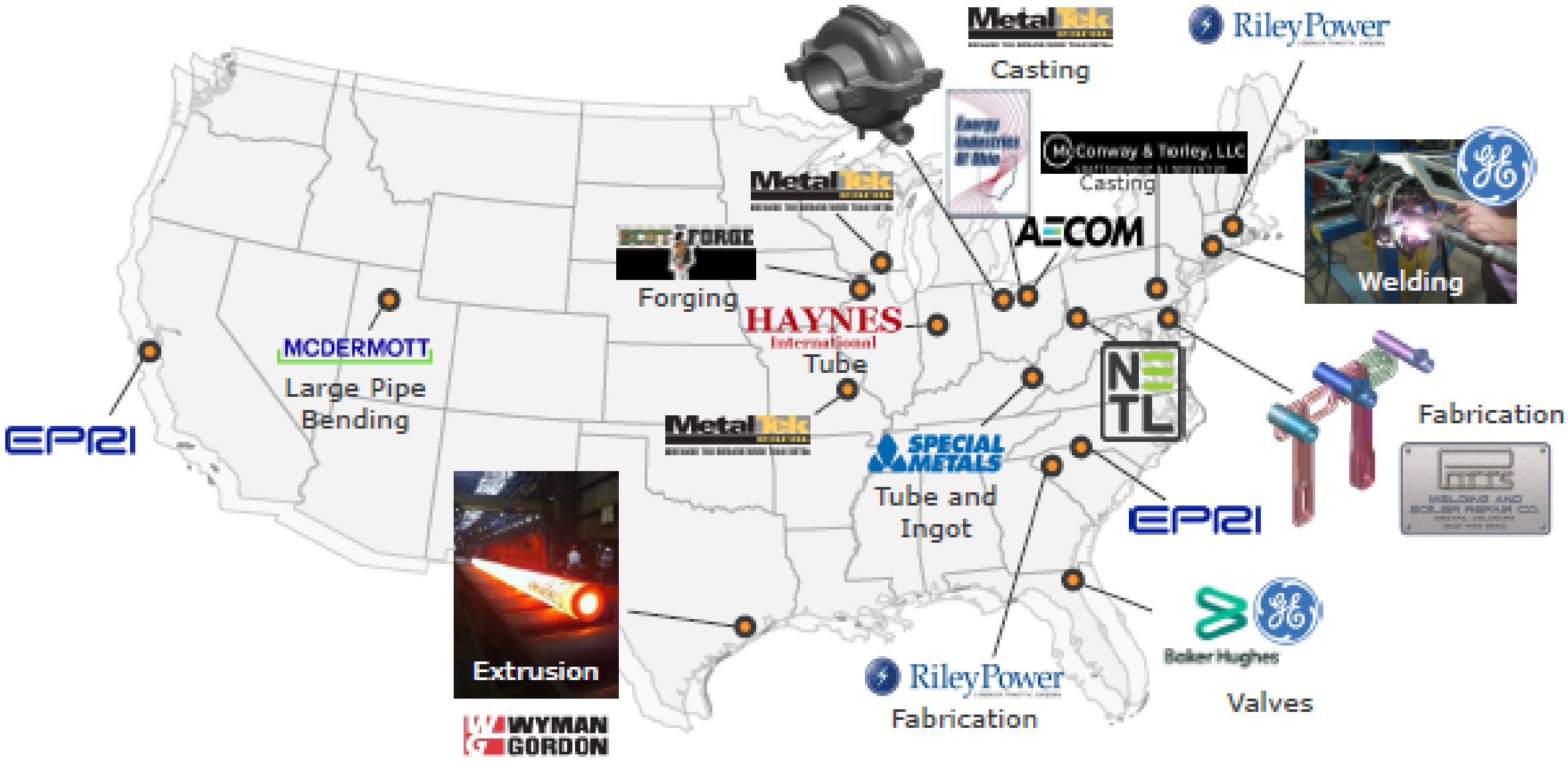
Federal – State – National Laboratory – Non Profit – For Profit
Cost Sharing Consortium



15 Years

ComTest

ComTest Phase II Participant Map



ComTest Phase II Project Team

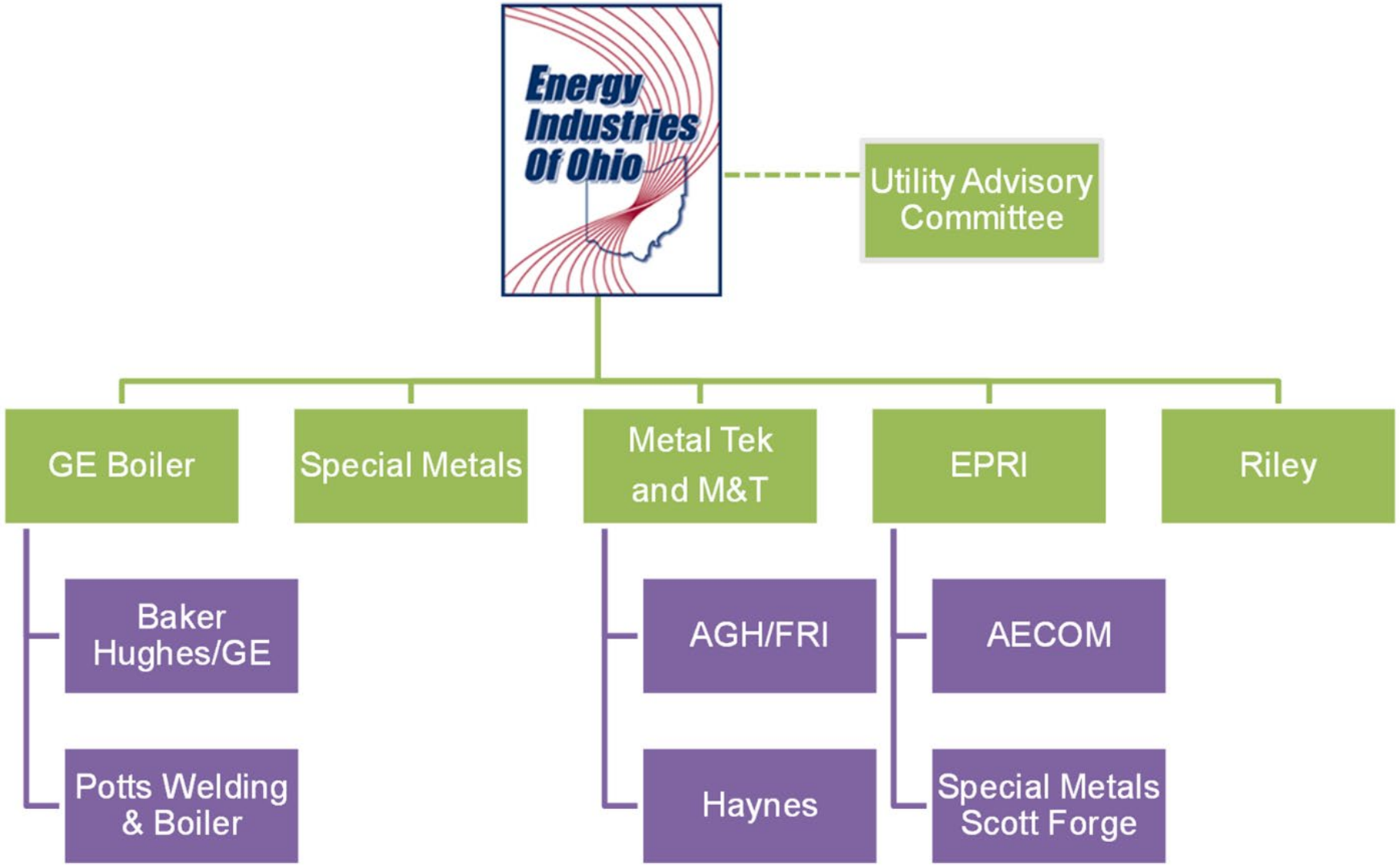
Team Member	Funder	Role
US DOE NETL	✓	Funder
OCDO (Ohio)	✓	Funder
EIO		Prime Contractor & Administration
EPRI	✓	Technical Lead
GE	✓	Supply of Fabrications and Valve
RILEY POWER		Welded Fabrications
METAL TEK & McCONWAY & TORLEY	✓	Supplier of Turbine Casting (10-ton Nozzle Carrier)
SPECIAL METALS	✓	Wye Forging and Header
SCOT FORGE		Steam Turbine Rotor Forging
AECOM		EPC Contractor

ComTest Utility Advisory Committee

- Help to shape and guide the project
- Prioritize work scope
- Ensure key technical needs are met
- Collaborate
- Provide utility perspective

Current Members
Southern Company
AEP
Duke
FirstEnergy
Tri-State

ComTest Phase II – Project Organization Chart



ComTest Phase II Work Plan

- Fabrication of components identified as being outside of the proven capabilities of the existing supply chain, including:
  - Steam turbine rotor forging and Haynes 282 nozzle carrier casting
  - Superheater and reheater header and tube assemblies
  - Large diameter pipe extrusions and forgings
  - Test valve articles to support ASME Code approval
- Key fabrication steps will also be done including boiler weld overlays and simulated field repairs
- Extensive inspection and quality assurance testing of the components
- ASME Code approval for key components

Significant fabrication work will be done with lessons learned provided

ComTest Phase II Project Scope Superheater and Valves

- GE concluded that the operational testing of a pilot scale A-USC superheater was not necessary to confidently design a commercial scale A-USC boiler
- GE recommended alternative focus for boiler components
  - Construction of **full-scale** SH/RH assembly and membrane panels
    - Thick-wall headers, pipes, tube stubs and tubes
    - Welding, simulated field erection, inspection, repair
  - Additional supply chain development on valves (long lead time)
    - PRV and PARV safety valves
    - National Board qualification testing for ASME Code approval

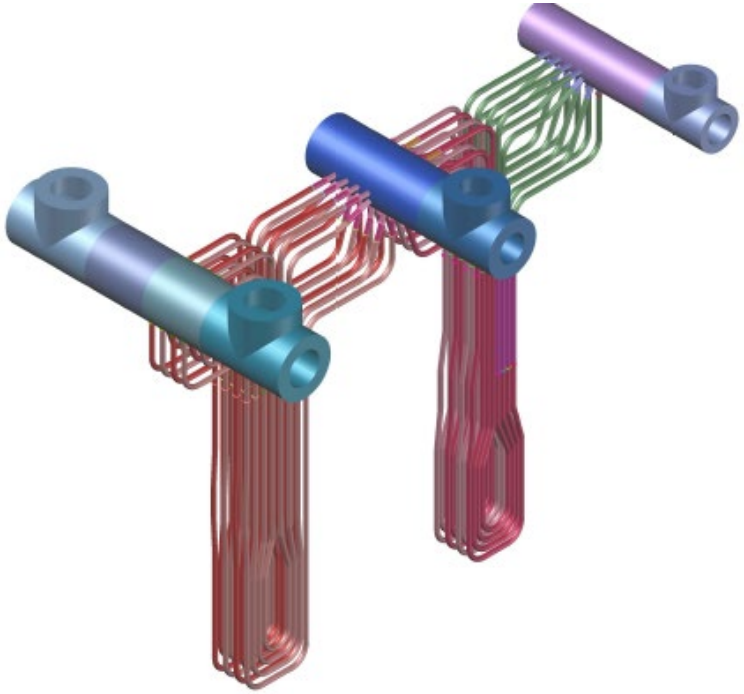
ComTest Phase II Project Scope Steam Turbine

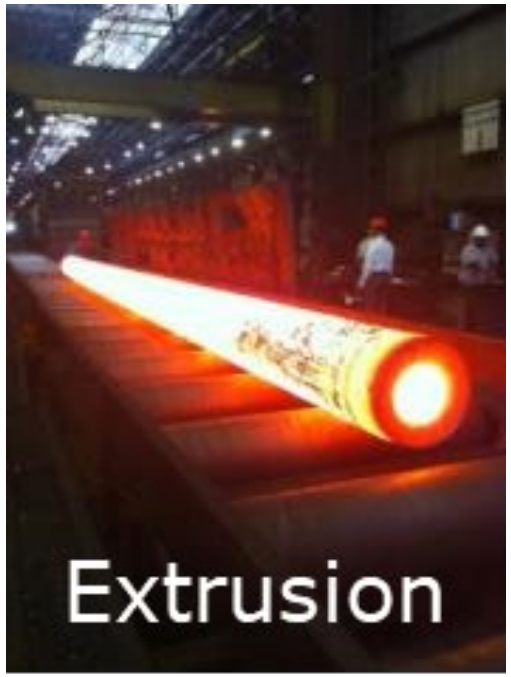
- GE concluded that the operational testing of an A-USC ComTest turbine was not needed to confidently design a commercial scale A-USC steam turbine, but
  - Want to verify that **full-scale** castings and forgings can be constructed
  - Have provided drawings of full-scale **800MW** equivalent components
  - Have provided test/inspection criteria to validate successful completion

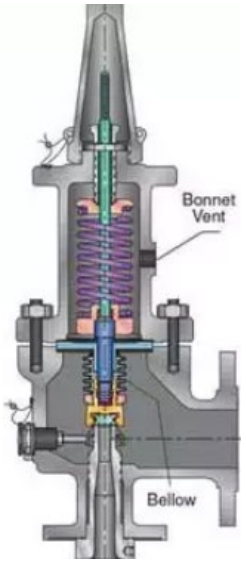
ComTest Phase II Current Activities

- Developing procurement specifications for **full-scale components**
- Identifying **supply chain** firms capable of producing nickel super alloy components
- Negotiating sub-awards, acquiring materials, maintaining a technical liaison with suppliers thru all phases of production
- Completing the **fabrication and production** of components
- Performing **materials testing** to ensure specifications achieved
- **Validating supply chain** fabrication methods
- Documenting testing and evaluations and **reporting results**

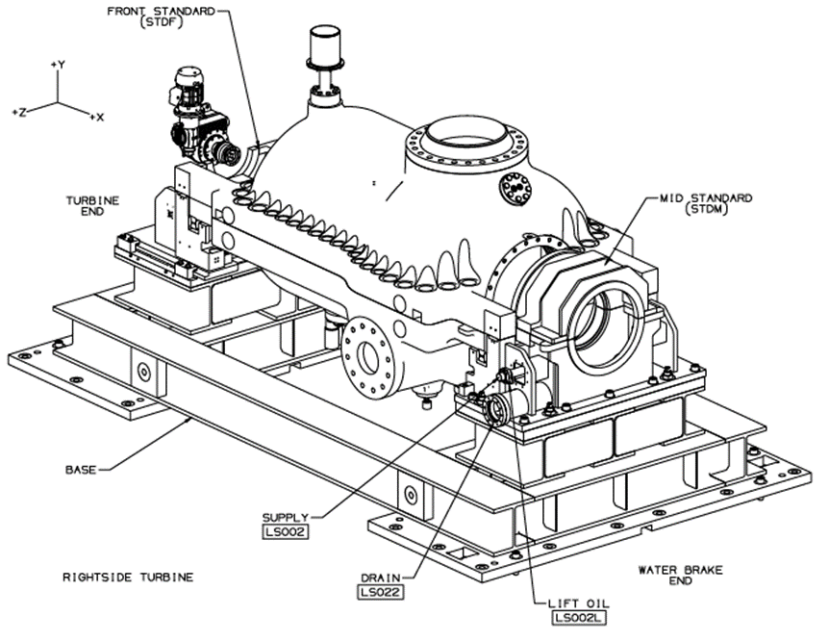
ComTest Phase II - Major Component Activity

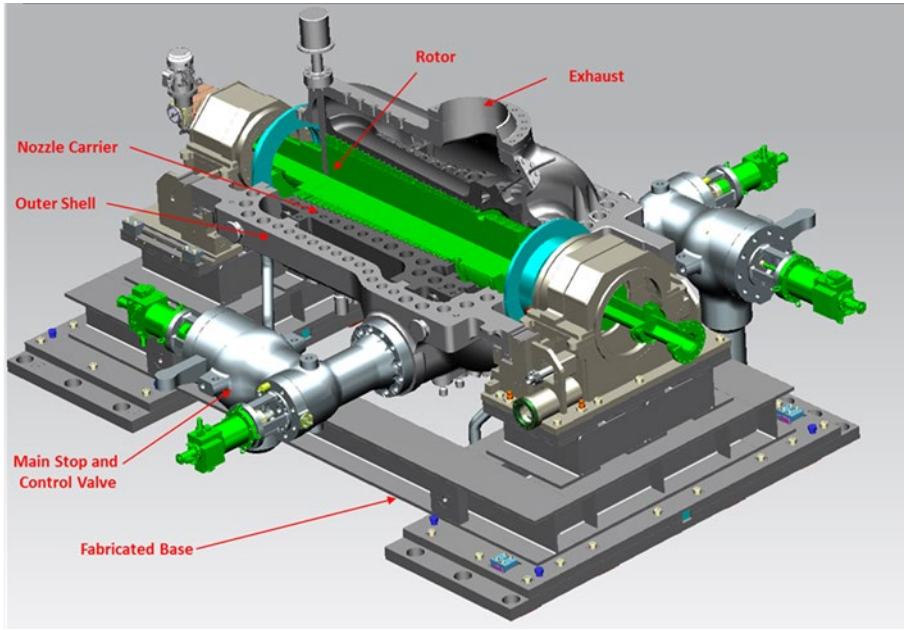


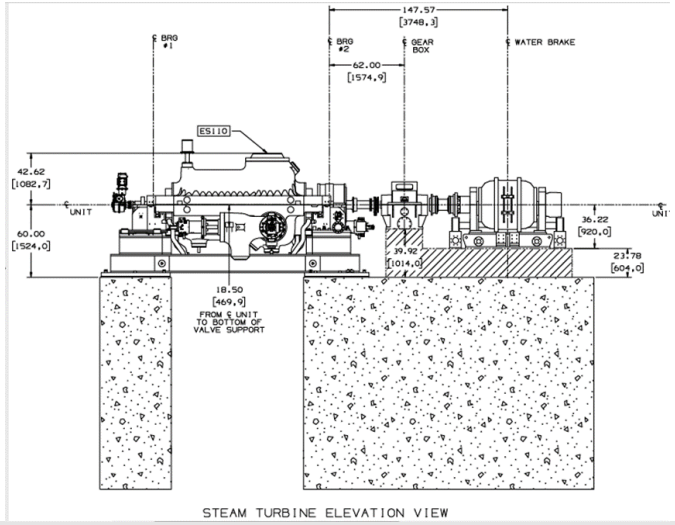




Steam Turbine Assembly – Nozzle Carrier

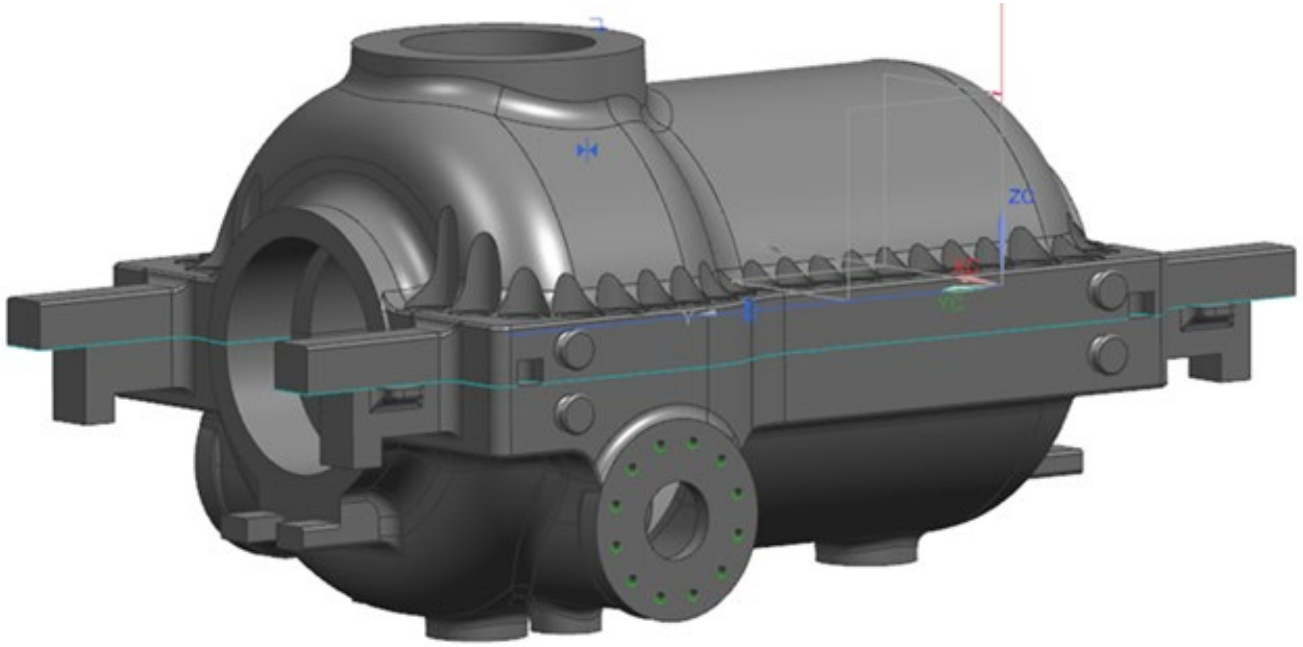


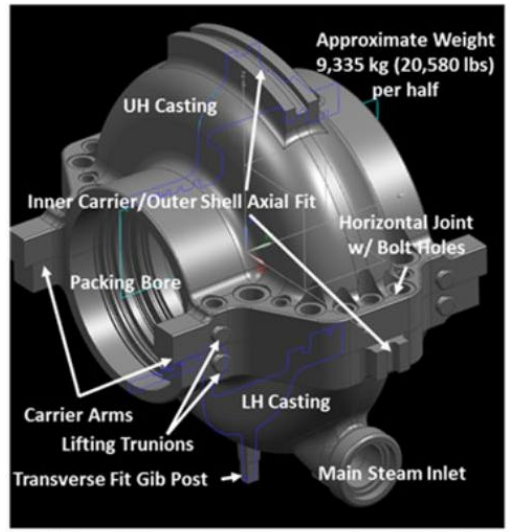


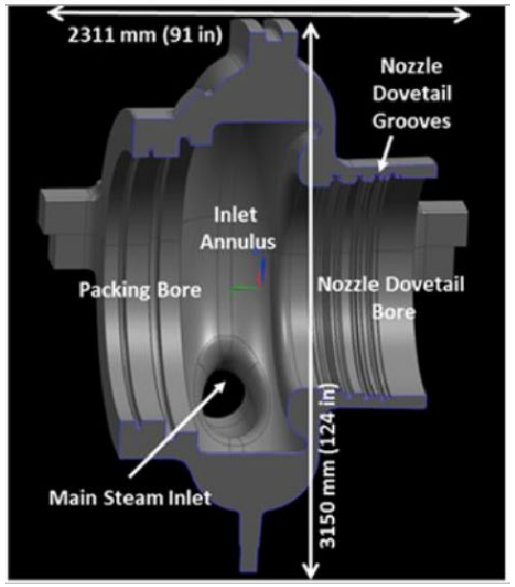


STEAM TURBINE ELEVATION VIEW

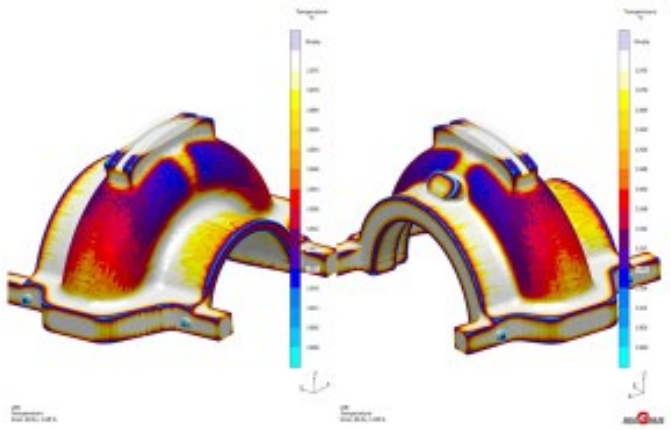
A-USC Steam Turbine Nozzle Carrier Casting (10 tons Haynes 282)
Note: Trial casting is upper section

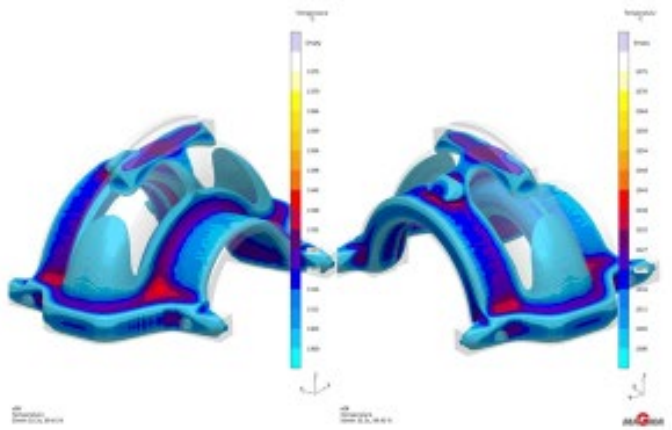


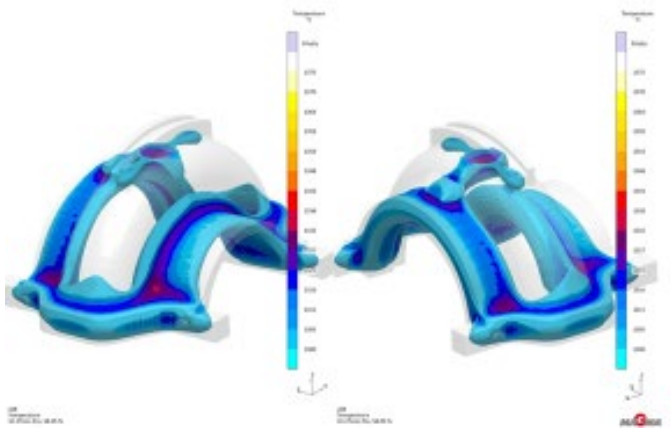


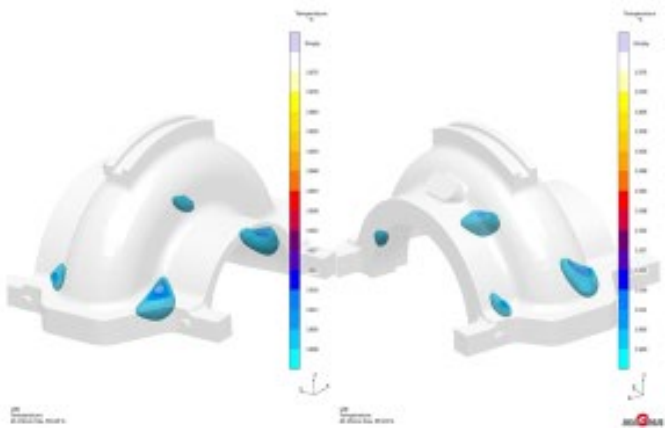


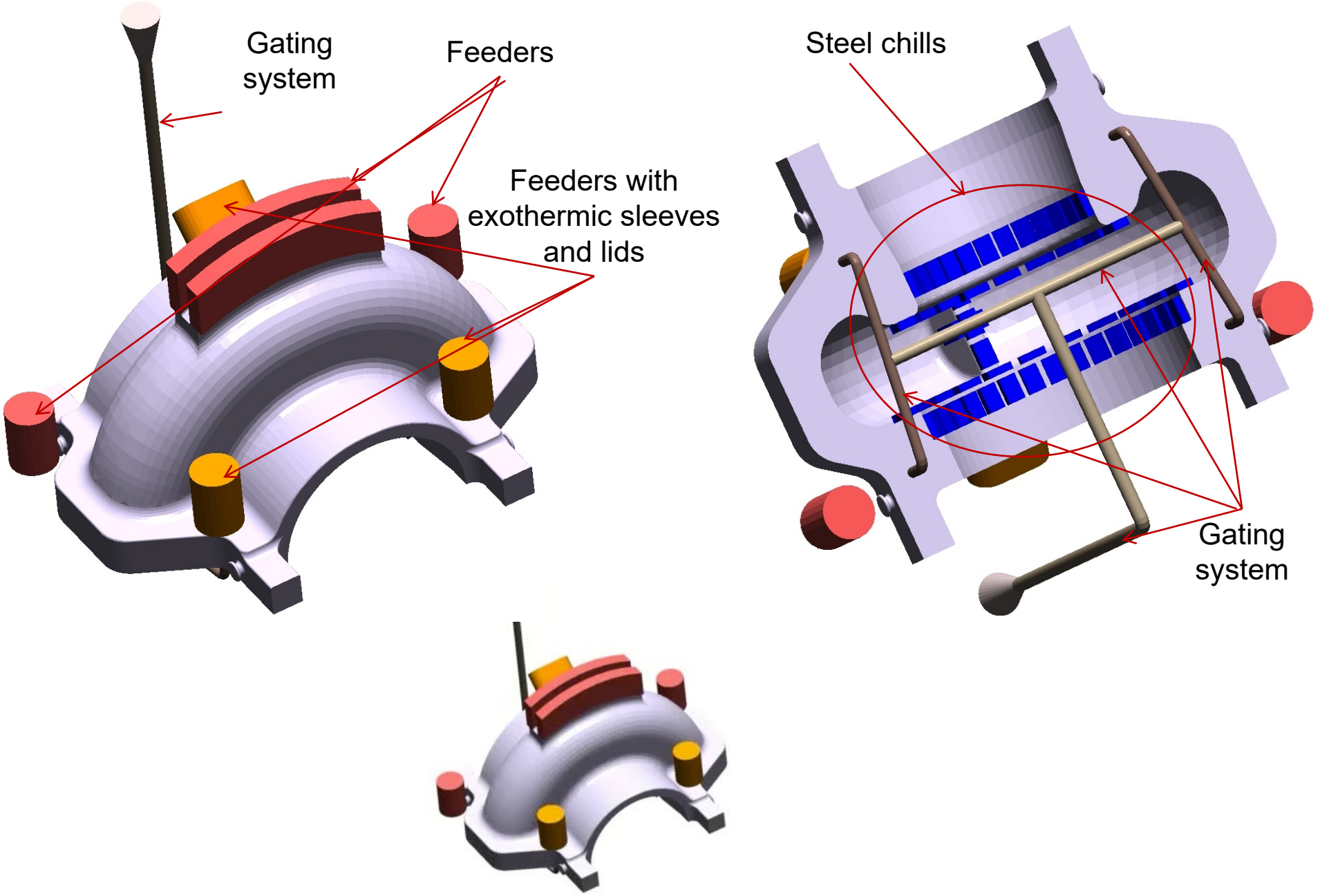
Solidification Modelling of Nozzle Casting Component





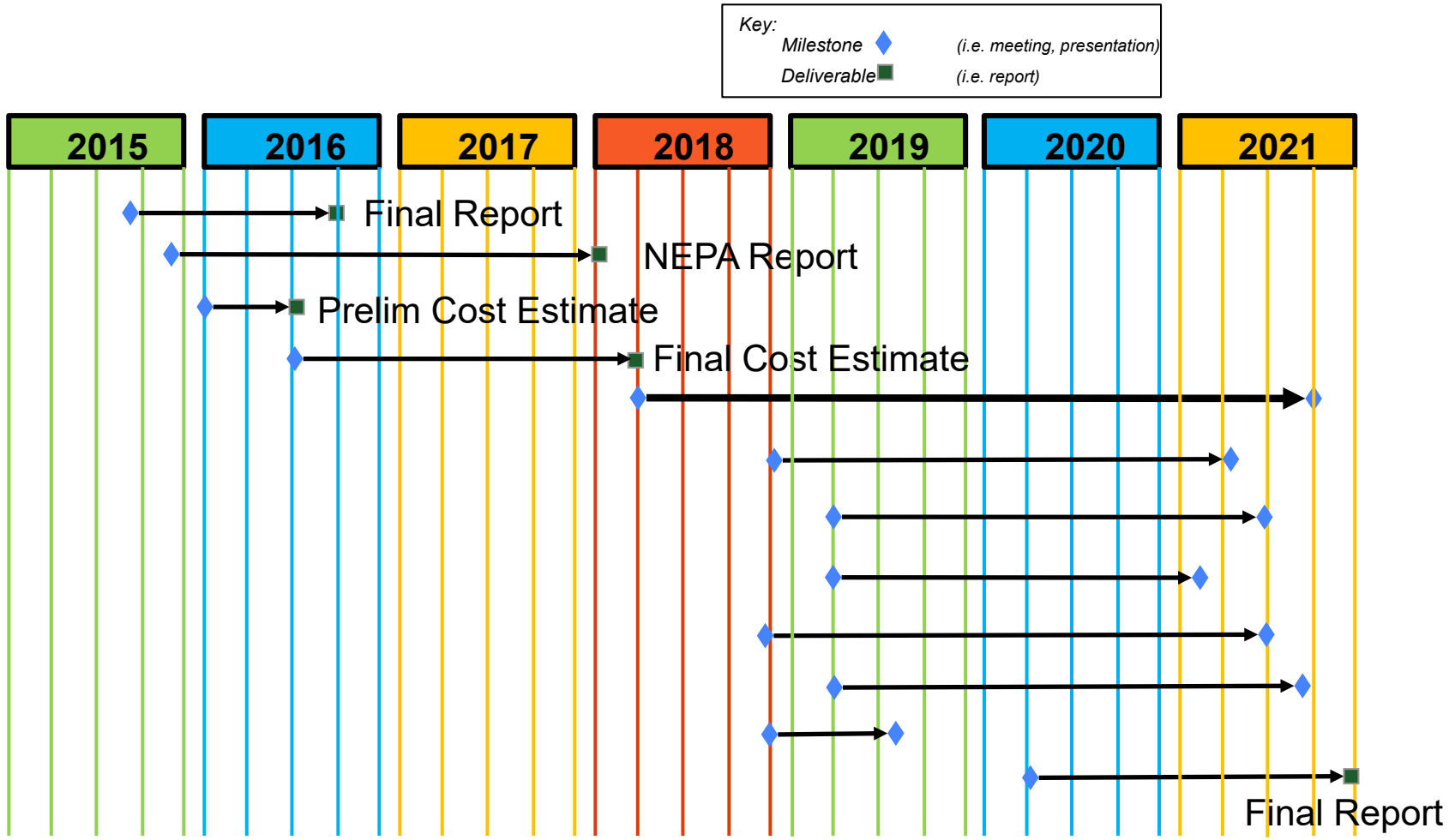






ComTest Schedule

- **Phase I**
  - Pre-FEED
  - NEPA
  - FEED
- Detailed Engineering
- **Phase II**
- Turbine Rotor Forging
- Nozzle Carrier Casting
- Valve Testing / NB Qualification
- Superheater Component Fab.
- Pipe Forgings and tube trials
- Metallurgical Testing Plan
- Evaluation & Reporting



Based upon July 23, 2020
Project Management Plan

Important Because… Cross-cutting Applicability to sCO2 Power Cycles, Solar Applications and others

- sCO2 power cycles share common materials, forgings and castings with A-USC technology.
- Synergies exist between ComTest and DOE's Supercritical Transformational Electric Power (STEP) project that will demonstrate a large-scale supercritical CO2 (sCO2) power plant.
- The STEP program will use a main stop and control valve that is essentially the same as the MSCV contemplated for the A-USC ComTest project.
  - Demonstrate manufacture of large Haynes 282 alloy valve body
  - Operate valve in sCO2 environment, at similar temperatures to A-USC

ComTest Support Acknowledgement

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