Advanced Ultra-Supercritical Component Testing

DOE Contract DE-FE0025064

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Goals: The A-USC Project will lead to…

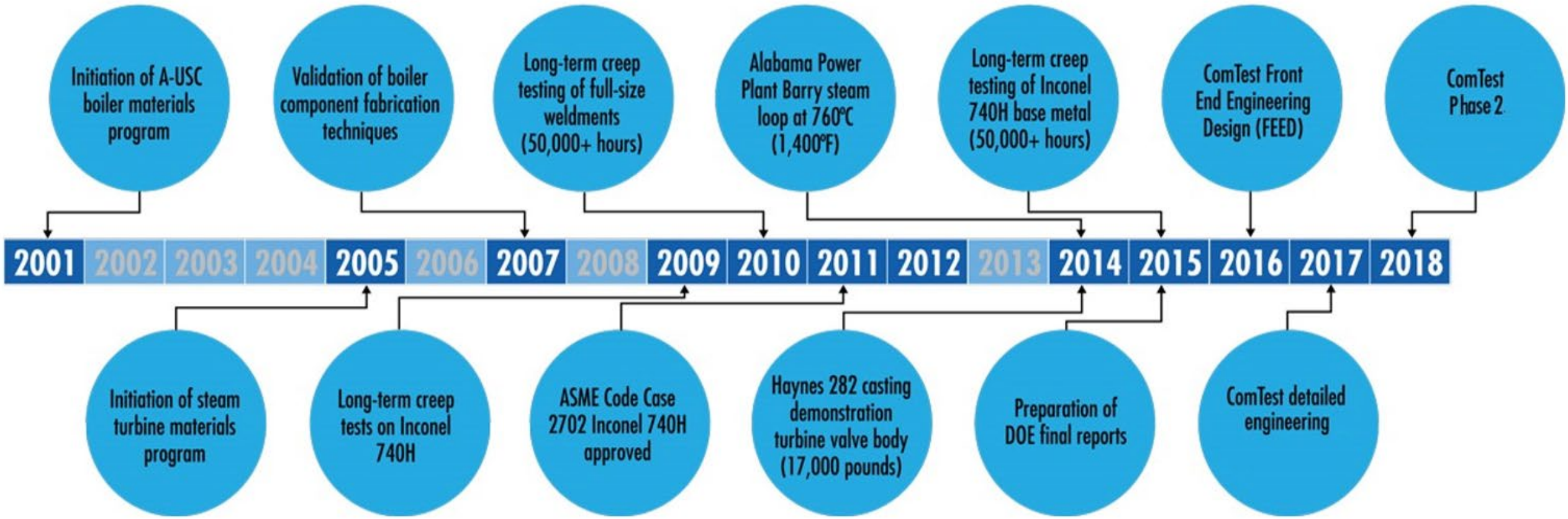
- **Higher efficiency** for new and existing fossil fuel plants
  - 10% above today's new state-of-the-art coal power plants, and
  - 25% above that of the average power plants in the U.S. existing fleet
- **Lower emissions** (NOx, SOx, CO_2)
- **Minimized risk** for utilities desiring to build A-USC 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 1000-1050°F (538-566°C)	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 for Rankine and other high-temperature power cycles

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

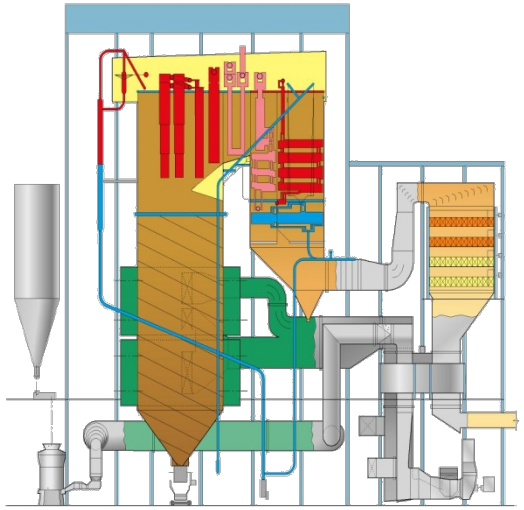
- Boiler Materials for Advanced Ultra-supercritical Coal Power Plant
  - DOE Contract: DE-FG26-01NT41175
  - OCDO Grant: CDO-D-05-02(A)
- Materials for Advanced Ultra-supercritical Steam Turbines
  - DOE Contract: DE-FE0000234
  - OCDO Grant: CDO-D-05-02(B)

Primary Technical Goals of A-USC Materials Programs

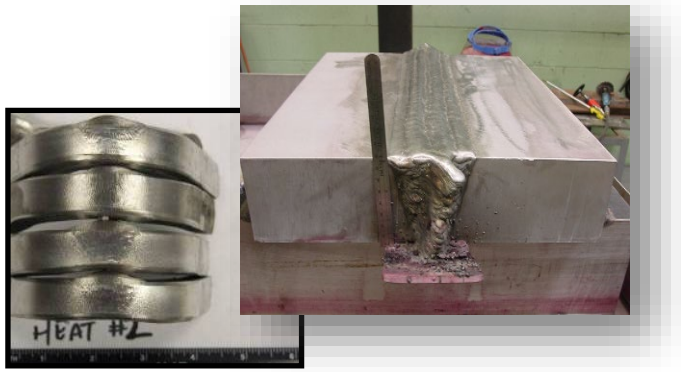
- Evaluate materials technology for A-USC
  - Focus on **nickel-based alloys**
  - Develop fabrication and joining technology for new alloys
- Consider the unique conditions for US program
  - Higher-temperatures than other international programs (760°C versus 700°C) means **additional alloys** evaluated
  - 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

Tasks Completed in A-USC Materials Programs

General design studies show favorable economics



Steam-Side Oxidation



Welding Technology Developments

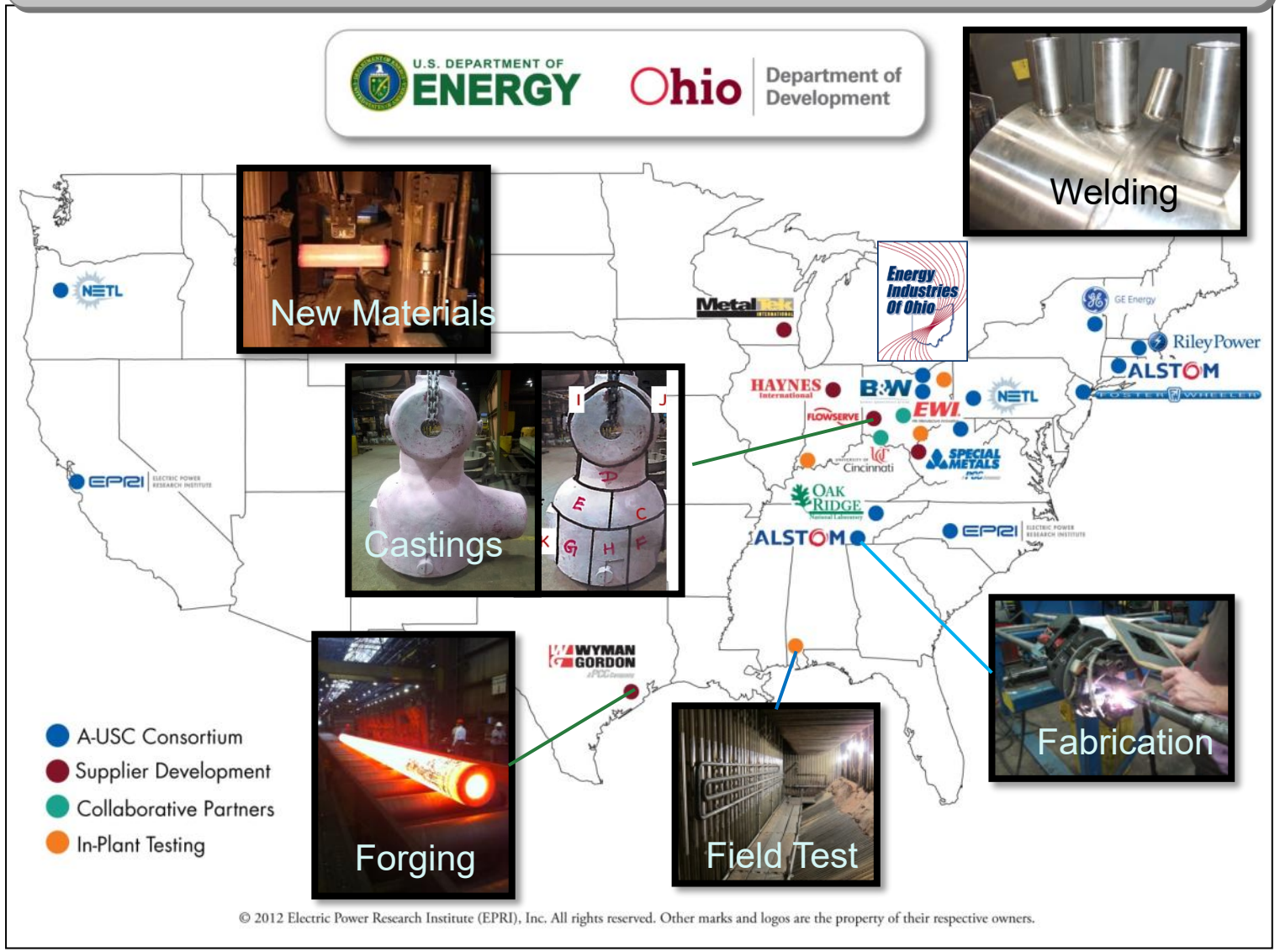
Fireside Corrosion (High-Sulfur Coal & In-Plant Testing)

Fabrication Processes

Turbine Component Scale-up

Next Step… Building Upon Prior Work

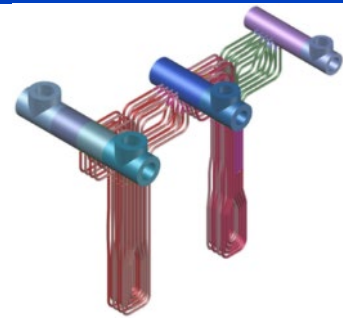
Federal – State – National Laboratory – Non Profit – For Profit
Cost Sharing Consortium



15 Years

ComTest

ComTest Project Overview



- ComTest is a $27M Department of Energy-funded project
- Phase 1, which began in November 2015, served to identify the technology gaps, as well as the scope and cost of required testing
- Phase 2, which was awarded in December 2018, includes an advanced manufacturing effort to complete US-based supply chain development for full commercial scale (800-850 MWe) A-USC components made of nickel-based alloys, components operating at up to 760°C.

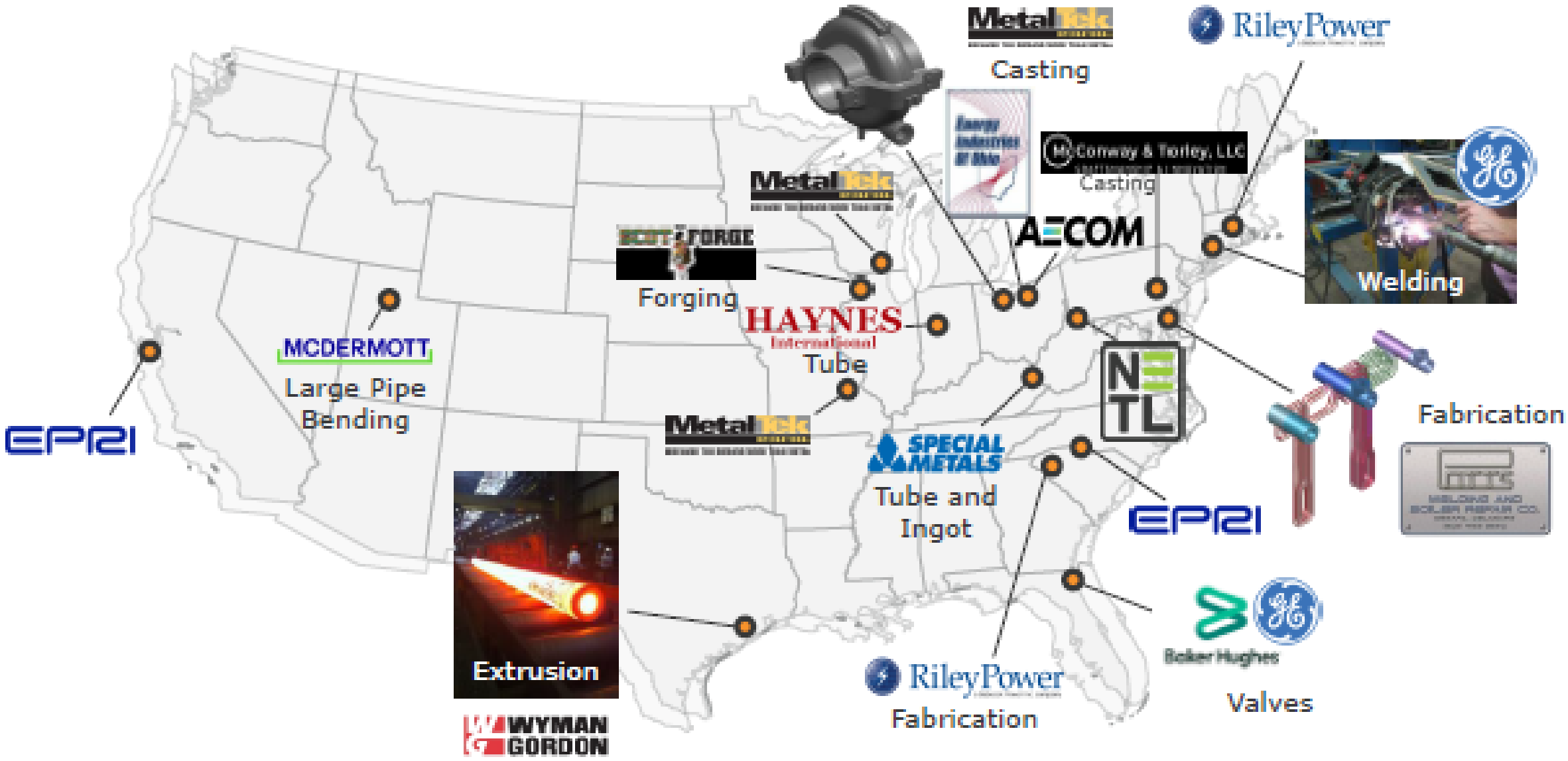
Close gaps to achieve readiness for commercial scale demonstration

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

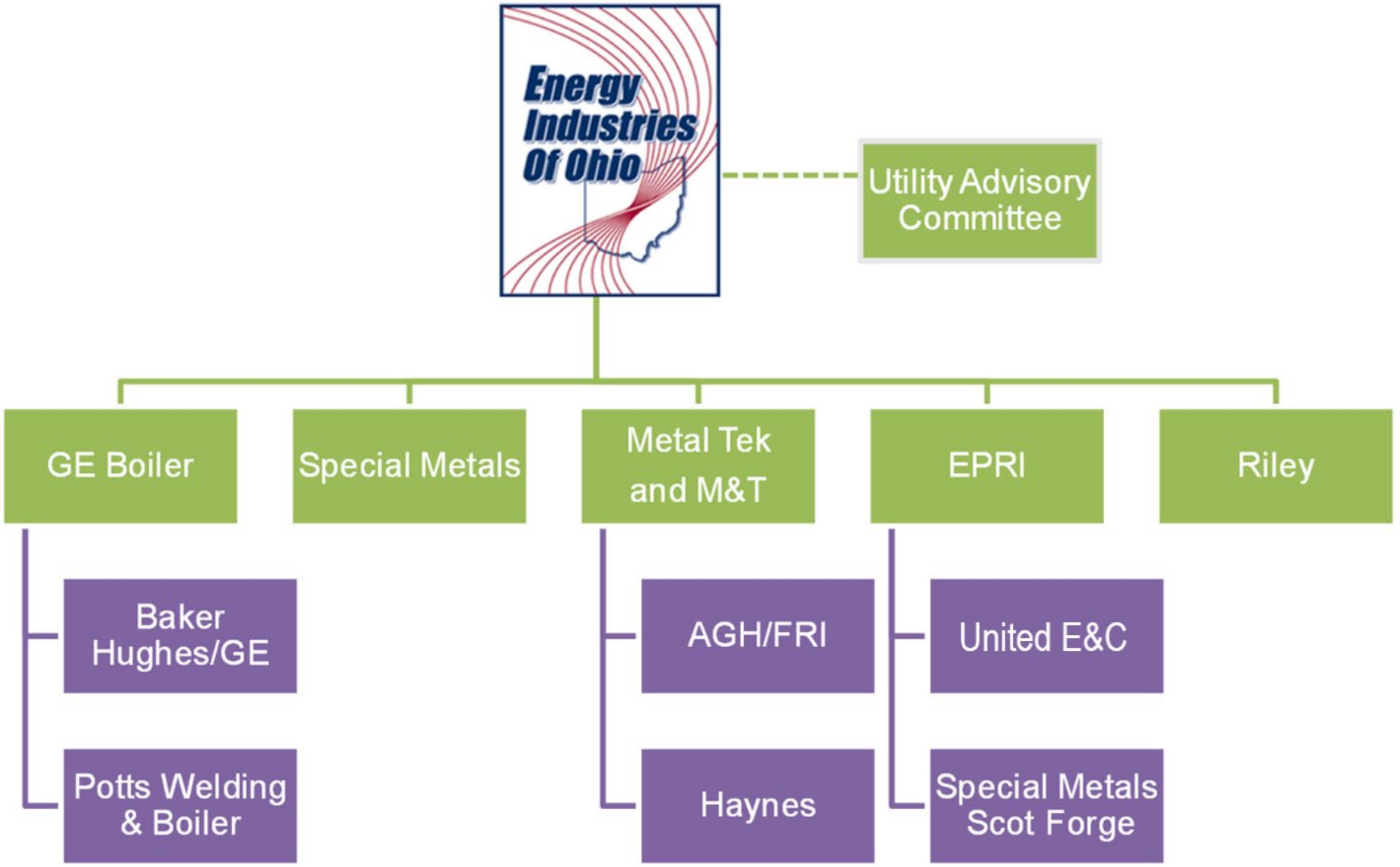
ComTest Phase II Participant Map



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, Pipe, Header, Ingot
SCOT FORGE		Steam Turbine Rotor Forging
UNITED E&C (formerly AECOM)		EPC Contractor / Master Schedule

ComTest Phase II – Project Organization Chart

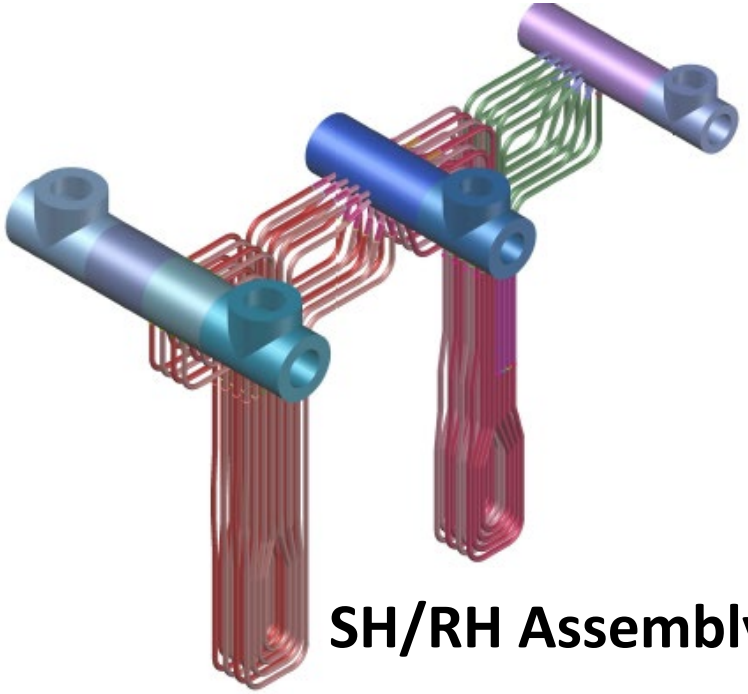


ComTest Phase II Work Plan

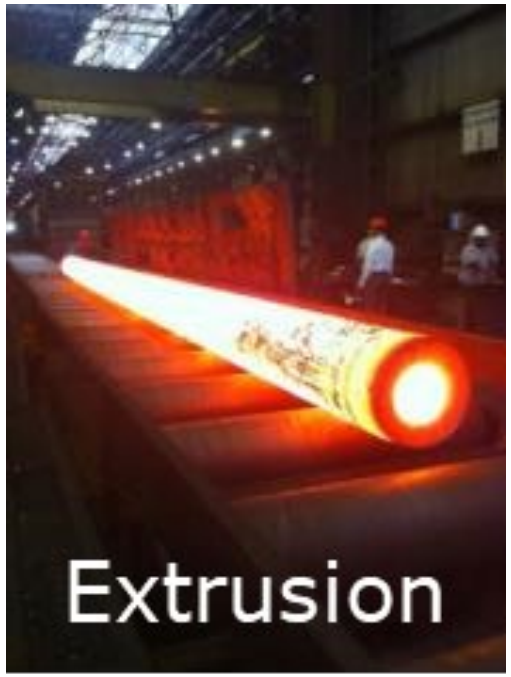
- Fabrication of components identified as being outside of the proven capabilities of the existing supply chain, including:
  - Steam turbine rotor forging and Haynes 282 nozzle carrier casting
  - Superheater and reheater header and tube assemblies
  - Large diameter pipe extrusions and forgings
  - 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 and processes

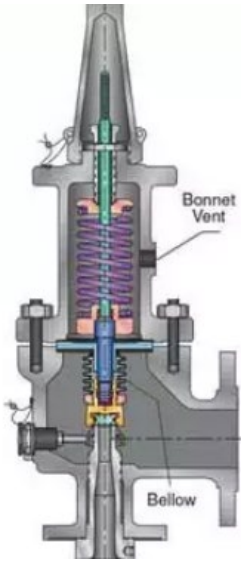
Significant fabrication work will be done with lessons learned provided

ComTest Phase II - Major Component Activity



SH/RH Assembly



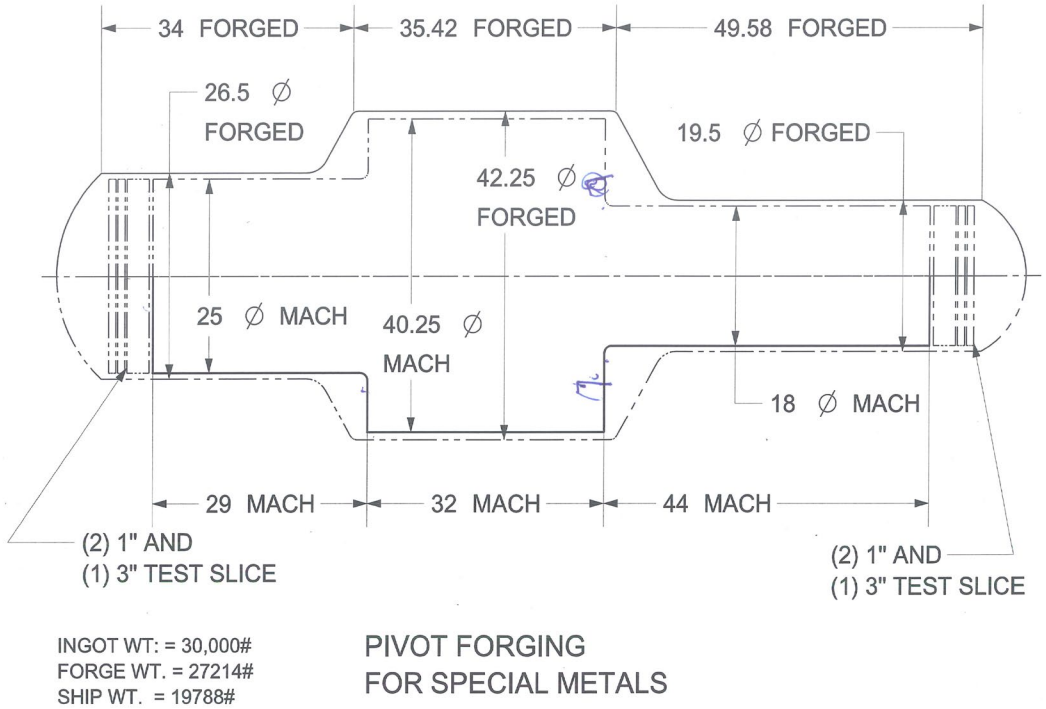


Steam Turbine Rotor Forging ComTest Phase II

Steam Turbine Rotor Forging

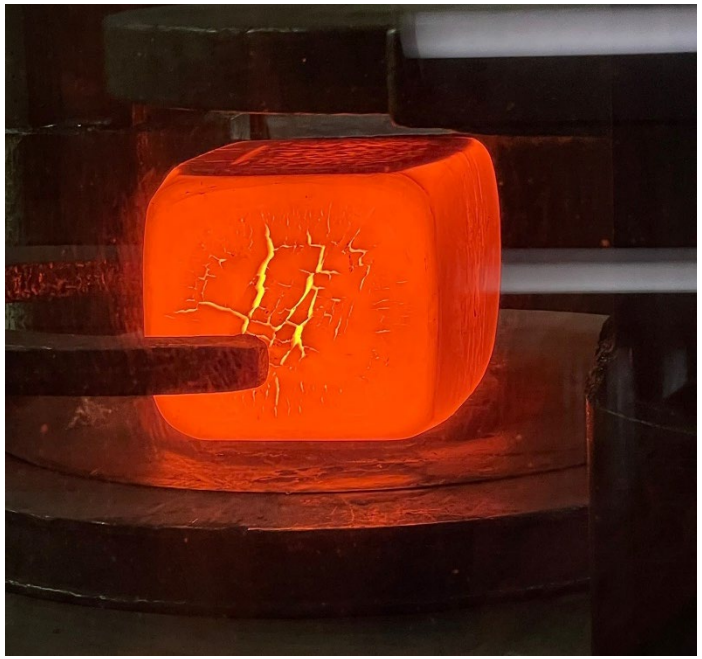
- Rotor Forging (Haynes Alloy 282)
  - Previous work with 24” (61 cm) diameter triple melt ingot to make 5,000 lb. (2,270 kg) pancake to simulate disk for bolted rotor turbine design
  - GE’s new welded rotor design uses a much larger shaft forging
    - Requires 36” (91 cm) diameter, 30,000 lb. (13,624 kg) triple melt ingot (largest possible)
    - Concerns about ingot segregation and cracking
    - Challenge to achieve fine grain in forging

Alloy 282 pancake forged at Wyman-Gordon



ComTest Phase II rotor forging

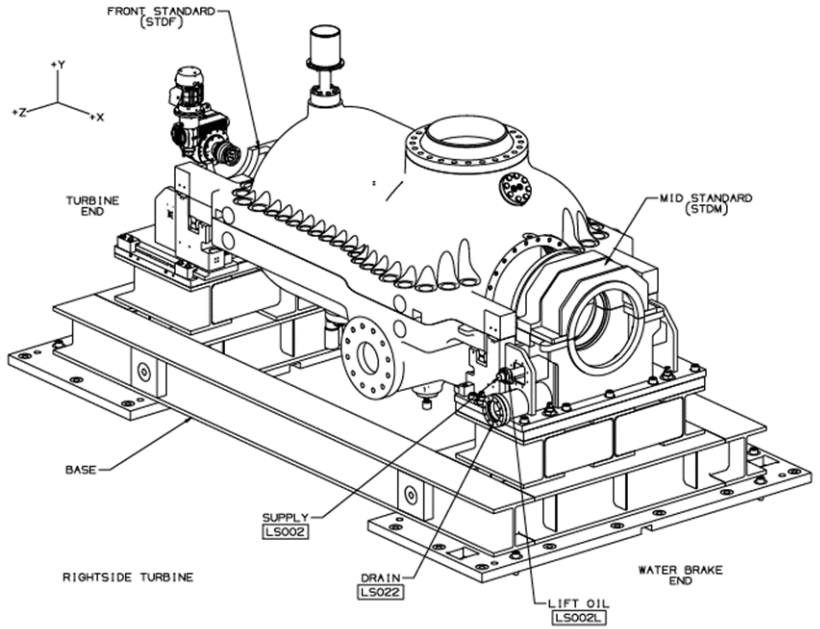
Steam Turbine Rotor - Forging Process

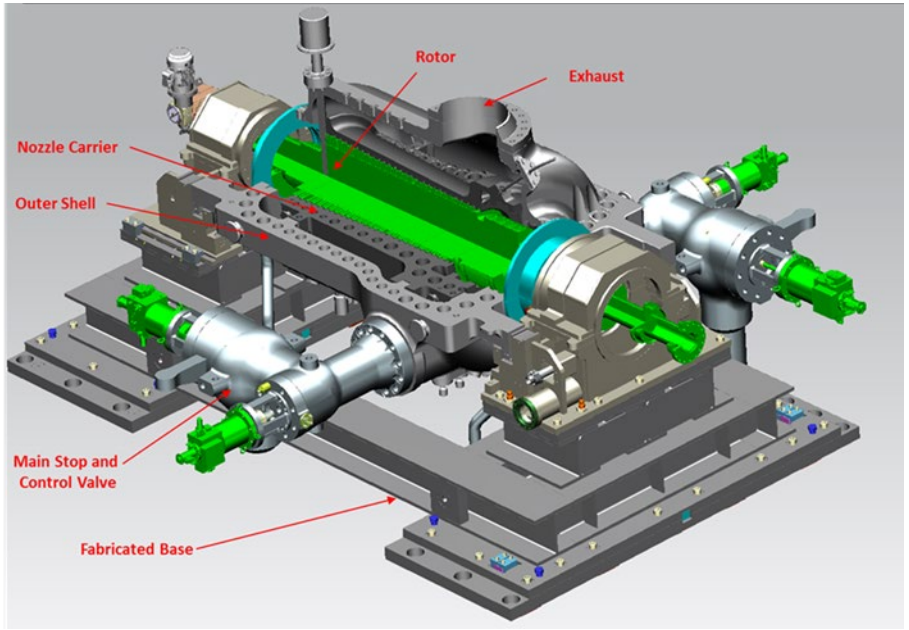


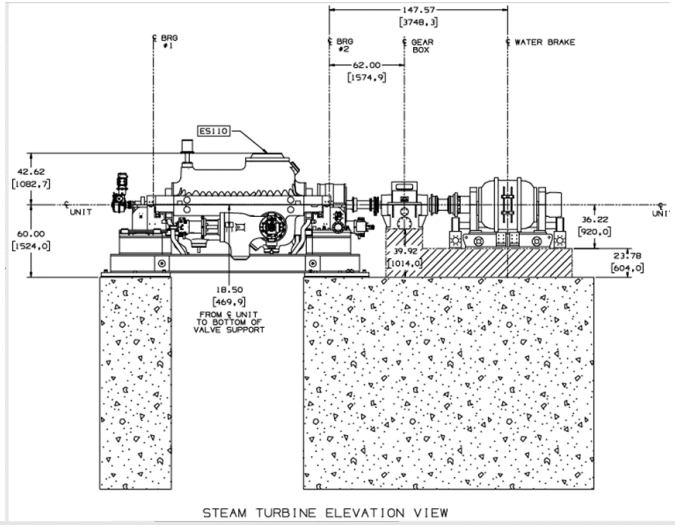
Steam Turbine Rotor Forging - Prior to Machining

Steam Turbine Nozzle Carrier Casting ComTest Phase II

Steam Turbine Assembly – Nozzle Carrier

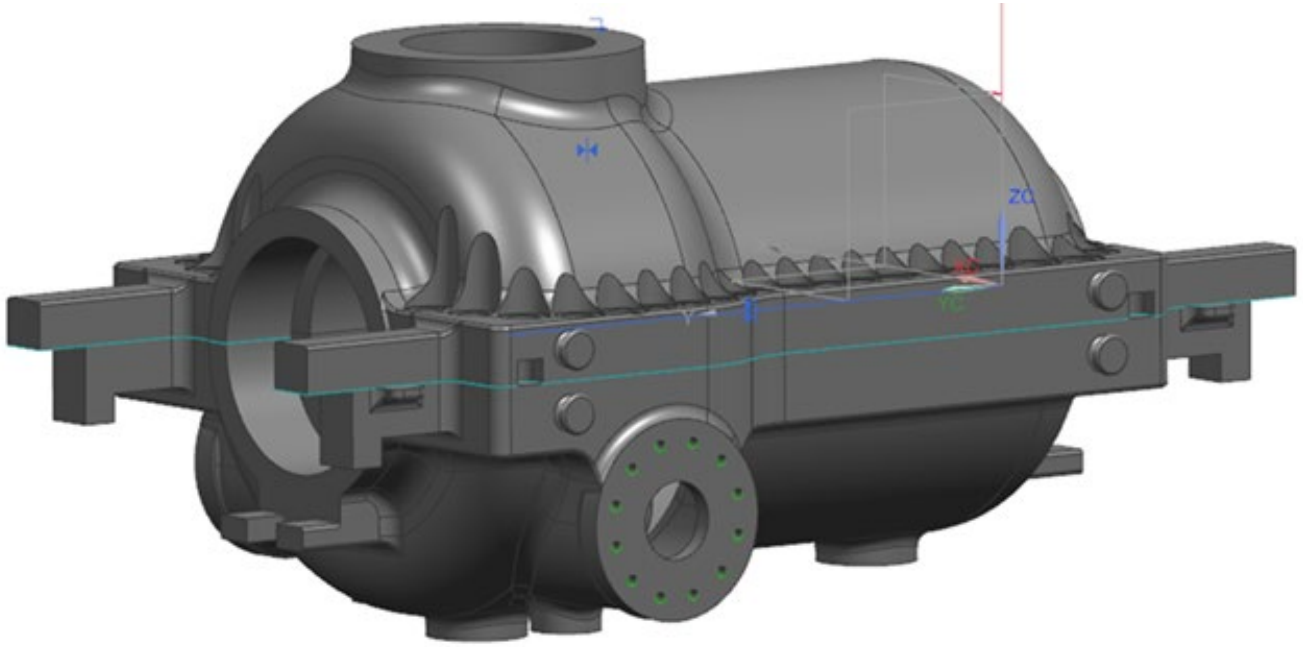


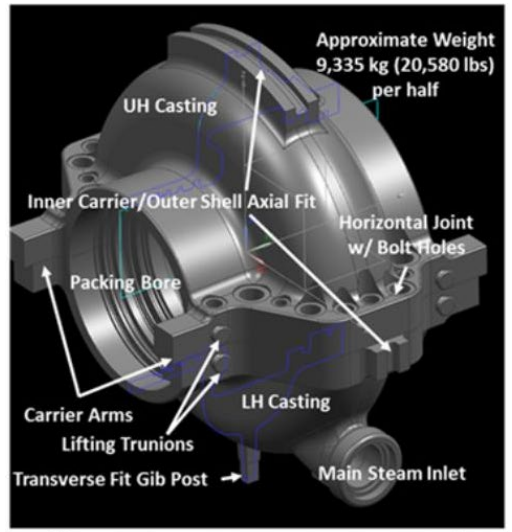


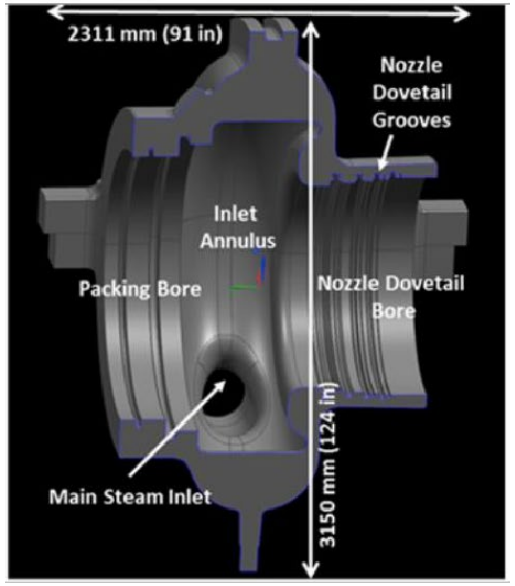


STEAM TURBINE ELEVATION VIEW

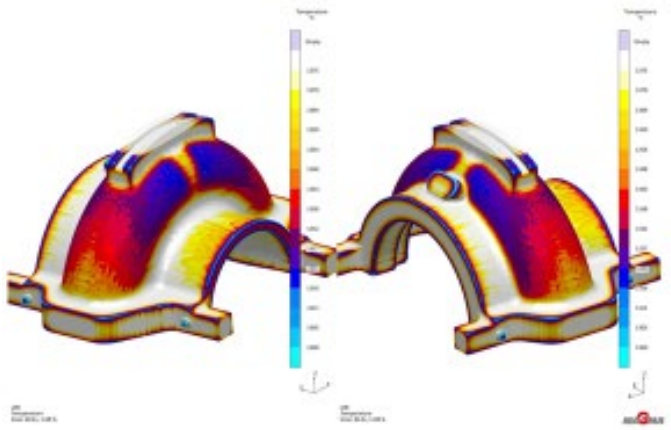
A-USC Steam Turbine Nozzle Carrier Casting (10 tons Haynes 282)
Note: Trial casting is upper section

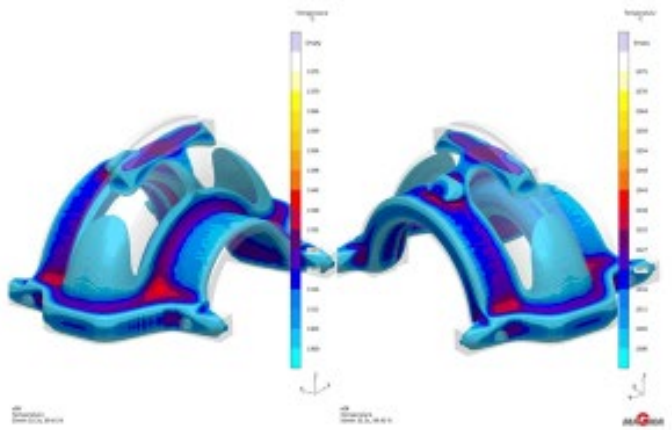


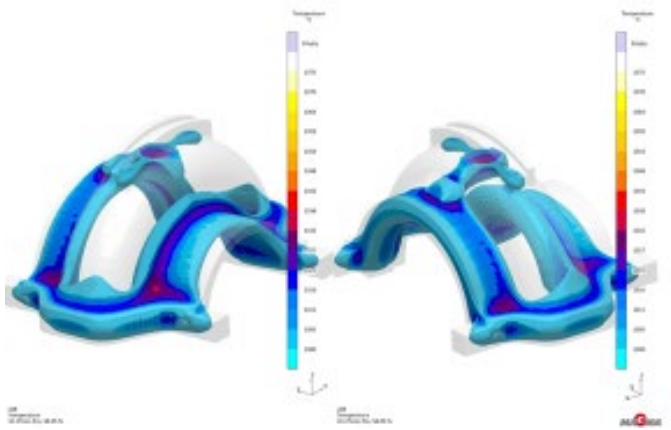


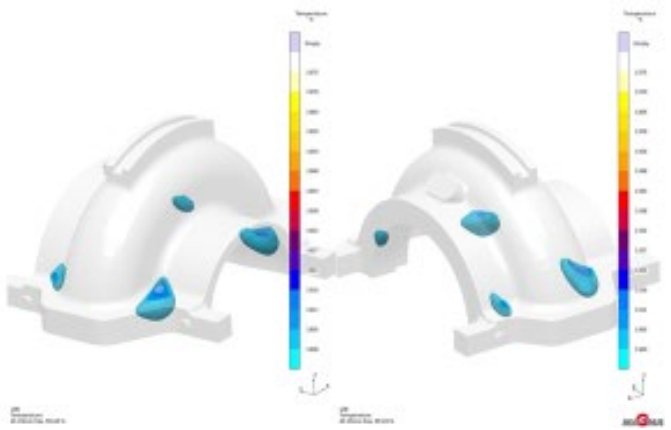


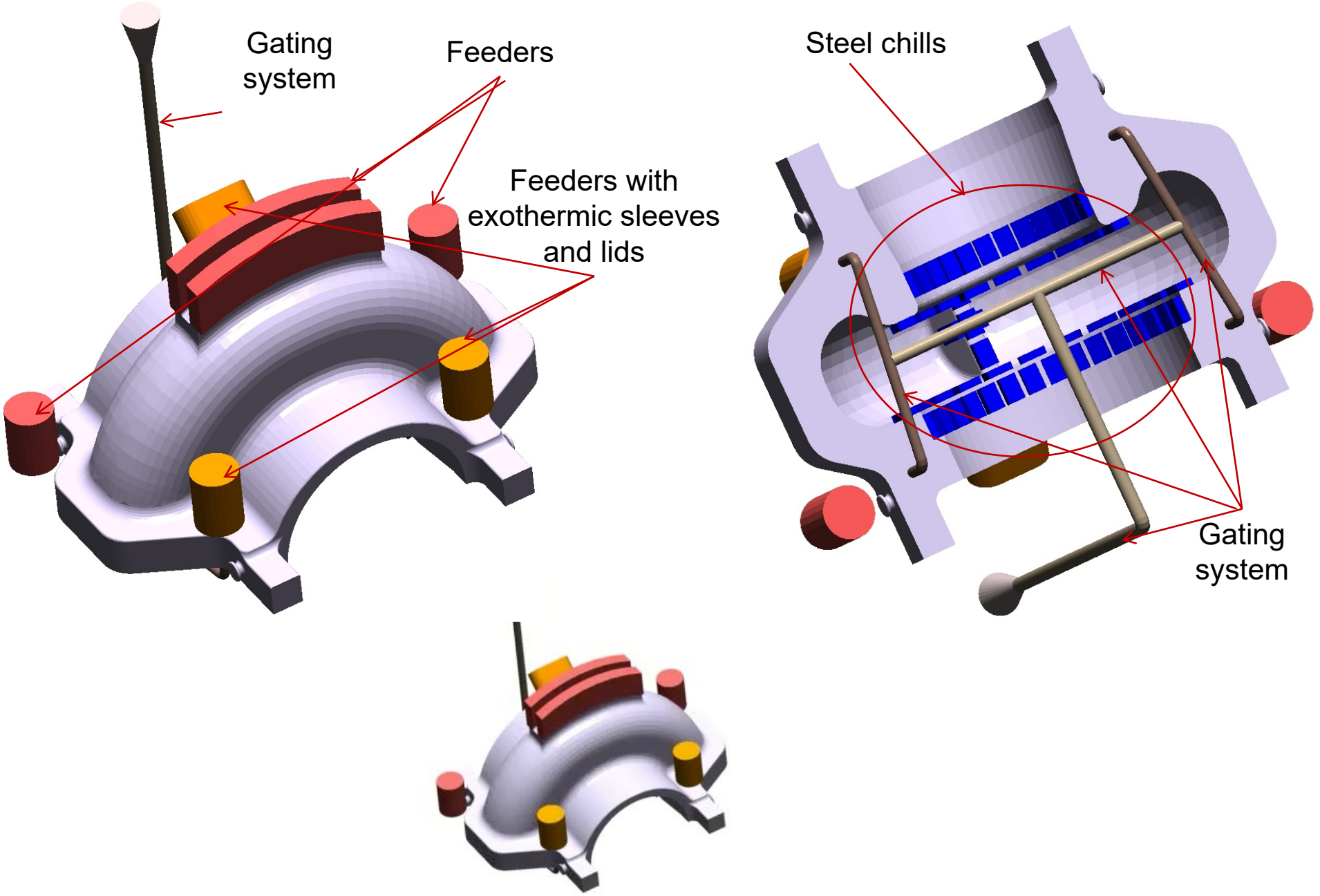
Solidification Modelling of Nozzle Casting Component









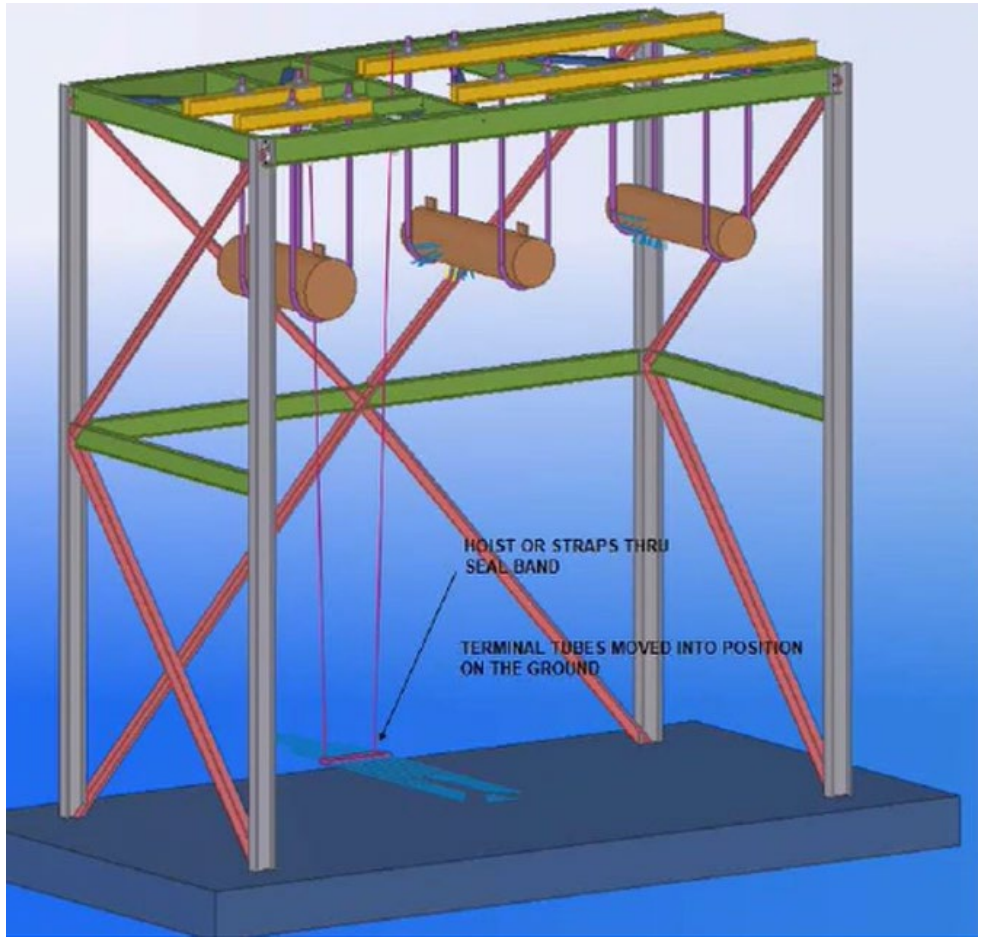


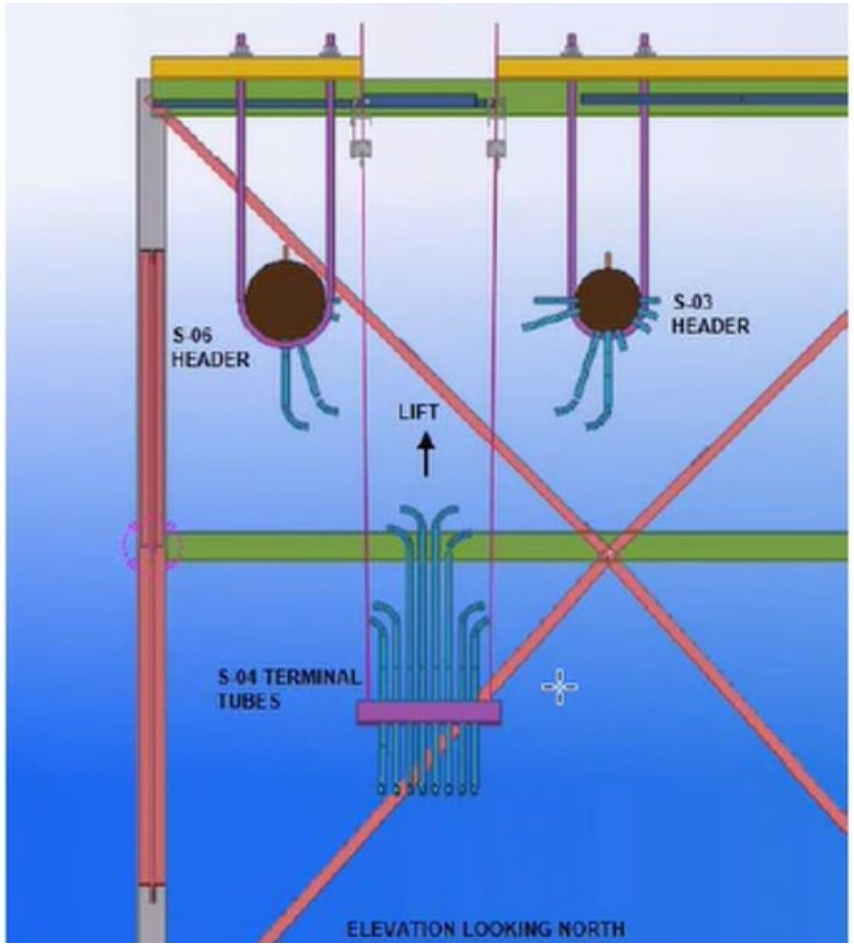
Completed Nozzle Carrier Casting (Prior to Machining)

Superheater / Reheater Assembly ComTest Phase II

Superheater / Reheater Assembly

Simulated Field Erection of SH/RH Assembly

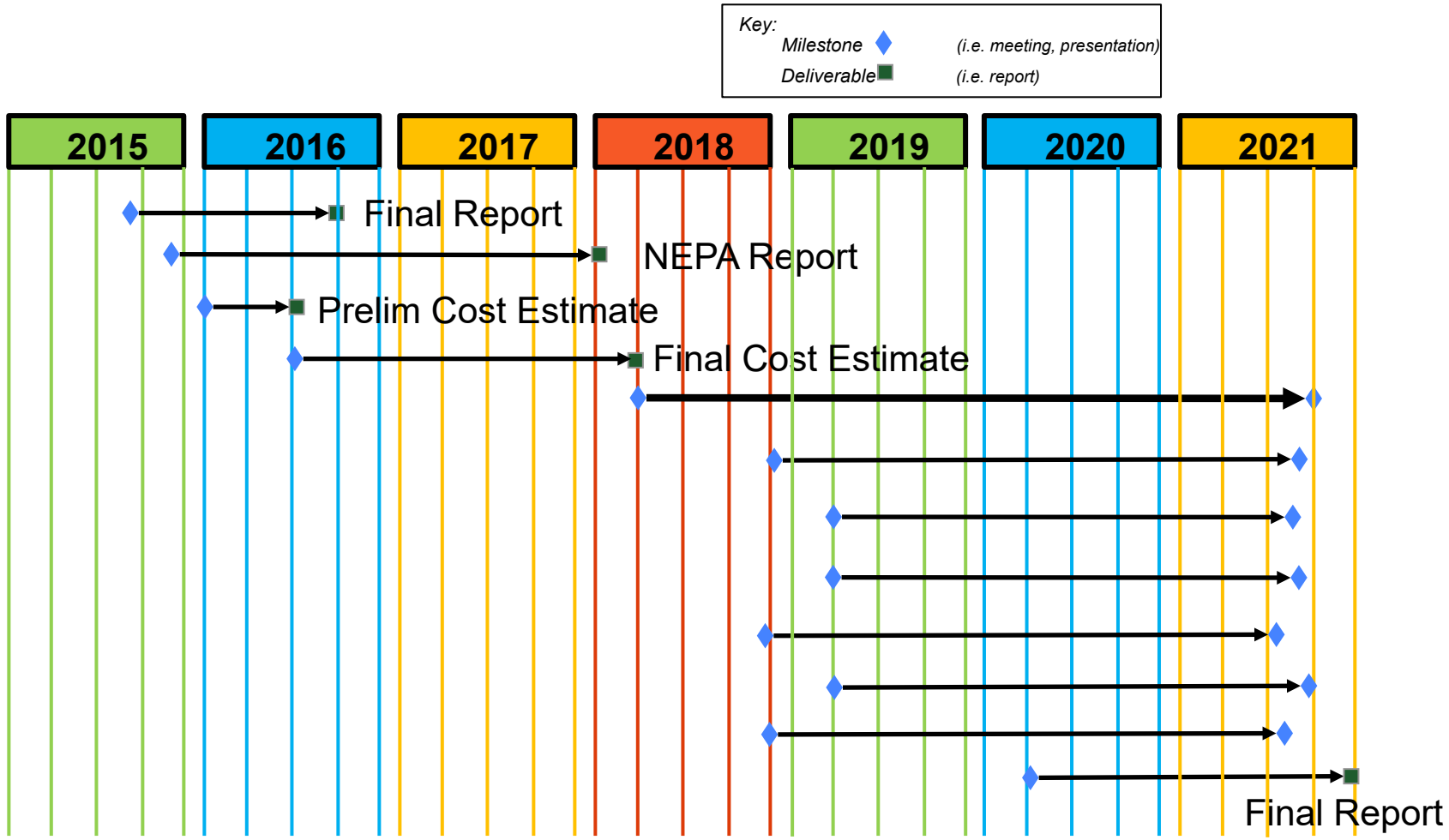




Project Schedule
ComTest Phase II

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 April 6, 2021
Project Management Plan

ComTest Support Acknowledgement

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